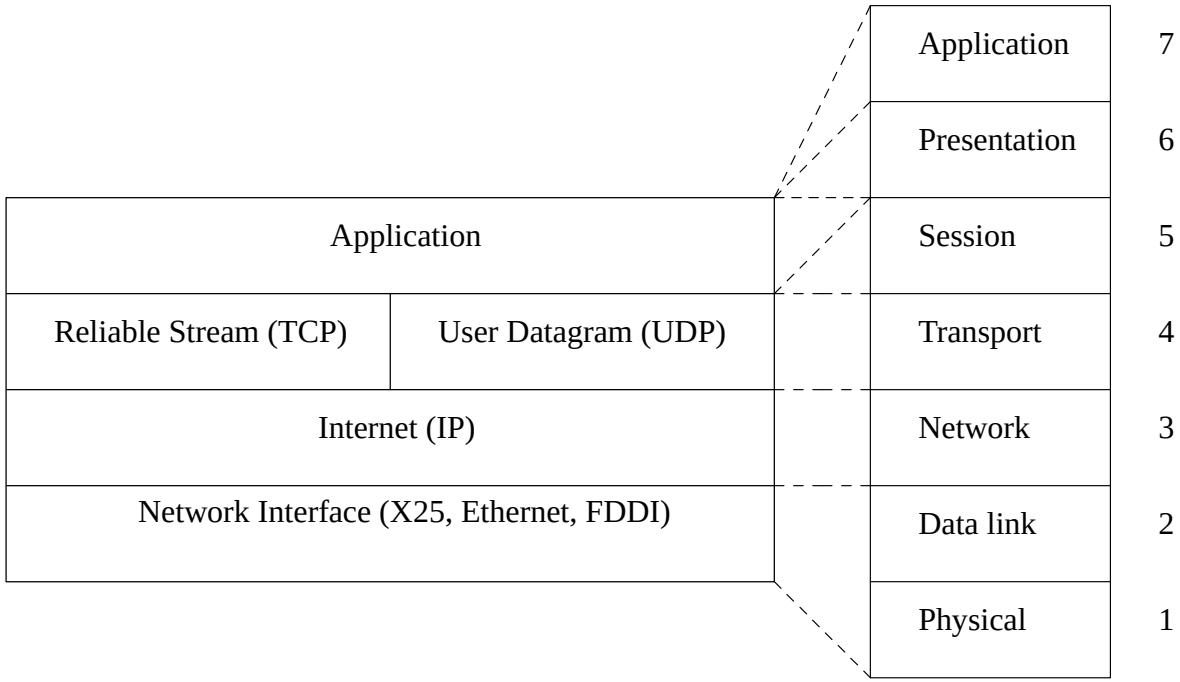
Introduction to the TCP/IP protocol suite

- TCP/IP has been around for longer than the ISO OSI 7 layer model
- the ISO OSI 7 layer model is useful as a reference model for explaining the function of data transmission
- practically TCP/IP has won but literature still uses the ISO OSI 7 layer model

ISO OSI 7 Layer model and the TCP/IP protocol stack

- there is not an exact match between the ISO OSI 7 layer reference model and the TCP/IP protocol stack

ISO OSI 7 Layer model and the TCP/IP protocol stack



TCP/IP protocol stack

ISO OSI 7 Layer model

Networking Glossary

- router
  - a special purpose, dedicated computer that attaches to two or more networks and routes IP datagrams from one to another
  - each router forwards a datagram to another router until the datagram reaches its destination

Networking Glossary

- hub
  - an electronic device that connects to several computers and serves as the centre of a LAN, often Ethernet using 100Base-T, 1000Base-T or 10000Base-T wiring

- firewall
  - a security mechanism placed between a company and the Internet to protect the company’s computers from attack

Networking Glossary

- hostname
  - the name assigned to a computer

- domain name
  - the name assigned to a computer
  - a name might consist of several words separated by periods (sometime abbreviated to FQDN, fully qualified domain name)

