

# Networking Fundamentals

# Overview

- Links two or more computers
- Share Resources
- Increases productivity
- Mostly plug and play today

# LANs, WANs, PANs, MANs, SANs, and WLANs

- Local Area Network – single building
- Wide Area Network – includes networks outside LAN
- Personal Area Network – very small network designed around one person.
  - Usually implemented with Bluetooth technology.
- Metropolitan Area Network – Bigger than LAN but not as big as WAN
- Storage Area Network – optimised large scale, long term data storage
- Wireless Local Area Network – Like a LAN but wireless

# Information Technology Evolution

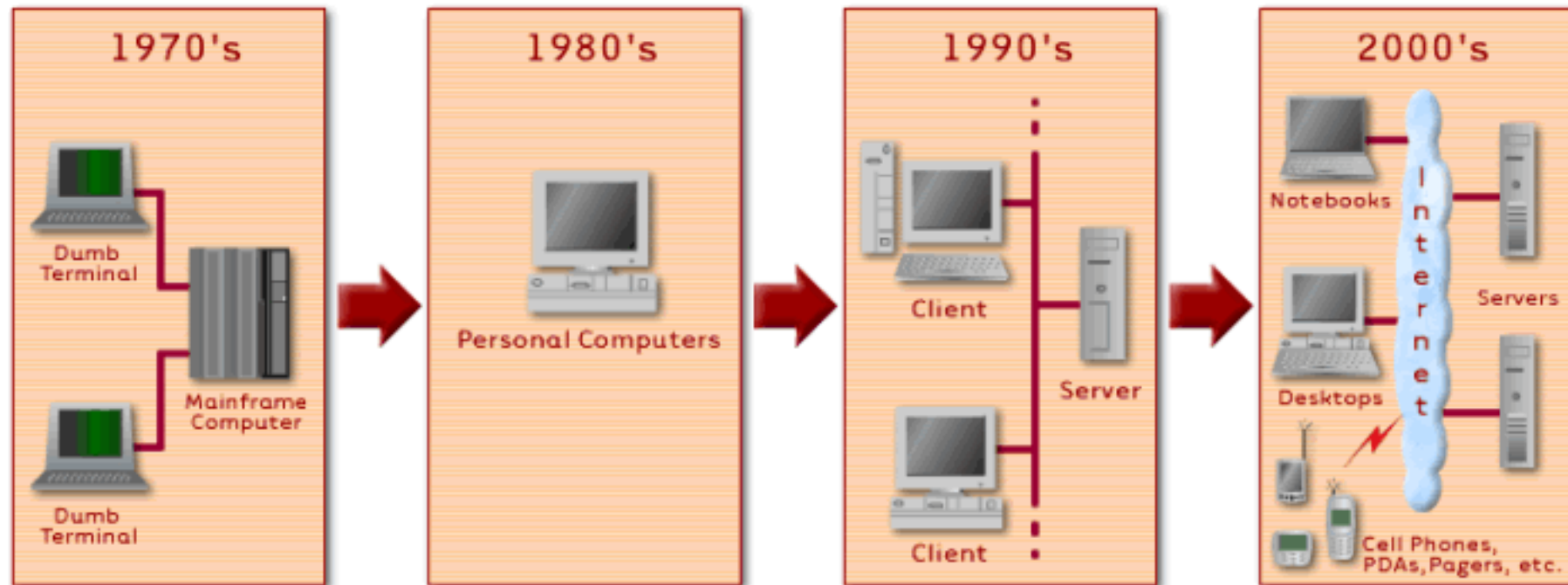


image source: <http://www.automatedbanking.com/news/june2/arc/arc.html>

- Mainframe - centralised processing
- Minicomputer – distributed processing
- Back end – process and store information
- Front End – data entry and minor processing

# Information Technology Evolution

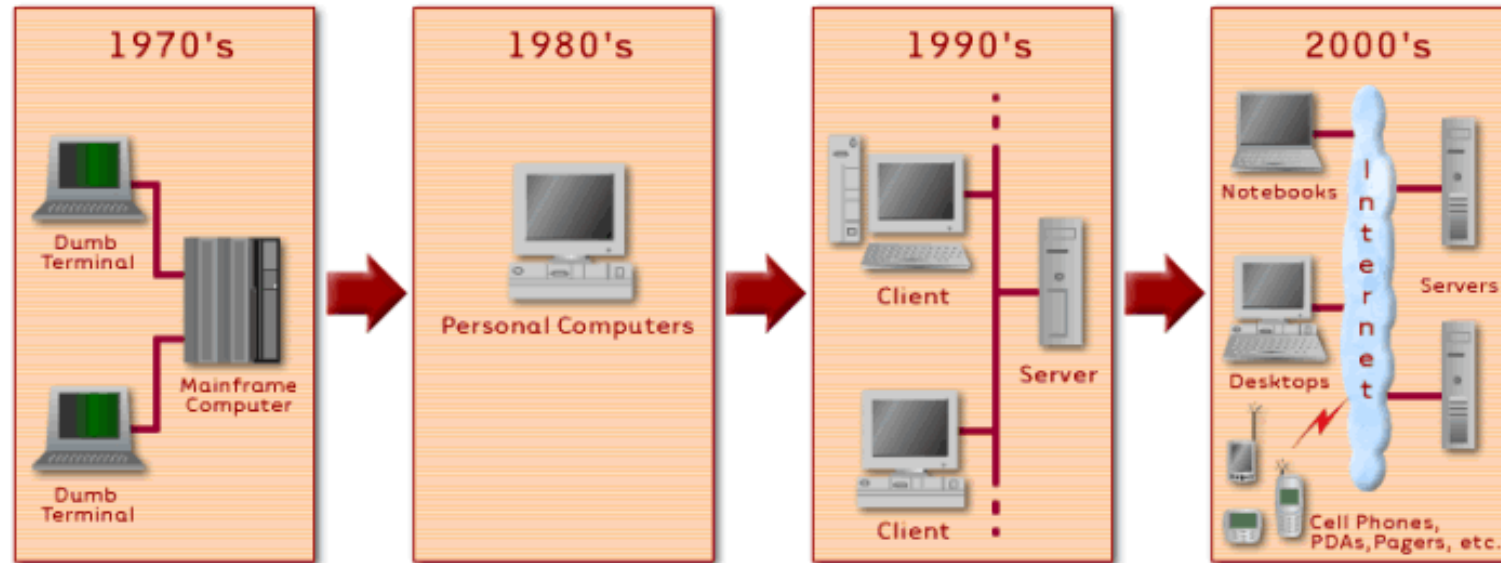
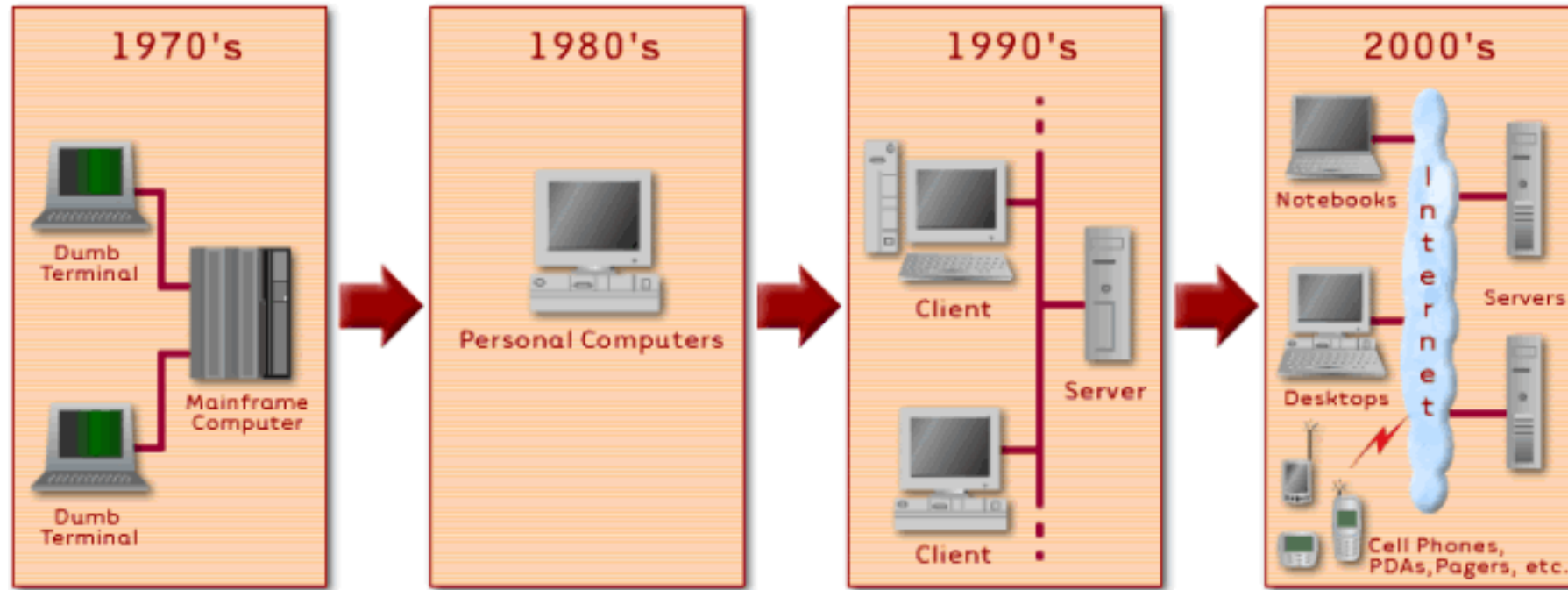


