INTERNET SYSTEMS

6CCS3INS

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INTERNET ARCHITECTURE & ADDRESSING

Questions

- How can we divide up the administration of the internet to make it manageable?
- When one part changes, how can we avoid replacing all the software which runs the internet (maintenance)?
- How can a host identify another host to send data to, when they are not directly connected?
- How can our addressing schemes handle varying numbers of hosts in organisations?

Outline

- **Internet architecture**

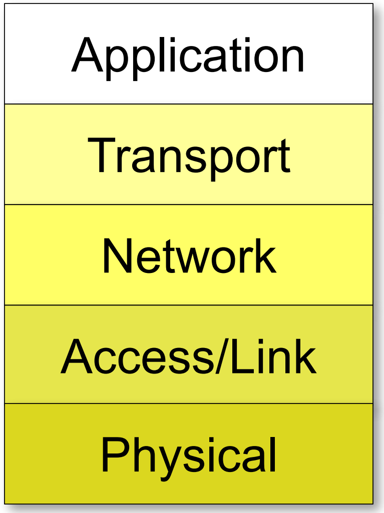
- Addressing hosts on the internet
  - IPv4 addressing
  - IPv6 addressing

Internet Architecture

- The main goal of the Internet Architecture was to:
  - connect existing networks
  - be robust in case of different link failures or whole sub-networks
    - routing functionality that can adapt to this phenomena
  - allow distributed management
  - support multiple types of services
  - allow host attachment with a low level of effort
  - be cost effective in terms of header overhead, retransmissions and routers capabilities needed

Internet Architecture: Layers

- Many Internet communication issues, including
  - Routing, Reliability, Flow control, Data format
- Internet as stack of layers each dealing with one or a few issues
  - Different ways to solve each issue, so different implementations of each layer
  - Combine the best solutions for any one problem
- Protocol Stack:
  - **Physical** layer provides the actual connectivity (copper, fiber, radio)
  - **Access** layer defines how to deliver data between two devices on the same network
  - **Network** layer defines how to route messages across networks
  - **Transport** defines how to provide reliable communication, so that data will not be lost or corrupted (TCP, UDP)
  - **Application** layer defines how programs request messages to be sent across the internet, using encryption, compression.



Protocols

- A protocol is a way of communicating
- It specifies details such as:
  - How to express information of a particular kind
  - How to respond when asked particular questions or given particular commands
  - What form of messages to expect

- Each layer implemented by multiple alternative protocols
- Each protocol guides the communication of hosts to solve the layer's issue

Access layer

- Defines how to deliver data between two devices on the same network

Network layer

- Defines how to route messages across networks

- **Internet Protocol (IP)**
  - For transferring messages between hosts anywhere on the internet
- **Internet Control Message Protocol (ICMP)**
  - Part of and supports IP
  - Used to report errors and other info back to sender of IP message
  - Itself sent over IP

Host-to-host transport layer

- Defines how to provide reliable communication, so that data will not be lost or corrupted

- **Transmission Control Protocol (TCP)**
  - Provides reliability measures: acknowledgements, flow control plus sessions and multiplexing
- **User Datagram Protocol (UDP)**
  - Allows data exchange across the network with a minimum of overhead
  - Provides a little reliability through checksums, but otherwise unreliable compared to TCP

Process / application layer

- Defines how programs can send messages across the internet, using encryption and compression etc.

- Many protocols, such as…
  - **Hypertext Transfer Protocol (HTTP)**
  - **Telnet**
  - **Simple Mail Transfer Protocol (SMTP)**
  - **File Transfer Protocol (FTP)**
  - **Post Office Protocol (POP)**
  - **Domain Name Service (DNS)**
  - **Dynamic Host Configuration Protocol (DHCP)**

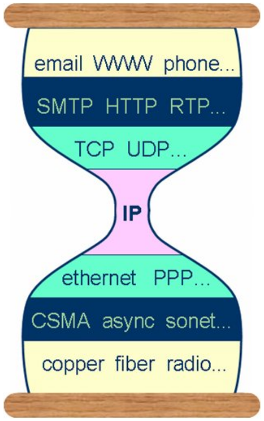
Internet Architecture: edge-oriented

- The success of the Internet is due to the edge-oriented approach of the architecture.
  - A **connectionless, packet-forwarding** infrastructure (“dumb network”) that positioned higher-level functionality at the edge of the network for robustness.

- The end-to-end argument, **intelligent edges** and **dump network** or in other words keep the infrastructure as simple as possible.
  - To reduced complexity of the core network.
  - New applications can be added without changing the core

(look for example in p2p!)

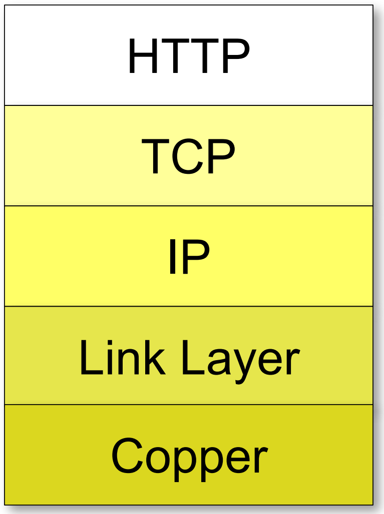
  - This is known as the hour glass model (with IP at the waist).



- With addresses that are
  - fixed-size numerical quantities, with a simple (net, host) hierarchy
  - applied to physical network interfaces, which can therefore be used for both naming a node and for routing to it.

