Introduction to Computer Networks

CS640

Efficient Addressing

https://pages.cs.wisc.edu/~mgliu/CS640/F22/

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Today

Last lecture

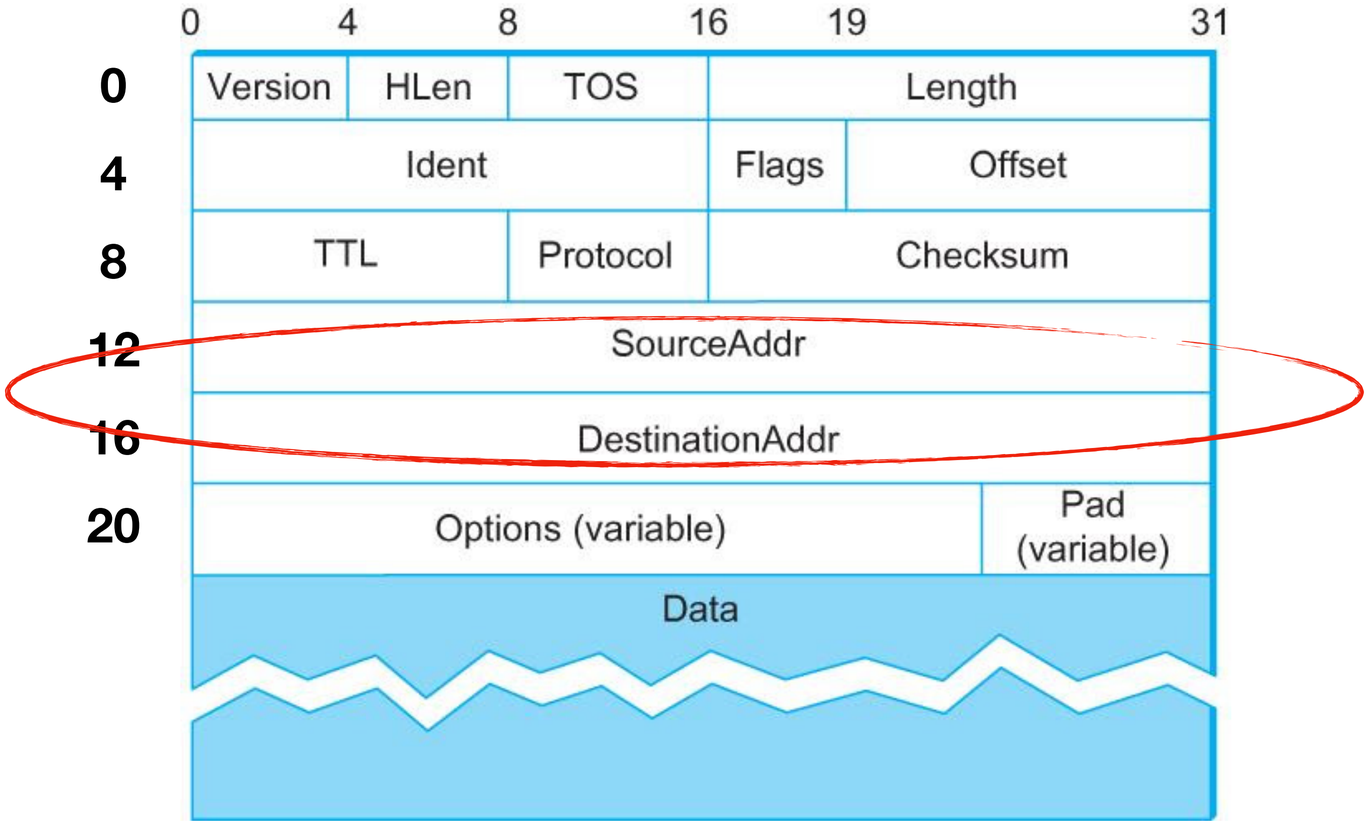
- What functionalities do the IP layer provide?

Today

- How to assign an IP address?

Announcements

- Lab2 is due tomorrow 10/14/2022, 11:59 PM
- Lab3 is released tomorrow


0
4
8
16
19
31
0
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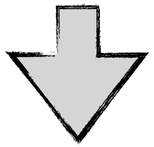
12
16
20
Version
HLen
TOS
Length
Ident
Flags
Offset
TTL
Protocol
Checksum
SourceAddr
DestinationAddr
Options (variable)
Pad
(variable)
Data

Q: How to assign an IP address?