Image source: <http://www.automatedbuildings.com/news/jan02/art/aic/aic.htm>

- PCs – not efficient in sharing information
- Demand for sharing files and resources increased
- Novell – first widely used network software
  - Only max 30 PCs and on one floor
  - File Locking (only one PC could access a file at a given time)

# Information Technology Evolution



- WANs – very expensive at first. Mainly government and large businesses
- Now a WAN can span several countries

# PAN

- Bluetooth network.
- 10 Meters
- WPAN – Wireless Personal Area Network. (IEEE 802.15.1)
- Temporary nature
- Normal wireless needs a router or access point – infrastructure
- Bluetooth – ad hoc network, no central point required
- Dynamically created network called *piconet*
- Bluetooth Piconet – a single device can connect up to a maximum of 7 other devices

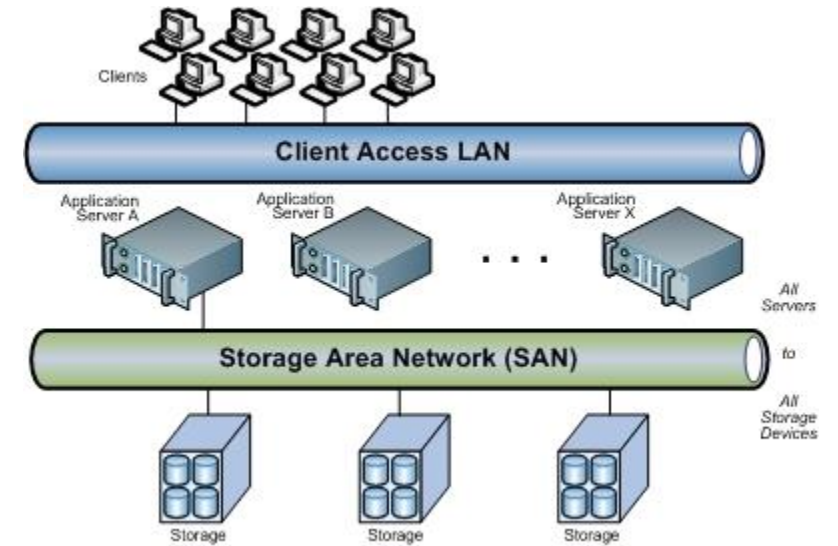
# MAN

- Larger than LAN but relatively small geographical network
- College Campus
- City / Town
  
- Difference between WAN and MAN?
  - Management – who owns it will define



# SANs

- Storage Area Network
  - Does what it says, storage!
- Network that just holds storage devices
  - Could be NAS HDDs or servers with lots of Disk Space just for storage
- No client computers or other servers on the network, for storage only

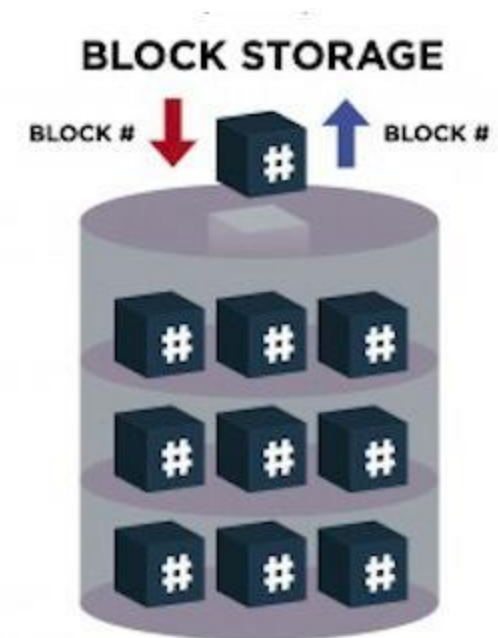


# SAN Benefits

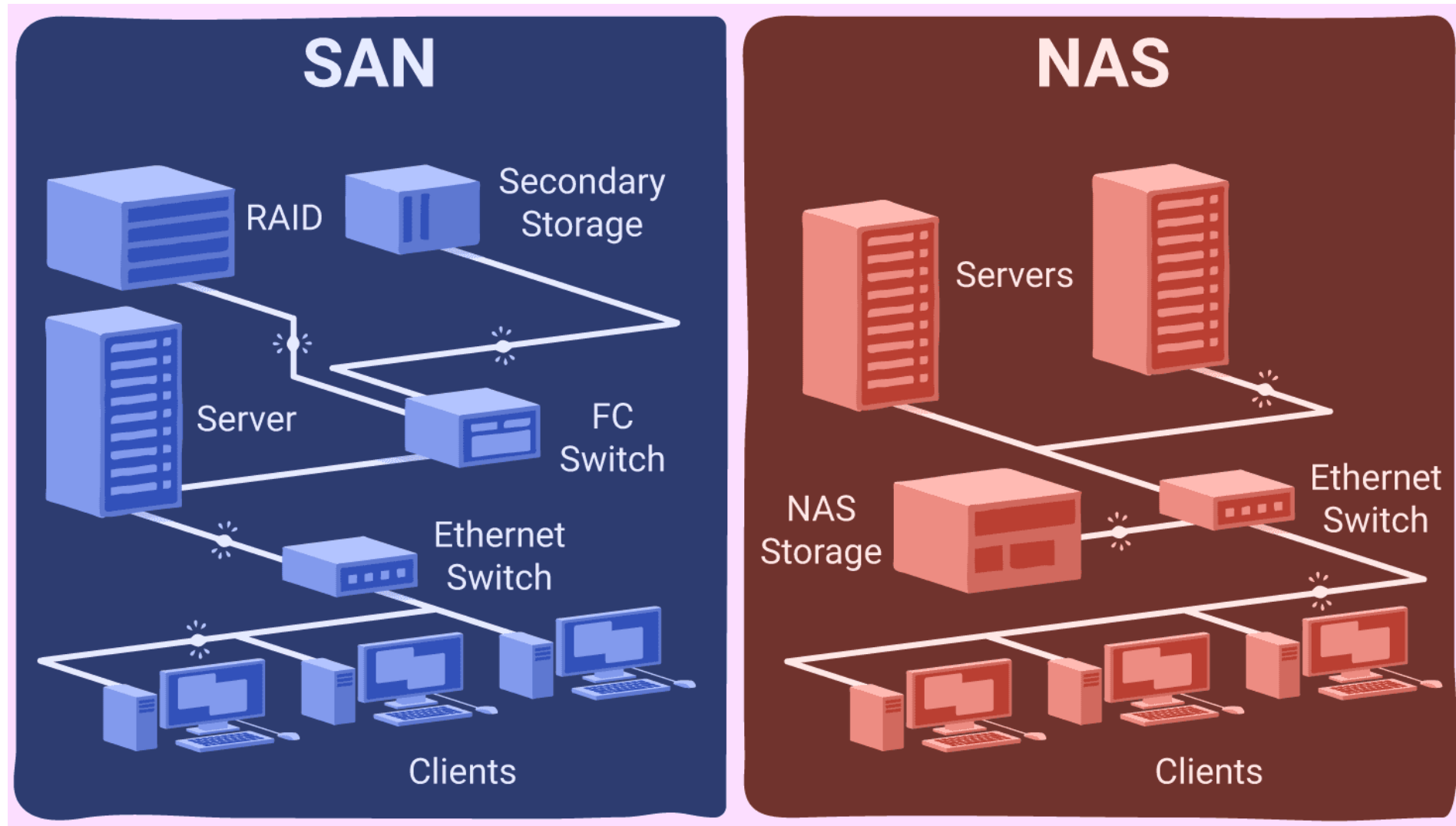
- Dedicated SANs relieve network loads
- Fast data access
  - Most use Fibre Channel (FC) connections
- Easily expandable
- Block Level storage
  - Very efficient
  - Different to file based systems
    - File structure good for humans, poor for data retrieval
    - Block storage splits data into equal size to store using unique ID

# Block Level Storage

- File structure good for humans, poor for data retrieval
- Block storage splits data into equal size to store using unique ID
  - Chunks are small and manageable
- Each block has a unique address so file structure not required
- Can modify contents of a block, not the whole file
- Data transfers are efficient and therefore faster
- Used in databases and SAN's
- Complicated to set up and manage though



# SAN v NAS



# Primary Network Components

- Servers
  - Clients / Workstations
  - Resources
- 
- Every network requires two or more of these items connected

# Servers

- Core component – critical
- Centralise control of resources
- Centralise security
- Simplifies administration – no it does!
- Load balancing – increases speed and performance
- Several critical roles
  - File servers
  - Print servers
  - Authentication
  - Remote access
  - Email
- Multipurpose and single purpose

# Servers

- Dedicated
  - Specific applications or services
  - Fewer resources
  - Improved network performance
  - For example - Web server
- Nondedicated
  - One or more services
  - Perform administrative actions
  - Front end for administrator
  - For example – A workgroup server with file, print and email servers running, but allows users to use it as a workstation.
  - Can also act as a workstation
- Networks today commonly have a combination of the two

# Workstations

- Where network users do their work.
- Also called clients
- Need a NIC (Network Interface Card)
- NIC requires client software and cable connection
- Most OS have network client software
- Server can just appear as a drive
  
- Requires users to be responsible!



