Internet Protocol (IP)

- IP is an addressing scheme for hosts on a network.
- The addressing hides the underlying physical view by creating a virtual network view.
- It also provides an
  - Unreliable,
  - Best-Effort and
  - Connectionless

  packet delivery protocol. Reliability and flow control is provided by TCP
- The IP address consists of a 32-bit unsigned binary value.
- It is usually expressed in a series of 4 byte integers separated by a decimal point
  - Ex 192.168.17.23
- Each host needs to have a unique IP address throughout the whole network is wishes to communicate with.
- Hosts containing a textual name (ex joe.com) is translated to an IP address using the DNS service, an application layer service.

IPv4 Addressing

- An IP address is usually split up into two numbers
  - <network><host>
- This is done to allow finding the target host much faster.
- The task of routing a packet to the appropriate network is done by a device called a *router*.
- Each IP datagram stores inside it the destination IP address in a header.
- A network is defined as those hosts having the same network number and each host on the same network is connected with each other using Layer 1 devices (i.e. devices that can only talk using Layer 1 language)
- Since all IP addresses need to be unique, then one needs to obtain an IP address (which are finite) to connect on the internet
  - ARIN, RIPE and APNIC
- One usually buys a range of addresses within the same network.
- Since networks tend to be of varying sizes, a classification of network numbers exists.

Class-based IP addresses

- There are 5 classes of IP addresses
  - Class A: start with '0', 7 bits for network, 24 bits for host
  - Class B: start with '10', 14 bits for network, 16 bits for the host
  - Class C: start with '110', 21 bits for the network, 8 bits for the host
  - Class D: start with '1110', used for Multicasting
  - Class E: start with '11110', reserved for future use
  - The host based past of the IP address is then regulated by the systems administrator.
  - To calculate the number of networks or hosts allowed, one needs to subtract two from each number since the first and last are always reserved.

Reserved IP Addresses

- Some IP addresses have special meaning and cannot be assigned.
- A component of an IP address that has all its bits equal to `0`, refers to ‘this’ network or host
  - In fact an IP address with all host bits set to zero is known as the *network address*.
- A component of an IP address that has all its bits equal to `1`, refers to all networks or hosts.
  - An IP address with all host bits set to one is known as the *broadcast address*.
- The address 127.0.0.0 is the loopback network.

IP Subnetting

- What happens when one has networks that do not correspond to the classes of IP addresses.
  - Changes in networks might also happen after one purchases IP addresses
- One splits the host part into a subnet number and then a host number
  - <network><subnet><host>
- The subnet and host are transparent to external networks
  - A local host knows about subnets
  - A foreign host does not know about the subnet and still sees subnet+host as one single host number.
- The division into subnets is performed by the local administrator.
- The routing is performed by a hierarchy of routers.
- This division is identified through the use of a *subnet mask*
  - Zeros represent the host part
  - Ones represent the network part
  - Ex 255.255.255.0 is a Class C address !!

Subnetting Methodology

- Subnet Addresses are also represented as /x where *x* is number of bits burrowed for network+subnet,
  - 255.255.255.0 is /24
- Note that performing an AND operation between the subnet mask and an IP address will give you the network+subnet address.
- The treatment of all 1s and all 0s applies to all three components of the IP address
  - Thus for each subnet range, the first and last are unusable.
- Following table shows subnet borrowing for Class C addresses (courtesy of Cisco)

Slash format	/25	/26	/27	/28	/29	/30	N/A	N/A
Mask	128	192	224	240	248	252	254	255
Bits borrowed	1	2	3	4	5	6	7	8
Value	128	64	32	16	8	4	2	1
Total Subnets		4	8	16	32	64		
Usable Subnets		2	6	14	30	62		
Total Hosts		64	32	16	8	4		
Usable Hosts		62	30	14	6	2		

Subnetting Example

- A company has bought the class C network address:
  - 193.188.34.0
- Yet it has 4 networks that each contain 20 PCs.
- Thus one can create the subnet borrowing 3 bits
  - 255.255.255.224 or /27
- Now one has six useable networks, each able to hold 30 hosts.
- Thus administrator can use the following
  - Network 1:193.188.34.32 hosts 193.188.34.33-193.188.34.62
  - Network 2:193.188.34.64 hosts 193.188.34.65-193.188.34.94
  - Network 3:193.188.34.96 hosts 193.188.34.97-193.188.34.126
  - Network 4:193.188.34.128 hosts 193.188.34.129-193.188.34.158

  and still has 2 unused networks and 10 unused host addresses for each of the first four networks.
- Note how the first and last subnet address cannot be used and result in wastage of 30 hosts each.

Types of Subnetting

- There are 4 types of Subnetting
  - Static Subnetting
    - All subnets use the same subnet mask
  - Variable Length subnetting
    - Each subnet uses a subnet mask that suits the network at hand. One ends up with multiple subnets of different sizes. This obviously requires from work to set up from the administrator.
  - Static + Variable Length Subnetting
    - Variable Length subnetting can only be allowed by using devices that are able to route data to the appropriate subnet.
    - Thus some routers will hide subnetting information from other routers

IP Routing

- IP needs to interconnect different networks and relay data between them
- This is done through a very important device: A router
  - A router acts simultaneously both as a normal host and also as a router
- A router has two or more physical network interfaces, thus is by default *multi-homed.* All hosts should be single-homed.
- A router with *partial routing information* stores inside it information about the following destinations
  - Hosts that are on the same network to which the router is physically connected
  - Hosts or networks about which explicit information has been provided
  - Hosts or networks about which the router has received explicit ICMP redirect packets
  - Default route to any other destination
- All this information is stored inside the *routing table*

Types of Routing

- There are two ways in which an incoming datagram will be sent
  - Direct Routing: If the destination host is on the same physical network as the source host, then the datagram is sent directly to the host through encapsulating it in the physical network frame
  - Indirect Routing: If the destination host is not directly connected, then the datagram is sent to a router (also known as *gateway*). The IP address of the first router is the only information required. The router might then pass it to the destination host or another router.
- Note that even if the hosts are on the same physical network, but are defined on different subnets, a router is still required.