Networking Glossary

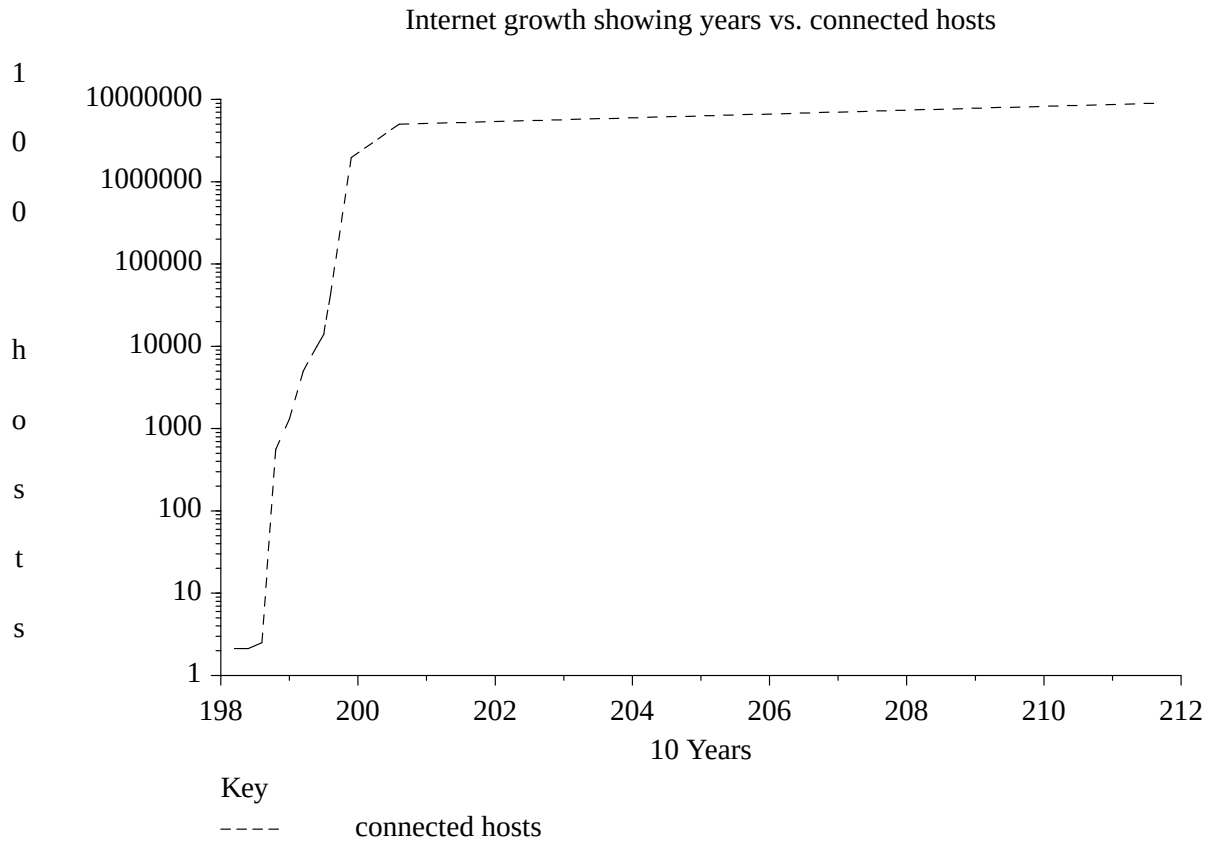
- gateway
  - a device used to connect two different networks, especially a connection to the Internet

TCP/IP

- many excellent references on TCP/IP
  - *Internetworking with TCP/IP: principles, protocols and architecture by Douglas Comer* †
  - *UNIX Network Programming* by Richard Stevens, chapter 4

History of TCP/IP and Internet

- part of the excitement about the Internet is its size and growth rate



History of TCP/IP and Internet (continued)