# Network Resources

- Printers
  - Scanners
  - Disk Storage
  - Databases
  - Applications
- 
- Lowers the cost of providing resources
  - Allows use of shared files – centralised location
  - Concurrent user licenses for software (site license)

# Network Operating Systems (NOSs)

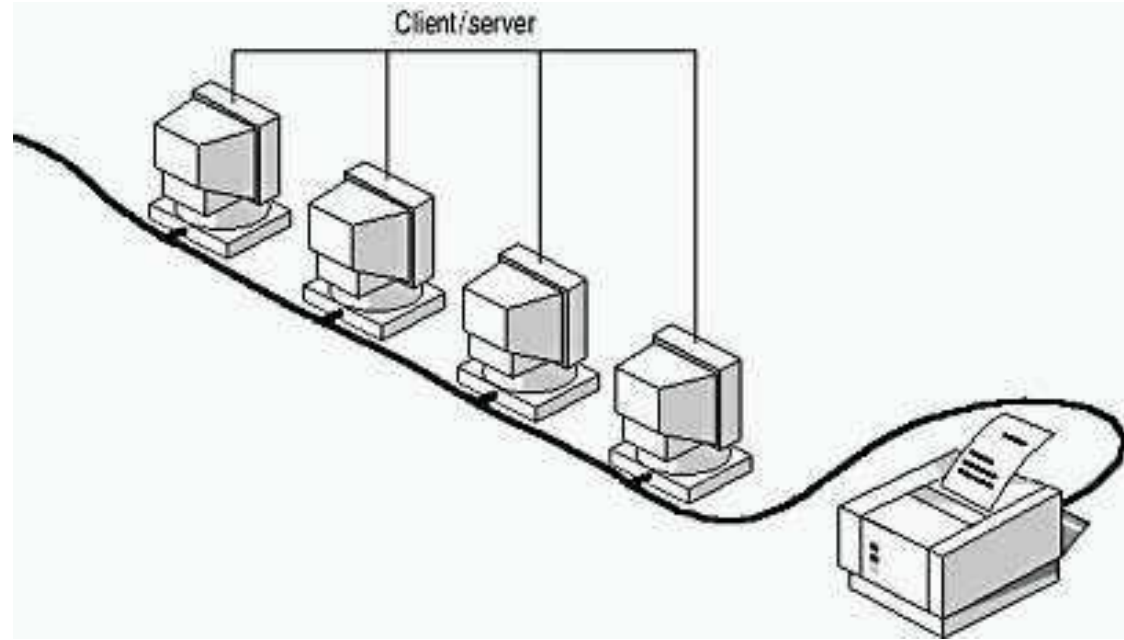
- PCs use OS, Networks have a NOS
- NOS controls communication between the resources
- NOS runs on the server
- NOS examples – Unix, Linux, Win Server, and macOS Server.

# Network Resource Access

- Peer to Peer
- Client – Server
  
- Networks need to be planned
  - For today's needs
  - For tomorrow's needs

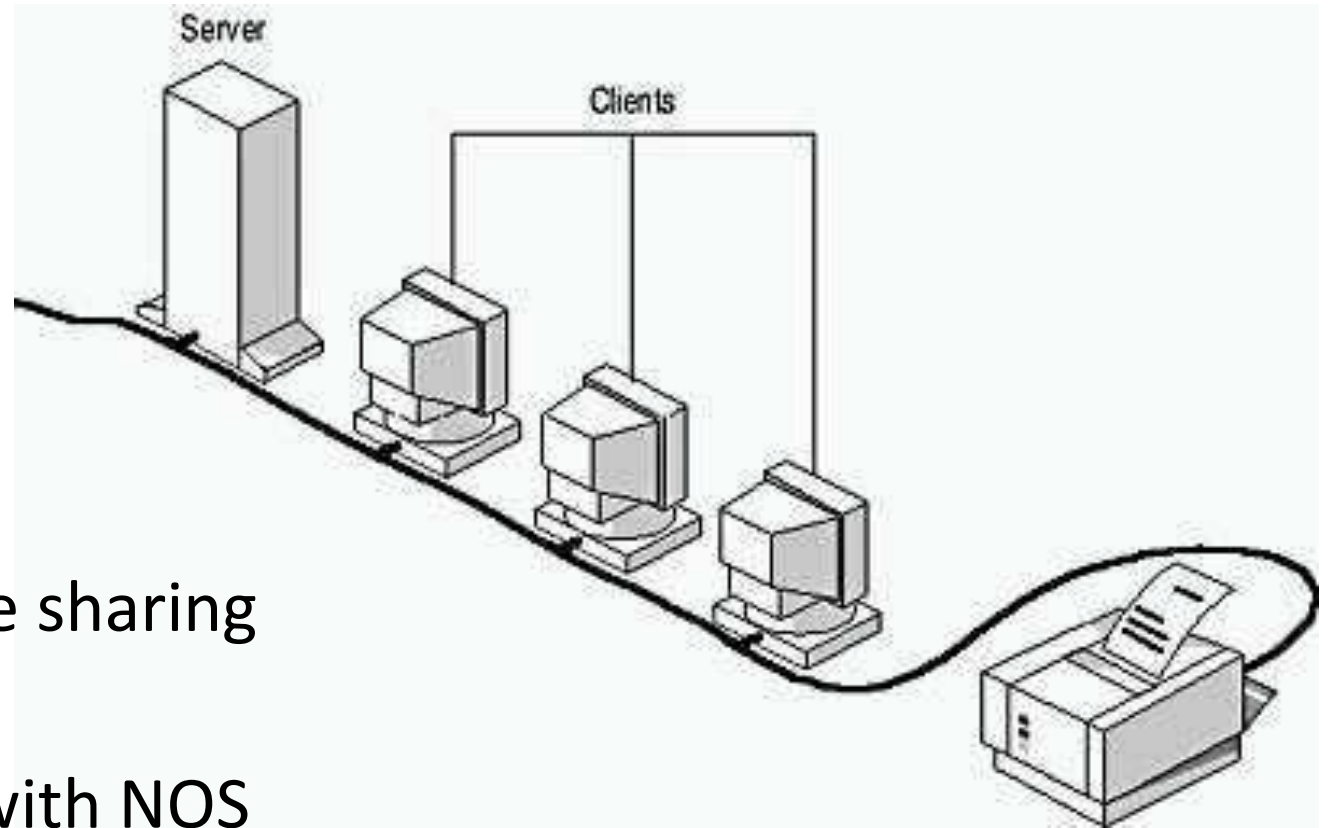
# Peer to Peer

- Simple, small, inexpensive
- Called workgroups
- No dedicated servers
- No centralised administration
- All computers are equal
- Low number of users
- Security is not an issue
- Each user sets up own shares / passwords
- Locating resources is hard



# Client Server

- More secure
- Centralised control
- Obviously have a server
- Allows easy backups, resource sharing
- Unlimited number of users
- Needs specialised hardware with NOS
- Cost more than peer to peer
- Often called 'domains'
- Allows growth and flexibility

