Introduction to IPv4 and IPv6

Session RST-102

Agenda

- IPv4 Addressing Concepts
- IPv6 Addressing Concepts
- Generic Routing Concepts
- Specific Routing Protocols
- Static and Defaults Routes
MAC Address

48 Bit Hexadecimal (Base16) Unique Layer Two Address

1234.5678.9ABC

First 24 Bits = Manufacture Code
Assigned By IEEE

0000.0cXX.XXXX

Second 24 Bits = Specific Interface,
Assigned by Manufacture

XXXX.XX00.0001

All F’s = Broadcast

FFFFFF.FFFF.FFFF

IPv4 Addressing

32 Bits

Network                             Host

8 Bits                               8 Bits

172 . 16 . 122 . 204
IPv4 Subnetting, Mask

Use Host Bits, Starting at the High Order Bit Position

IPv4 Address Classes

Class A:

Start | 1 | 0 | 0 | 0 | 0
End | 126 | 255 | 255 | 254 | Mask | 255 | 0 | 0 | 0 | 0

Class B:

Start | 128 | 0 | 0 | 0 | 0 | End | 191 | 255 | 255 | 254 | Mask | 255 | 255 | 0 | 0 | 0

Class C:

Start | 192 | 0 | 0 | 0 | 0 | End | 226 | 255 | 255 | 254 | Mask | 255 | 255 | 255 | 0 | 0

Class D: For Multicast
IPv4 Address Mask Formats

Cisco IOS® Will Display Different Mask Formats at Different Times

- hexadecimal 172.16.31.6 0xFFFFFFFF
- decimal ---- 172.16.31.6 255.255.255.0
- bitcount --- 172.16.31.6/24
- terminal network-format [bitcount|decimal|hexadecimal]

Why IPv6

- #1 reason was for the address space
  - Only 40% v4 space now left, by 2005 to 2011, all gone.
- Simplify IP address assignment
- Always on addressing
- NAT is not an optimal solution
- Enhanced mobility standards
Larger Address Space

IPv4 = 32 bits

IPv6 = 128 bits

IPv4
32 bits
≈ 4,200,000,000 possible addressable nodes

IPv6
128 bits: 4 times the size in bits
≈ 3.4 * 10^38 possible addressable nodes
≈ 340,282,366,920,938,463,374,374,607,432,768,211,456

IPv6 Addressing

“preferred” form: 1080:0:FF:8:800:200C:417A
compressed form: FF01:0:0:0:0:0:0:43
becomes FF01::43
IPv4-compatible: 0:0:0:0:0:0:13.1.68.3
or ::13.1.68.3

Link-Local address
Have a limited scope of the link
Are automatically configured using MAC address

Site-Local address
Have a limited scope of the site
Contain the inside topology of the site with the subnet ID

Aggregatable Global Unicast address
Addresses for generic use of IPv6
Structured as a hierarchy to keep the aggregation
IPv6 Technology Scope

<table>
<thead>
<tr>
<th>IP Service</th>
<th>IPv4 Solution</th>
<th>IPv6 Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>32-bit, Network Address Translation</td>
<td>128-bit, NAT-PT</td>
</tr>
<tr>
<td>Addressing Range</td>
<td>DHCP, ZeroConf</td>
<td>Serverless, ZeroConf, Reconfiguration, DHCP</td>
</tr>
<tr>
<td>Autoconfiguration</td>
<td>IPSec</td>
<td>IPSec Mandated, works End-to-End</td>
</tr>
<tr>
<td>Security</td>
<td>Mobile IP</td>
<td>Mobile IP with Direct Routing</td>
</tr>
<tr>
<td>Mobility</td>
<td>Differentiated Service, Integrated Service</td>
<td>Differentiated Service, Integrated Service</td>
</tr>
<tr>
<td>Quality-of-Service</td>
<td>PIM/Multicast BGP</td>
<td>PIM/Multicast BGP, Scope Identifier</td>
</tr>
<tr>
<td>IP Multicast</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IPv6 @ Cisco Systems

- Co-chair of IETF IPv6 WG and NGtrans WG
- Well known Cisco 6Bone router
  - ~ 50 tunnels with other companies acts as 6to4 relay
  - Official Cisco IPv6 prefix registered to ARIN (2001:0420::/35)
- ‘Founding member’ of the IPv6 Forum
- Official CCO IPv6 page is [www.cisco.com/ipv6](http://www.cisco.com/ipv6)
  - Cisco IPv6 statement of direction published last June
  - Cisco IOS IPv6 EFT available for free since 3 years
  - ~Around 500 sites running worldwide
- Ready to deliver a commercial release of Cisco IOS IPv6
  - Including Cisco IOS IPv6 training and TAC support
IPv4 ARP
Finding the IP Address on the LAN

