Summary of the Internet Protocol (v4, v6), Mobile IP (v4, v6), ICMP, IGMP and Subnetting Fundamentals

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Interaction Goals

- Introduction to the Internet Protocol
- IP, ICMP and IGMP (v4)
- Mobile IP (v4)
- IPv6, ICMPv6
- Mobile IPv6
- Recommended Readings

Internet Protocol (IP): What is it?

- IP **stands for the Internet Protocol**. It works at the Internet Layer (the OSI network layer equivalent) in the TCP / IP stack.
- IP **has two prominent** versions: **the** IPv4 (**which was designed in keeping with the technologies of the early Seventies) and the** IPv6 **(which is the latest version).**
- The IPv6 **does away with some features of the** IPv4 **while adds many new features**.
- One **basic advantage of the new version is the enlarged address space (adequate for a reasonably long time)**.

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Major Goals of the IPv4 Design:

- Simplification of the Network Layer functionality across an internetwork.
- Reduction in the packet processing time at the routers compared to its earlier version.
- Providing support for an acceptable scheme of addresses.
- Reduction in **the size of** Routing Tables.

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IPv4: The Header Structure

0 31

Ver.	IHL	Type of Service	Total Length
Identification	Flags	Fragment Offset	
TTL	Protocol Type	Header Checksum	
Source Address (32-bit)			
Destination Address (32-bit)			
Options+Padding			

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IPv4: The Header Structure

0 … 31

Ver. 4-bit	IHL 4-bit	Type of Service 8-bit	Total Length 16-bit
Identification 16-bit		Flags 3-bit	Fragment Offset 13-bit
TTL 8-bit	Protocol Type 8-bit	Header Checksum 16-bit	
Source Address 32-bit			
Destination Address 32-bit			
Options + Padding			

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IPv6: The Header Structure

0 4 16 31

Ver. (4-bit)	TClass (8-bit)	Flow Label (20-bit)
Payload Length (16-bit)	Next Header (8-bit)	Hop Limit (8-bit)
Source Address (128-bit)		
Destination Address (128-bit)		

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IPv4 Options:

- Security Option
- Strict Source Routing Option
- Loose Source Routing Option
- Record Route Option
- Timestamp Option

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IPv4 and the World of Classes:

- In the IPv4, any address is 32-bit long and is represented in four parts of one byte each separated by decimal points or dots.
- There exist two ways of looking at the IPv4 world:
  - Class-based view (A, B, C, D, E)
  - Classless view
- The 32-bit address comprises of two parts:
  - Network address / identifier
  - Host address / identifier

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IPv4 and the World of Classes ...

- In the class-based / classfull version, the classes are designated based on the first few bits of the Network Address portion of the IP address.
- For instance:
  - If the first bit in this field is 0 (zero), it is referred to as a Class-A IP address.
  - If the first two bits in this field are 10 , it is referred to as a Class-B IP address.
  - If the first three bits in this field are 110 , it is referred to as a Class-C IP address.

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IPv4 and the World of Classes ...

- In Class-A address, the first byte constitutes the Network Address and remaining three bytes constitute Host Addresses.
- In Class-B address, the first two bytes constitute the Network Address and the remaining two bytes constitute Host Addresses.
- In Class-C address, the first three bytes constitute the Network Address and the remaining byte represents the Host Addresses.

IPv4 and the World of Classes ...

- Example of a Class-A address:

  12.0.0.3

  Here, 12 is the Network Address whereas 3 is the Host Address.

  (Technically, this means: Network Address is 12.0.0.0 and the Host Address is 0.0.0.3.)