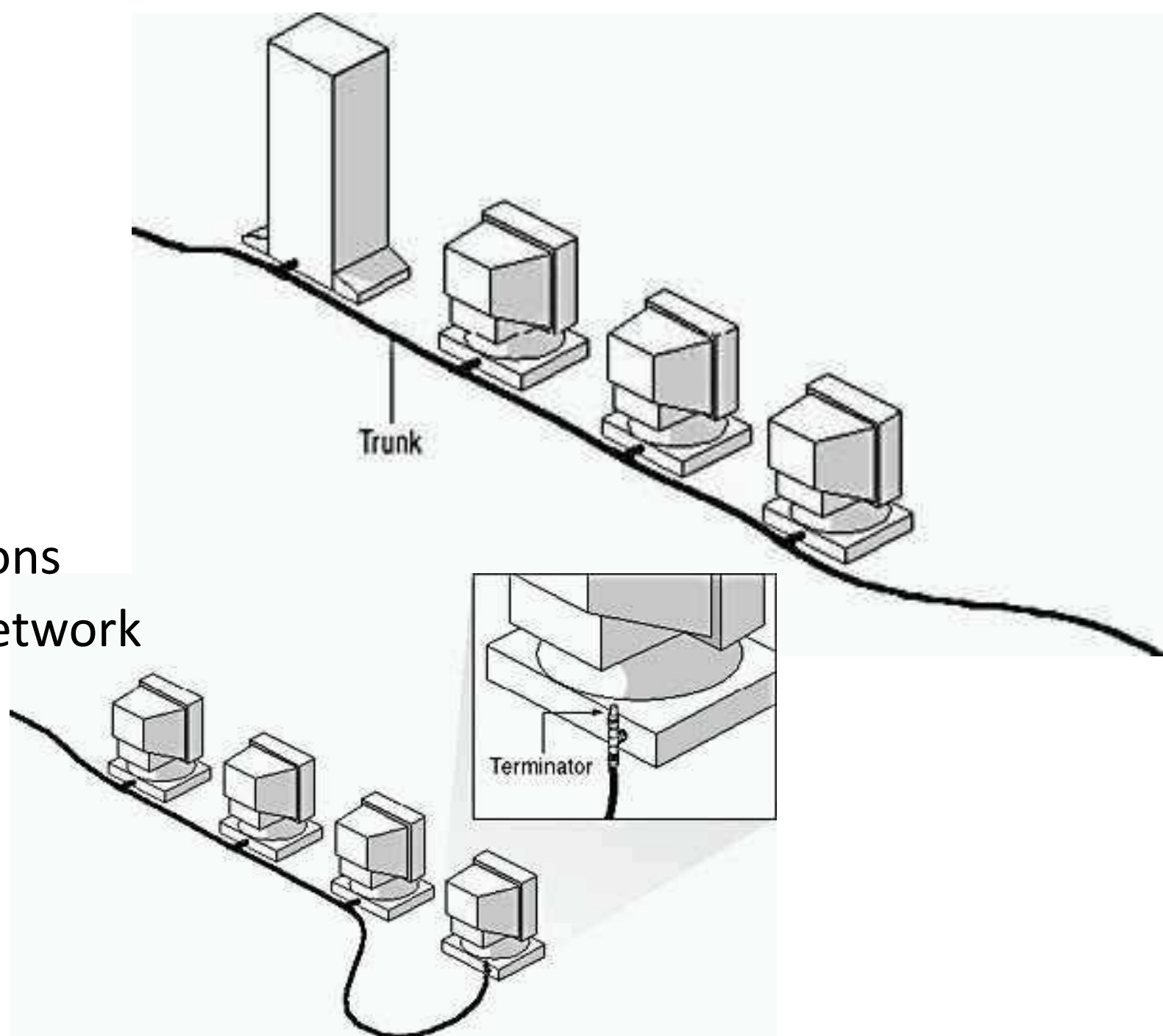


# Network Topologies

- Topology – way of laying out a network
- 5 Primary types
  1. Bus
  2. Star
  3. Ring
  4. Mesh
  5. Hybrid
- Each has advantages and disadvantages

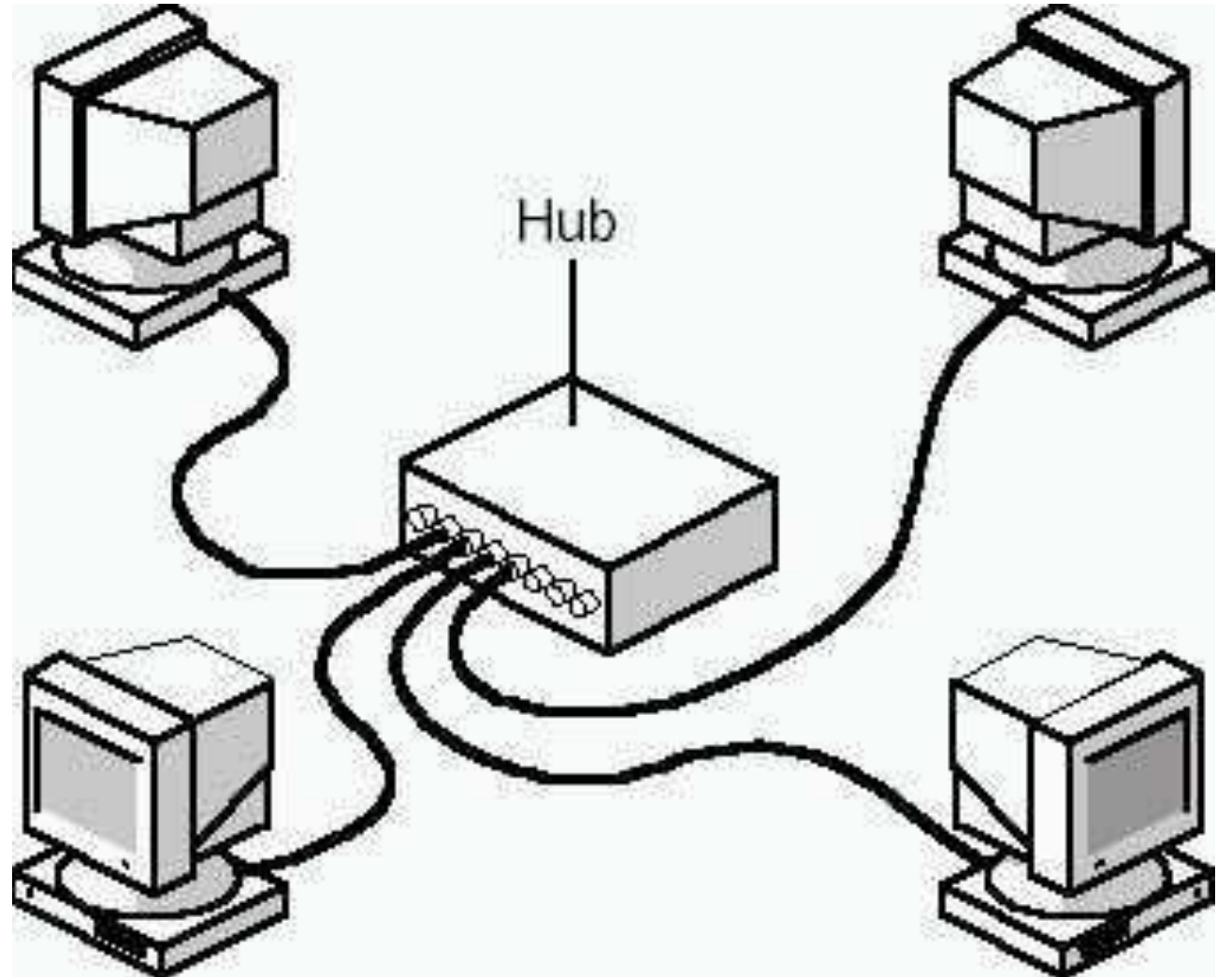
# Bus Topology

- Simplest
- Cheapest to set up
- Single cable called trunk
- Least amount of cable
- Difficulty adding workstations
- Cable breaks will disrupt network
- Expensive to maintain
- Terminators on cable ends
- Rare today



