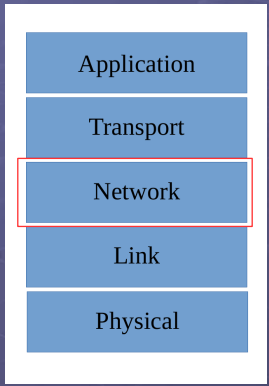
Systems and Devices 2 (Network)
Lec 4a: Network Layer

Before we get started ...

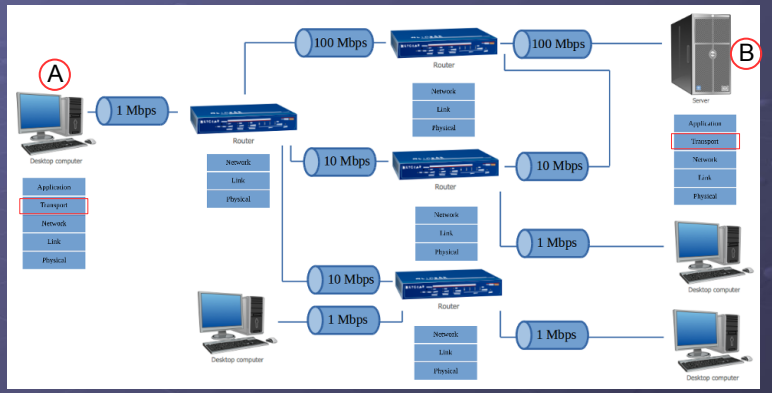
- We have looked at how packets are transferred at the transport layer i.e. process to process, using:
  - TCP, UDP, port numbers etc
  - BUT, we have not considered how packets get from one host to another e.g. how does a switch know which cable to transmit a packet down to get to a specific destination?
- Moving down to the network layer i.e. host to host communications, using :
  - Internet protocol (IPv4 and IPv6)
  - Hubs, switches, routers, and bridges ...
    - Routing and forwarding algorithms
      - Here be dragons :)

Internet protocol stack



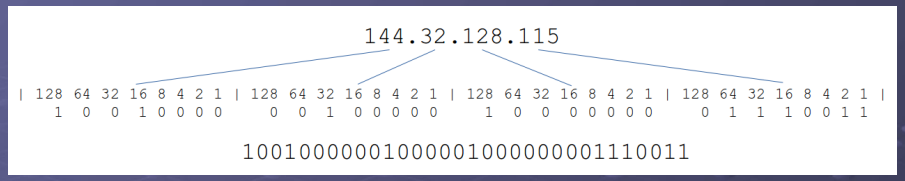
- Application layer
- Transport
- Network (layer 3)
  - Routing protocols to direct packets (**datagrams**) from one host to another across the network of networks that form the Internet. All based around:
    - Internet protocol (IP)
- Link
- Physical

The problem ...



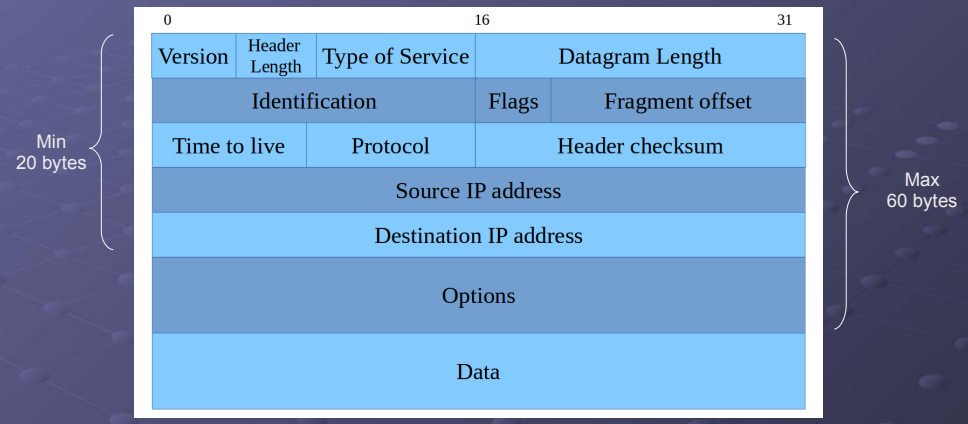
- Q: how do we get a packet from A to B when we don't know where B is in the world?
  - How are hosts A and B identified on a network?

IPv4



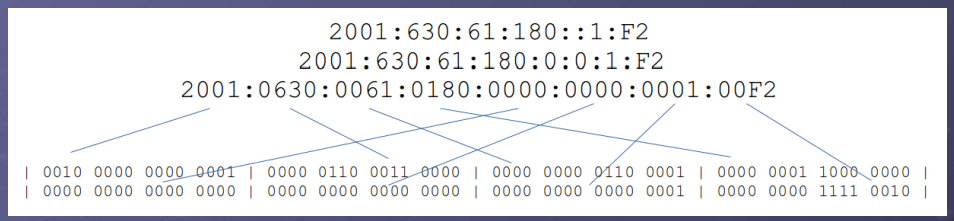
- Internet Protocol v4
  - RFC 791: https://tools.ietf.org/html/rfc791
  - Created in 1970s, IPv4 in 1981, the core internet protocol.
  - IP encapsulates data into a datagram i.e. header and payload, providing a connectionless service.
  - Network interfaces on each host and router “must” have a globally unique IP address.
    - IPv4 32bit address
    - Represented using the dot notation

IPv4



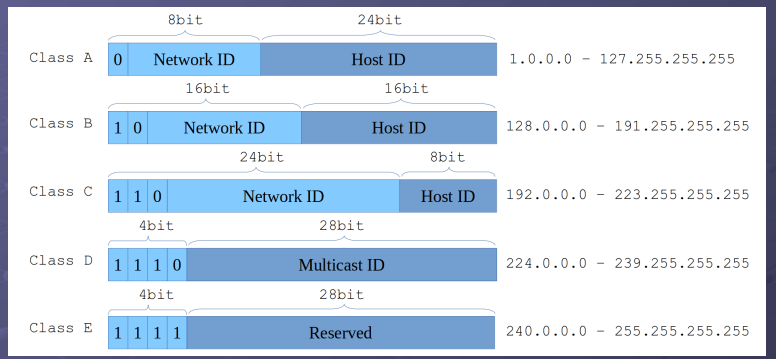
- IP header depending on option fields used can vary from 20-60B.