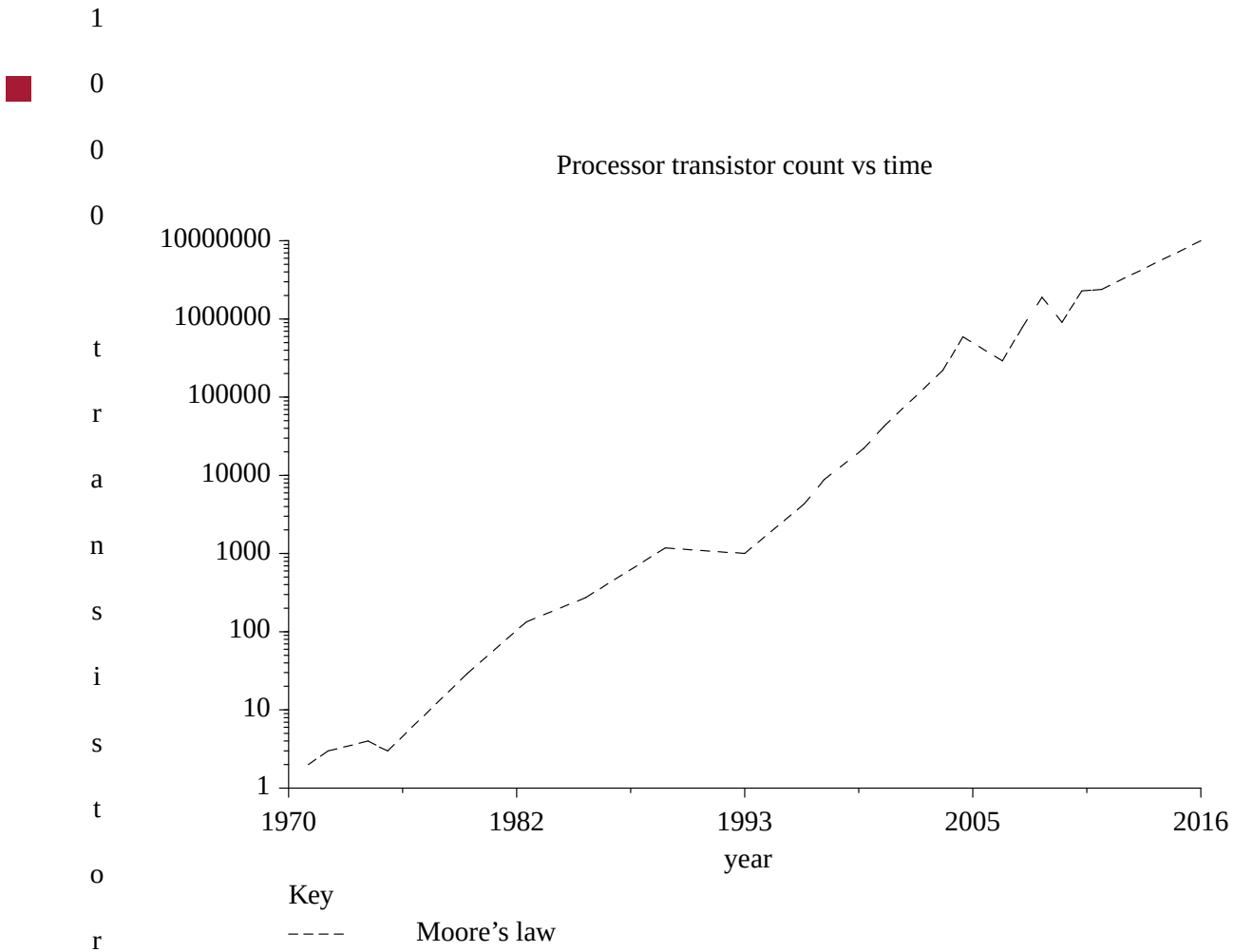
- DARPA was the main funding agency for packet-switched research in the USA DOD
  - began working on the Internet in the mid 1970s
  - design a protocol that would recover if various nodes disappeared
  - DOD had in mind a nuclear war!
  - wanted a nervous system to carry all military information in USA
- by 1980 TCP/IP protocol had been designed
- the physical network was called the ARPANET which consisted of
  - point to point connections
  - packet switching over radio networks
  - satellite communication channels

History of TCP/IP and Internet

- January 1983 DARPA demanded that all computer attach to ARPANET via TCP/IP
  - TCP/IP implementations were available at low cost
  - most (90%) Computer Science departments were running BSD Unix
  - TCP/IP available in source form for BSD systems

- growth
  - 1987 Internet growing at 15% per month (Comer p.6)
  - soon after that it began to double each year!