# Star Topology

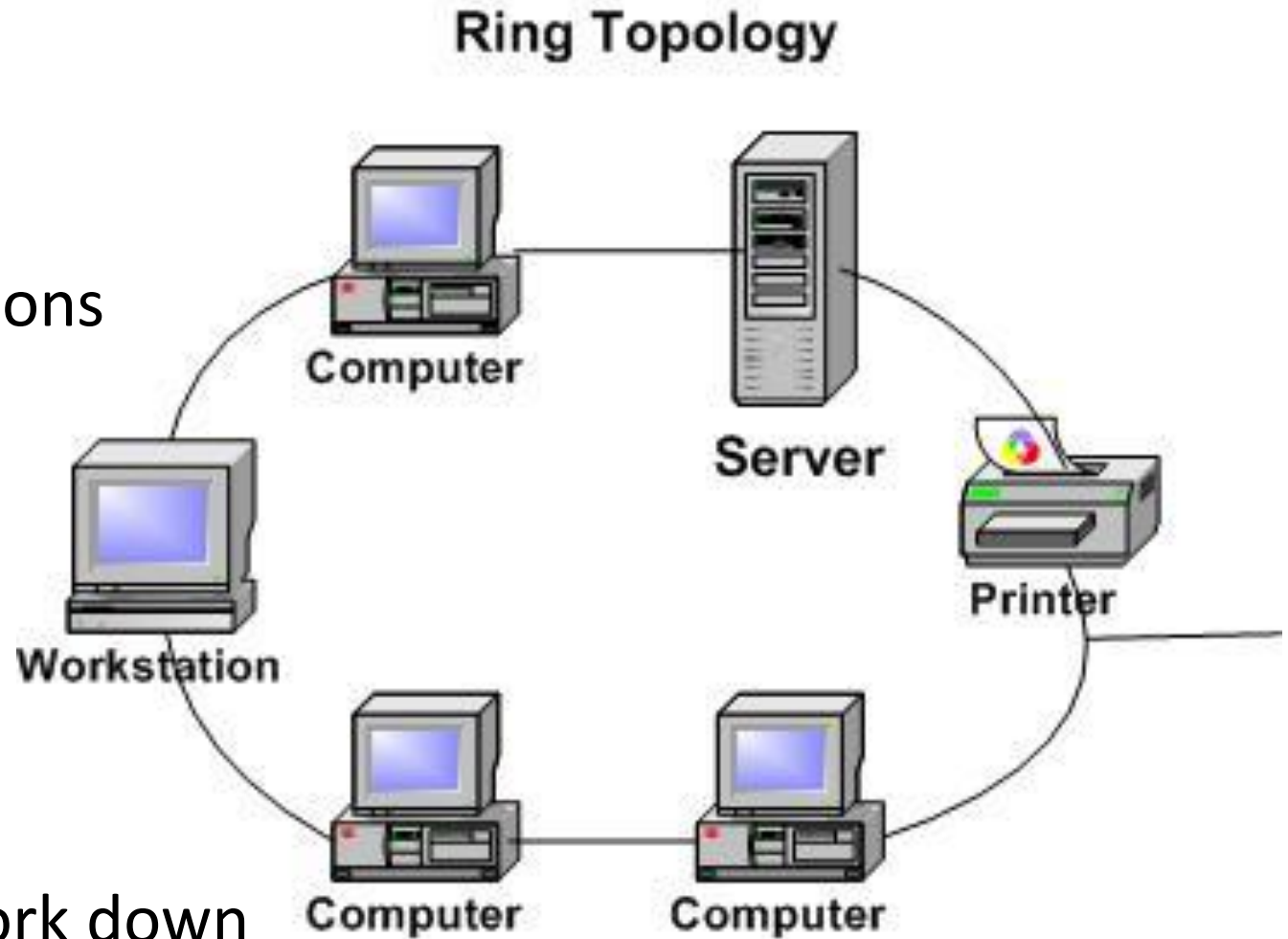
- Hub (or switch) central
- Single point of failure
- Easy to add workstations
- Fault tolerant
- Easy to install
- Most common today
- Lots of cables!





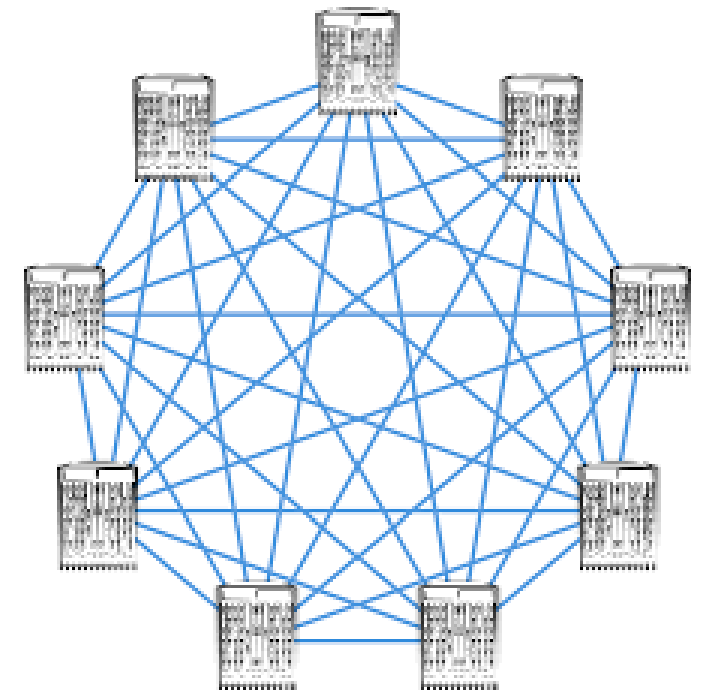
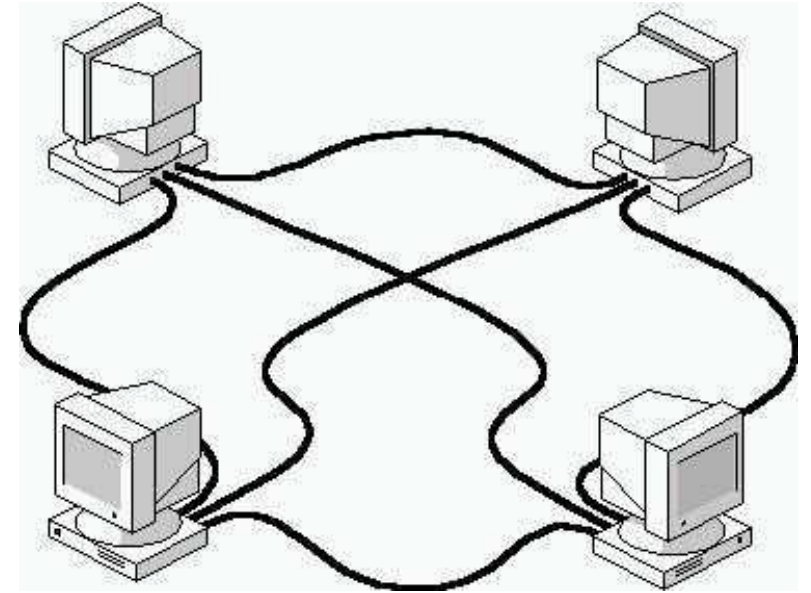
# Ring Topology

- Similar to bus but no terminations
- Unidirectional
- Each PC is a repeater
- Difficult to add new PC
- Expensive to implement
- Very rare (possibly extinct!)
- One PC failure can bring network down
- Token passing



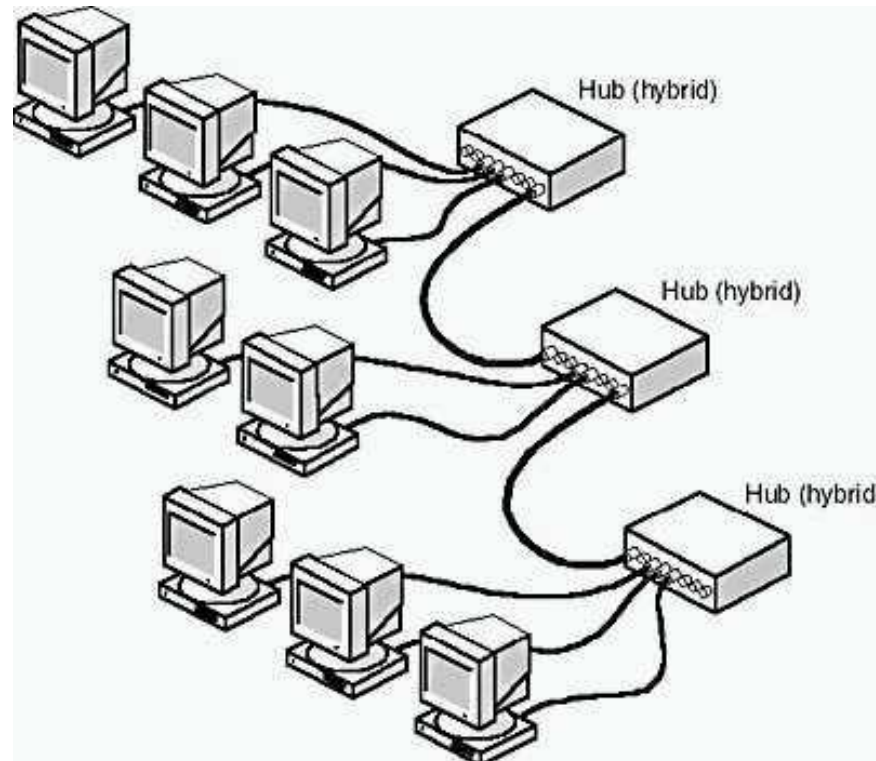
# Mesh Topology

- Physically most complex
- Each PC connected to all PCs
- Rare in LANs
- Superior redundancy (data gets through)
- Expensive to install
- More than 5 items is very complex
- Implemented in some WANs
- Routers search for routes



