Scalability Challenge
+ suppose hos/s had arbitrary addresses
  - every router would need a lot of information
  - ...to know how to direct packets toward the host
- Every machine would need a slot on the forwarding table in this manner.
- Instead uses first 3 bytes to represent the network and the last byte to represent the host.

*Scalability Improved*

Address Allocation:

Classes:
A 0*: very large, /8 blocks :: (Ex => 18.0.0.0/8)
B 10*: large /16 blocks extra 8 bytes to determine local hosts :: (Ex => 128.112.0.0/16)
C 110*: small /24 blocks Standard :: (Ex => 192.20.225.0 /24)
D 1110*: Multicast groups
E 11110*: Reserved for future use.

Classless Inter-Domain Routing (CIDR)
- Hierarchical Address allocation
- Use two 32 bit #’s to represent a network
  > Network # = IP address & Mask.
- Prefixes are key to Internet scalability
  - Address allocated in contiguous chunks
  - Routing protocols and packet forwarding based on prefixes
  - Routing tables contain ~300,000--~400,000 prefixes
- Allows for network numbers like 12.4.0.0/15 (one byte better than class b)
- Subnetting allows for far more individual addresses
**Scalability: Address Aggregation**

- Provider can direct packets given only the network mask and a /##
- Aggregate multiple addresses under one provider to increase the number of addresses that can be given by that provider
- Take lowest subnet mask (aka, /8 over /24), and find out how to reach those customers.
- However, if two providers are in contact with the same customer than the aggregation would prevent the router from knowing who to send the packet through
- before CIDR there was a steep growth in need for addresses and the hardware could not keep up

**Obtaining a block of addresses**

- Prefix is assigned by provider and addresses are assigned by the institution that receives the prefix,
- 'whois -h' Unix command will provide information on who owns an IP
- Not enough IPv4 addresses for everyone but all machines cannot use IPv6. We will have to live with IPv4 for now until

**Internetworking**

- What is internetwork
  > An arbitrary collection of networks interconnected to provide some sort of host-host to packet delivery service
- What is IP
  > IP stands for Internet Protocol
  > Key tool used today to build scalable heterogeneous internetworks
  > It runs on all nodes in a collection of networks and defines the infrastructure that allows these nodes and networks to function as a single logical network.
- Transfers packets from one network to another as a series of networks.
- If it cannot reach the host on the current network forwards the pack to the next.
- IP Service Model
  > Packet delivery model
    - Connectionless model for data delivery
    - Best-effort delivery (unreliable service)
      - Packets are lost
      - Packets are delivered out of order
- IP does not guarantee a packet makes it all the way there i.e. Best Effort
- MTU (Maximum Transmission Unit) is cap on transfer rate to allow equal flow.
- Depending on the transfer rate a large packet may need to be broken up when encountering a slower medium like PPP
- IP Fragmentation and Reassembly
> Each network has MTU (max transmission unit)
- Ethernet (1,500 bytes), FDDI (4500 bytes)

Strategy
- Fragmentation occurs in a router when it receives a datagram that it wants to forward over a network which has (MTU < datagram)
- Reassembly is done at the receiving host
- All the fragments carry the same identifier in the Ident field
- Fragments are self-contained datagrams
- IP does not recover from missing fragments
- Flag set in packet header (0 or 1) indicating if there are any more packets. Contains offset as well

- If flag is set to one it means another packet is coming.
- Offset is the starting position of the packet in the series of bytes. An offset of 64 means that the packet is holding information that should be placed starting at byte 65
- Subnet mask is first 3 bytes. The 3rd byte is the subnet ID
- Router receives packet and checks with interfaces, if it does not match an interface than it is forwarded to the next available next hop
- If given 171.69 and 171.69.10 and a packet needs to go to 171.69.10.5 it will send to 171.69.10 because it is more accurate and is the longest match

Address Resolution Protocol
- ARP packet format allows users to find out mac addresses given an IP address
- A way to contact the DHCP (Dynamic Host Configuration Protocol) server is in every network (whether through a relay or direct to a server) and as soon as a device is connected or booted it sends a message to that server to receive an IP address
- ICMP (Internet Control Message Protocol) Compiles an error message and sends it back to the source of the message when a router or host is unable to process an IP datagram successfully.

> Defines a collection of error messages that are sent back to the source host whenever a router or host is unable to process an IP datagram successfully
  - Destination host unreachable due to link or node failure
  - Reassembly process failed
  - TTL has reached 0
  - IP header checksum failed
    - ICMP-redirect
      - From router to a source host