- ARP = Address Resolution Protocol
- Host and routers have pre assigned MAC addresses
- Host A sends a ARP request for router R1
- The ARP request is a broadcast packet for IPv4 Multicast IPv6
- R1 replies with ARP response unicast address
- Now both Host A and Router R1 have the IP and MAC address for each other in their ARP Table
- IPv6 is the same but ARP is multicast instead of broadcast

IPv4 Address Configuration

- IPv4 routing is enabled by default in IOS
  Can be disabled: `no ip routing`
- To configure an IPv4 address in IOS, just go to the interface and add an ip address and mask:
  ```
  RouterA#configure terminal
  RouterA(config)#interface loopback 0
  RouterA(config-if)#
  ip address 10.10.10.10 255.255.0.0
  ```
Enabling IPv6 on Cisco

- To enable IPv6 on a Cisco router, you must:
  - Enable IPv6 traffic forwarding
    ```
    ipv6 unicast-routing
    ```
  - Enable IPv6 on the interface(s) by configuring an IPv6 address on the interface
    ```
    ipv6 address <ipv6addr> [<prefix-length>]
    ```
    ```
    ipv6 enable
    ```
  - Can be used, but only for link-local addresses

Host IPv4 Address Assignment

- Can be configured
- Automatic via dynamic host configuration protocol (DHCP)
- Host broadcasts, servers respond with:
  - IP address
  - Subnet mask
  - Default router
  - DNS servers
  - Others items…
Host IPv6 Address Assignment

- Larger address space enables:
  - The use of link-layer addresses inside the address space
  - Autoconfiguration with "no collisions".
  - Offers "plug and play" + multiple addresses

How Do I Get There from Here

- Path choice is based on location
- Location is represented by an address
Discontiguous IP Subnet

Where is 172.16.0.0?

Routing Protocols Will By Default Summarize Major Networks

Variable Length Subnet Mask

Conserve IP Addresses
IPv4 Address Configuration

- IPv4 routing is enabled by default in IOS
- Just go to the interface and add an ip address and mask:

  ```
  RouterA# configure terminal
  RouterA(config)#interface loopback 0
  RouterA(config-if)#ip address ip-address subnet-mask
  ```

Agenda

- IPv4 Addressing Concepts
- IPv6 Addressing Concepts
- Generic Routing Concepts
- Specific Routing Protocols
- Static and Defaults Routes
Convergence

- Time required for router to identify and use an alternate path
- Dependent on timer values and algorithm
- Difficult to predict precisely

Load Balancing

- Equal cost paths
- Rapid failover
- For further details look to ST301
Load Balancing

- Unequal cost load balancing: EIGRP

Holddown

- Sets minimum convergence time
- Prevents forwarding loops

I Will Ignore Routes to X While in Holddown
Forwarding Loop: A Routing Disagreement

- Packets do not get to the destination
- Temporary traffic surge until convergence

Split Horizon

Do not send routing data back in the direction from which it came
Split Horizon

Frame Relay Multipoint Network

Router 2, 3, 4 All Advertise Their Respective Ethernets to Router 1, Router 1 Knows All Networks

Split Horizon

Frame Relay Network

Router 1 Advertises Network D to Routers 2, 3, 4

Router 1 Knows All Networks but Will Only Advertise D out of S0 Because it Learned A, B, C from S0
Metrics (Cost)

- Numeric value used to choose among paths
- RIP/RIPv2 is hop count
- OSPF/ISIS is interface cost (bandwidth)
- (E)IGRP is compound
- BGP can be complicated
- Path determination depends on metric

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Routing Protocols

- No neighbor state protocol, RIP, IGRP
- Neighbor state protocols EIGRP, OSPF, BGP, ISIS
- Each routing protocol offers features that can make it desirable as part of an internetwork design

Routing Protocol Goals

- Optimal path selection
- Loop-free routing
- Fast convergence
- Limited design administration
- Minimize update traffic
- Handle address limitations
- Support hierarchical topology
- Incorporate rapid convergence
- Easy to configure
- Adapts to changes easily and quickly
- Does not create a lot of traffic
- Scales to a large size
- Compatible with existing hosts and routers
- Supports variable length subnet masks and discontiguous subnets
- Supports policy routing
IP RIP