# Hybrid Typology

- Mix of the other typologies
- Most networks are this
- Eg - Star Bus



# Typologies Advantages / Disadvantages

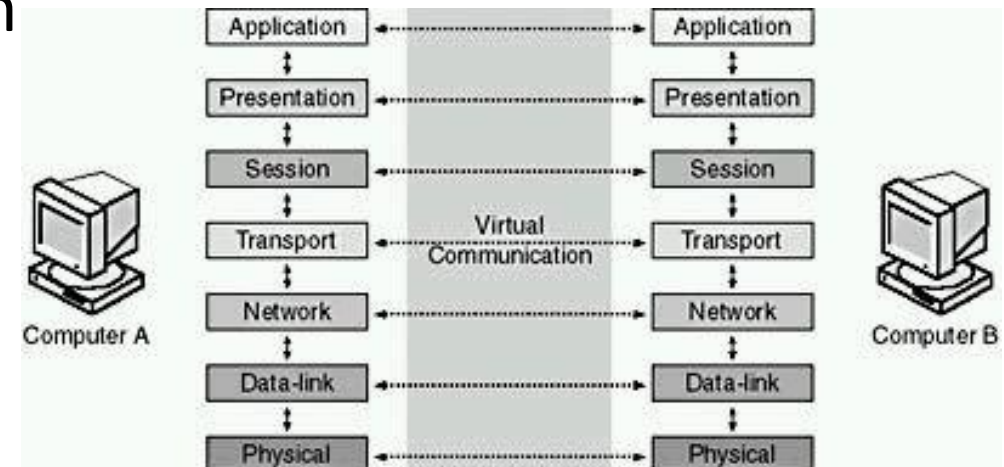
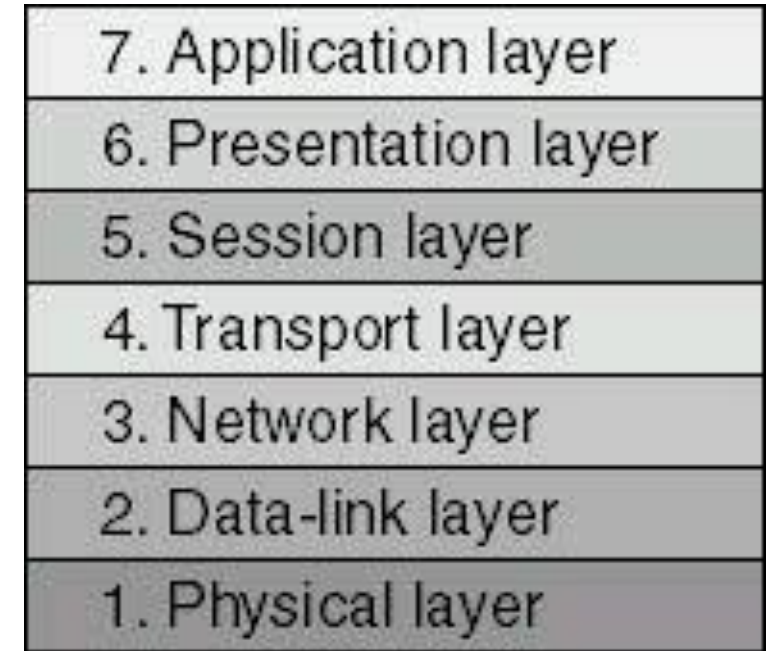
Topology	Advantages	Disadvantages
Bus	Cheap. Easy to install	Difficult to reconfigure. A break in the bus disables the entire network
Star	Cheap. Very easy to install and reconfigure. Resilient to a single cable failure	More expensive than bus
Ring	Efficient. Easy to install.	Difficult reconfiguration. Very expensive. Relies on all PCs working
Mesh	Superior fault tolerance	Reconfiguration is extremely difficult, extremely expensive, and very complex.
Hybrid	Allows a combination of the best features of each typology	Complex, but not as bad as mesh.

# Network Communication

- Protocol – rules used on a network to communicate
- Standards keep communications clear
- All are based on the OSI 7 layer model
- OSI – Open Systems Interconnection
- Layers provide communication to layer above or below
- No network implements it! (But are referenced as we shall see)

# OSI 7 Layers

- **All People Seem To Need Data Processing**
- Layers 1 and 2 define NIC physical definitions
- The Higher layer, the more complex the task
- Layers separated by interfaces
- Each layer appears in communication with equivalent layer at other end
- Only Physical Layer can pass information



- Read <https://fossbytes.com/osi-model-7-layers-osi-model-explained/>

Application	To allow access to network resources	7
Presentation	To translate, encrypt, and compress data	6
Session	To establish, manage, and terminate sessions	5
Transport	To provide reliable process-to-process message delivery and error recovery	4
Network	To move packets from source to destination; to provide internetworking	3
Data link	To organize bits into frames; to provide hop-to-hop delivery	2
Physical	To transmit bits over a medium; to provide mechanical and electrical specifications	1

# Helpful Youtube Videos

- <https://www.youtube.com/watch?v=8po34lqTKpE>
- <https://www.youtube.com/watch?v=LANW3m7UgWs>
- [https://www.youtube.com/watch?v=vv4y\\_uOneC0](https://www.youtube.com/watch?v=vv4y_uOneC0)



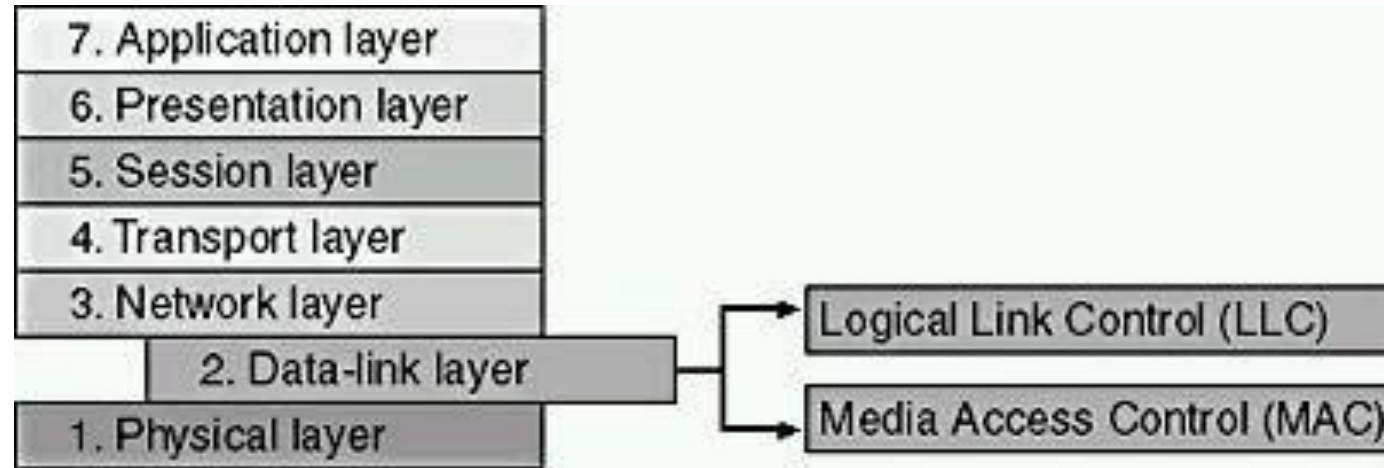
# IEEE 802 Standards

- Bottom 3 layers of OSI are about hardware. IEEE 802 enhances.
- IEEE - Institute of Electrical and Electronics Engineers
- The 802 specifications set standards for:
  - Network interface cards (NICs).
  - Wide area network (WAN) components.
  - Components used to create twisted-pair and coaxial cable networks
- The 802 specifications define the ways NICs access and transfer data over physical media

# IEEE 802 (Do not remember these!)

- 802.1 Sets Internetworking standards related to network management.
- 802.2 Defines the general standard for the data-link layer. The IEEE divides this layer into two sublayers: the LLC and MAC layers (discussed in the previous lesson). The MAC layer varies with different network types and is defined by standard IEEE 802.3.
- **802.3 Defines the MAC layer for bus networks that use Carrier-Sense Multiple Access with Collision Detection (CSMA/CD). This is the Ethernet Standard.**
- 802.4 Defines the MAC layer for bus networks that use a token-passing mechanism (Token Bus LAN).
- 802.5 Defines the MAC layer for token ring networks (Token Ring LAN).
- 802.6 Sets standards for metropolitan area networks (MANs), which are data networks designed for towns or cities. In terms of geographic breadth, MANs are larger than LANs, but smaller than WANs. MANs are usually characterized by very-high-speed connections using fiber-optic cables or other digital media.
- 802.7 Used by the Broadband Technical Advisory Group.
- 802.8 Used by the Fiber-Optic Technical Advisory Group.
- 802.9 Defines integrated voice/data networks.
- 802.10 Defines network security.
- 802.11 Defines wireless network standards. (You probably have heard of these 802.11g and 802.11n)
- 802.12 Defines Demand Priority Access LAN, 100BaseVG-AnyLAN.
- 802.13 Unused.
- 802.14 Defines cable modem standards.
- 802.15 Defines wireless personal area networks (WPAN).
- 802.16 Defines broadband wireless standards.

# 802 Data Link Layer (Again not for memory!)



- Logical Link Control (LLC) Establishing and terminating links, controlling frame traffic, sequencing frames, and acknowledging frames
- Media Access Control (MAC) Managing media access, delimiting frames, checking frame errors, and recognizing frame addresses

# 802.3 CSMA/CD - Ethernet

- CS – Carrier Sense. All the computers are listening on the network at all times.
- MA – Multiple Access. Multiple computers have access to the network – similar to a conference call. However, we can't all talk at once as that causes an error. If two network devices communicate at the same time a data collision takes place.
- CD – Collision Detection. Collisions detected so the sender resends the packet, having waited for a small time before resending. This is repeated until the data is successfully sent.
- Networks of 100 or more computers will mean collisions are regularly taking place.