Q1: Who owns the IP address?
Q2: What are the requirements?
Q3: What is the approach?

Q1: Who owns the IP address?

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A: Host.

- An IP address is assigned to a host, but is associated with a communication port (i.e., interface)
- A host can own multiple IP addresses
- A host can reconfigure its IP address

Q2: What are the requirements?

Q2: What are the requirements?

A: Global uniqueness.

- IP provides a single logical network
- Impossible!

Q3: What is the approach?

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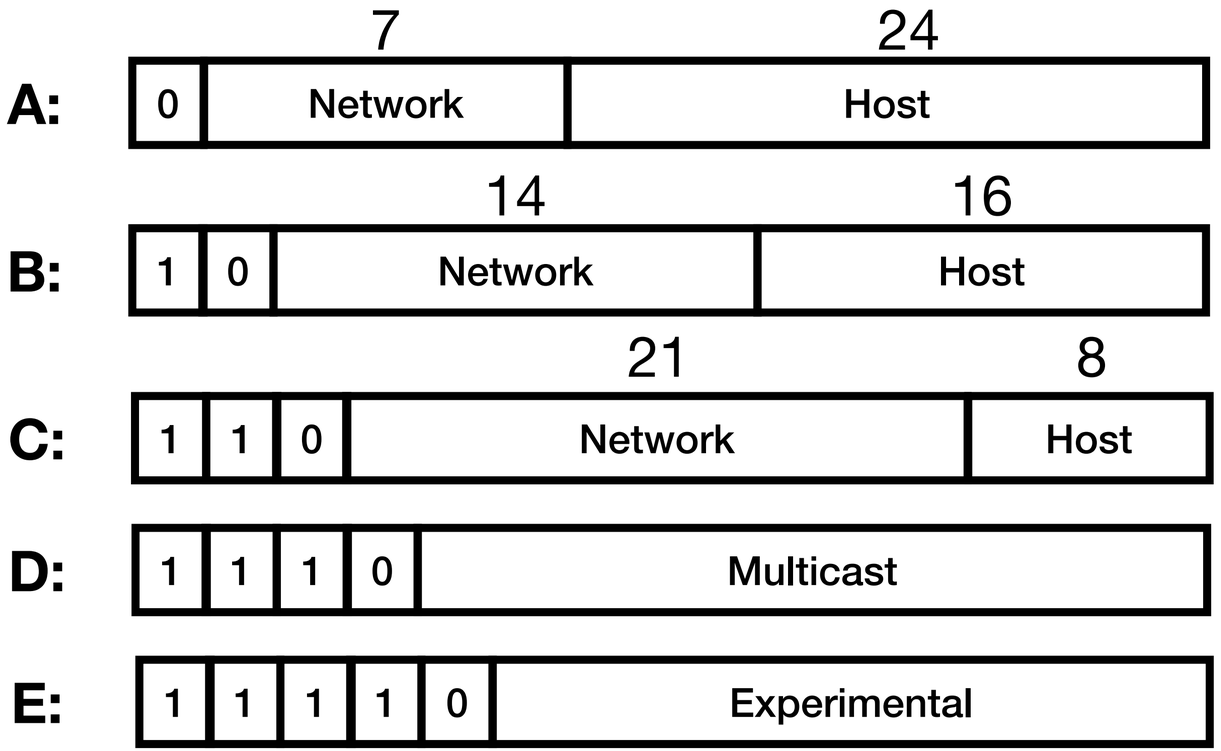
A: Hierarchical addresses.

- Assigned by ICANN (Internet Corporation for Assigned Names and Numbers)

IPv4 address

Divide the 32-bit address to <network, host>



IPv4 address

Divide the 32-bit address to <network, host>

Classful addressing

- Class A: 1.0.0.0 to 127.0.0.0
- Class B: 128.0.0.0 to 191.255.0.0
- Class C: 192.0.0.0 to 223.255.255.0

Dot representation

- Four decimal integers separated by dots
- best-linux.cs.wisc.edu: 128.105.37.175

IPv4 address

Divide the 32-bit address to <network, host>

ICANN assigns the network number (or IP address range) for an organization, but not for individual hosts!