- Routing information protocol
- Widely available
- Hop count metric
- Periodic update
- Easy to implement
- One of the first available
- RFC 1058
  - Simple = limited
  - Slow convergence
  - No VLSM
  - No discontiguous subnets
  - Max 15 Hops

RIP—Distance Vector

Send RIP Routing Table to Neighbors
Broadcast Routing Updates

All Stations Have to Listen to Rip Broadcast’s

RIP V1

S 10.1.1.1 D 255.255.255.255

RIP Metric

Hops

Path A

R2

3 Hops

T1

T1

R1

56k

R3

Path B

2 Hops

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Presentation_ID.scr
RIPv2

- RFC 1723
- Advertises masks
- Variable length subnet masks
- Route summarization
- Routing updates use multicast
- Authenticated updates using MD5
- RFC 2080 RIPng for IPv6 in IOS 12.2(1)T

Multicast Routing Updates

S 10.1.1.1  D 224.0.0.9  RIP V2  Multicast
When to Use RIPv2

- Subnet mask support
- Reduce broadcast load
- Validated updates
- Multivendor environment
- Be very sure network will stay small

IGRP

- Interior Gateway Routing Protocol
- Cisco developed
- Distance vector
- Compound metric
- Cisco IOS 9.21
- Periodic update
- No VLSM
- Default timers produce slow convergence
IGRP Compound Metric

- Bandwidth
- Delay
- Reliability
- Load
- MTU

\[
\text{Metric} = ((K_1 \times \text{BW} + \frac{K_2 \times \text{BW}}{256-\text{load}} + K_3 \times \text{delay})) \times \frac{K_5}{\text{reliability} + K_4})
\]

How the IGRP Metrics Work

- Bandwidth dominates short paths
- Delay dominates long paths
- Configure bandwidth on all interfaces
Enhanced IGRP

- Extremely fast convergence
- VLSM support
- Discontiguous subnets
- Arbitrary route summarization
- Supports prefix and host routing
- Best of DV and LS
- Low overhead
- Guaranteed loop-free
- Reliable, incremental update-based
- Multiprotocol: IP, IPX®, AppleTalk
- Easy to configure

Advanced Distance Vector

- Construct neighbor tables
- Construct topology tables
- Compute routes

On Startup Routing Tables Are Exchanged; Routing Table Built Based on Best Paths from Topology Table
**EIGRP Tables**

- Topology table
- Acted upon by DUAL
- All routes advertised by neighbors
- List of neighbors for each route
- Routes passive or active
- Neighbor table
- Keeps adjacent neighbor’s address
- Keeps the hold time
- Information for reliable transport

**Diffusing Update Algorithm (DUAL)**

- DUAL is a loop-free routing algorithm that performs a diffused computation of a routing table
  - Uses a new routing algorithm
  - Achieves fast convergence
  - Network changes propagate only to affected nodes (“bounded updates”)
- No need for route holddown
When to Use EIGRP

- Very large, complex networks
- VLSM
- For fast convergence
- Less constrained network design
- Multiprotocol support

Link State Routing

- Topology Information Is Kept in a Database Separate from the Forwarding Table
- OSPF
- IS-IS
Link State Routing

- Neighbor discovery
- Constructing an LSA (Link State Advertisement)
- Distribute LSA
- Compute routes using SPF (Shortest Path First)
- On network failure
  - New LSAs flooded
  - All routers recompute link state databases

OSPF

- Open Shortest Path First
- Link state or SPF technology
- Developed by OSPF working group of IETF (RFC 2178)
- Designed expressly for TCP/IP Internet environment
- Fast convergence
- Variable-length subnet masks
- Discontiguous subnets
- No periodic updates
- Route authentication
- RFC 2740 OSPF for IPv6
OSPF Areas and Rules

• Backbone area (0) must be present
• All other areas must have connection to backbone
• Backbone must be contiguous
• Do not partition area (0)

When to Use OSPF

• Large hierarchical networks
• Complex networks, except...
  • Topology restrictive
  • Additional network design
• VLSM
• Fast convergence
• Multivendor
IS-IS

- IS = Intermediate System
- Dual IS-IS
- Integrated IS-IS
- Metric can be 8 or 10 bits wide
- All interfaces default to 10
- ISO 10589
- Two types of areas:
  - Level 1 other areas
  - Level 2 backbone
- Default for each level
- Much like OSPF