# Network Interface Cards (NIC)

- Physical adapter between PC and network cable
- Prepares data, sends data, and controls data flow
- Different for the different network bus types
- We have also looked at motherboard slot types and the fastest for NICs
- NIC can provide a bottleneck to network performance
- NIC can be USB

# NIC Performance

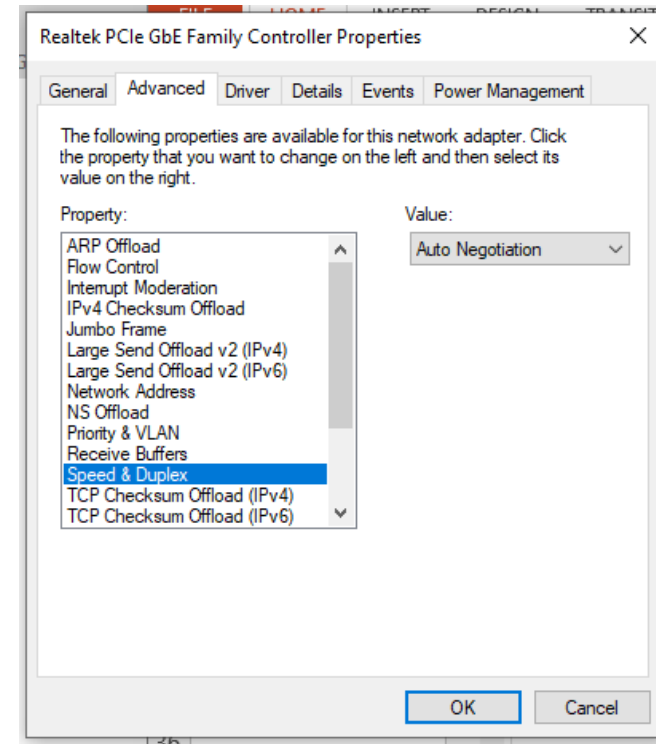
- Need NIC to optimise network performance
- Need to get fastest card for network type
  - For example if network supports 802.11b/g/n use a 802.11n card
- Two PCs must agree on:
  - Maximum size of the data frames
  - Amount of data sent before sending confirmation
  - The time between the transmissions
  - Time to wait before sending confirmation
  - Transmission speed
  - Type of network bus

# NIC Duplex mode

- Half Duplex
  - Only one device can send data at any given time
- Full Duplex
  - PC can send and receive data simultaneously
  - Superior performance over half duplex
  - Some FAST Ethernet NICs can operate at 200Mbps (2x 100Mbps of half duplex)
  - Eliminates collisions

# NIC Speed and Duplex Setting

- From Control Panel
  - Network and Sharing Centre > Change Adapter Settings
- Right Click on Ethernet and Select Properties
- Select Configure and then the advance Tab
- Speed and Duplex can be found in the list.





# NIC Configuration

- Each card must have a unique hardware address – MAC address
- MAC – Media Access Control
- PCs with same MACs will not be able to communicate on network
- IEEE standard and they assign blocks of addresses to manufacturers
- Manufacturers will hardwire the address on the card
  - Incredibly rare that you will get two the same.
- Driver software allow communication to/from OS
- Drivers operate at the Data Link Layer of OSI model

# MAC Address

```
C:\Windows\system32\cmd.exe
Node Type . . . . . : Hybrid
IP Routing Enabled. . . . . : No
WINS Proxy Enabled. . . . . : No

Wireless LAN adapter Wireless Network Connection:

Connection-specific DNS Suffix . : 
Description . . . . . : RangeMax Dual Band Wireless-N USB Adapter
Physical Address. . . . . : 00-1B-2F-BB-4C-98
DHCP Enabled . . . . . : Yes
Autoconfiguration Enabled . . . . . : Yes
Link-local IPv6 Address . . . . . : fe80::584f:f015:fab:10dc%24(Preferred)
IPv4 Address. . . . . : 10.0.0.4(Preferred)
Subnet Mask . . . . . : 255.255.255.0
Lease Obtained. . . . . : Miercoles, Pebrero 08, 2012 8:53:15 PM
Lease Expires . . . . . : Huebes, Pebrero 09, 2012 8:53:15 PM
Default Gateway . . . . . : 10.0.0.1
DHCP Server . . . . . : 10.0.0.1
DNS Servers . . . . . : 10.0.0.1
NetBIOS over Tcpip. . . . . : Enabled

Ethernet adapter Local Area Connection:

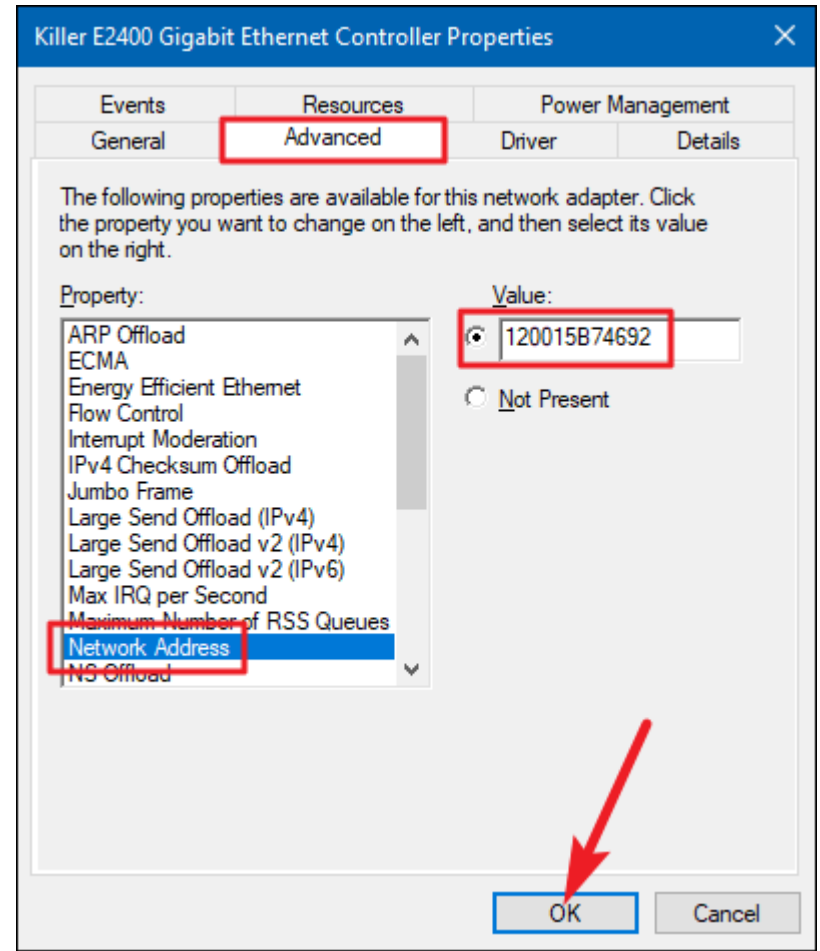
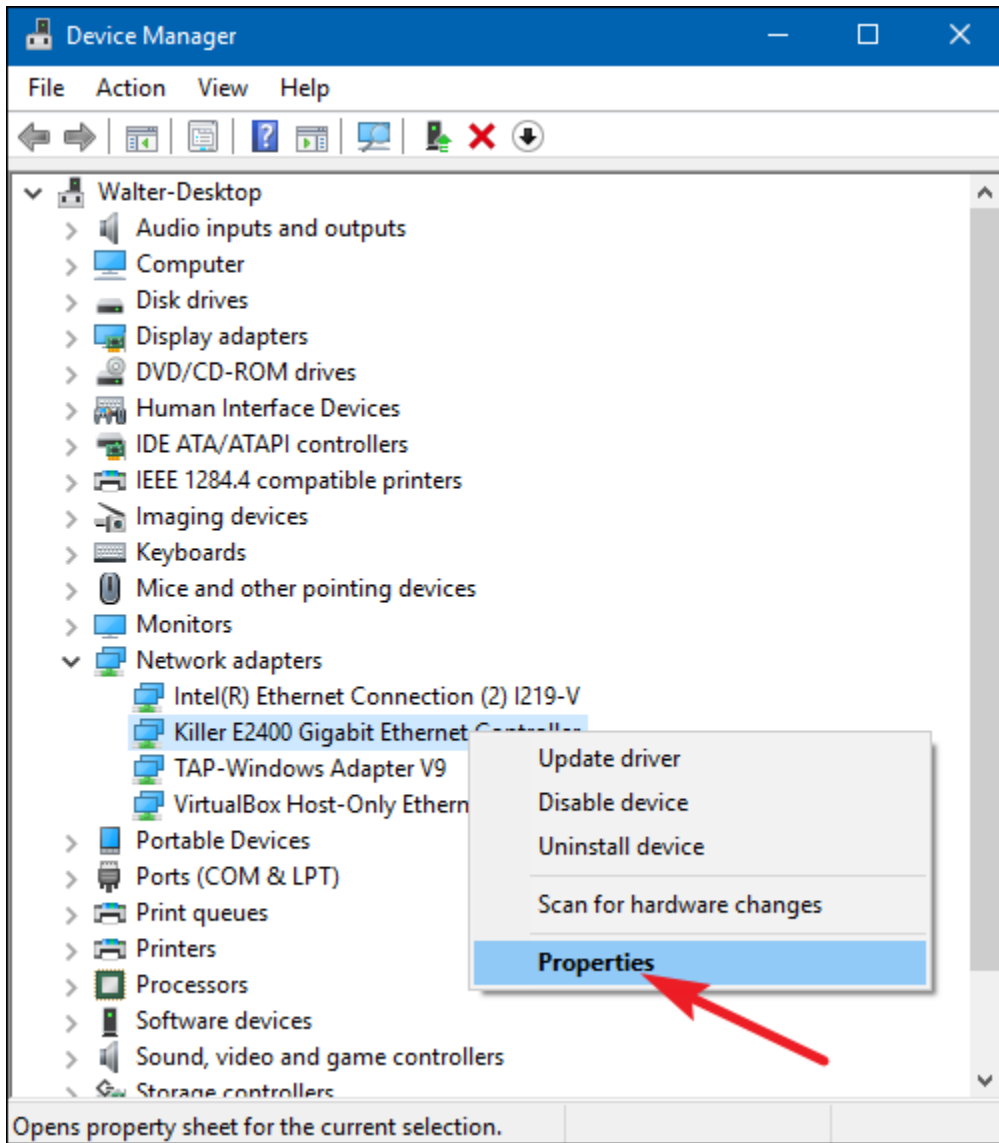
Media State . . . . . : Media disconnected
```

