ETHERNET

The Technology
and a Polemic History

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Ethernet Technology Today

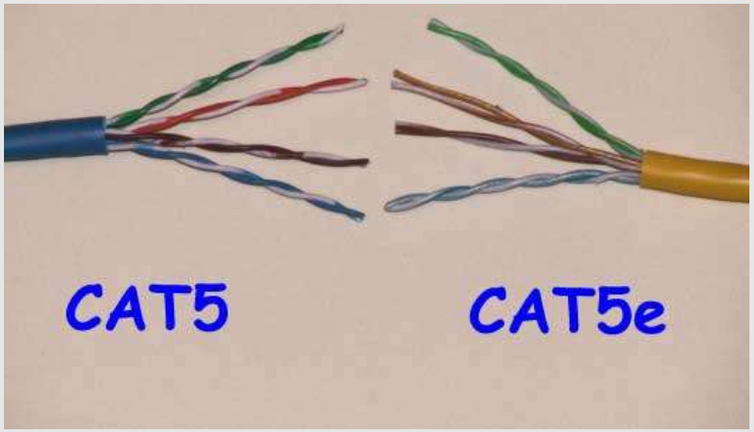
- **The predominant networking technology for Local Area Networks**
- **Used more and more for Wide Area Networks**
- **Runs at 10M, 100M, 1G, 10Gbits/sec over copper and Fibre Optic connections**
- **Simple cheap Unshielded Twisted Pair cabling supports all speeds upto 1Gbits/sec over distances of upto 100m**
- **Network Interfaces cards and Networking devices are cheap commodity items**

Ethernet Where it fits in....

- **It sits at Layers 1 and 2 of the ISO 7 layer model.**
- **Standards define, among other things....**
  - **the physical cabling**
  - **the way in which 1's and 0's are encoded in the light or electrical signals carried by the cabling**
  - **a frame format and addressing to standardise the exchange of data**
- **Ethernet is traditionally used for building LANs, but is now being used also for WAN connections**

Ethernet Copper Connections - 1

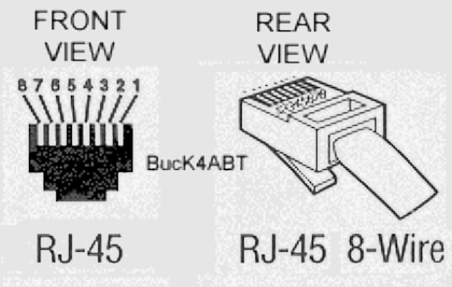
- **UTP cabling almost universal, runs up to 100m possible**
- **Connectors are 8 pin RJ45**
- **Cable is 8 core, consisting of 4 twisted pairs, the quality of the cable being indicated by a number:**
  - **Cat3 good for 10M, 10BaseT**
  - **Cat5 good for 100M, 100BaseTx**
  - **Cat5e good for 1G, 1000BaseT**
  - **Cat6 good for suppliers profits**



- http://www.lanshack.com/cat5e-tutorial.asp

Ethernet Copper Connections - 2

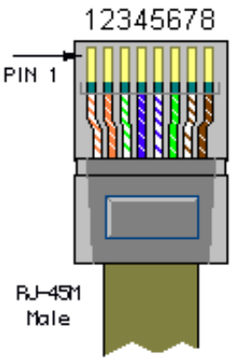
- **For 10M and 100M ethernet only 2 pairs are used: for 100M the remaining 2 pairs should be wired straight thru'**
- **Switch and Hub sockets are generally wired as "crossed", hence only a straight cable is needed to connect a computer. Often such sockets are marked with an 'X'.**
- **Use a "crossed" cables to connect computer to computer or switch to switch.**



Crossover Cable	
RJ-45 PIN	RJ-45 PIN
1 Rx+	3 Tx+
2 Rc-	6 Tx-
3 Tx+	1 Rc+
6 Tx-	2 Rc-

1-orange/white
2-orange
3-green/white
4-blue
5-blue/white
6-green
7-brown/white
8-brown