- Example of a Class-B address:

  180.16.0.1

- Example of a Class-C address:

  192.12.7.8

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IPv4 and the World of Classes …

- Class-A Address Range:
  1.0.0.0 - 127.255.255.255
- Class-B Address Range:
  128.0.0.0 - 191.255.255.255
- Class-C Address Range:
  192.0.0.0 - 223.255.255.255
- Class-D Address Range:
  224.0.0.0 - 239.255.255.255
- Class-E Address Range:
  240.0.0.0 - 247.255.255.255

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Concept of Subnetting and Subnet Masks

- An IPv4 Subnetwork is often referred to mean a subset of one of the three IPv4 classes (A, B and C).
- A Subnet Mask is a sequence of bits that is used to separate Network and Host Addresses from each other. This mask divides the Address portion into another set of Network-Host Addresses.
- Types of Subnetting:
  - Fixed-Length Subnetting / Basic Subnetting
  - Variable-Length Subnetting
- Types of Masks:
  - Natural Masks
  - Extra-natural Masks

More on Masking …

- Natural Mask for Class-A: 255.0.0.0
- Natural Mask for Class-B: 255.255.0.0
- Natural Mask for Class-C: 255.255.255.0
- Why masks?
  - They help in separating network address from the host address.
  - They make subnetting possible.
  - The subnetting in turn helps in fighting the IPv4 Address Depletion problem in some limited but effective way.
  - Every LAN segment is usually associated with at least one network number (more are possible) and if no subnetting is done, only one segment can use a given network address.

More on Masking …

- <u>Variable Length Subnet Masking</u>

  In this scheme, a given network can be masked with masks of different lengths thereby providing required flexibility of having network segments as required (instead of just dividing a given network into ‘n’ number of networks of equal sizes ---- as is the case with the fixed-length subnetting).

  (All masks have a string of ‘1’s to the left and string of ‘0’s to the right.)

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The Classless Inter-Domain Routing (CIDR) in IPv4 Subnets:

<u>Primary Objective:</u>

- Finding a temporary solution to the IPv4 Address space depletion

<u>The basic idea behind the CIDR:</u>

- Allocate the unallocated set of Class-C IPv4 network addresses in variable-sized address blocks.
- These blocks, in effect, refer to contiguous Class-C IPv4 network addresses.

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The Classless Inter-Domain Routing (CIDR) ...

The RFC 1519 allocation rules for the IPv4 world:

1. The whole world was suggested to be divided into four zones each of which could use nearly 32 Million Addresses:
   - Asia-Pacific:
   - Central-Southern America
   - Europe
   - North America

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The Classless Inter-Domain Routing (CIDR) ...

<u>The RFC 1519 allocation rules for the IPv4 world ...</u>

2. A set of nearly 320000000 addresses were suggested to set aside for future use.

3. If a router 'X' get a packet that belongs to the IPv4 addresses of one these four zones, the packet is simply forwarded to the zonal gateway.

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The Classless Inter-Domain Routing (CIDR) ...

The Supernetting:

- Terms ‘Aggregation’, ‘CIDR Block allocation’, ‘Supernetting’ etc. are often used interchangeably in the IPv4-CIDR literature. **(This is however, done in casual discussion alone!)**
- In principle, ‘a network whose prefix-boundary has lesser number of bits than the natural mask of the network itself, is called a Supernet’.

Two ways to represent the same CIDR address are :

- 199.28.0.0/16
- 199.28.0.0 255.255.0.0

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The Internet Control Message Protocol (ICMP):

- During the normal operation of the Internet, many a times, errors, crashes and some other unexpected events may occur.
- The protocol, that reports these problems to the Routers is called the Internet Control Message Protocol (ICMP).

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The Internet Control Message Protocol (ICMP) ...

- Some of the common ICMP messages include:
  - Echo Request
  - Echo Reply
  - Timestamp Request
  - Timestamp Reply
  - Redirect
  - Destination Unreachable
  - Time Expired / Exceeded

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Mobile IP

- The variant of the Internet Protocol which has been specifically designed for providing support for Mobile Hosts willing to communicate over the Internet is called as the Mobile IP.
- It is the result of deliberations of a special IETF workgroup and has been described in the RFC.