IPv6



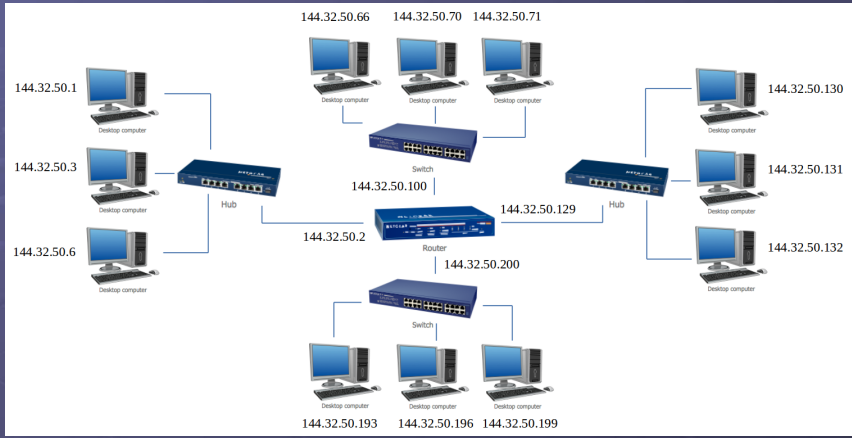
- Internet Protocol v6
  - RFC 2460: https://tools.ietf.org/html/rfc2460
  - Draft standard created in 1998 to overcome the issues of IPv4 address exhaustion.
    - IPv6 128bit address.
    - Represented using eight, four digit hexadecimal notation
  - Note : IPv4 is a “dead” protocol, but we still live in the land of IPv4 for a little longer (maybe forever?).

IPv4



- Q: how are IP addresses allocated in a network?
  - In the beginning we had network classes i.e. we used classful addressing, IP address broken down into network and host ID.
  - Advantage: simple. Disadvantage: wasteful.

Example network



- Q: how do we organise hosts on a network?

IPv4

```
Class A network mask : 255.0.0.0
Class B network mask : 255.255.0.0
Class C network mask : 255.255.255.0
```

```
                                                    Host ID
Network addr:    144.32.50.6       10010000.00100000.00110010.00000110
Network mask:    255.255.255.0     11111111.11111111.11111111.00000000
Network ID:       144.32.50.0      10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192   11111111.11111111.11111111.11000000
mask
                Network ID                    Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```

- A: In the early Internet top level organisation by network class i.e. A, B or C. Top 4bits of IP address identifies class.

IPv4

```
Class A network mask : 255.0.0.0
Class B network mask : 255.255.0.0
Class C network mask : 255.255.255.0
```

Class B IP address
16bit Network ID / 16bit Host ID

```
                                                    Host ID
Network addr:    144.32.50.6       10010000.00100000.00110010.00000110
Network mask:    255.255.255.0     11111111.11111111.11111111.00000000
Network ID:       144.32.50.0      10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192   11111111.11111111.11111111.11000000
mask
                Network ID                    Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
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Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```

- 144 = 10010000 = Class B.

IPv4

```
Class A network mask : 255.0.0.0
Class B network mask : 255.255.0.0
Class C network mask : 255.255.255.0
```

Use some of the Host ID bits in the Network ID i.e. a subnet

```
                                                    Host ID
Network addr:    144.32.50.6       10010000.00100000.00110010.00000110
Network mask:    255.255.255.0     11111111.11111111.11111111.00000000
Network ID:       144.32.50.0      10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192   11111111.11111111.11111111.11000000
mask
                Network ID                    Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```

- We can then break this network down into subnets using a network mask, 1s = network ID, 0s = host ID

IPv4

```
Class A network mask : 255.0.0.0
Class B network mask : 255.255.0.0
Class C network mask : 255.255.255.0
                                                        Host ID

Network addr:   144.32.50.6      10010000.00100000.00110010.00000110
Network mask:   255.255.255.0    11111111.11111111.11111111.00000000
Network ID:      144.32.50.0     10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192  11111111.11111111.11111111.11000000
mask
            Network ID                    Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```

- Need to organise hosts by function or location. Hosts are not just assigned a random IP address i.e. need subnets
  - Host ID all 0s (network addr) and all 1s (broadcast addr) reserved