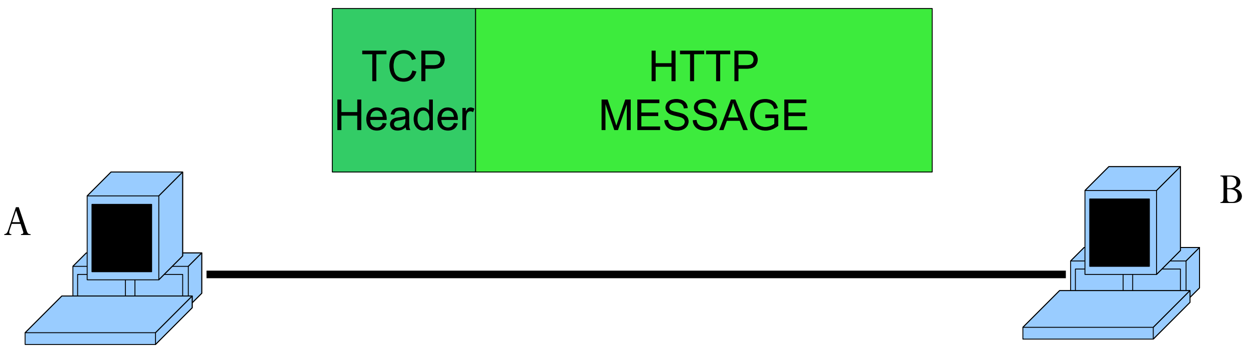
Packet Transmission

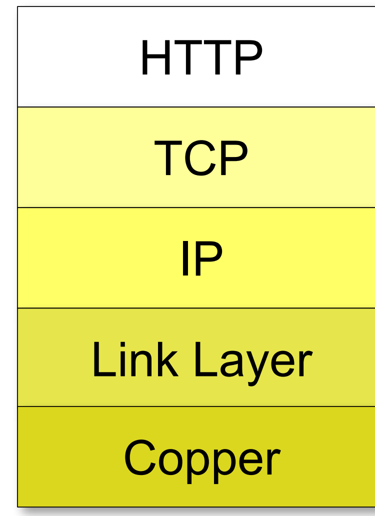
User **A** runs HTTP application



Packet Transmission

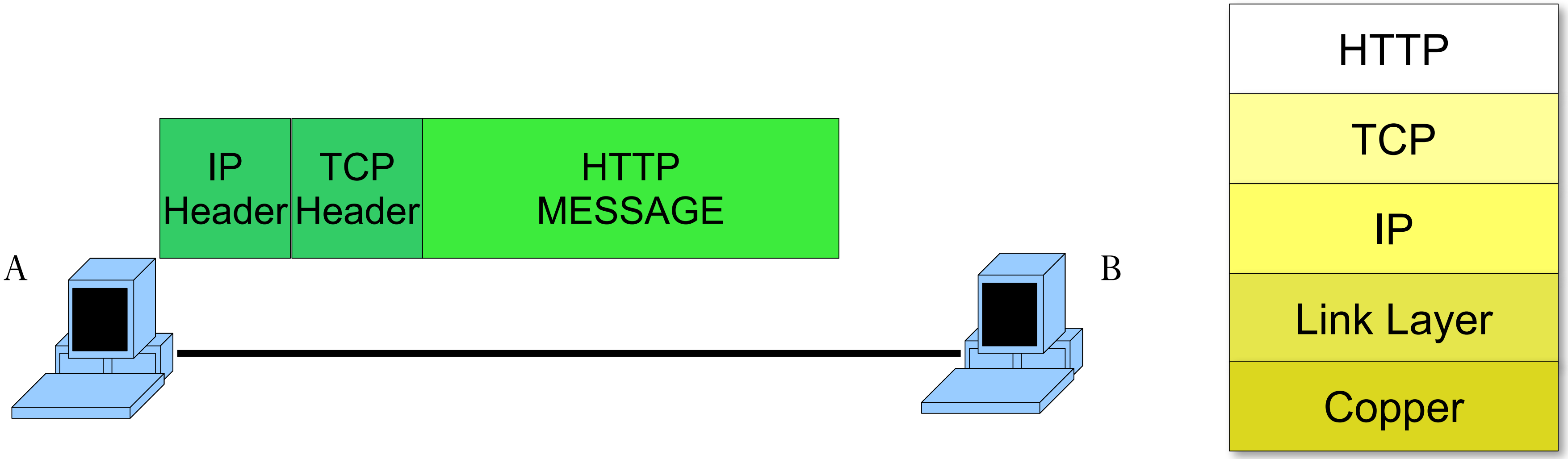
TCP adds header including packet number, and the time out





Packet Transmission

IP adds header including host A and B addresses



IP Fragmentation

- Different link layer technologies can carry packets of different size.
  - The maximum amount of data that the a link layer packet can carry is called Maximum Transfer Unit (MTU).
  - Because the IP is encapsulated within the link layer this MTU puts a limit in the maximum size of the IP packet.

MTU	Commonly Used
	Maximum size of link layer
17914	16 Mbit/sec token ring
8166	Token Bus (IEEE 802.4)
4464	4 Mbit/sec token ring (IEEE 802.5)
1500	Ethernet
1500	PPP (typical; can vary widely)
576	X.25 Networks

- If the outbound link has smaller MTU than the IP packet that the router want to sent, the solution is Fragmentation

Outline

- Internet architecture
- **Addressing hosts on the internet**
  - IPv4 addressing
  - IPv6 addressing

Networks

- In order for two computers to communicate, there must be a connection between them
  - Through cables
  - Through the air (wireless)
- A **network** is a set of computers connected directly or indirectly through another computer
- A computer that is part of a network is called a **node** of that network
- A node from which messages are sent/received is a **host**
- Other kinds of nodes are **routers**

Routing and addresses

- Generally, one host wants to communicate data with another host that is not directly connected
- To allow this to happen, data is **routed**:
  - A path is found along a series of connected nodes
  - Data is sent from one to the next along the path until reaching its destination
- How can a sender identify which receiver it wishes to communicate with, so that a route to it can be found?
- It uses the **address** of the host

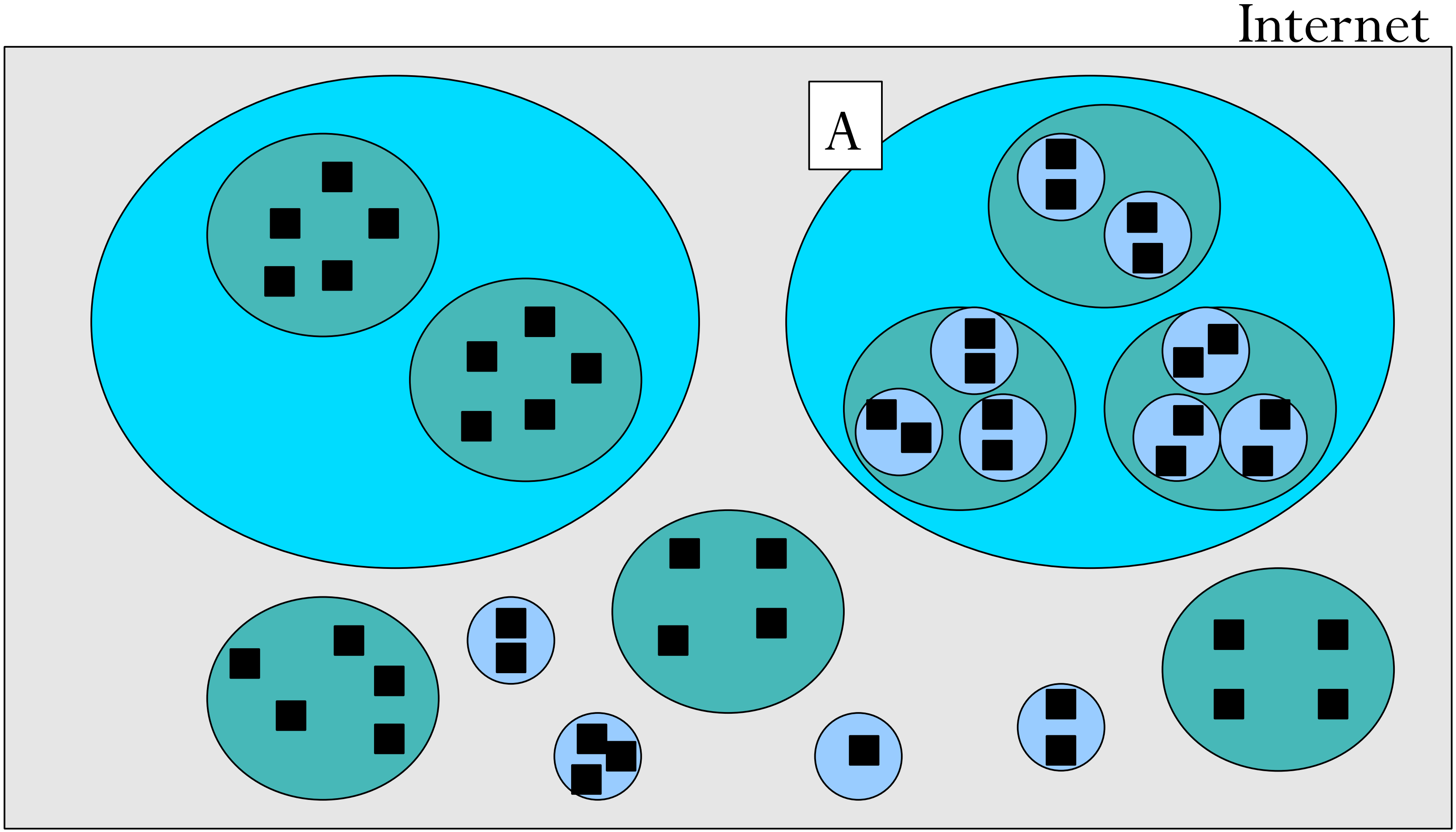
The Internet Protocol

- IP is the **network** layer, a packet delivery service (host-to-host), that is
  - Connectionless: each datagram is independent of all others.
  - Unreliable: there is no guaranteed delivery
- Responsible for:
  - Fragmentation / Reassembly (based on MTU).
  - Routing.