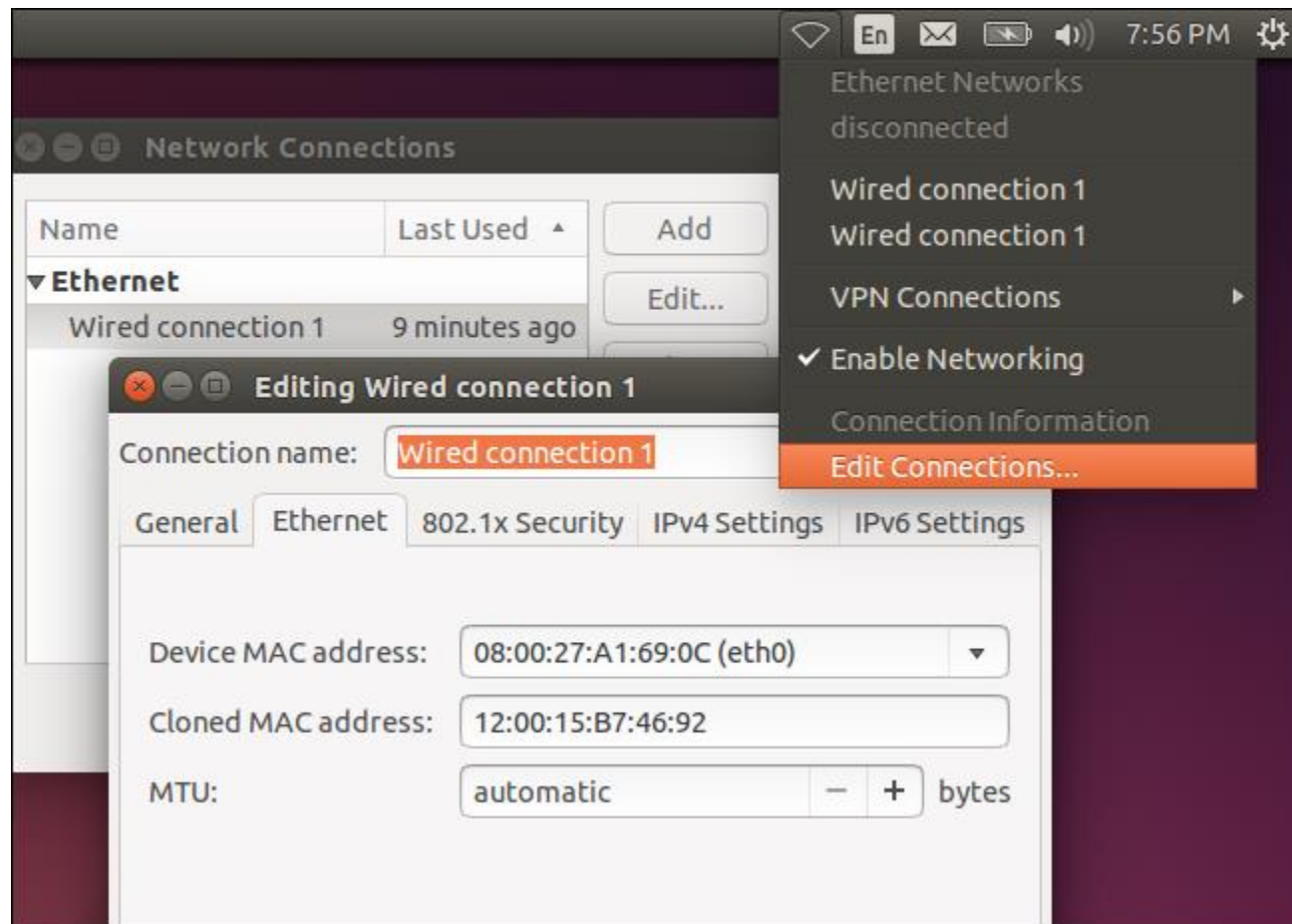
```
wikihow@wikihow: ~
wikihow@wikihow:~$ ifconfig -a
eth0      Link encap:Ethernet  HWaddr 08:00:27:15:84:10
          inet addr:10.0.2.15  Bcast:10.0.2.255  Mask:255.255.255.0
          inet6 addr: fe80::a00:27ff:fe15:8410/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:90 errors:0 dropped:0 overruns:0 frame:0
          TX packets:133 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:30496 (30.4 KB)  TX bytes:10000 (10.0 KB)

lo        Link encap:Local Loopback
          inet addr:127.0.0.1  Mask:255.0.0.0
          inet6 addr: ::1/128 Scope:Host
          UP LOOPBACK RUNNING  MTU:65536  Metric:1
          RX packets:88 errors:0 dropped:0 overruns:0 frame:0
          TX packets:88 errors:0 dropped:0 overruns:0 carrier:0
          collisions:0 txqueuelen:0
          RX bytes:8214 (8.2 KB)  TX bytes:8214 (8.2 KB)

wikihow@wikihow:~$
```

- <https://www.howtogeek.com/192173/how-and-why-to-change-your-mac-address-on-windows-linux-and-mac/>





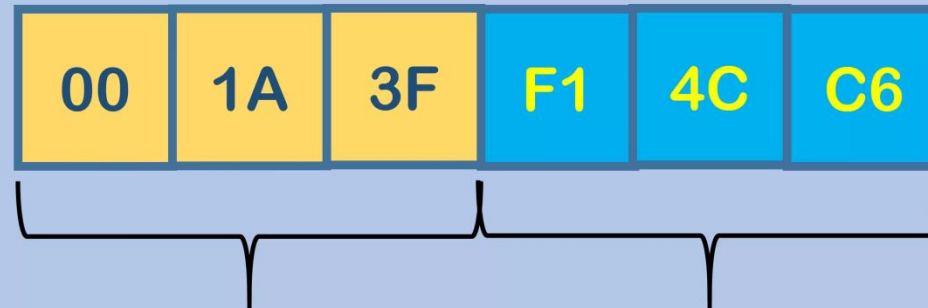
```
chris@ubuntu1404vbox: ~  
chris@ubuntu1404vbox:~$ sudo ifconfig eth0 down  
chris@ubuntu1404vbox:~$ sudo ifconfig eth0 hw ether 12:00:15:b7:36:92  
chris@ubuntu1404vbox:~$ sudo ifconfig eth0 up  
chris@ubuntu1404vbox:~$
```

# MAC Address

- OUI – Vendor Number
- UAI – Serial Number

## MAC

### Media Access Control Address



Organizationally Unique Identifier    Universally Administered Address

# Hexadecimal Numbers

- **Decimal** – 10 values
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- **Hexadecimal** – 16 values
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
  - A has the value 10, B means 11, C means 12, D is 13, E is 14 and F has the value 15

# MAC v IP

- Will cover IP addresses later, slide for information only

## MAC address vs IP address

### MAC address

- 48 bit address
- Works at OSI layer 2 (link layer)
- Physical address
- Fixed, assigned by manufacturer

**00:0C:F5:09:56:E8**

### IP address

- 32 bit address
- Works at OSI layer 3 (network layer)
- Logical address
- Can change depending on the network environment

**150.60.122.98**