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CLASSFUL/CLASSLESS NETWORK ADDRESSING

Classful Network Addressing: Released 1981: RFC 790|RFC 791: **How IPv4 allocated**
- Established to provide 3 different sized networks: Large | Medium | Small
- Class A | B | C : Defined w/specific format for high order bits

High order bits: Far left bits in 32-bit addresses

Class A	○ Starts at 0 ○ Large organizations ○ All addresses from 0.0.0.0 – 127.255.255.255 [00000000 – 01111111] ○ 0.0.0.0 Default routing | 127.0.0.0 Loopback testing
Class B	○ Starts at 10 ○ Medium-to-large organizations ○ All addresses from 128.0.0.0 – 191.255.255.255 [10000000 – 10111111]
Class C	○ Starts at 110 ○ Small-to-medium organizations ○ All addresses from 192.0.0.0 – 223.255.255.255 [11000000 – 11011111]
Class D	○ Start at 1110 ○ Reserved for multicasting/future use ○ Multicast addresses: ID group of hosts part of multicast group ○ Helps reduce amt of packet processing done by hosts: Particularly broadcast media (Ethernet LANs) ○ RIPv2/EIGRP/OSPF designated multicast addresses ▪ RIP 224.0.0.9 | EIGRP 224.0.0.10 | OSPF 224.0.0.5/224.0.0.6
Class E	○ Start at 1111 ○ Reserved for experimental/future use

Classful subnet masks: Specified in RFC 790: Each network class has default subnet mask associated w/it

Class A	○ 1st octet to ID network portion of address | 255.0.0.0 classful subnet mask ○ Only 7 bits left in 1st octet (1st bit is always 0): 2^7/128 networks ○ 126 networks | 2 reserved addresses | 0.0.0.0/8 and 127.0.0.0/8 ▪ 24 bits in host: Each address: Potential for 16million individual host addresses
Class B	○ 1st 2 octets to ID network portion of address ○ 1st 2 bits established as 1/0: 14 bits remained in 1st 2 octets for assigning networks ○ 16,384 class B network addresses ○ B/c each class B contained 16 bits in host portion: 65,534 addresses ▪ 2 addresses reserved for network/broadcast
Class C	○ 1st 3 octets to ID network portion of network address ○ 1st 3 bits established as 1/1/0: 21 bits remained for assigning networks ○ Over 2 million networks ○ Each network only had 8 bits in host portion: 254 possible host addresses

Advantage of assigning specific default subnet masks to each class? Made routing update messages smaller
- Classful routing protocols: Don't include subnet mask info in updates
- Receiving router applies default mask based on value of 1st octet which ID's class

Routing Example

- Routing protocols [RIPv1] only need to propagate network address of known routes/don't need subnet mask in r-update
- Due to router receiving r-update determining subnet mask: Examines value of 1st octet in network address
- Or by applying its ingress int mask for subnetted routes: Subnet mask was directly related to network address

Waste

Classful addressing specified in RFCs 790|791 resulted in huge waste of address space

- In old days: Organizations assigned entire classful network address from A/B/C

Class A	○ 50% of address space ○ 126 organizations assigned class A network address ○ Each could provide addresses for up to 16 million hosts ○ Very large organizations allocated entire address blocks ○ Some companies/gov't orgs still have them ▪ Example: GE owns 3.0.0.0/8 | Apple owns 17.0.0.0/8 | USPS owns 56.0.0.0/8
Class B	○ 25% of address space ○ 16,384 orgs could be assigned class B/each could support up to 65,534 hosts ○ Only largest orgs/gov'ts could use all addresses ○ Like class A, many IP's in class B space were wasted
Class C	○ 12.5% of address space ○ Many were able to get class C: Limited in number of hosts they could connect ○ Often too small for most midsize orgs
Classes D/E	○ Used for multicasting and reserved addresses.