Moores Law


Processor transistor count vs time
10000000
1000000
100000
10000
1000
100
10
1
1970
1982
1993
2005
2016
year
Key
Moore’s law

History of TCP/IP

- some reasons why
  - reference implementation of TCP/IP in BSD Unix (1983) 4.3 BSD and 4.4 BSD
  - inexpensive microprocessors (1983)
  - inexpensive wide area fiber optic cable - carrying a high throughput of data (1984)
  - deployment of DNS (Domain Name System) (dynamic ASCII to number lookup system)

Internet for the masses

- in early 1990’s Tim Berner’s Lee was working at CERN and as a bye product of high energy physics was working on document management system
- he created a hypertext markup language which was to become HTML
- HTTP is the protocol which WWW clients and servers obey
- people mistakenly think the HTTP is the Internet

Introduction to TCP/IP

- LANs have developed greatly over the last 20 years
  - there are a large variety of LANs
  - different LANs in different departments and countries
  - equipment can be bought on an incremental basis
  - evolution not revolution - cost savings

- can be really effective if applications can talk to one another across the different LANs
  - companies with different departments can share resources

Introduction to TCP/IP

- one solution is for an operating system to provide this multivendor integration
  - alternatively a standard network protocol could be designed

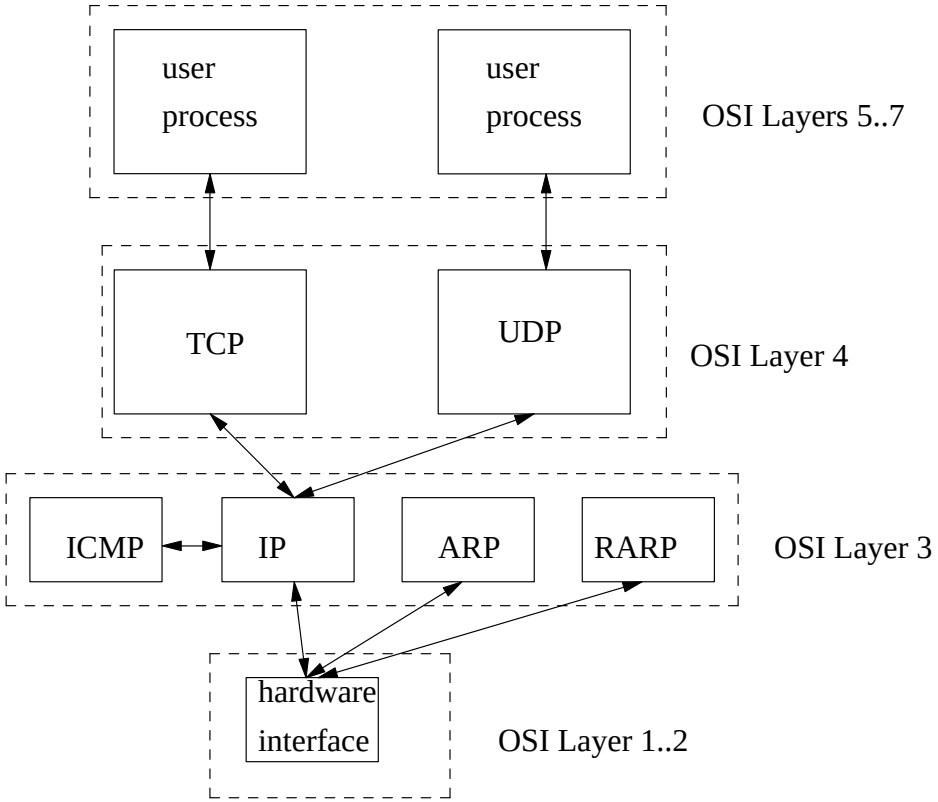
- Internet Protocol (IP) - so called because it allows communication between LANs

Problems/benefits of TCP/IP

- what problems exist if we want to link up many LANs?
  - unique addressing
  - hardware independent

- obvious benefits of the Internet

TCP/IP Protocol Overview



TCP/IP Protocol Summary

- Internet Prococol
  - provides the packet delivery service for TCP, UDP and ICMP
  - user processes do not normally explicitly generate IP datagrams

- an IP address is a virtual address, it was not constructed with a preconceived piece of hardware in mind

TCP/IP Protocol Summary

- Address Resolution Protocol
  - maps an Internet address into a hardware address

- Reverse Address Resolution Protocol
  - maps a hardware address into an Internet address.

TCP and UDP

- primarily there are two transport protocols used with IP: TCP and UDP
  - remember that IP may provide an unreliable service

- **Transmission Control Protocol (TCP)**
  - provides a flexible two-way byte stream protocol (byte stream allows addressing *within* a host - to user, process or service)
  - *provides a bidirectional pipe*
  - the source and destination address are called a *Port*
  - TCP is the most popular transport protocol on top of IP
  - it uses sliding window technique to provide a reliable service
  - it uses a three way handshake to establish a connection
  - and a two way handshake to disconnect

User Datagram Protocol (UDP)

- is an unreliable datagram protocol and is deliberately simple
  - it does not ensure that packets arrive in order, un duplicated, or even at all!