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Mobile IP …

- Why the Mobile IP had to be devised?
  - The basic IP has an Addressing Scheme that comprises of Class Id., Network Number and Host Number. Therefore, any packet intended for a given Mobile Host shall have no problem as long as the MH stays on the Home LAN; since Routers all over the world can continue to use the Class plus Network Address information to route any information to it. The problem of discontinuation of service would arise as soon as soon as the MH moves out of its Home Zone; since now, the Routers would still continue to send traffic meant for this MH to the Home LAN address they have in the know of!

Mobile IP …

- Why the Mobile IP had to be devised …
  - One solution to this problem could have been assigning a new IP address to this MH once it moved away from its Home Zone. However, this is a non-solution primarily because such an assignment would require this information to be specifically sent to a large number of Routers, Databases and of course the intending communicators / collaborators, every time such a transition takes place. Given the large amount of transactions and inconvenience involved in implementing this solution and increasing number of people using the MHs, this would translate into a huge network traffic / bandwidth requirement by itself.

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Mobile IP …

- Why the Mobile IP had to be devised …
  - Yet another possible solution could have been requiring the Routers to take routing decisions on the complete IPv4 address, instead of the customary Class-Id. plus Network Address. This, again, is a non-solution since the this requirement would translate into the requirement of huge Routing Table space, which in turn would mean the unacceptably high cost of transmission over the Internet.
  - Clearly, any acceptable solution had to avoid these traps and at the same time should have provided the required mobility, along with the continuity of communication at an acceptably low cost and without forcing the existing software to undergo any major change. **And, thus the Mobile IP was born!**

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Mobile IP …

- **Goals of the Mobile IP Design:**
  - **Just because the Mobile Hosts are to be accommodated, the Stationary Hosts should not be required to make any change in their local software.**
  - **Routers, all over the world, should not be required to alter their Routing Software as well as Routing Table structures or entries merely for this purpose.**
  - **Databases and other collaborating entities should not be required to be explicitly informed of the changed Id. of the MH.**
  - **No extra cost should be required to be added to the transactions while an MH was in its home zone.**
  - **As a consequence of some of the above referred goals, an important goal of not assigning a new IP address to the MH was added to the IETF-WG list.**

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Mobile IP …

The Proposed Solution:

- Each of the site supporting Mobile IP should create an Agent called ‘Home Agent’ / ‘Home Address Agent’. This HA / HAA should be in charge of keeping track of which MHs of its home network are currently visiting a foreign network zone; and providing support services to these MHs as per need.
- Each site supporting the visiting MHs should create its own Agent called ‘Foreign Agent’ / ‘Care-of Agent’. This FA / COA should be responsible for identifying the visiting MHs, keeping their track, authenticating their credentials by communicating with the corresponding HA / HAA and providing support services as per need.

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Mobile IP …

The Proposed Solution …

- Whenever anyone sends packets for a MH that is currently visiting a foreign zone, the Router at the home zone attempts to resolve the address of the intended MH in the usual way of employing the ARP. The response to this ARP broadcast then comes from the HA / HAA, which supplies its address to the enquiring Router. A technique called Gratutious ARP (G-ARP) is used to take care of invalid cache-entry in the Router.
- Once the packet is received by the HA / HAA, it encapsulates it and passes it to the IP address of the COA / FA, who on receipt, decapsulates and sends the packet to the visiting MH.
- This is immediately followed by sending the IP address of the current COA / FA to the original sender, so that any subsequent communication could use this new address thereafter.

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The Address Resolution Protocol (ARP):

- All computers in the IP world must be associated with one IP address or the other.
- For the purpose of actual delivery of a packet, the packet has to be sent through the Host-to-Network layer which means, for actual transmission the association of a given IP address to the lower layer address (say an Ethernet Adapter address / MAC Sub-layer Address) is required.
- The protocol that permits a machine holding an IP address to enquire about this lower layer address is called the ‘Address Resolution Protocol’ (ARP).

