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School of Applied Sciences (B.Sc. In Computing)

COMP 225: Network and System Administration
Notes #7: Internet Protocol

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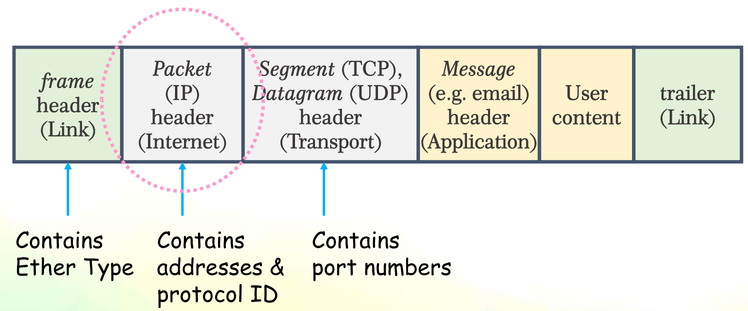
To Cover

- Internet Protocol (IP) naming and addressing
- Format and basic operations
- Address resolution
- IP packet control

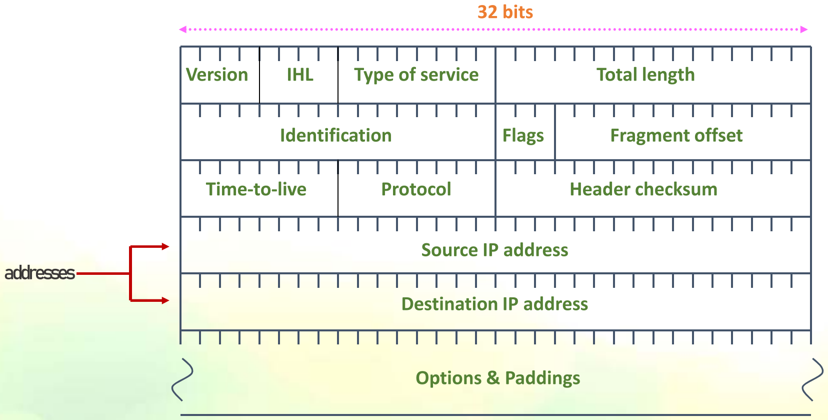
The Internet Layer

- Basic functions: addressing, routing with sub-networks resolution and forwarding!!
- Traditionally
  - Connectionless
  - Serving best effort traffic: unreliable, and no performance guarantees
- Today, in addition to best effect traffic
  - Traffic type classification
  - QoS routing

A Typical Structure of a Transmitting Frame



IPv4 Header Format



IP Address

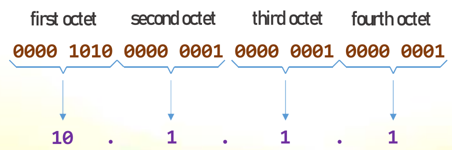
- An network ID reveals the location of an entity on the Internet, and routers know how to route a packet there
- Should be unique to identify each end host
- For host-to-host connections:
  - 32-bit IPv4 addresses: 4,294,967,296 or 2^{32} (about 4 trillion) # of addresses
  - 128-bit IPv6 addresses: 340,282,366,920,938,463,463,374,607,431,768,211,456 or 2^{128} (about 340 undecillion) # of addresses

IP Address Assignment

- The Internet Assigned Number Authority (IANA)
  - Assigns IPv4 addresses to the five Regional Internet Registries (RIRs) in /8 address blocks; IANA is also responsible for allocating IPv6 address space to RIRs
- Five RIRs are
  - African Network Information Centre (AFRINIC): Africa
  - American Registry for Internet Numbers (ARIN): United States, Canada, some parts of the Caribbean region, and Antarctica
  - Asia-Pacific Network Information Centre (APNIC): Asia, Australia, New Zealand, and neighboring countries
  - Latin America and Caribbean Network Information Centre (LACNIC): Central America, South America, and most of the Caribbean region
  - Réseaux IP Européens (RIPE) Network Coordination Centre: Europe, the Middle East, and Central Asia

IPv4

- Starting from IPv4 – since early 1980s
- Latest version: IETF RFC 791, Sept. 1981
- 32-bit address space represented in dotted-decimal notation
- Dotted decimal notation: *x.y.z.n*
  - where $x, y, z, n \in \{0,..,255\}$
  - e.g. 128.100.10.2



Address Classes (IPv4)

- Initially and historically, IPv4 address was classified into two parts
  - Network address and host address
- There were 5 classes, and only unicast classes *A* to *C* are mostly used

	1st octet	2nd octet	3rd octet	4th octet
Class A	0 network	host address		
Class B	1 0 network address		host address	
Class C	1 1 0 network address			host
Class D	1 1 1 0 multicast address			
Class E	1 1 1 1 reserved for experiments			

How to Identify the Network Address?

- Define the network mask (netmask)
  - Also 32-bit in size, only use 1's or 0's
  - Network address = incoming IP address & netmask

Bit-wise AND

					In dotted-decimal notation
An IPv4 address	0000 1010	0000 0001	0000 0001	0000 0001	10.1.1.1
Corresponding netmask	1111 1111	0000 0000	0000 0000	0000 0000	255.0.0.0
&	0000 1010	0000 0000	0000 0000	0000 0000	
	10 .	0 .	0 .	0	

- Result: 10.0.0.0 – class A address

How to Determine Netmask?