- it sends discrete datagrams, and delivers messages that arrive to the appropriate *Port* (same addressing schema as TCP)
  - a *port* may belong to a user, process or service
  - the standard Internet name service, DNS, uses UDP
  - it can be regarded as multiplexing many users, processes and services through one IP address

- UDP has no standard connection procedure and no disconnect procedure

IP technical introduction

- IP centerpiece of the TCP/IP protocol stack. It hides the differences between data link protocols from the transport protocols that the end user applications use
  - can replace old data link technologies with new faster technologies
  - application independent

- IP defines a virtual network address space
  - if you are connected to the Internet then your network has a unique IP address
  - within that network address your machine has a unique host id.

IP technical introduction

- IP provides a connectionless packet delivery service
  - it routes small messages from one machine to another on the addressed within that message
  - connectionless service routes each packet separately and therefore does not guarantee reliable delivery
  - having connectionless packet delivery as the basis for all Internet services makes it adaptable to a wide range of hardware
  - connectionless packet delivery is often termed *datagram*

IP (continued)

- the IP protocol works as follows:
  - transport layer split up a message into datagrams of <=64k bytes

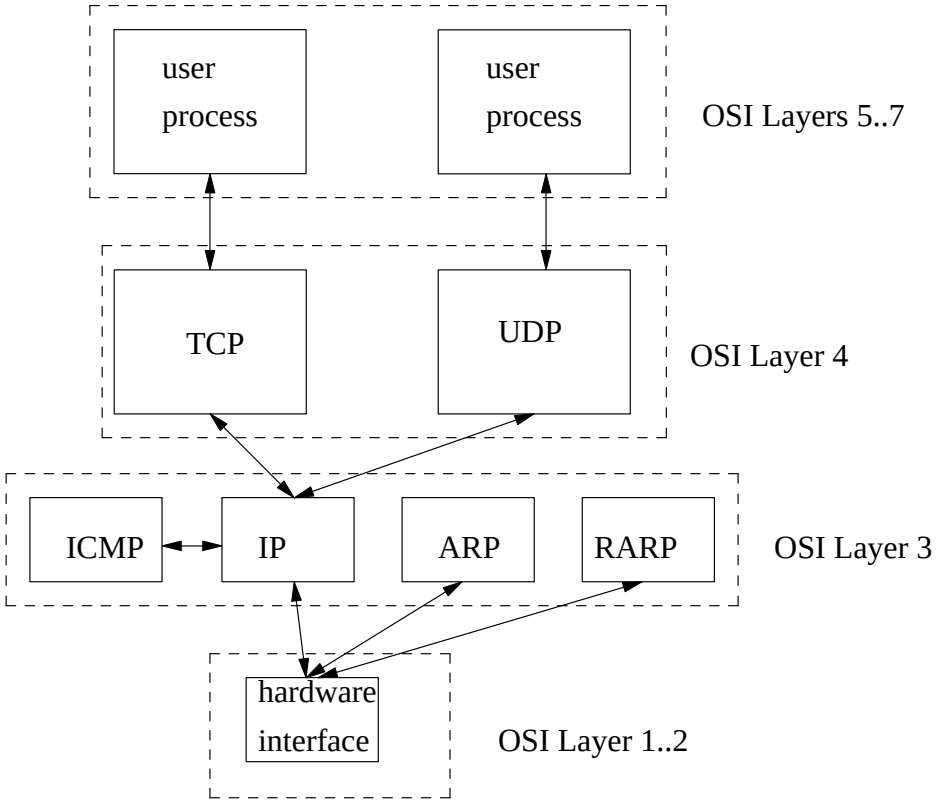
- transport layer gives a datagram to the IP layer
  - datagram is transmitted through the Internet
  - a hop at a time (gateway to gateway)
  - a datagram maybe divided into smaller units at any hop

- datagram is reassembled at the destination machine
  - original message is constructed
  - delivered to the corresponding transport layer