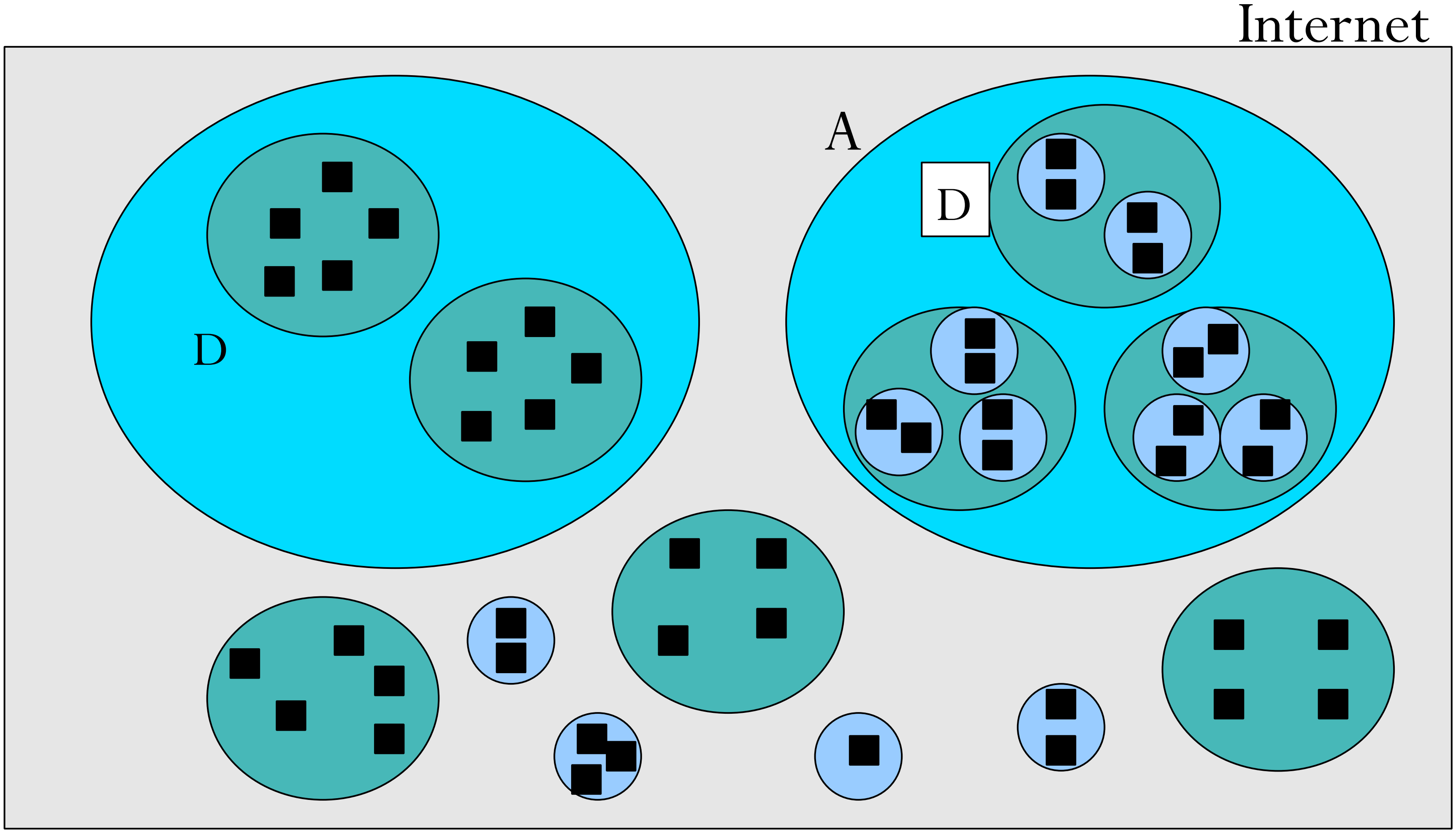
IP addresses

- IP includes a structure for addressing hosts
  - In the global Internet every host and router must have one globally unique address
  - IP address technically are associated with an interface and NOT with a host
- Currently, the internet primarily uses version 4 (IPv4)
  - IPv6 compatibility is being deployed slowly.
- Why IPv6 is needed (short/long term advantages)
  - Increased Address Space
    - We are running out of Internet addressing.
  - Lack of Security at the Network layer
  - Quality of Service for end-to-end networking.
  - supporting new features for applications