Straight Through Cable	
RJ-45 PIN	RJ-45 PIN
1 Tx+	1 Rc+
2 Tx-	2 Rc-
3 Rc+	3 Tx+
6 Rc-	6 Tx-



Ethernet Copper Connections - 3

- **For Gigabit Ethernet (1000BaseT) - all 4 pairs are used - in both directions at the same time!**
  - **In general straight through cables are used in all situations.**
  - **Often a cross over cable will still work**
- **Gigabit over copper needs very carefull attention to installation and use of high performance components to guarantee reliable operation .**

Ethernet Fibre Optic Connections

- **Fibre Optical connections are used in electrical noisy environments, or for long haul connections**
- **All Fibre Optic types are supported, multi-mode and single-mode.**
- **Different power laser drivers allow use over short distances and upto distances of 500Km.**
- **For more info than you really need to know see:**

  ftp://ftp.iol.unh.edu/pub/gec/training/ethernet_evolution.pdf or
  http://www.lanshack.com/fiber-optic-tutorial.asp

Ethernet Joining Computers

- **Use a cross- over cable to link 2 computers for the simplest Ethernet network**
- **More than 2 computers? You need an ethernet switch. Just plug in and go - use a straight cable from computer to switch.**
- **Need to join 2 switches - use a cross- over cable or a straight cable to an "Uplink" socket if present. You'll still need a cross- over cable to join 2 "Uplink" sockets.**

Ethernet Frame Format

- **Ethernet Data is transmitted in chunks called Frames**
- **Frames have the following structure:**
  - **6 bytes Destination MAC Address**
  - **6 bytes Source MAC Address**
  - **2 bytes Frame Type**
    - **e.g 0x800 for IP data, 0x806 for ARP**
  - **0- 1500 bytes of data**
  - **0- 46 bytes of padding (min. frame size is 64 bytes)**
  - **4 bytes CRC-32 checksum**

Ethernet MAC Addresses

- **Every ethernet device has a unique 6 byte address**
  - **The first 3 bytes indicate the manufacturer**
  - **The last 3 bytes are issued by that manufacturer**
- **e.g. 00:90:0B:00:6C:D6**
  - **00:90:0B is LANNER ELECTRONICS, INC**
- **A special address, all 1's (FF:FF:FF:FF:FF:FF), is the broadcast address. A frame sent to this address is sent to everything on the LAN, and everything should listen on this address.**

Ethernet How Switches work

- **Switches maintain a table of which source MAC addresses have been seen, on which switch ports.**
- **On the arrival of an ethernet frame, the switch looks up the destination address in the table, sending the frame down any port found. The source address and arrival port of the frame are added into the table.**
- **If the destination address is not in the table, then the switch floods the frame down all Ports.**
- **Addresses are removed from the table if not seen for a period, usually a few minutes.**

Ethernet Modern Limits

- **The amount of broadcast traffic provides the basic limit to the size of a modern switched Ethernet LAN. The more computers, the more broadcasts.**
- **For Internet Protocol (IP), where broadcast traffic is not high, several hundred computers can share one LAN.**
- **There is no inherent limit to the physical size of a switched Ethernet . But switches do have a limit for the MAC address table - typically several thousand.**
- **Ethernet Networks are typically joined together or to other network types by suitable Layer 3 routers.**

Ethernet The Advanced Stuff

- **VLANs**
  - **Carrying multiple different Ethernet lan traffic over common links.**
- **Trunking**
  - **Combining several inter-switch links to form one larger capacity virtual link**
- **Spanning Tree**
  - **A protocol for preventing loops and creating resilience in switched networks**
- **Also QoS, Auto-negotiation, Wireless, etc etc.....**

Ethernet What about.....