IPv4

```
Class A network mask : 255.0.0.0
Class B network mask : 255.255.0.0
Class C network mask : 255.255.255.0
                                                        Host ID

Network addr:   144.32.50.6      10010000.00100000.00110010.00000110
Network mask:   255.255.255.0    11111111.11111111.11111111.00000000
Network ID:      144.32.50.0     10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192  11111111.11111111.11111111.11000000
mask                                                          00
            Network ID                    Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62   <-
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
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Class C network mask : 255.255.255.0
                                                        Host ID

Network addr:   144.32.50.6      10010000.00100000.00110010.00000110
Network mask:   255.255.255.0    11111111.11111111.11111111.00000000
Network ID:      144.32.50.0     10010000.00100000.00110010.00000000

Network subnet: 255.255          111.1111 .11111111.11000000
mask                                                          00
            Network ID                    Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62   <-
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```

Q : Why not 63?

Q : Why not 0?

- Need to organise hosts by function or location. Hosts are not just assigned a random IP address i.e. need subnets
  - Host ID all 0s (network addr) and all 1s (broadcast addr) reserved

IPv4

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Class A network mask : 255.0.0.0
Class B network mask : 255.255.0.0
Class C network mask : 255.255.255.0
                                                        Host ID

Network addr:   144.32.50.6      10010000.00100000.00110010.00000110
Network mask:   255.255.255.0    11111111.11111111.11111111.00000000
Network ID:      144.32.50.0     10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192  11111111.11111111.11111111.11000000
mask                                                          01
            Network ID                    Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126  <-
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Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```

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IPv4

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Class A network mask : 255.0.0.0
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Class C network mask : 255.255.255.0
                                                          Host ID

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Network mask:    255.255.255.0     11111111.11111111.11111111.00000000
Network ID:      144.32.50.0       10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192   11111111.11111111.11111111.11000000
mask                                                          10
             Network ID                      Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190  <=
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```

- Need to organise hosts by function or location. Hosts are not just assigned a random IP address i.e. need subnets
  - Host ID all 0s (network addr) and all 1s (broadcast addr) reserved

IPv4

```
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Class B network mask : 255.255.0.0
Class C network mask : 255.255.255.0
                                                          Host ID

Network addr:    144.32.50.6       10010000.00100000.00110010.00000110
Network mask:    255.255.255.0     11111111.11111111.11111111.00000000
Network ID:      144.32.50.0       10010000.00100000.00110010.00000000

Network subnet: 255.255.255.192   11111111.11111111.11111111.11000000
mask                                                          11
             Network ID                      Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254  <=
```
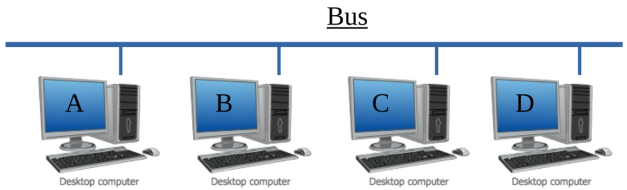

- Need to organise hosts by function or location. Hosts are not just assigned a random IP address i.e. need subnets
  - Host ID all 0s (network addr) and all 1s (broadcast addr) reserved

Broadcast and Collision Domains

```
             Network ID                      Host ID range
Subnet 0 : 144.32.50.0    : 144.32.50.1    - 144.32.50.62
Subnet 1 : 144.32.50.64   : 144.32.50.65   - 144.32.50.126
Subnet 2 : 144.32.50.128  : 144.32.50.129  - 144.32.50.190
Subnet 3 : 144.32.50.192  : 144.32.50.193  - 144.32.50.254
```



- Broadcast domain : hosts that will respond to a broadcast address i.e. are on the same subnet
- Collision domain : hosts that are sharing the same communication channel.

IPv4

```
Class C network mask : 255.255.255.0

Network addr:    144.32.50.6       10010000.00100000.00110010.00000110
Network mask:    255.255.255.0     11111111.11111111.11111111.00000000
Network ID:      144.32.50.0       10010000.00100000.00110010.00000000

CIDR notation
                 144.32.50.6/24 or 144.32.50.0/24

Network subnet: 255.255.255.192   11111111.11111111.11111111.11000000
mask

Subnet 0 : 144.32.50.0/26         Subnet 1 : 144.32.50.64/26
Subnet 2 : 144.32.50.128/26       Subnet 3 : 144.32.50.192/26
```

- To simplify routing and free-up unused network addresses, network ID allocation moved to classless addressing
  - CIDR : Classless Inter-Domain Routing, variable length subnet masking (VLSM), no longer limited to classes A, B and C.

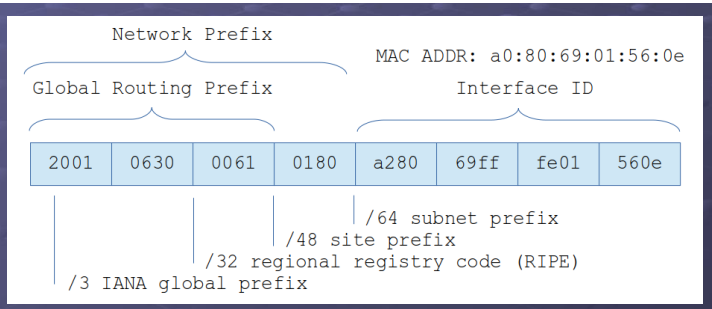
Quick Quizzz

```
CIDR notation:  144.32.50.0/26

Network subnet: 255.255.255.192  11111111.11111111.11111111.11000000
mask

Network address A: 144.32.50.110
Network address B: 144.32.50.120
Network address C: 144.32.50.130
Network address D: 144.32.50.150
Network address E: 144.32.50.190
Network address F: 144.32.50.200
```

- Given the above subnet mask which of these IP addresses are on the same subnets i.e. have the same network address?

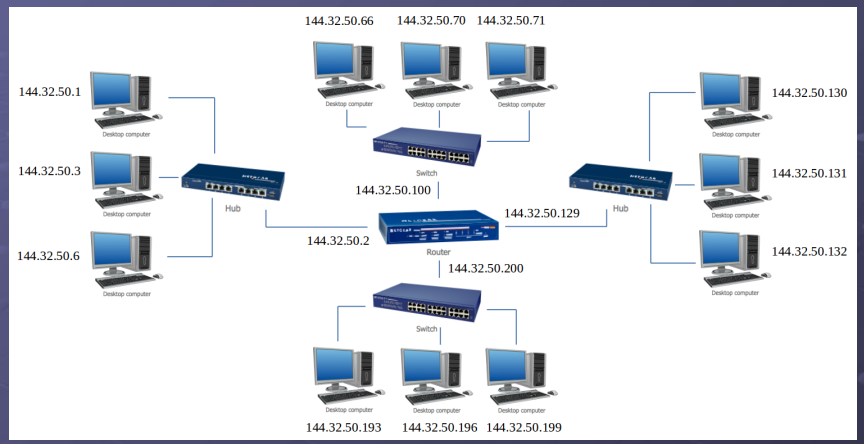
IPv6