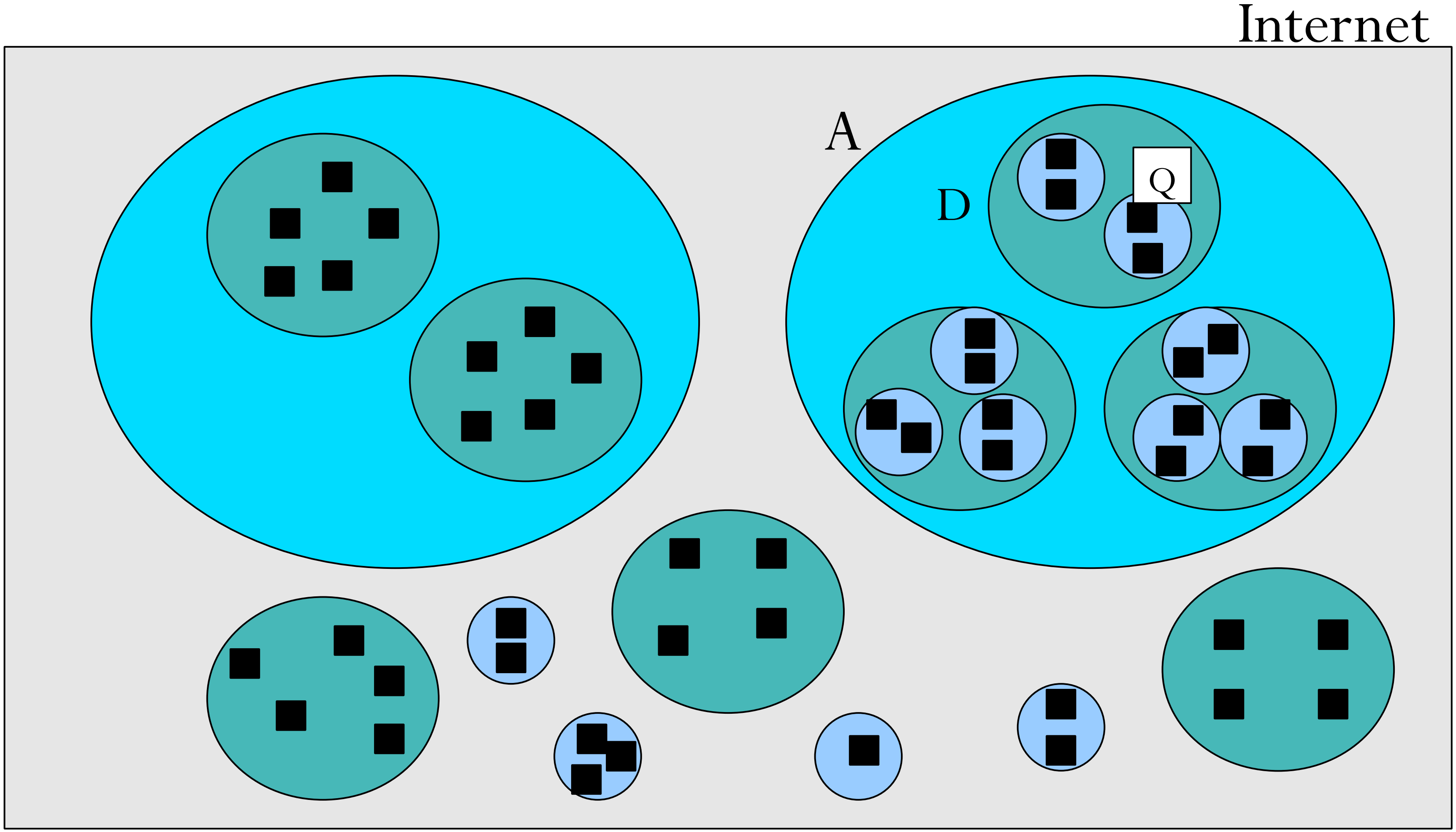
Hierarchical addressing



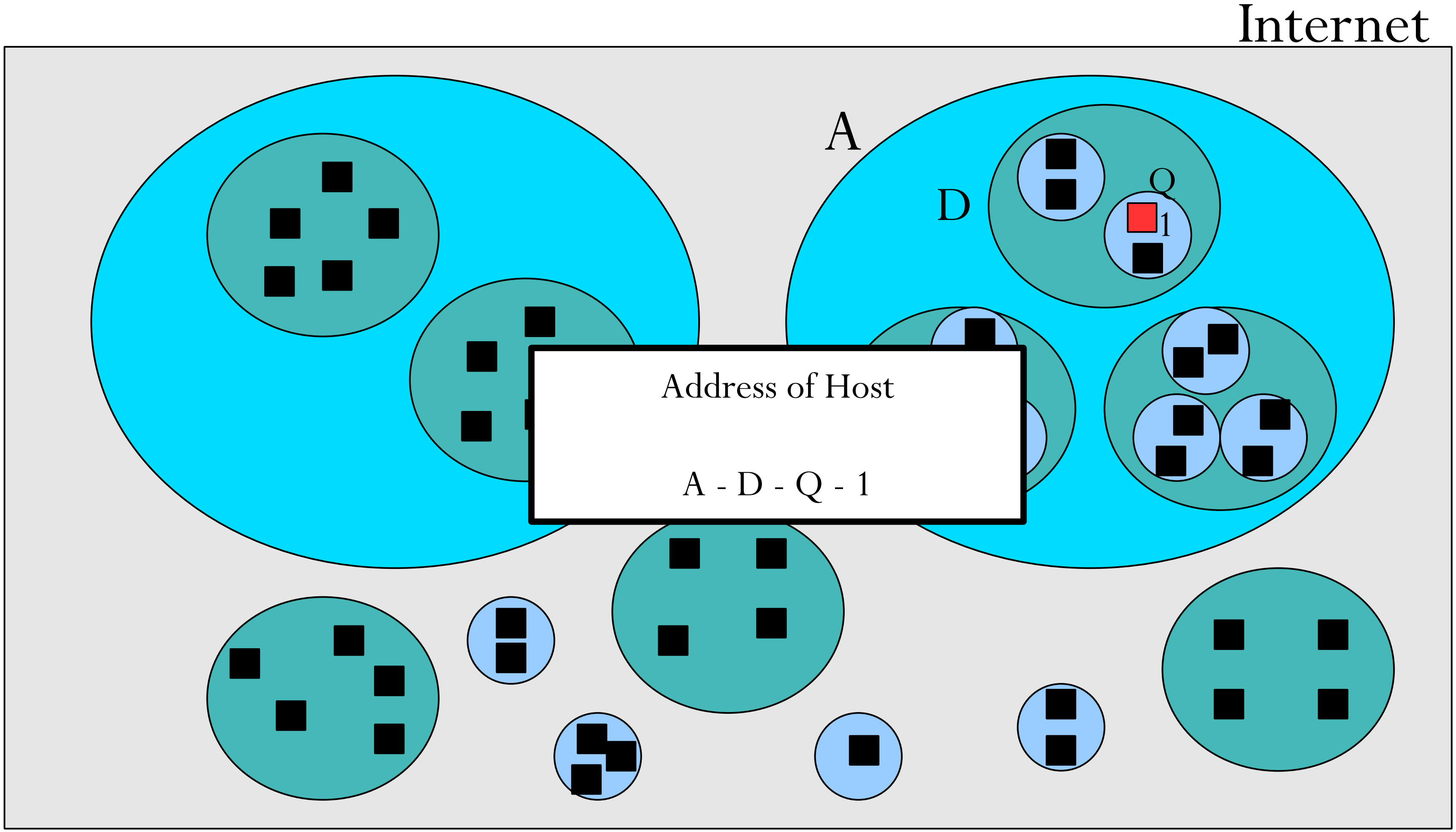
Hierarchical addressing



Hierarchical addressing

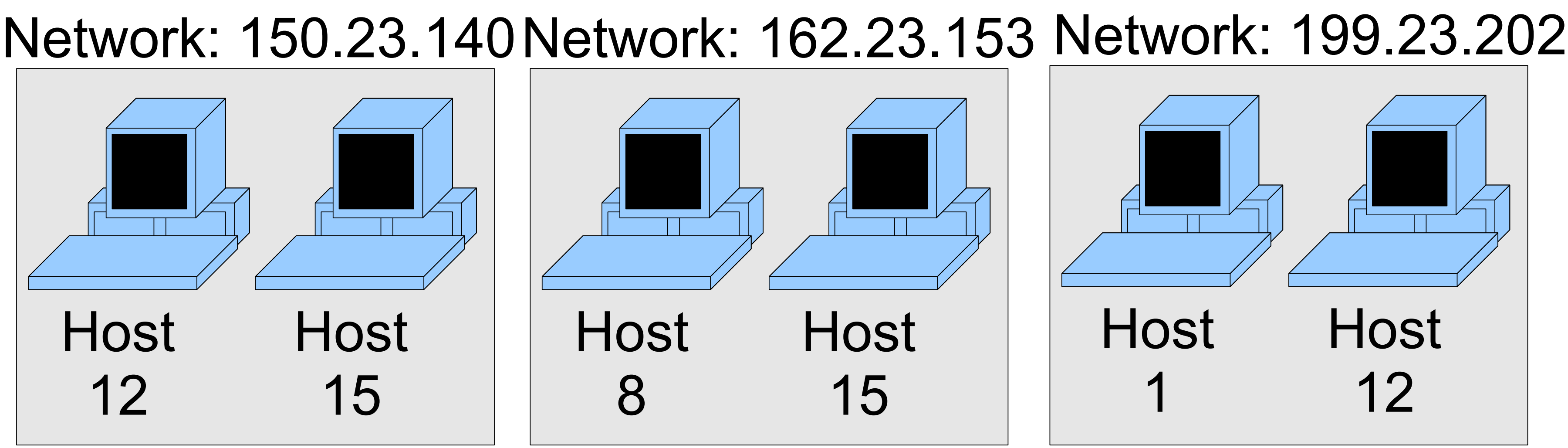


Hierarchical addressing



Address structure

- The internet is divided into **networks**
- Each network has a **network prefix**
- Each host in a network has a **host identifier**
- Together these make the IP address



Network prefix

- Global routers pass each message down to the local network router for the given network prefix, then the local router passes the message to the host with the given host ID
- To determine which part of an address is the network prefix, routers need to know how long the prefix is for each address

Host ID

- Host ID is the remaining bits after the network prefix
- With N bits, we can allocate 2^N different addresses
- In IPv4, two addresses per network are reserved, so we can actually have only $2^N - 2$ hosts on the network
- The reserved addresses are called the network address and broadcast address – we will come back to these later
- For example
  - An IPv4 network prefix is 23 bits long
  - So the host ID is 9 bits (because $32 - 23 = 9$)
  - So the network can hold 510 hosts (because $2^9 - 2 = 510$)

Allocating addresses

- Network prefixes assigned by Internet Corporation for Assigned Names and Numbers (ICANN) through Network Information Centres (NIC)
- Owners of each network assign host identifiers

- Some network prefixes are guaranteed not to be allocated
  - Can be used privately, e.g. home networks
  - Will never conflict with internet host address
- Others reserved for special technical purposes

A Fast Binary Review

- We are accustomed to the decimal system a base 10 system
- The number 124_{10} is 100+20+4 or
  - $1x10^2+2x10^1+4x10^0$
  - 1x100+2x10+4x1

A Fast Binary Review

- The binary number system is a base 2 system
- 01111100_2 is
  - $0x2^7+1x2^6+1x2^5+1x2^4+1x2^3+1x2^2+0x2^1+0x2^0$
  - $0x128+1x64+1x32+1x16+1x8+1x4+0x2+0x1$
  - $64+32+16+8+4$ or 124_{10}