- **....Collisions, Repeaters, Coax Cable, CSMA/CD, Transceivers, AUI, etc, (yawn), etc.**
- **It's all old history. No one builds a new ethernet network with anything but switches, UTP and maybe some Fibre Optic cable nowadays. The rest is legacy, or my home network :-)**
- **Modern Ethernet is a Frame format, agreed encoding schemes, speeds, and physical media definitions. Cheap Switches have made shared media and collisions redundant.**
- **Why Ethernet everywhere anyway? And this isn't how it all started.....**

Ethernet The Beginning.....

1971 - Intel 4004 - first Commercial Microprocessor

1973 - Bob Metcalfe's Harvard Ph.D. Thesis outlines idea for Ethernet - tested on Xerox PARC's Alto computers. First network called the Alto Aloha System - an early version ran at 3Mbits/sec. Metcalfe later used the idea of the "lumeniferous ether" to rename the technology.

1974 - Intel 8080 - first 8 bit microprocessor

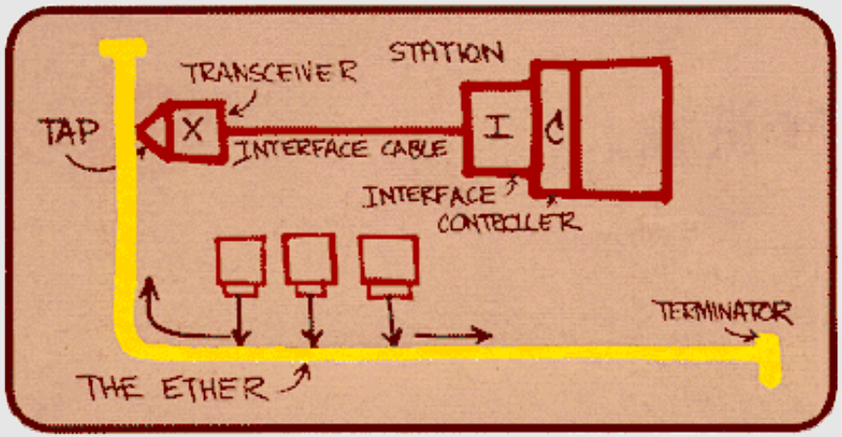
1979 - Momentum built to standardise "Ethernet". DEC, Intel and

- 1980 Xerox published "DIX" standard for 10Mb/s Ethernet.

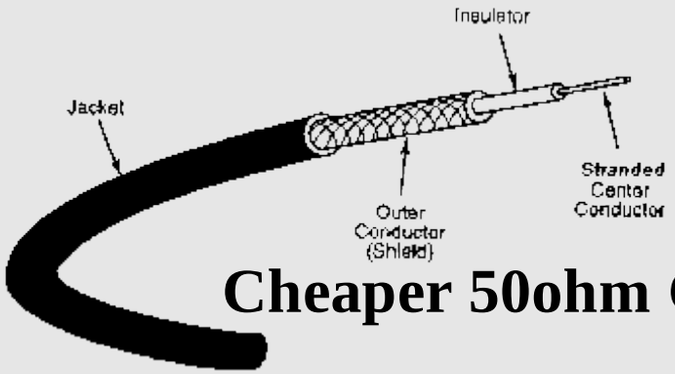
Ethernet Shared Coax 1

- **Physical Cable was 50ohm Coax Cable**

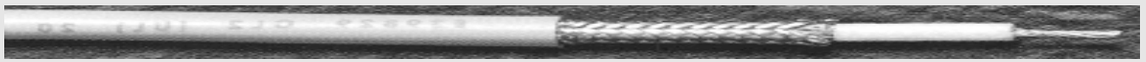
- **Each end of the cable is terminated with a 50ohm terminator to prevent signals being reflected. The Cable could be upto 500m**
- **Computers were connected via an AUI cable to a transceiver fastened to the coax cable.**
- **Metcalfe's original drawing**



Ethernet Shared Coax 2



Cheaper 50ohm Coax Cable



Used just like its big brother, but with run lengths upto 185m

Ethernet CSMA/CD

- **Access to the cable was shared, and the protocol that allowed multiple computers to share the network was CSMA/CD**
- **CARRIER SENSE MULTIPLE ACCESS**
  - **Before attempting to transmit listen to see if anyone else is**
- **COLLISION DETECT**
  - **If all clear transmit and listen to the signal. If the signal is distorted then someone else has transmitted at the same time and caused a collision. Maintain your transmission for at least 64 bytes, then stop, wait a random short interval and repeat from the top.**
- **Only one computer can transmit at once**