```
2000::/3      Unique Global     internet routeable, unicast/anycast
fd00::/8      Unique Local      locally routeable, not internet routeable, unicast
fe80::/10     Link Local        local network only
ff00::/8      Multicast         no broadcast
```



- The IP block 2001:630::/32 is allocated to Janet.
- Typically a 64bit network prefix + 64bit interface ID

Example network



- Q: Whats the difference between a hub, switch and a router?

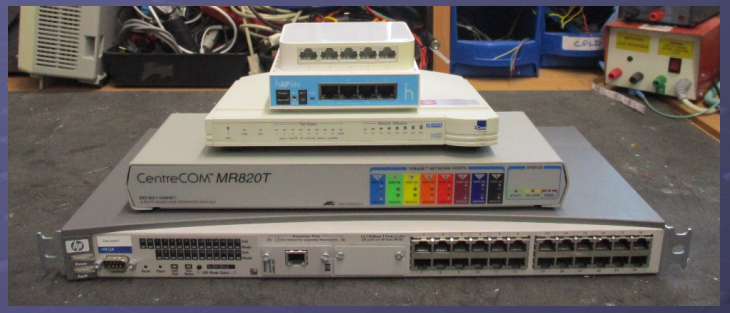
Network building blocks

- Hub (layer 1): or repeater, multiple ports, incoming signals repeated on each output port, “collisions” can occur, only one signal can be active at a time.
  - In general have been replaced by switches.
  - For info on collisions refer to CSMA/CD : http://bit.ly/3oME2Ra
- Switch (mostly layer 2, sometimes 3): learns what host is connected to a port and forwards signals to the correct ports. Collisions can not occur, but could drop packets.
  - Store and forward, packets buffered in memory
- Router (layer 3): uses destination IP addr combined with static and dynamic routing tables to forward packets to the correct ports. Congestion control i.e. RX buffer
  - Tail drop, random early detection (RED) etc.

Network building blocks

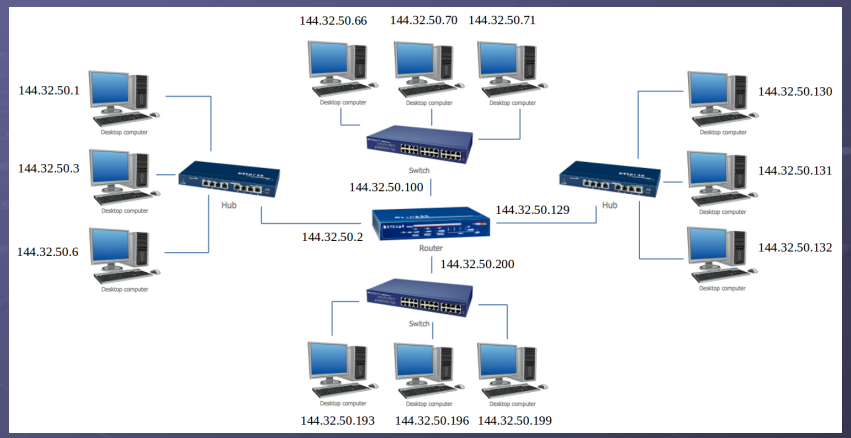
- Bridge (layer 2): originally used in hub based systems to divide “collision domains”, similar to a switch, learns what packets to forward, creates a single aggregated network from multiple segments.
  - Transparent bridging, store and forward
  - A common broadcast domain made from two or more collision domains
- Gateway: a network node that acts as an access point (AP) to another network i.e. a router.
  - Default gateway: in a Small Office / Home Office (SOHO) this is typically a ADSL router, connecting the local network to the Internet

Demo



- Networking stuff
  - 10,100,1000 Mb/s. Full / Half duplex, 4 -24 ports
  - Note, we will be looking at the physical layer (layer 1) in more detail in later lectures

Quick Quizzz



- Q: how many collision domains and broadcast domains are there in this network?

My home network

```
mike@mike-firewall:~$ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.1.254   0.0.0.0         UG    0      0        0 enp6s2
192.168.1.0     0.0.0.0         255.255.255.0   U     0      0        0 enp6s2
192.168.10.0    0.0.0.0         255.255.255.0   U     0      0        0 enp6s1
192.168.20.0    0.0.0.0         255.255.255.0   U     0      0        0 enp6s0
192.168.30.0    0.0.0.0         255.255.255.0   U     0      0        0 enp0s25
192.168.50.0    0.0.0.0         255.255.255.0   U     0      0        0 wlp5s0
192.168.60.0    0.0.0.0         255.255.255.0   U     0      0        0 wlp5s0_0
mike@mike-firewall:~$
```