- Four decimal integers separated by dots
- best-linux.cs.wisc.edu: 128.105.37.175

Host IP Assignment #1: Manual Configuration

Most host operating systems provide a way to manual configure the IP information for the host

Drawbacks of manual configuration

- A lot of work to configure all the hosts in a large network
- The configuration process is error-prune

Host IP Assignment #2: DHCP

Dynamic Host Configuration Protocol

- A dedicated service for assigning IP for each administrative domain

A DHCP server maintains a pool of available addresses

- Maintain the mapping between hosts and IP addresses
- Each IP is associated with a lease to ensure flexibility
- Leases are periodically refreshed

How DHCP works

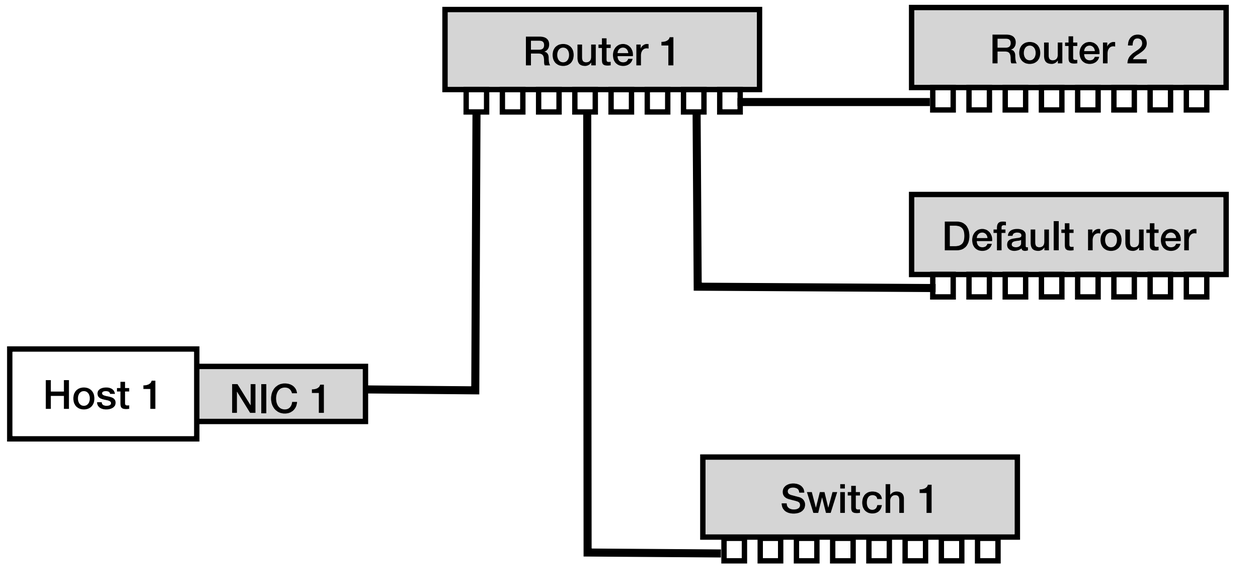
#1: The newly booted or attached host sends a specialized IP broadcast message to its network

- DHCP has its own header format
- Broadcast IP address: 255.255.255.255
- Use the Ethernet MAC address to distinguish itself from others

#2: The DHCP server replies to the host with an assigned IP address and metadata

- A DHCP server can also be responsible for multiple administrative domains
- A domain could hold a relay agent that interacts with the central DHCP server

Forwarding in a Router



Network Number	Forwarding Port (NextHop)
1	Port 1 (Host 1)
2	Port 4 (Switch 1)
3	Port 8 (Router 2)

Forwarding in a Router

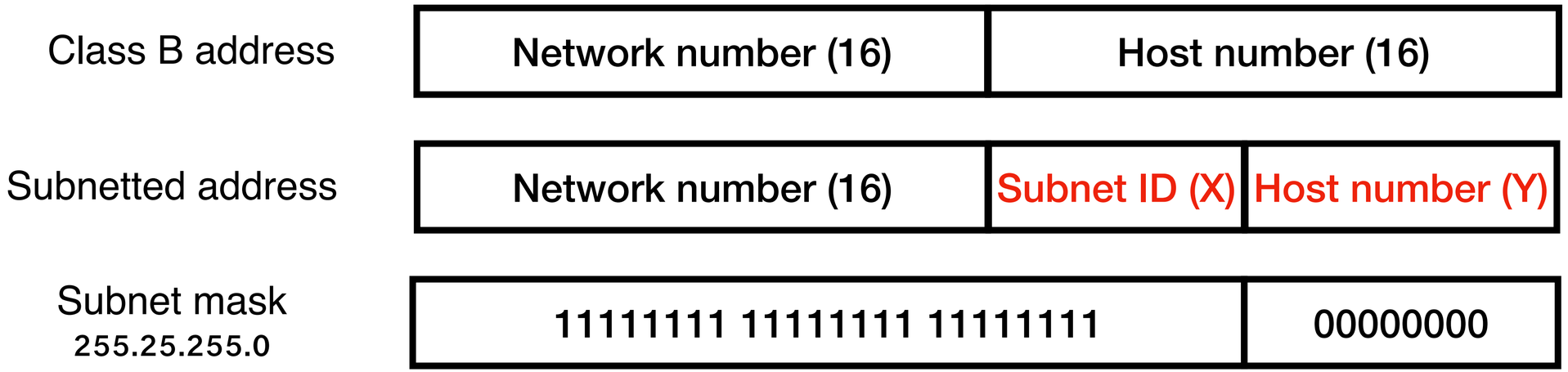
```
D = destination IP address
N = networkNum(D)

if N == Network Number of one of my interfaces
    Deliver packet over that interface
Else
    if N is in my lookup table
        deliver datagram to next Hop corresp. to N
    else
        deliver datagram to default router
```