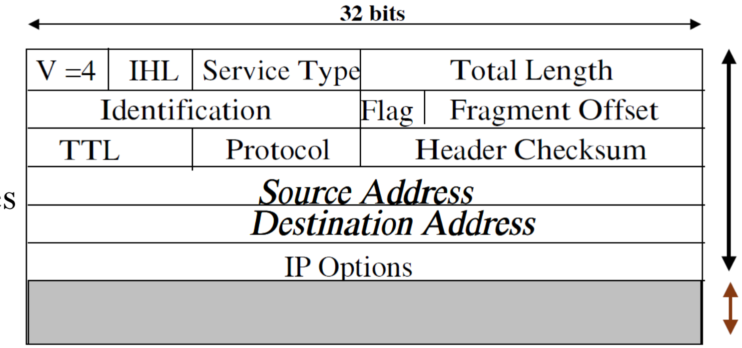
Decimal Equivalents of 8-Bit Patterns

128	64	32	16	8	4	2	1	
1	0	0	0	0	0	0	0	= 128
1	1	0	0	0	0	0	0	= 192
1	1	1	0	0	0	0	0	= 224
1	1	1	1	0	0	0	0	= 240
1	1	1	1	1	0	0	0	= 248
1	1	1	1	1	1	0	0	= 252
1	1	1	1	1	1	1	0	= 254
1	1	1	1	1	1	1	1	= 255

Outline

- Internet architecture
- **Addressing hosts on the internet**
  - **IPv4 addressing**
  - IPv6 addressing

IPv4 Addressing



- IPv4 addresses are 32bits long.
  - With N bits, we can allocate 2^N different addresses
  - 32 bits = 4,294,967,296 different addresses

- In order to provide the flexibility required to support different size networks, the designers decided to divide the IP address space into **three** different address classes:
  - Class A, Class B, and Class C - “classful” addressing.
  - Two additional classes later added:
    - Class D addresses used to support IP Multicasting.
    - Class E addresses are reserved for experimental use.

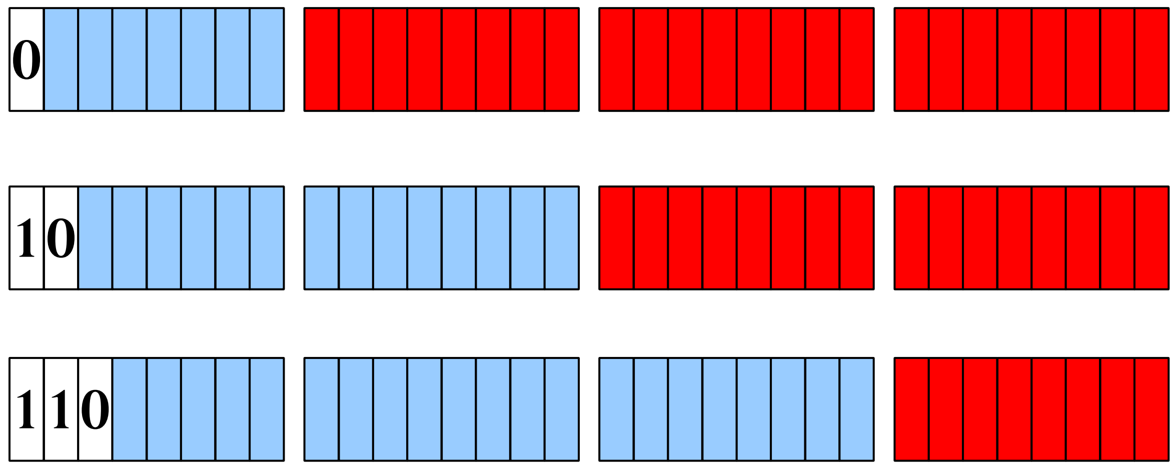
- Every IP address consists of two parts, one identifying the network and one identifying the Host.
  - The Class of the address and the subnet mask determine which part belongs to the network address and which part belongs to the node address.

IPv4 addresses by class

- IP addresses were split into
  - Class ID
  - Network ID
  - Host ID

Network prefix

- Class A
- Class B
- Class C



Class A addressing (or /8s networks)

- Class A is for very large networks
  - 8-bit network-prefix with the highest order bit set to 0
  - 24-bit host-number

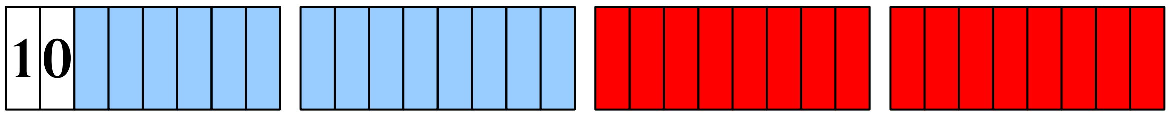
- A maximum of 126 (2^ 7 -2) /8 networks can be defined.
  - the /8 network 0.0.0.0 is reserved for use as the default route and the /8 network 127.0.0.0 (also written 127/8 or 127.0.0.0/8) has been reserved for the "loopback" function.

- Each /8 supports a maximum of **16,777,214** (2^24 -2) hosts per network.
  - all-0s ("this network") and all-1s ("broadcast") host-numbers may not be assigned to individual hosts.

- Since the /8 address block contains 2^31 individual addresses and theIPv4 address space contains a maximum of 2^32 (4,294,967,296) addresses,
  - the /8 address space is 50% of the total IPv4 unicast address space.
  - range: from 1 to 126

Class B addressing (or /16s networks)

- Class B is for smaller networks
  - 16-bit network-prefix with the two higher order bits set to “10”
  - 16-bit host-number

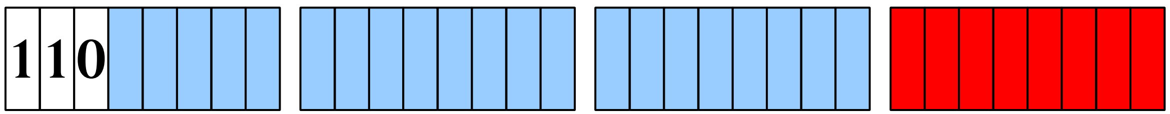


- A maximum of 16,384 (2^ 14) /16 networks can be defined
- Each /16s supports **65,534** (2^16 -2) hosts per network.

- Since the entire /16 address block contains 2^30 (1,073,741,824) addresses,
  - it represents 25% of the total IPv4 unicast address space.
  - Range from 128 to 191

Class C addressing (or /24s networks)

- Class C is for much smaller networks
  - 24-bit network-prefix with the three higher order bits set to “110”
  - 8-bit host-number



- A maximum of 2,097,152 (2^{21}) /24 networks can be defined.
- Each /24s supports 254 ($2^8 - 2$) hosts per network.

- Since the entire /24 address block contains 2^{29} addresses,
  - it represents 12.5% (or 1/8th) of the total IPv4 unicast address space.
  - Range from192 to 223

Example IP addresses

- 1.22.11.12 Class A
- 137.22.11.12 Class B
- 201.22.11.12 Class C
- 193.92.96.255 /24 Broadcast address
  - All "1"s at the host part represent the broadcast address.
  - The **broadcast address** is the address used to send a message to all hosts on the network
- 193.92.96.0 /24 Network address
  - All "0"s at the host part represent the network address
  - The **network address** is an IP address for the network as a whole, as used by routers to know where to send the messages

Classful addressing

- Limitations with the classful addressing:
  - A class C or/24, which supports 254 hosts, is too small while a class B or /16, which supports 65,534 hosts, is too large.
    - For example an organization with 2000 hosts will go for /16!.