```
mike@mike-Linux-Box ~ $ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.30.254  0.0.0.0         UG    100    0        0 eno1
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 enp5s0
192.168.0.0     0.0.0.0         255.255.255.0   U     100    0        0 enp5s0
192.168.30.0    0.0.0.0         255.255.255.0   U     100    0        0 eno1
mike@mike-Linux-Box ~ $
```

- Route command : route -n
  - 0.0.0.0 : invalid or unknown host
  - 0.0.0.0 / 0 : default route
  - The most complete (longest) match wins

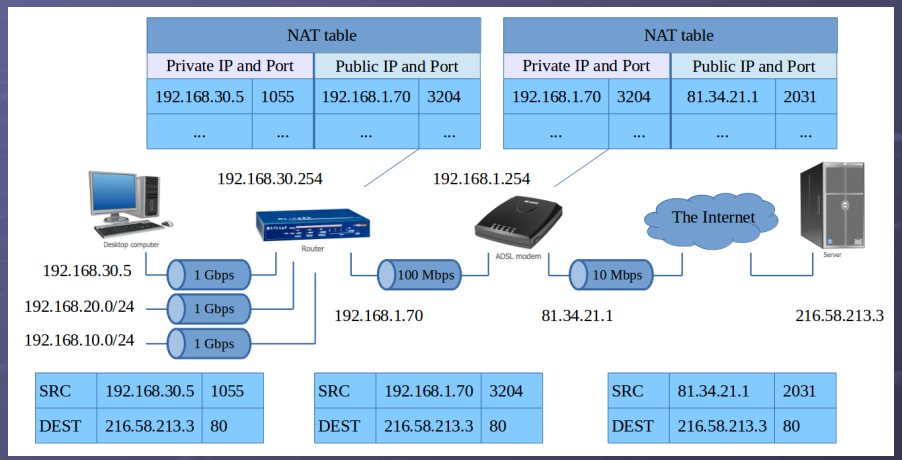
Local IP Addresses

- Not all hosts need to be connected to the internet e.g. machines on your local network e.g. printer, network attached storage (NAS), media servers etc.
  - Private network: ip addresses for hosts that do not need to be internet visible. Assigned specific address ranges i.e. should not be used on the internet:
    - 10.0.0.0 / 8 (255.0.0.0)
    - 172.16.0.0 / 12 (255.240.0.0)
    - 192.168.0.0 / 16 (255.255.0.0)
  - DHCP failed to connect subnet (not routable, local network only)
    - 169.254.0.0 / 16
- These IP address ranges will be dropped by your ISP i.e. locally routable, not globally routeable addresses.

NAT

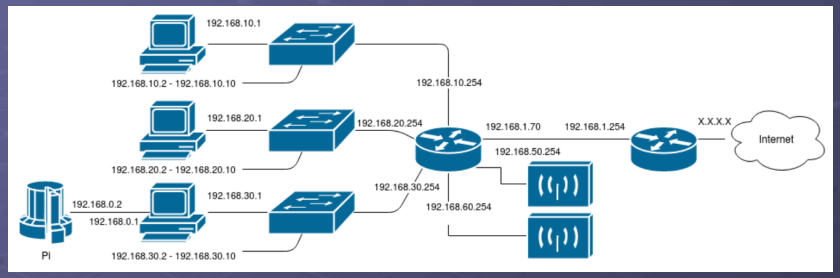
- Q : but how can these hosts (private IP addresses) access resources on the internet?
- A : we can use network address translation (NAT) to convert a local IP to a global IP address:
  - A few different flavours : port, dynamic, static ...
  - IP masquerading / overloading
    - Change IP address to public (ADSL), update checksums based on ports used.
    - Router maintains a table of who is communicating over what src / dest port and updates local IP address accordingly for all incoming and outgoing segments.
- In the previous home network example we have two NATed networks.

NAT



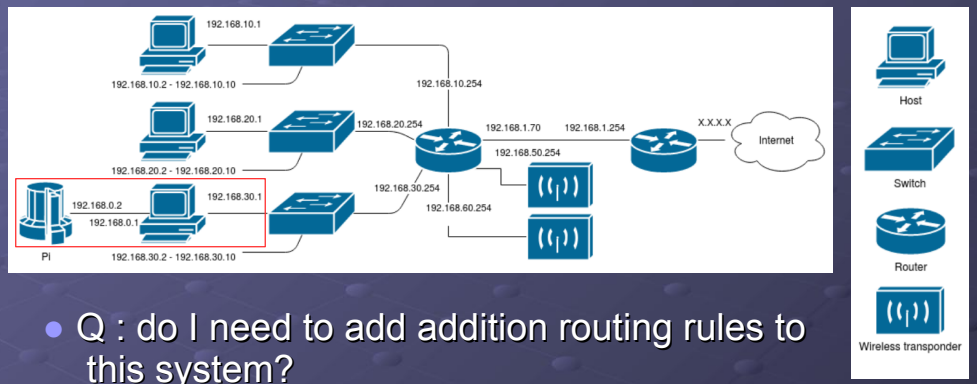
- Home network setup.

Static routing



- Q : do I need to add addition routing rules to this system?
  - What happens if host 192.168.30.1 pings 192.168.0.2?
  - What happens if host 192.168.30.1 pings 192.168.10.2?
  - What happens if host 192.168.30.1 pings 8.8.8.8?

Static routing



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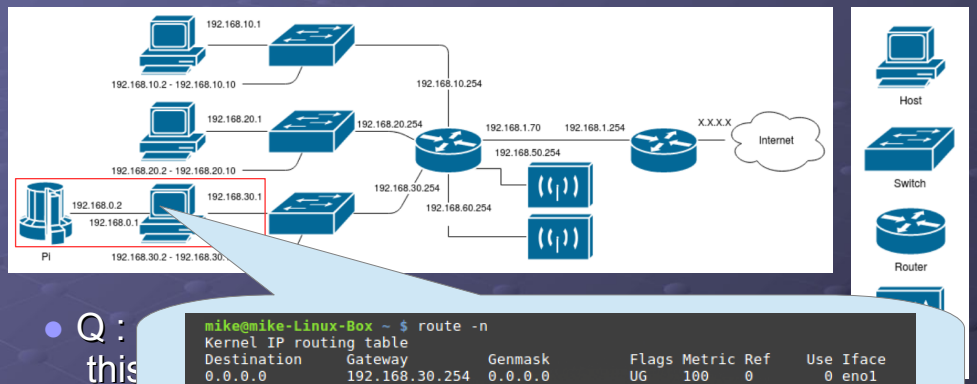
  - What happens if host 192.168.30.1 pings 192.168.0.2?
  - What happens if host 192.168.30.1 pings 192.168.10.2?
  - What happens if host 192.168.30.1 pings 8.8.8.8?

Static routing

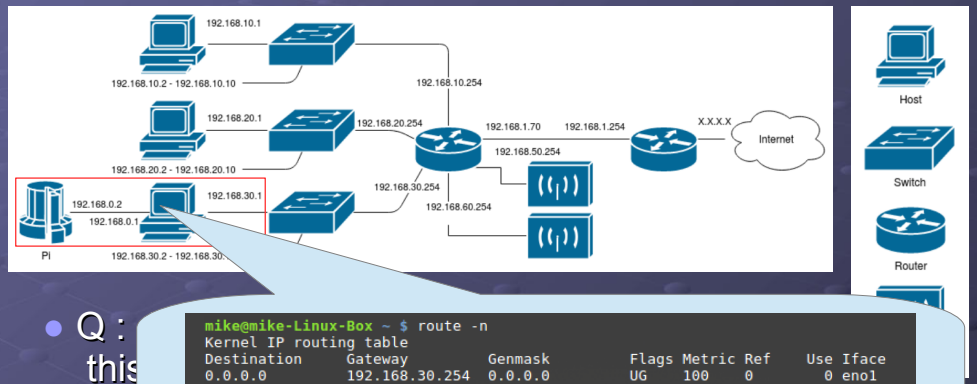


- Q :
  - W
  - W
  - Wh