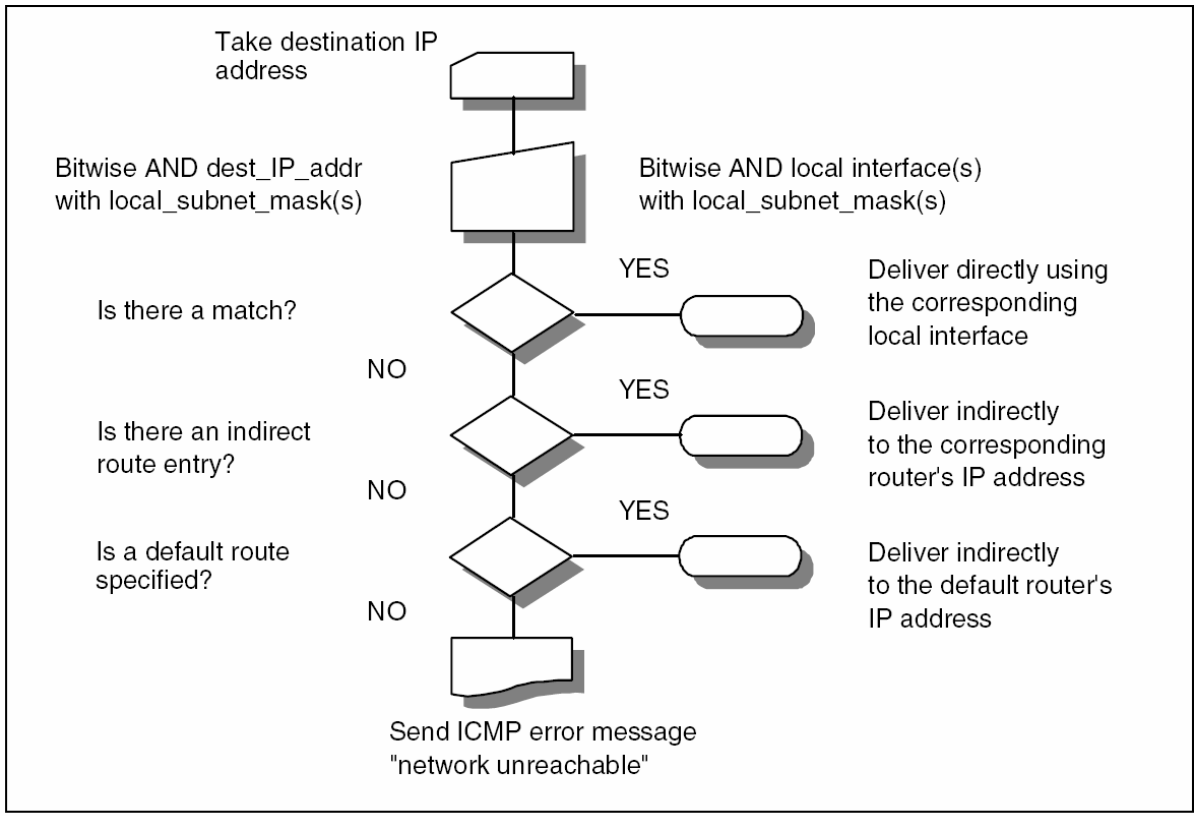
Routing Tables

- Each host stores inside it the following mapping
  - Destination IP network address
  - IP address of router
- This information is called the IP routing table and is initialised at startup.
  - The Routing Table is used only for indirect routing.
- To view routing table type `route` on Linux and `route print` on Windows
- There are three types of information usually found in routing tables
  - Direct routes reachable through one router's IP address.
  - Indirect routes reachable through one or more routers' IP address
  - Default route when the above do not apply.
- Thus all entries normally contain destination network and then an IP address or an interface to reach that network.
- In addition, routing tables normally contain the loopback address 127.0.0.1

Routing Algorithm

- To allow a host to differentiate between destinations intended for the local network and those which are not the following is executed:
  - If destination IP network address is equal to host's network address
    - IP datagram is sent on local network
    - If not, IP datagram is sent to gateway corresponding to destination IP network address or to the default gateway
- To allow for subnets the following has to be done
  - If AND(destination IP Address, subnet mask) equals
    AND (my IP Address, subnet mask) then send to local network, otherwise send to corresponding gateway
- This implies that each host needs to know about subnetting, otherwise that host will be unable to communicate with hosts on different subnets but on the same network.
- When a destination is on the same network, the destination IP is the same as the destination host's IP address and the physical address is that of the destination host.
- When a destination is on another network, the destination IP is STILL the same as the destination host's IP address, yet the physical address is that of the router.

Full Routing Algorithm



- This algorithm is the same for routers as for hosts, the only difference is that for routes, this algorithm is performed for each interface.
- Routers are also able to update their routing table using Routing Protocols