- 1993 IETF standardised the Classless Interdomain Routing (CIDR)
  - In CIDRised networks the Network part of the IP address can be **ANY** number of bits long (rather than being constrained to 8,16 or 24)

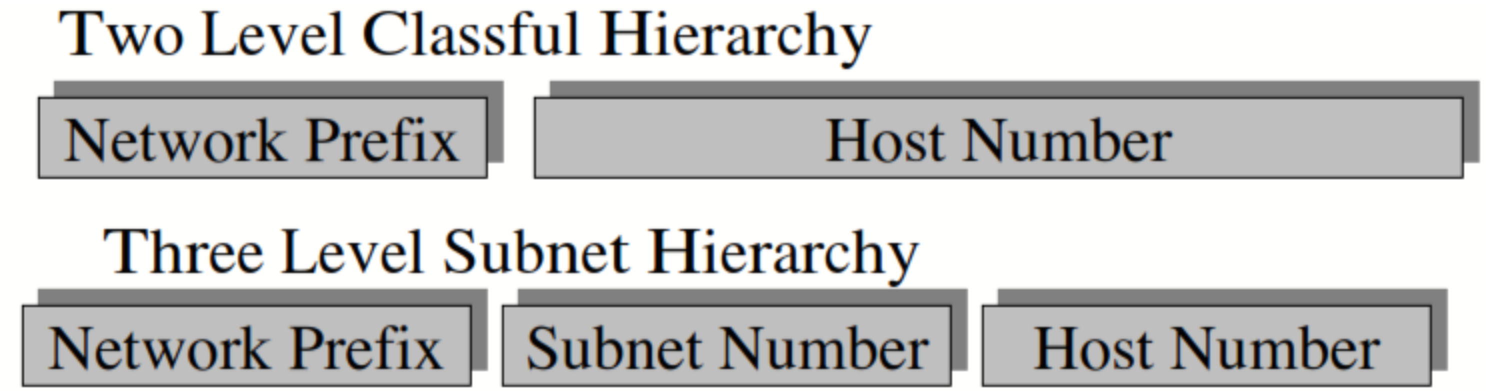
- For the example of organisation with 2000 hosts,
  - IP addresses of the form a.b.c.d/21 can be allocated (2046 hosts).
  - the first 21 bits specify the organisation's network address and are common for all the hosts inside the network,
  - The remaining 11 bits can specify a specific host inside this network.
  - In a real case scenario the 2000 hosts will be further divided using the last 11 bits in subnets to create different networks inside the organisation

- Today, address classes are ignored.
  - Instead, routers are explicitly told the length of prefix to look for

Subnets

- RFC 950 defined a standard procedure to support subnetting of a single Class A,B or C network into smaller pieces.
  - Internet Routing Tables were beginning to grow
  - Local administrators had to request another network number from the Internet before a new network installed into the organization.

- These problems were attacked by introducing another level of hierarchy to the IP addressing structure



Network Mask

- In a Binary format the 1's represent the portion of the IP address that is Network number and the 0's represent the portion of the IP that is the Host number

- Default Subnet Masks
  - Class A:

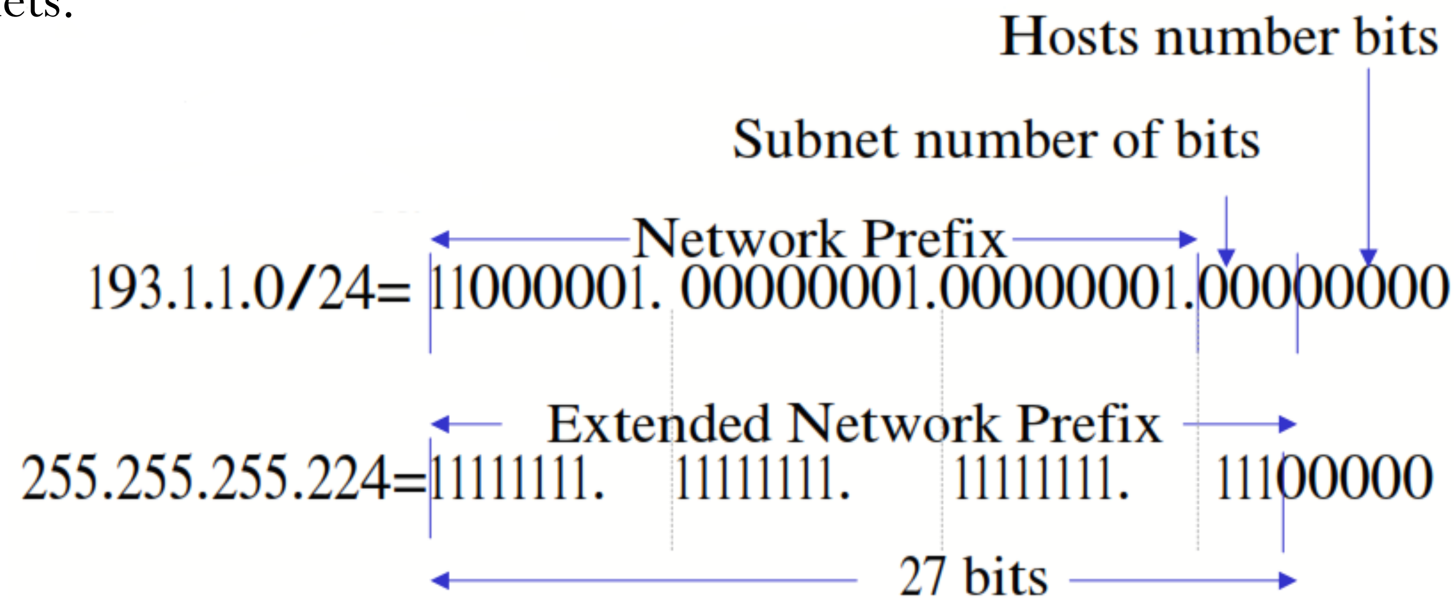
  11111111.00000000.00000000.00000000 255.0.0.0
  - Class B:

  11111111.11111111. 00000000. 00000000 255.255.0.0
  - Class C:

  11111111.11111111.11111111.00000000 255.255.255.0

Example 1 – part 1

- **Organisation has assigned the network number 193.1.1.0/24 and wants to have 6 subnets, where the largest one need to support up to 25 hosts.**
  - The first step is to determine the number of bits required to define the 6 subnets.



Example 1 – part 2

- **Organisation has assigned the network number 193.1.1.0/24 and wants to have 6 subnets, where the largest one need to support up to 25 hosts.**
- The eight subnets then will be:

Base Net: 11000001.00000001.00000001 .00000000 = 193.1.1.0/24

Subnet #0: 11000001.00000001.00000001. **000**00000 = 193.1.1.0/27

Subnet #1: 11000001.00000001.00000001. **001**00000 = 193.1.1.32/27

Subnet #2: 11000001.00000001.00000001. **010**00000 = 193.1.1.64/27

Subnet #3: 11000001.00000001.00000001. **011**00000 = 193.1.1.96/27

Subnet #4: 11000001.00000001.00000001. **100**00000 = 193.1.1.128/27

Subnet #5: 11000001.00000001.00000001. **101**00000 = 193.1.1.160/27

Subnet #6: 11000001.00000001.00000001. **110**00000 = 193.1.1.192/27

Subnet #7: 11000001.00000001.00000001. **111**00000 = 193.1.1.224/27

Example 1 – part 3

- **Organisation has assigned the network number 193.1.1.0/24 and wants to have 6 subnets, where the largest one need to support up to 25 hosts.**

- We have two unused subnets that can be reserved for future growth.

- A 27-bit ENP leaves 5 bits to define host addresses on each subnet.
  - each subnetwork with a 27-bit prefix represents 32 individual IP addresses.
  - since the all-0s and all-1s host addresses cannot be allocated, there are 30 assignable host addresses on each subnet.

Example 1 – part 4

- **Organisation has assigned the network number 193.1.1.0/24 and wants to have 6 subnets, where the largest one need to support up to 25 hosts.**
- The eight subnets then will be:

Base Net: 11000001.00000001.00000001 .00000000 = 193.1.1.0/24

Subnet #0: 11000001.00000001.00000001. **000**00000 = 193.1.1.0/27

Subnet #1: 11000001.00000001.00000001. **001**00000 = 193.1.1.32/27

Subnet #2: 11000001.00000001.00000001. **010**00000 = 193.1.1.64/27

Subnet #3: 11000001.00000001.00000001. **011**00000 = 193.1.1.96/27

Subnet #4: 11000001.00000001.00000001. **100**00000 = 193.1.1.128/27

Subnet #5: 11000001.00000001.00000001. **101**00000 = 193.1.1.160/27

Subnet #6: 11000001.00000001.00000001. **110**00000 = 193.1.1.192/27

Subnet #7: 11000001.00000001.00000001. **111**00000 = 193.1.1.224/27

Example 1 – part 4

- **Organisation has assigned the network number 193.1.1.0/24 and wants to have 6 subnets, where the largest one need to support up to 25 hosts.**
- For the host addresses we are using all the 5 bits except all 0 (subnet) and 1's (broadcast)

Subnet #2: 11000001.00000001.00000001.**010**00000 = 193.1.1.64/27

Host #1: 11000001.00000001.00000001.**010**00001 = 193.1.1.65/27

Host #2: 11000001.00000001.00000001.**010**00010 = 193.1.1.66/27

Host #3: 11000001.00000001.00000001.**010**00011 = 193.1.1.67/27

Host #4: 11000001.00000001.00000001.**010**00100 = 193.1.1.68/27

Host #5: 11000001.00000001.00000001.**010**00101 = 193.1.1.69/27

....