```
mike@mike-Linux-Box ~ $ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.30.254  0.0.0.0         UG    100    0        0 eno1
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 enp5s0
192.168.0.0     0.0.0.0         255.255.255.0   U     100    0        0 enp5s0
192.168.30.0    0.0.0.0         255.255.255.0   U     100    0        0 eno1
mike@mike-Linux-Box ~ $
```

DEST : 192.168.0.2

Static routing

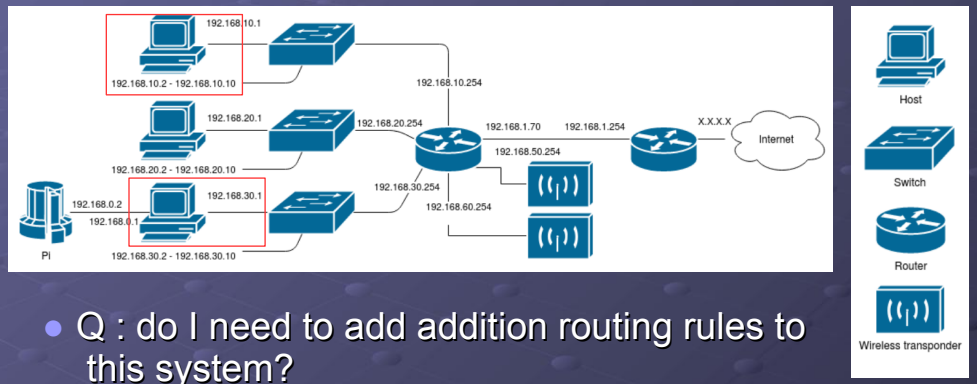


- Q :
  - W
  - W
  - Wh

```
mike@mike-Linux-Box ~ $ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.30.254  0.0.0.0         UG    100    0        0 eno1
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 enp5s0
192.168.0.0     0.0.0.0         255.255.255.0   U     100    0        0 enp5s0
192.168.30.0    0.0.0.0         255.255.255.0   U     100    0        0 eno1
mike@mike-Linux-Box ~ $
```

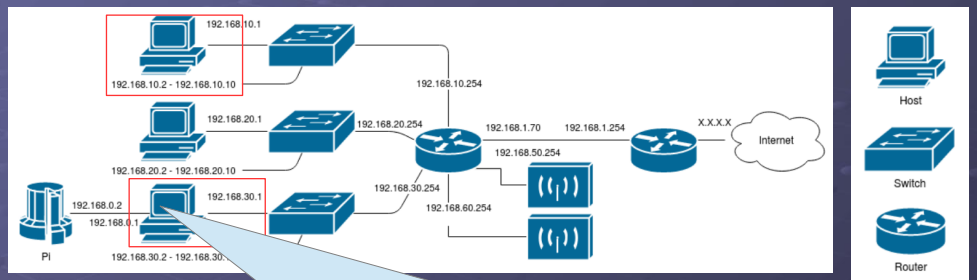
DEST : 192.168.0.2

Static routing



- Q : do I need to add addition routing rules to this system?
  - What happens if host 192.168.30.1 pings 192.168.0.2?
  - What happens if host 192.168.30.1 pings 192.168.10.2?
  - What happens if host 192.168.30.1 pings 8.8.8.8?

Static routing

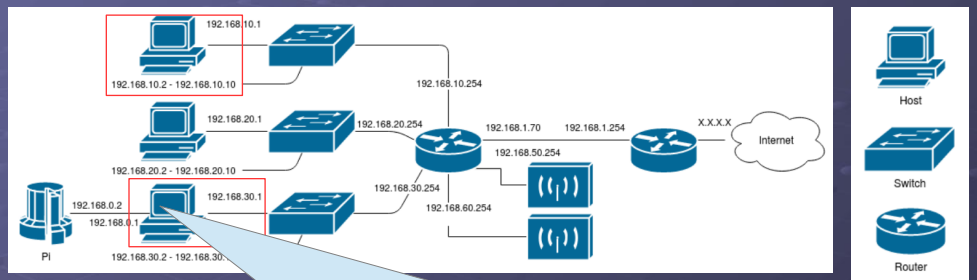


- Q :
  this
  - W
  - W
  - Wh