TCP/IP Support Protocols

- are another reason TCP/IPs popularity

TCP/IP Support Protocols



TCP/IP Protocol Summary

- Transmission Control Protocol
  - connection-oriented protocol
  - reliable, full duplex, byte stream for user processes
- User Data Protocol
  - connectionless protocol for user processes
  - unreliable
- Internet Control Message Protocol
  - handles error and control information between gateways and hosts
  - *normally* generated by TCP/IP networking software itself, not the user processes

TCP/IP Protocol Summary

- Internet Protocol
  - provides the packet delivery service for TCP, UDP and ICMP
  - user processes do not normally explicitly generate IP datagrams
- Address Resolution Protocol maps an Internet address into a hardware address
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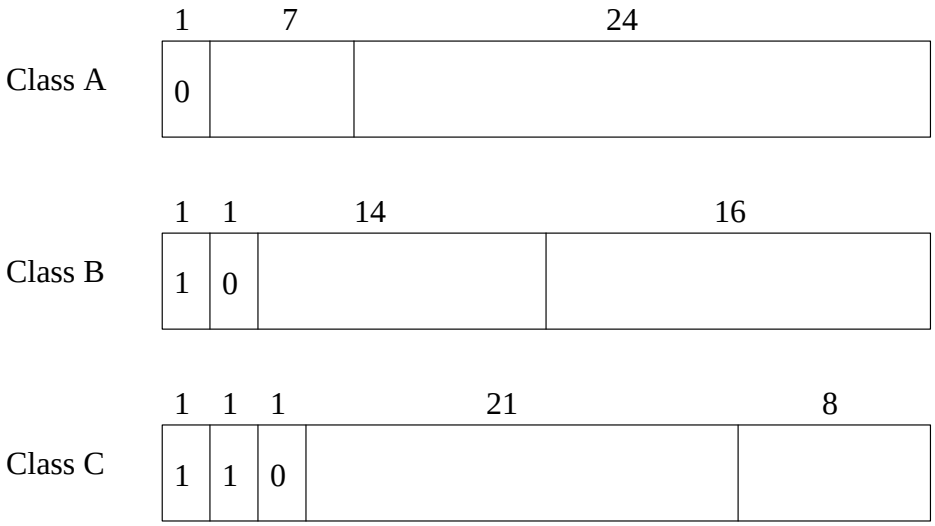
IP Classes



- for example `193.63.129.1` is a class C address as we convert the first byte of the address `193` into binary and examine the top 3 bits of a byte

IP Classes

- there are 127 class A networks
  - each can have 16,777,216 hosts
- there are 16,384 class B networks
  - each can have 65,336 hosts
- there are 2,097,152 class C networks
  - each of which have 256 hosts
- note that in practice the host byte values 0 and 255 are reserved for network and broadcast respectively

Private addresses in class A, B and C

- in addition each class A, B and C have a private network address
- class A
  - reserves the range 10.0.0.0 - 10.255.255.255 (16,777,216 hosts)
- class B
  - 172.16.0.0 - 172.31.255.255 (1,048,576 hosts)
- class C
  - 192.168.0.0 - 192.168.255.255 (65,536 hosts)

Example IP Static Configuration

- Case study - adding a machine onto the Computer Science network

- the IP network in Computer Studies connects:
  - Apple computers
  - Windows computers
  - Raspberry Pi machines
  - Debian and Mint GNU/Linux clients and servers
  - routers and various print services, etc

Example IP Static Configuration

- each machine may run a different protocol above the IP layer if they wish
  - but most machines will run the IP protocol

- the Computer Studies IP network is connected (via a gateway) to the University of Glamorgan IP network
  - in turn is connected to the world IP network via another gateway (through the University of Glamorgan 1M bit line)

Example IP Static Configuration

- *every* IP address actually refers to the interface card and **NOT** the machine!

- thus a gateway machine will have at least two interface cards

- to add a new machine `floppsie` onto the Computer Studies network
  - floppsie's interface card has to be assigned a unique IP address
  - first three numbers the same as the Computer Science network (193.63.130)
  - class C network - means first 3 bytes are always the same
  - last number is the interface card number (hostid) 52
  - 193.63.130.52

Example IP Static Configuration

- software on the new machine needs to know:
  - the gateway on the Computer Studies network to other networks
  - its own interface card IP address
  - the *nameserver* IP address. The *nameserver* translates all ASCII names to IP numerical addresses.
  - hop metric given with each gateway

IP Configuration