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The Reverse Address Resolution Protocol (RARP):

- As indicated earlier, all computers in the IP world must be associated with at least one IP address that is associated with a MAC Sub-Layer address for the purpose of communication; therefore, a machine that knows just its Mac address will need to learn / discover about the associated IP Address as well.
- The protocol that permits a machine holding its lower layer address (say its Ethernet Address) to enquire about its associated IP address is called the 'Reverse Address Resolution Protocol' (RARP).

What is different in IPv4 and IPv6?

1. Options were replaced by Extension Headers.
2. IPv6 has a Flow Label field in its header primarily meant for supporting the real-time applications.
3. The Total Length field of IPv4 was replaced with the Payload Length field.
4. The Protocol Type field of the IPv4 was replaced with the Next Header Type field.
5. The Time-To-Live field of the IPv4 was replaced with the Hop Limit field .

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IPv6 Versus IPv4 ...

6. Autoconfiguration capability supported for the first time.

7. Built-in provisions for security made available for the first time explicitly.

8. Support for Jumbograms has been added.

9. Both permit Fragmentation, but the IPv6 format keeps it in an extension header specifically meant for the job unlike the IPv4 format in which this information was to be maintained in a fixed field within the IP header.

10. The Service Type field has been replaced by the) Flow Label field.

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IPv6 Versus IPv4 ...

11. The IPv6 header has no Header Checksum field.
12. In IPv4, there were five address classes (A to C of Network / Host combination types, D for Multicasting and E reserved for future use). In IPv6, the IPv4 Classes have been replaced with Types.
13. Unlike the IPv4, that permits a two-level hierarchy of network and host prefixes, the IPv6 proposes to offer multi-level hierarchy or even multiple hierarchies of prefixes. In IPv6, the first byte of the address refers to the type of address.

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Recommended Readings:

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- A. S. Tanenbaum: Computer Networks, Fourth Edition, PHI, 1996.
- C. Huitema: IPv6, Second Edition, Prentice-Hall PTR, 1998.
- U. D. Black: Computer Networks, Second Edition, PHI, 1993.
- D. Bertsekas and R. Gallager: Computer Networks, Second Edition, PHI, 1992.
- G. R. McClain (Ed.): Handbook of Networking and Connectivity, AP Professional (Academic Press), 1994.

Recommended Readings ...

- RFC 1009 (Requirements for Internet Gateways)
- RFC 1254 (Gateway Congestion Control)
- RFC 1360 (Official Protocol Standards of the Internet Architecture Board)
- RFC 1124 (Policy Issues in Interconnecting Networks)
- RFC 1125 (Policy Requirements for Inter-Administrative Domain Routing)
- RFC 781 (IP Timestamp)
- RFC 791 (IP)
- RFC 815 (IP Datagram Reassembly)
- RFC 1042 (IP over IEEE 802.3)
- RFC 1011 (Official IP)

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Recommended Readings ...

- RFC 1883 (IPv6 Specification)
- RFC 1825 (IP Security Architecture)
- RFC 1826 (IP Authentication Header)
- RFC 1827 (IP Encapsulation Security Payload)
- RFC 1828 (IP Authentication using MD5)
- RFC 1175 (FYI : A very useful reference-list on Internetworking related information)
- RFC 1208 (Glossary of Networking Terms)
- Smoot Carl-Mitchell & John S. Quarterman: Practical Internetworking with TCP / IP and UNIX, Addison-Wesley, Reading, 1993. (This book does not really discuss the IPv6. This however, helps the reader to take a look at the pre-IPv6 days and realize the wisdom of evolution of the IP.)

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Recommended Readings …

- Larry Hughes: Introduction to Data Communication: A Practical Approach, Narosa Publishers, 1997.
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- W. Buchanan: Advanced Data Communication and Networks, Chapman & Hall, London, 1997.
- Uyless D. Black: TCP / IP & Related Protocols, Second Edition, McGraw-Hill, N. Y., 1995.
- RFC 1519 (CIDR)
- RFC 1997 (BGP community attribute)
- Bassam Hallabi: Internet Routing Architectures, Cisco Press, New Riders Publishing, 1997.
- RFC 904 (Exterior Gateway Protocol)

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