```
mike@mike-Linux-Box ~ $ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.30.254  0.0.0.0         UG    100    0        0 eno1
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 enp5s0
192.168.0.0     0.0.0.0         255.255.255.0   U     100    0        0 enp5s0
192.168.30.0    0.0.0.0         255.255.255.0   U     100    0        0 eno1
mike@mike-Linux-Box ~ $
```

DEST : 192.168.10.2

Static routing



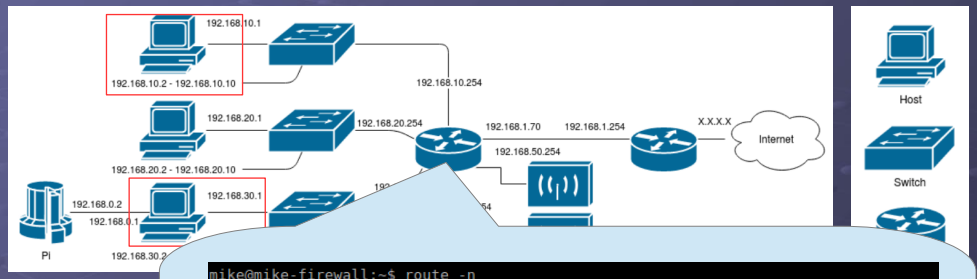
- Q :
  this
  - W
  - W
  - Wh

```
mike@mike-Linux-Box ~ $ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.30.254  0.0.0.0         UG    100    0        0 eno1
169.254.0.0     0.0.0.0         255.255.0.0     U     1000   0        0 enp5s0
192.168.0.0     0.0.0.0         255.255.255.0   U     100    0        0 enp5s0
192.168.30.0    0.0.0.0         255.255.255.0   U     100    0        0 eno1
mike@mike-Linux-Box ~ $
```

DEST : 192.168.10.2

University of York : M Freeman 2024

Static routing



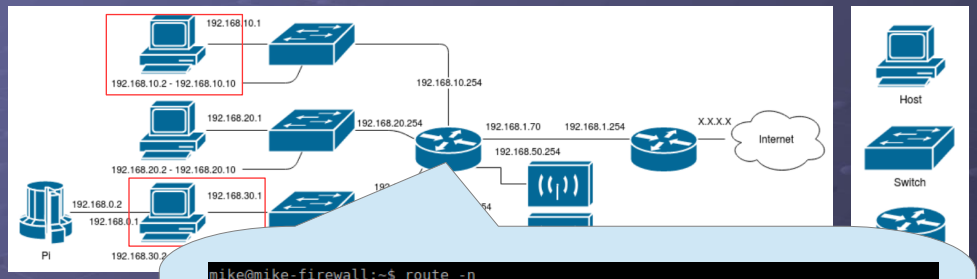
- Q : d
  this
  - Wh
  - Wh
  - What

```
mike@mike-firewall:~$ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.1.254   0.0.0.0         UG    0      0        0 enp6s2
192.168.1.0     0.0.0.0         255.255.255.0   U     0      0        0 enp6s2
192.168.10.0    0.0.0.0         255.255.255.0   U     0      0        0 enp6s1
192.168.20.0    0.0.0.0         255.255.255.0   U     0      0        0 enp6s0
192.168.30.0    0.0.0.0         255.255.255.0   U     0      0        0 enp0s25
192.168.50.0    0.0.0.0         255.255.255.0   U     0      0        0 wlp5s0
192.168.60.0    0.0.0.0         255.255.255.0   U     0      0        0 wlp5s0_0
mike@mike-firewall:~$
```

DEST : 192.168.10.2

University of York : M Freeman 2024

Static routing



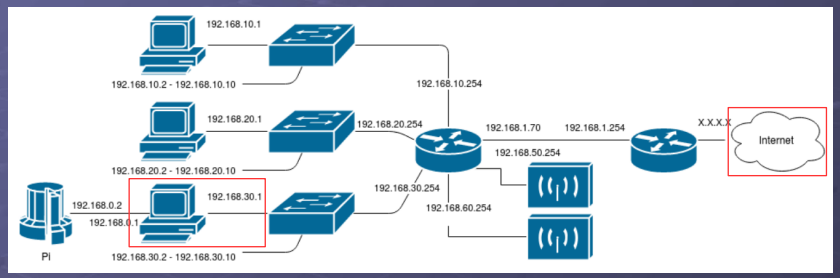
- Q : d
  this
  - Wh
  - Wh
  - What