- The initial few bits of the first octet of the incoming IP packet determines both the network address and netmask

Class		Size of Network Address	Netmask
A	1st bit = 0	8-bit	255.0.0.0
B	1st two bits = 10	16-bit	255.255.0.0
C	1st three bits = 110	24-bit	255.255.255.0

- The first octet of class A address is from 0000 0000 to 0111 1111
- If in decimal numbers, from 0 to 127

Then

- Class A (**0**.x.x.x to **127**.x.x.x)
  - Network mask **255.0.0.0** (the leftmost 8 bits are network address)
  - 16,777,124 hosts for each class A network
- Class B (**128**.x.x.x to **191**.x.x.x)
  - Network mask **255.255.0.0**
  - 65,534 hosts for each class B network
- Class C (**192**.x.x.x to **223**.x.x.x)
  - Network mask **255.255.255.0**
  - 254 hosts for each class C network
- Remarks: class D (**224**.x.x.x to **239**.x.x.x) for multicast; class E not used... :_(

2 fewer hosts, why? Explain later...

Problems with Classful Designs

In fact, all IPv4 addresses exhausted around 2011

- Difficult to find one organization which needs a class A address (more than 16 million hosts)
- Even for one class B network address, how often we can find a company using up to 60,000 host computers
- Problems:
  - ⇒ Inflexible for different network sizes
  - ⇒ ***Concept of subnets*** created for handling smaller network sizes
- Moreover, IP address exhausted rapidly if giving out one class A network address easily

In fact, all IPv4 addresses exhausted around 2011

Subnetting – Resizing a Network

- Example: If a service provider has a class B network to give, e.g., 136.28.0.0 with netmask 255.255.0.0. Then a company *X* requests only 8 IP host addresses, then what can service provider do?
- Normally, 3 bits are enough for 8 addresses, but IPv4 addressing has two special address designs
  - One for network address
  - One for broadcast address in the network

  2 fewer hosts, why? Explain later...
- Hence, the provider gives out 136.28.1.0 with **subnet mask 255.255.255.240**, this is a class B address but the network size is smaller than a class C address

Subnetting (cont'd)

- Netmask no longer based on class A, B or C
- E.g., 255.255.255.240 ≡ 1111 1111 . 1111 1111 . 1111 1111 . 1111 0000, there are 28 one's, a simpler notation is

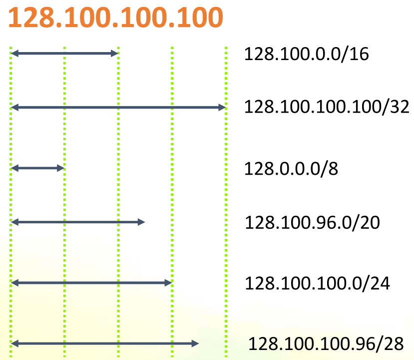
  network address / size of netmask
- Hence, the last example is 136.28.1.0/28

2 Fewer Host Addresses

- For the last example, we call this network 136.28.1.0/28
  - There are 4 bits for the host address, but
  - The 136.28.1.0 is the **network name** (the network address) – should not be assigned to any host
  - For broadcasting, all bits for host address are set to 1's, i.e., 136.28.1.15 is the **broadcast address** – cannot be assigned to any host
- Therefore, given *n* bits for host addresses, we have $(2^n - 2)$ for host address assignments
  - If *n* = 8, we have 254 host addresses

Summary on IPv4 Addressing

- Natural class B network
  mask 255.255.0.0
- Host address
  mask 255.255.255.255
- Supernetted range of Class B's
  mask 255.0.0.0
- Class B with 4 bits subnetting
  mask 255.255.240.0
- Class B with 8 bits subnetting
  mask 255.255.255.0
- Class B with 12 bits subnetting
  mask 255.255.255.240



Reserved Private IPv4 Addresses

- Reserved private addresses are critical in extending life of IPv4
- **10**.x.x.x ⇒ private class A networks
- **172.16**.x.x to **176.31**.x.x ⇒ private class B networks
- **192.168**.x.x ⇒ private class C networks

How to Extend the Life of IPv4?

- NAT – network address translation for private addresses
  - Private IP addresses can be used for those local networks setting behind a firewall or NAT (Network Address Translation) device
  - Of course, any networks not connected to the Internet can use any IPv4 addresses
- Use no classes, e.g., CIDR (classless inter-domain routing)
- Notation: *x.y.z.n/m*
  - Network address: *x.y.z.n*
  - Length of netmask: *m*

Special Addresses

- **0.0.0.0**

⇒ Unknown local host address, this network host

⇒ This **consumes one Class A network address**, sorry :_(

- **255.255.255.255**

⇒ Local LAN broadcast address, cannot cross routers; Class E, erh??

- **127.0.0.1** ⇒ local host loopback

⇒ This **consumes another Class A network address** too, sorry :_(
  - Never leaves local computer
  - Other 127.x.x.x addresses are rarely used, except Linux occasionally uses 127.0.1.1

IPv6 Coming…

- All IPv4 was exhausted around 2011
- But "short-term" solutions to IPv4 address exhaustion: CIDR and NAT with private IPv4 addresses
  - CIDR (Classless Inter-Domain Routing)
  - NAT (Network Address Translation)
  - Private addresses
- Long-term solution: IPv6