Problem: network numbers are limited!

Subnet: one more address hierarchy

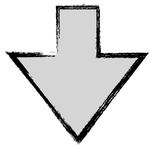
- Subnet mask: define a variable partition of the original host number part
- Subnets are not visible from the rest of the Internet

Subnet Number = IP address & subnet mask



Routing Table

Network Number	Forwarding Port (NextHop)
128.1.0.0 (class B)	Port 1
128.2.0.0 (class B)	Port 2
2.0.0.0 (class A)	Port 3



Subnet Number	Subnet mask	NextHop
128.1.0.0 (class B)	255.255.128.0	Port 1
128.1.128.0 (class B)	255.255.128.0	Port 2
2.0.0.0 (class A)	255.255.255.0	Port 3

Forwarding in a Router (Updated)

```
D = destination IP address
for each entry (SubnetNum, SubnetMask, NextHop)
    D1 = SubnetMask & D
    if D1 = SubnetNum
        if NextHop is an interface
            deliver datagram directly to D
        else
            deliver datagram to NextHop
```

Suppose you are building networks for one organization that has 200 hosts, what kind of IP addresses do you want to apply?

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Suppose you are building networks for one organization that has 64000 hosts, what kind of IP addresses do you want to apply?

Suppose you are building networks for one organization that has 257 hosts, what kind of IP addresses do you want to apply?

Supernetting

Key idea: aggregate multiple assigned addresses to a single address

CIDR (Classless Inter-Domain Routing) address

- Breaks rigid boundaries between address classes
- Slash notation - also called a “prefix”
- `128.211.168.0/21` for addresses `128.211.168.0 - 128.211.175.255`
- `/8`, `/16`, `/24` correspond to traditional class A, B, C categories

Put Everything Together

Network number can be any length, from 2 to 32 bits

Longest prefix match (LPM) is needed

Subnet Number	Prefix/Subnet mask	NextHop
171.69.0.0	255.255.0.0	Port 1
171.69.128.0	255.255.255.0	Port 2

Terminology

1. Host
2. NIC
3. Multi-port I/O bridge
4. Protocol
5. RTT
6. Packet
7. Header
8. Payload
9. BDP
10. Baud rate
11. Frame/Framing
12. Parity bit
13. Checksum
14. Ethernet
15. MAC
16. (L2) Switch
17. Broadcast
18. Acknowledgement
19. Timeout
20. Datagram
21. TTL
22. MTU
23. Best effort
24. (L3) Router
25. Subnet mask
26. CIDR

Principle

1. Layering
2. Minimal States
3. Hierarchy

Technique

1. NRZ Encoding
2. NRZI Encoding
3. Manchester Encoding
4. 4B/5B Encoding
5. Byte Stuffing
6. Byte Counting
7. Bit Stuffing
8. 2-D Parity
9. CRC
10. MAC Learning
11. Store-and-Forward
12. Cut-through
13. Spanning Tree
14. CSMA/CD
15. Stop-and-Wait
16. Sliding Window
16. Fragmentation and Reassembly
17. Path MTU discovery
18. DHCP
19. Subnetting
20. Supernetting
21. Longest prefix match

Summary

Today's takeaways

#1: IP addresses are hierarchical

#2: Subnet and Supernet enable arbitrary network numbers and improve the efficiency of IP address allocation

Next lecture

- Distance vector routing