BGP

- RFC 1771
- Border Gateway Protocol
- Exterior routing protocol (vs. interior)
- Uses TCP for transport
- Many options for policy enforcement
- Classless Inter Domain Routing (CIDR)
- Widely used for Internet backbone
- AS=Autonomous Systems
- IPv6 RFC 2858 and 2545 in IOS 12.2(1)T
BGP Basics

- Runs over TCP
- Path vector protocol
- Incremental update

Internal BGP (IBGP) Peering

- BGP peer within the same AS
- Not required to be directly connected
- IBGP neighbors should be fully meshed
- Few BGP speakers in corporate network
External BGP (EBGP) Peering

- Between BGP speakers in different AS
- Should be directly connected
- Don’t run an IGP between EBGP peers

Policy Drives BGP Requirements

- Policy for AS 100: Always use AS 300 path to reach AS 400
- Designed for traffic engineering
When Not to Use BGP

- Avoid BGP configuration by using default networks and static routes
  Appropriate when the local policy is the same as the ISP policy

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Static Routes

- Routes configured manually
- Useful when few or just one route exist
- Can be administrative burden
- Frequently used for default route

IP Forwarding from the Routers Perspective

- Two routing tables
  - RIP routing table
  - OSPF routing table
- Both routing tables are combined to form only one forwarding table
- This is what you see when you type “show ip route”
- Caching techniques are used to speed up the router forwarding
- There can be one of many
- Speedup or caching techniques
  - Fast Cache
  - CEF
  - Netflow
  - Optimum
### Forwarding Table

**One Forwarding Table per Router**

**One Routing Table per Routing Protocol**

<table>
<thead>
<tr>
<th>Network #</th>
<th>Interface</th>
<th>Next Hop</th>
<th>Metric</th>
<th>Age</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>198.113.181.0</td>
<td>Ethernet0</td>
<td>192.150.42.177</td>
<td>[170/304793]</td>
<td>02:03:50</td>
<td>D</td>
</tr>
<tr>
<td>198.113.178.0</td>
<td>Ethernet0</td>
<td>192.150.42.177</td>
<td>[110/9936]</td>
<td>02:03:50</td>
<td>O</td>
</tr>
<tr>
<td>192.168.96.0</td>
<td>Ethernet0</td>
<td>192.150.42.177</td>
<td>[120/3]</td>
<td>00:00:20</td>
<td>R</td>
</tr>
<tr>
<td>192.168.97.0</td>
<td>Ethernet0</td>
<td>192.150.42.177</td>
<td></td>
<td></td>
<td>C</td>
</tr>
</tbody>
</table>

### Building the Forwarding Table

- **Directly connected**
  - Routes that the router is attached to
- **Static**
  - Routes are manually defined
- **Dynamic**
  - Routes protocol are learned from a protocol
**Administrative Distance**

- The router treats different route sources with a different preference

<table>
<thead>
<tr>
<th>Route Source</th>
<th>Default Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connected Interface</td>
<td>0</td>
</tr>
<tr>
<td>Static Route</td>
<td>1</td>
</tr>
<tr>
<td>Enhanced IGRP Summary Route</td>
<td>5</td>
</tr>
<tr>
<td>External BGP</td>
<td>20</td>
</tr>
<tr>
<td>Internal Enhanced IGRP</td>
<td>90</td>
</tr>
<tr>
<td>IGRP</td>
<td>100</td>
</tr>
<tr>
<td>OSPF</td>
<td>110</td>
</tr>
<tr>
<td>IS-IS</td>
<td>115</td>
</tr>
<tr>
<td>RIP</td>
<td>120</td>
</tr>
<tr>
<td>EGP</td>
<td>140</td>
</tr>
<tr>
<td>External Enhanced IGRP</td>
<td>170</td>
</tr>
<tr>
<td>Internal BGP</td>
<td>200</td>
</tr>
<tr>
<td>Unknown, Discard Route</td>
<td>255</td>
</tr>
</tbody>
</table>

**Floating Static Routes**

- A static route with a high distance
- Can be overridden by dynamic info

```
ip route 172.16.1.0 255.255.255.0 172.16.4.1
ip route 172.16.1.0 255.255.255.0 172.16.3.1 140
```
Default Routes

- Route used if no match is found in forwarding table
- Can be carried by routing protocols
- Two models
  - Special network number: 0.0.0.0/0
    - Flagged in routing protocol
- Protocols support multiple models