Overall result? Wasteful addressing scheme: Better solution had to be developed

Classless Inter-Domain Routing (CIDR): Introduced 1993

Internet grew in early 90s: So did size of r-tables maintained by Internet routers under classful

- IETF introduced CIDR in RFC 1517
- **CIDR** replaced classful/address classes (A/B/C)
- **CIDR:** Network address no longer determined by value of 1st octet
- Network portion determined by subnet mask (AKA network prefix/prefix length) | /8 /19 etc…

ISPs no longer limited to /8, /16, or /24 subnet mask: Efficiently allocate space using any prefix length starting with /8+

CIDR reduces r-table size/manages IPv4 space better using:

Route summarization	○ AKA prefix aggregation ○ Routes summarized into single route to reduce size of tables ▪ Example: 1 summary static route can replace 7 specific static route statements
Supernetting	○ When route summarization mask is a smaller value than default traditional classful mask ○ Supernet = always route summary | Route summary? Not always supernet

CIDR and Route Summarization Supernet summarizes multiple network addresses w/mask smaller than classful mask

Determine summary route/mask for group of networks	1. List networks in binary fmt 2. Count # of far left matching bits: ID's prefix length/subnet mask for summarized route 3. Copy matching bits/add 0 bits to rest of address to determine summarized network address ○ Can be config by both static routes/classless routing protocols

Static Routing CIDR Example

- Smaller r-tables makes lookup process better: Fewer routes to search
- If 1 static route can be used instead of multiple static routes: Size of table reduced
- A single static route can be used to represent dozens/hundreds/thousands of routes

Classless Routing Protocol

- Classful r-protocols can't send supernet routes
- Why? B/c receiving router auto applies default classful mask to network address in r-update
- Propagating VLSM/supernet routes requires classless routing protocol (RIPv2/OSPF/EIGRP)
- Classless r-protocols advertise network addresses w/associated masks
- When supernet route is in r-table (ex: static route) a classful r-protocol doesn't include that route in updates

Fixed-Length Subnet Masking (FLSM)	○ Same number of addresses allocated for each subnet ○ If all subnets have same requirements for # of hosts: ▪ Fixed size add blocks would be sufficient ○ AKA Traditional subnetting ○ Same mask applied all subnets: Creates subnets of equal size
Variable-Length Subnet Masking (VLSM)	○ Designed to avoid waste ○ Mask length varies on how many bits borrowed for particular subnet: "Variable" ○ Allows network space to be divided into unequal parts ○ VLSM subnetting similar to traditional subnetting ▪ Bits borrowed to create subnets ○ Formulas to calc # of hosts per subnet/# of subnets created still apply ○ Network is 1st subnetted: Then the subnets are subnetted again ▪ Process can be repeated multiple times to create subnets of various sizes

VLSM in Action: Allows use of different masks for each subnet: Subnetting a subnet or sub-subnetting

Route Summarization

Route summarization	AKA route aggregation ○ Advertising contiguous set of addresses as single address w/less-specific, shorter subnet mask ○ CIDR: A form of route summarization/synonymous w/term supernetting
CIDR	○ Ignores limitation of classful boundaries ○ Allows summarization w/masks smaller than default classful mask ○ Summarization helps reduce # of entries in r-updates/lowers # of entries in local r-tables ○ Helps reduce BW/faster r-table lookups

Calculate Summary Route: Summarizing networks into single address/mask:

1. List networks in binary format
2. Count # of far-left matching bits to determine mask for summary route
3. Copy matching bits/then add 0 bits to determine summarized network address

Summarize IPv6 Network Addresses: 128 bits long/in hex: Similar to IPv4: Requires extra steps due to abbr IPv6 /hex conversion

Multiple static IPv6 routes can be summarized into single static IPv6 if:

- Destination networks contiguous/can be summarized into single network address
- Multiple static routes all use same exit int/next-hop IPv6

Summarize IPv6 networks into single prefix/prefix-length:

1. List network addresses (prefixes)/ID part where addresses differ
2. Expand IPv6 if abbreviated
3. Convert differing section from hex to binary
4. Count # of far left matching bits to determine prefix-length for the summary route
    1. Can also convert lowest/highest network addresses to binary to find matching bits
5. Copy matching bits/add 0 bits to determine summarized network address (prefix)
6. Convert binary section back to hex
7. Append prefix of summary route

Floating Static Routes: Static routes that have an AD greater than AD of another static/dynamic route

- Good for providing backup link: Default: AD of 1: Preferable to routes learned from dynamic r-protocols

AD of common dynamic r-protocols

EIGRP	90
IGRP	100
OSPF	110
IS-IS	115
RIP	**120**

AD of static route can be increased to make route less desirable than other static/dynamic route

- "Floats": Unused when route w/better AD active: If preferred lost: floating can take over
- Encapsulation independent: Can be used to fwd packets out any int regardless of encapsulation type
- Affected by convergence time

Troubleshoot Missing Route

Problems	○ int fails/service provider drops connection/links oversaturated ○ wrong config/change in network
IOS troubleshooting	ping/traceroute show ip route show ip int br show cdp neighbors detail