Host #29: 11000001.00000001.00000001.**010**11101 = 193.1.1.93/27

Host #30: 11000001.00000001.00000001.**010** 11110 = 193.1.1.94/27

Example 1 – part 5

- **Organisation has assigned the network number 193.1.1.0/24 and wants to have 6 subnets, where the largest one need to support up to 25 hosts.**

- Defining the Broadcast Address for Each Subnet
  - The broadcast address for Subnet #2 is the all 1's host address, or
  - 11000001.00000001.00000001.01011111 = 193.1.1.95

- Note that the broadcast address for Subnet #2 is exactly one less than the base address for Subnet #3 (193.1.1.96).
  - This is always the case – the broadcast address for Subnet#n is one less than the base address for Subnet #(n+1).

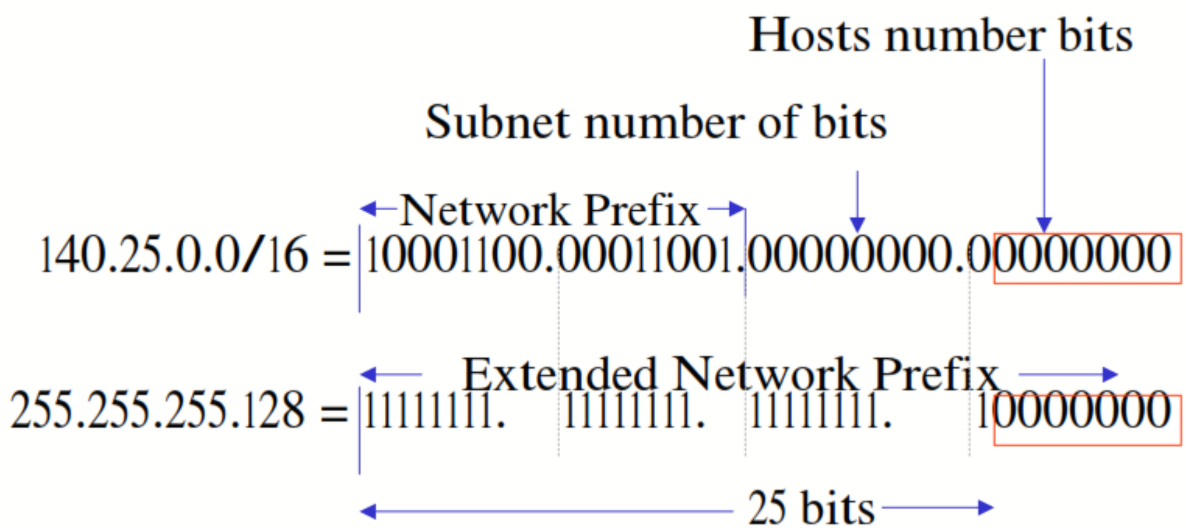
Example 2 – part 1

- **Organisation has assigned the network number 140.25.0.16/16 and it needs to create a set of subnets that supports up to 60 hosts on each subnet.**

- Step one: number of bits required to define 60 hosts on each subnet is 6 bits
  - 6 bits define 64-2=62 host address
  - in order to take into account future growth we select 7 bits which define 126 addresses per subnet.
- Determine the subnet mask/extended-prefix length:

Example 2 – part 2

- **Organisation has assigned the network number 140.25.0.16/16 and it needs to create a set of subnets that supports up to 60 hosts on each subnet.**
  - Step two: determine the subnet mask/extended-prefix length



Example 2 – part 3

- **Organisation has assigned the network number 140.25.0.16/16 and it needs to create a set of subnets that supports up to 60 hosts on each subnet.**
- Defining Each of the Subnet Numbers: the 9 bits allocated in the subnet portion of the IP address allows 512 different subnetworks.

Base Net: 10001100.00011001.00000000.00000000 = 140.25.0.0/16

Subnet 0: 10001100.00011001.00000000.00000000 = 140.25.0.0/25

Subnet 1: 10001100.00011001.00000000.10000000 = 140.25.0.128/25

Subnet 2: 10001100.00011001.00000001.00000000 = 140.25.1.0/25

Subnet 3: 10001100.00011001.00000001.10000000 = 140.25.1.128/25

Subnet 4: 10001100.00011001.00000010.00000000 = 140.25.2.0/25

....
.....

Subnet 511: 10001100.00011001.11111111.10000000 = 140.25.255.128/25

Example 2 – part 3

- **Organisation has assigned the network number 140.25.0.16/16 and it needs to create a set of subnets that supports up to 60 hosts on each subnet.**
- Defining Each of the Subnet Numbers: the 9 bits allocated in the subnet portion of the IP address allows 512 different subnetworks.

Base Net: 10001100.00011001.00000000.00000000 = 140.25.0.0/16

Subnet 0: 10001100.00011001.00000000.00000000 = 140.25.0.0/25

Subnet 1: 10001100.00011001.00000000.10000000 = 140.25.0.128/25

Subnet 2: 10001100.00011001.00000001.00000000 = 140.25.1.0/25

Subnet 3: 10001100.00011001.00000001.10000000 = 140.25.1.128/25

Subnet 4: 10001100.00011001.00000010.00000000 = 140.25.2.0/25

....

.....

Subnet 511: 10001100.00011001.11111111.10000000 = 140.25.255.128/25

Example 2 – part 4

- **Organisation has assigned the network number 140.25.0.16/16 and it needs to create a set of subnets that supports up to 60 hosts on each subnet.**
- Defining Hosts Addresses for Each Subnet: The 7 allocated bits will give 126 different host ID.
- For subnet 3 for example we have:

Subnet #3:	10001100.00011001.00000001.10000000 = 140.25.1.128/25
Host 1:	10001100.00011001.00000001.10000001 = 140.25.1.129/25
Host 2:	10001100.00011001.00000001.10000010 = 140.25.1.130/25
Host 3:	10001100.00011001.00000001.10000011 = 140.25.1.131/25

……………………………………………………………………………………

Host 126: 10001100.00011001.00000001.11111110 = 140.25.1.254/25

Example 2 – part 5

- **Organisation has assigned the network number 140.25.0.16/16 and it needs to create a set of subnets that supports up to 60 hosts on each subnet.**

- Defining the Broadcast Address for Each Subnet:
- For subnet 3 again this address will be the following:
  - 10001100.00011001.00000001.11111111 = 140.25.1.255

Subnets and route aggregation

- KCL's IP addresses could be divided by departments

KCL network: **137.73.0.0 /16**

Informatics network: **137.73.8.0 /23**

Informatics subnet ID is 0000100 (binary) or 4 (decimal)

A host in informatics: 137.73.9.232 /23

10001001.01001001.00001001.11101000

- The global/UK router needs to look at the first 16 bits to determine it is a KCL address
  - The KCL router needs to look at the first 23 bits to determine it is an Informatics address
  - The Informatics router needs to look at the last 9 bits (after the first 23 bits) to determine which host the message is for

Problems with fixed length subnetting

- Different subnets can have different numbers of hosts, e.g. Department of Informatics may have a lot more computers than Department of English

- As the subnet ID gets longer, the number of bits left for addressing hosts reduces
- For example:
  - to distinguish 300 subnets, you need a subnet ID of 9 bits (as $2^8 = 256$ and $2^9 = 512$)
  - If you have a /16 network and a subnet ID of 9 bits, this leaves 7 bits for host IDs, at most 126 hosts ($2^7 – 2$)
- What if a department needs 200 hosts?