Creating a Default Route

- RIP, RIPv2: network 0.0.0.0
- IGRP, EIGRP: ip default-network
- OSPF, ISIS default originate
- default gateway is for “host mode”
- Use of network 0.0.0.0 preferred
**Default IP Subnet**

- Two defaults
  - For unknown networks
  - For unknown subnets
- Controlled by `ip classless`

**Comparison of Routing Protocols**

<table>
<thead>
<tr>
<th>Scalability</th>
<th>Link State</th>
<th>Traditional Distance Vector</th>
<th>Advanced Distance Vector</th>
<th>Path Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>Excellent Low</td>
<td>Low High</td>
<td>Excellent Low</td>
<td>Outstanding Low</td>
</tr>
<tr>
<td>Memory</td>
<td>High High</td>
<td>Low Low</td>
<td>Moderate Low</td>
<td>High Moderate</td>
</tr>
<tr>
<td>CPU</td>
<td>Fast Moderate</td>
<td>Slow Easy</td>
<td>Fast Easy</td>
<td>Moderate Moderate</td>
</tr>
<tr>
<td>Convergence Configuration</td>
<td>Fast Moderate</td>
<td>Slow Easy</td>
<td>Fast Easy</td>
<td>Moderate Moderate</td>
</tr>
</tbody>
</table>
Internet Routing Protocols

- IP routing protocols are characterized as

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Proprietary</th>
<th>Function</th>
<th>Updates</th>
<th>Metric</th>
<th>VLSM</th>
<th>Summ</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIP</td>
<td>DV</td>
<td>No</td>
<td>Interior</td>
<td>30 Sec</td>
<td>Hops</td>
<td>No</td>
<td>Auto</td>
</tr>
<tr>
<td>RIPv2</td>
<td>DV</td>
<td>No</td>
<td>Interior</td>
<td>30 Sec</td>
<td>Hops</td>
<td>Yes</td>
<td>Auto</td>
</tr>
<tr>
<td>IGRP</td>
<td>DV</td>
<td>Yes</td>
<td>Interior</td>
<td>90 Sec</td>
<td>Comp</td>
<td>No</td>
<td>Auto</td>
</tr>
<tr>
<td>EIGRP</td>
<td>Adv DV</td>
<td>Yes</td>
<td>Interior</td>
<td>Trig</td>
<td>Comp</td>
<td>Yes</td>
<td>Both</td>
</tr>
<tr>
<td>OSPF</td>
<td>LS</td>
<td>No</td>
<td>Interior</td>
<td>Trig</td>
<td>Cost</td>
<td>Yes</td>
<td>Man</td>
</tr>
<tr>
<td>IS-IS</td>
<td>LS</td>
<td>No</td>
<td>Interior</td>
<td>Trig</td>
<td>Cost</td>
<td>Yes</td>
<td>Auto</td>
</tr>
<tr>
<td>BGP</td>
<td>Path Vec</td>
<td>No</td>
<td>Exterior</td>
<td>Incr</td>
<td>N/A</td>
<td>Yes</td>
<td>Auto</td>
</tr>
</tbody>
</table>

Topology/Technology Considerations

- Routing and services overhead is usually not a big deal when you have a lot of bandwidth (i.e. LANs)
- Protect WAN bandwidth using update-based protocols—more bandwidth and buffers for application traffic
- High densities of sub (interfaces) can cause “hot spots” and router CPU overload
- NBMA (Non-Broadcast Multi-Access) technologies always require good design practices
For Further Reference...

- **EIGRP Network Design Solutions**
  by Ivan Pepelnjak, (ISBN: 1578701651)

- **Interconnections: Bridges and Routers**
  by Radia Perlman (ISBN: 0-20156-332-0)

- **Internetworking with TCP/IP, Volume 1: Principles, Protocols, and Architecture**

- **IP Routing Fundamentals**
  by Mark Sportack (ISBN: 1-57870-071-x)

- **IP Routing Primer**

- **OSPF Network Design Solutions**

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For Further Reference...

- **Routing in the Internet**

- **OSPF Network Design Solutions**

- **ISP Survival Guide: Strategies for Running a Competitive ISP**
  by Geoff Huston (ISBN: 0-47131-499-4)

- **Internet Routing Architectures**
Thank You

- Related sessions:
  RST-103 Introduction to Link State Protocols
  RST-111 Introduction to BGP
  RST-205 Deploying IPv6
  RST-209 Deploying IGRP/EIGRP
  RSY-207 Deploying OSPF
  RST-210 Deploying BGP4

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Session RST-102
Please Complete Your Evaluation Form

Session RST-102