```
mike@mike-firewall:~$ route -n
Kernel IP routing table
Destination     Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0         192.168.1.254   0.0.0.0         UG    0      0        0 enp6s2
192.168.1.0     0.0.0.0         255.255.255.0   U     0      0        0 enp6s2
192.168.10.0    0.0.0.0         255.255.255.0   U     0      0        0 enp6s1
192.168.20.0    0.0.0.0         255.255.255.0   U     0      0        0 enp6s0
192.168.30.0    0.0.0.0         255.255.255.0   U     0      0        0 enp0s25
192.168.50.0    0.0.0.0         255.255.255.0   U     0      0        0 wlp5s0
192.168.60.0    0.0.0.0         255.255.255.0   U     0      0        0 wlp5s0_0
mike@mike-firewall:~$
```

DEST : 192.168.10.2

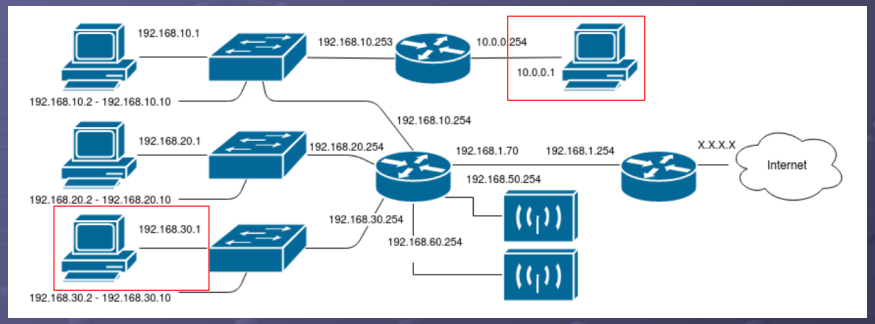
University of York : M Freeman 2024

Quick Quizzz



- Q : do I need to add addition routing rules to this system?
  - What happens if host 192.168.30.1 pings 192.168.0.2?
  - What happens if host 192.168.30.1 pings 192.168.10.2?
  - What happens if host 192.168.30.1 pings 8.8.8.8?

Quick Quizzz

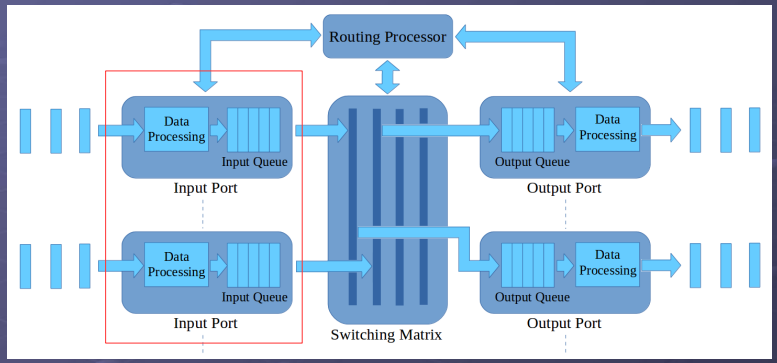


- Q : do I need to add addition routing rules to this system? Where should we add these rules?
  - What happens if host 192.168.30.1 pings 10.0.0.1?
  - route add -net X.X.X.X netmask X.X.X.X gw X.X.X.X

What's inside a router?

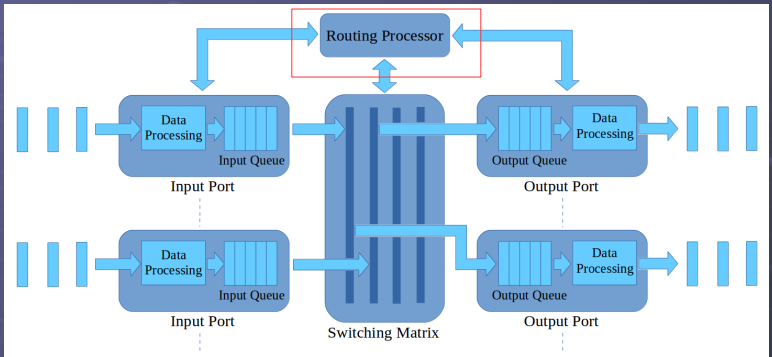
- From the quick quizzz we see that a router must contain a routing table (forwarding table) i.e. when it receives a network packet it has to work out what it should do with it.
  - Router has to decide what interface to forward the packet to
- From previous lectures we know that packet switching uses the store and forward technique, therefore, a router must be capable of receiving a complete network packet before forwarding it.
  - Internal operations are lot faster than physical media, therefore, need input/output buffers for full duplex operations.

Router



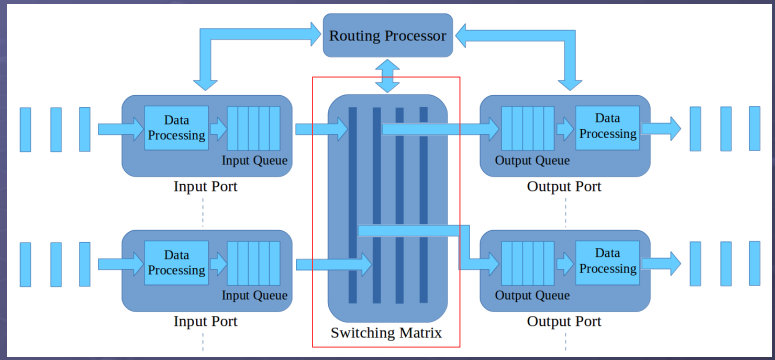
- Input ports: process link layer signal, IP lookup function to determine output port, forward control packets to routing processor.
  - Ternary Content Addressable Memory (TCAM)

Router



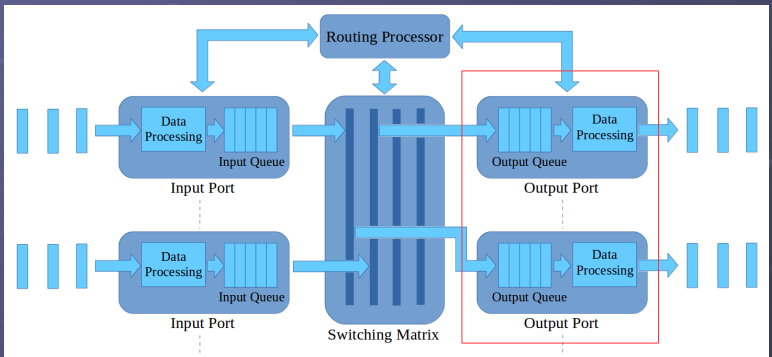
- Routing processor: processes routing protocols, updates routing tables, maintains forwarding table used by input ports, monitors link state.

Router



- Switching matrix: connects an input queue/port to an output queue/port using crossbar, shared memory or bus etc. Connection determined by forwarding table in input port.

Router



- Output ports: retransmit received packet onto the selected out port.

Quick Quizzz

- Q : what type of communication networks are used inside the router i.e. circuit / packet switching?
- Q: if a 10Gbps input port receives packets containing 64bytes of data how long does it have to determine the correct output port?
- Q: what happens if the router can not process packets at this speed?

Summary

- We have identified how hosts are identified on a network i.e. IP addresses, and how these are connected together i.e. hubs, switches and routers.
- A key element of transferring packets across a network are routers, these decide where packets should go next based on their routing tables
- However, we still have some unanswered questions:
  - What do the other fields in the IP header do?
    - For next time research the TTL and Fragmentation fields
  - How do we build a router's routing table i.e. do we have to do this manually or is there a protocol for that :)