Example subnetting problem

- A /24 network needs the following five subnets
  - Subnets P, Q, R require 12 hosts each
  - Subnet S requires 36 hosts
  - Subnet T requires 90 hosts

- 254 available addresses in the network ($2^8 - 2 = 254$)
- If we use a 3 bit subnet ID
  - We can accommodate all subnets, as $2^3 = 8$ and we have 5 subnets
  - But each has only 30 hosts, as $8 - 3 = 5$ host ID bits, so $2^5 - 2 = 30$ hosts
- If we use a 1 bit subnet ID
  - Enough hosts per subnet, as $2^7 - 2 = 126$ hosts
  - But only 2 subnets, as $2^1 = 2$

Variable length subnetting

- To solve this problem, we use **variable length** subnets
- Using variable subnet ID lengths, we iteratively divide up the host ID space, first into large blocks, then into smaller ones
  - First, to accommodate the largest subnet, T, we use 1 bit to split the T subnet from the rest
  - We then accommodate the second largest subnet, S, by splitting the remainder: S needs 6 bits for host IDs, so use 1 more bit to split S from the rest
  - Finally, we need 2 bits to split subnets P, Q and R

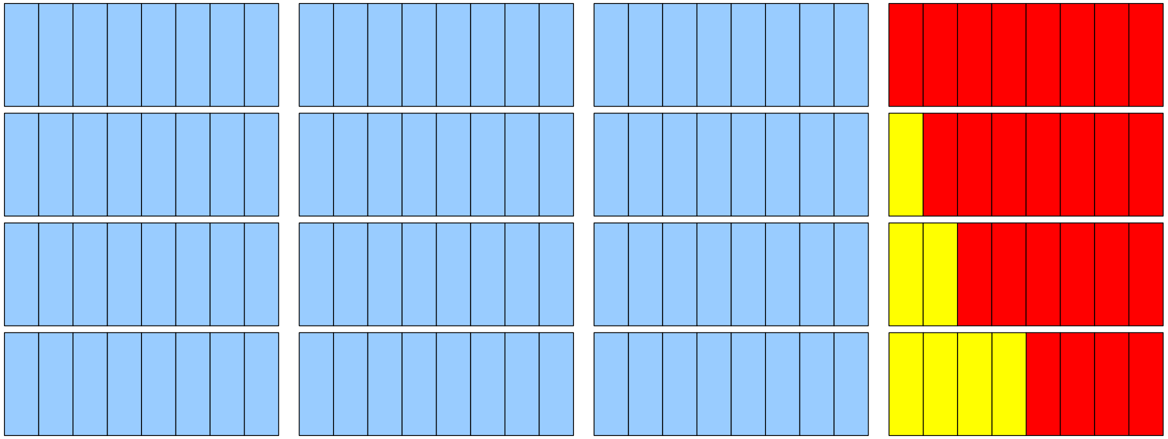
Variable length subnet masks

- As the number of bits used for the subnet prefix vary, so the subnet masks vary for each variable length subnet
- Subnet T has addresses **X.X.X.X /25**
  - 24 bits for network prefix + 1 for subnet ID
  - 25 bits on extended network prefix!
- Subnet S has addresses **X.X.X.X /26**
  - 26 bits on extended network prefix!
- Subnets P, Q, R have addresses **X.X.X.X /28**
  - 28 bits on extended network prefix!

Variable length subnets example

- /24 network
  - Subnets P, Q, R require 12 hosts each
  - Subnet S requires 36 hosts
  - Subnet T requires 90 hosts

- Network
  - T : /25
  - S : /26
  - PQR: /28



Variable length subnets example

T: 10001001 01001001 00001001 0 . . . .

137.73.9.0 /25

S: 10001001 01001001 00001001 10 . . . . . .

137.73.9.128 /26

P: 10001001 01001001 00001001 1100 . . . .

Q: 10001001 01001001 00001001 1101 . . . .

R: 10001001 01001001 00001001 1110 . . . .

137.73.9.192 /28

137.73.9.208 /28

137.73.9.224 /28

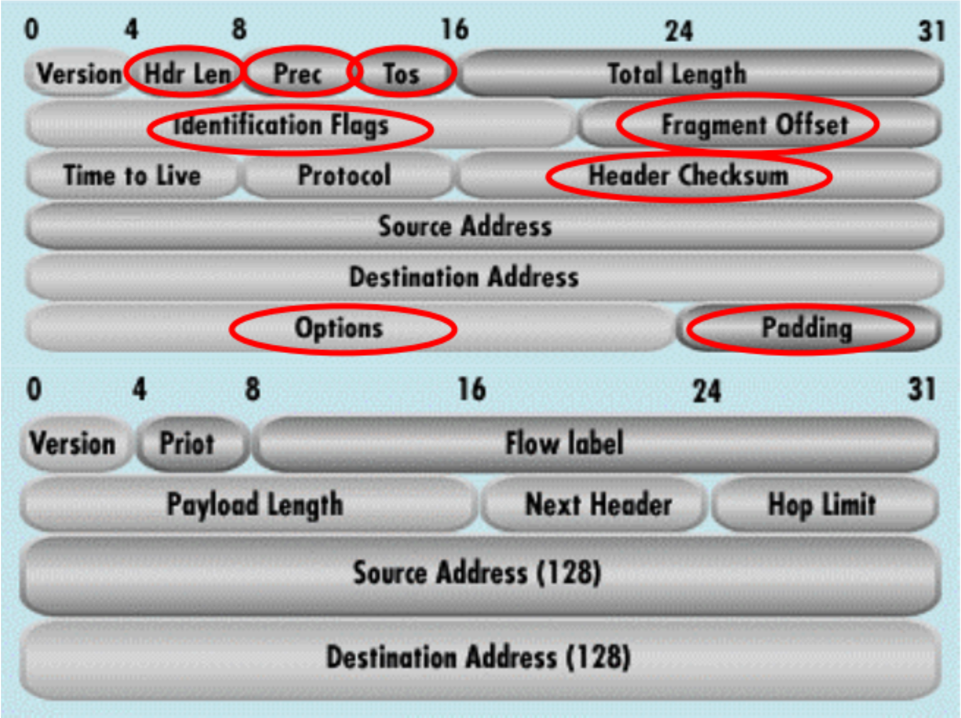
Outline

- Internet architecture

- **Addressing hosts on the internet**
  - IPv4 addressing
  - **IPv6 addressing**

IPv6 header

- IPv6 Addresses are
  - 4 times bigger (16 Bytes) than IPv4.
- IPv6 header is
  - only twice the size of the IPv4 header.



IPv6 addresses

- An IPv6 address uses 16 bytes / 128 bits
  - All IPv6 local networks are /64, removing the need for variable length subnetting at the local level
- Expressed in hexadecimal 16-bit words with

  21DA:D3:0:2F3B:2AA:FF:FE28:9C5A
- Uses the same prefix length notation as IPv4:

  21DA:D3:0:2F3B:2AA:FF:FE28:9C5A /64
- An IPv6 address identifies one or more **interfaces** rather than hosts
  - One network node may have many interfaces
- Each interface may be used to identify the node for a different purpose or application

IPv6 address types

- IPv6 divides addresses into three types
  - **Unicast**: Address for a single interface
  - **Anycast**: Address for one host of a group
    - When a message is sent to an anycast address, it is delivered to one of the hosts with that address
  - **Multicast**: Address for a group of hosts
    - When a message is sent to an multicast address, it is delivered to all of the hosts with that address

Multicast and link-local

- Unlike IPv4, IPv6 does not restrict structure of addresses (there are no address classes)
- However, there are two prefixes which have special meanings:

- Multicast: 11111111
- Link-Local Unicast: 1111111010

  - Multicast addresses are used for addressing a group of hosts
  - There are no broadcast addresses for networks as in IPv4

Unspecified and loopback addresses

- Two special addresses may never be assigned to interfaces

- Unspecified Address 0:0:0:0:0:0:0:0
  - Indicates absence or no knowledge of an address

- Loopback Address 0:0:0:0:0:0:0:1
  - Used by a host to send messages back to itself

Extra Reading

1. W. Richard Stevens, "*TCP/IP Illustrated, Volume 1: The Protocols*", Addison-Wesley Professional computing series, 1994

2. James F. Kurose and Keith W. Ross, "*Computer Networking. A Top-Down Approach Featuring the Internet*", Addison-Wesley, 2000

3. *The TCP/IP guide*: http://www.tcpipguide.com/