Ethernet Competition

- **1981 IBM's Token Ring Specification Published**
  - **A special data frame called a token is circulated round the computers on the ring. If you hold the token you can transmit a data frame to another computer.**
- **1982 Cambridge Ring standard published - much loved by Academia - and it became a National Standard!**
- **There were several other proprietary LAN technologies in use**
- **1982 - 3COM introduces its first product, Etherlink, the first PC Ethernet network interface card.**

Ethernet 1980s Pros/Cons

- **Pros**
  - **Simplicity**
  - **Open standard**
  - **Simple Cabling**
- **Cons**
  - **Simplicity, people did not believe it worked**
  - **Easy to get cabling wrong**
  - **Complex rules for large networks using Repeaters**

Ethernet **F.U.D.**

- **IBM - the 70s and 80s Microsoft - waged a war of Fear Uncertainty and Doubt against Ethernet, while charging for licenses to 3rd parties to produce Token Ring Technology.**
- **FUD survives even into the 90s 'Token ring networks had significantly superior performance and reliability compared to early shared- media implementations of Ethernet, and were widely adopted as a higher- performance alternative to shared- media Ethernet.'**
- **IBM commercial sites installed Token Ring, DEC commercial sites and computer science departments installed Ethernet and UK Universities installed Cambridge Ring!**

Ethernet Counter F.U.D.

- **1988 "Measured Capacity of an Ethernet: Myths and Reality"**
  ftp://gatekeeper.research.compaq.com/pub/DEC/WRL/research-reports/WRL-TR-88.4.pdf
  - **"The most well-known myth is that Ethernets saturate at an offered load of 37%. This is a fair summary of what happens for certain worst-case assumptions, but has very little to do with reality."**
- **Ethernets actually worked, despite the IBM FUD and academic studies purporting to show that CSMA/CD wouldn't allow high loads!**
- **IP was run over Ethernet before Token Ring, because of IBM hostility to IP.**

Ethernet Enter the IEEE 802.3

- **1985 "IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications."**

- **This specifies an Ethernet-like system. But recommends a frame format where the 'Type' field becomes a 'Frame Length' field, and changes to allow the frame type to be encapsulated.**
- **But IETF (and ultimately everyone) ignores that and retains the DIX frame format, though there ensues a decade of confusion over this. Everyone still calls it Ethernet, and with some justification.**
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Ethernet Faster & Bigger World

- **1985 Intel Release first of i386 Family**
- **1987 FOIRL longer reach over FO upto 2Km**
- **The FUD continues, faster has to be token ring.....**
- **1987 FDDI MAC Layer standard issued**
  - **A 100M Dual Token Ring resilient technology for LAN and MAN capable of surviving a break in the ring.**
- **1988 FDDI PHY Layer standard issued**
  - **FDDI Hugely complex - complete spec not out till.... 1994 FDDI Station Management spec issued!**

Ethernet shakes off coax.....

- **1990 10BaseT standardised - Ethernet over UTP**
- **Still at 10M, but with seperate copper circuits for TX and RX data can now be transmitted in both directions at the same time - just like FO.**
- **Ethernet ceases to be a 'bus' and becomes a 'star'. The difficult cabling issue goes away - a cabling problem to one computer doesn't affect other computers. It becomes more managable, it fits into the structured cabling schemes used for phone etc. Suddenly it is mainstream.**

Ethernet Gets Faster

- **Switches join the scene**
- **Early 90's people dreamed up heresies like Bridges with more than 2 ports. Microprocessor developments meant compute power could handle data internally at speeds of 100's Mbits/sec, allowing to switch data between 16 x 10M Ethernet ports at full wire speeds, and in full duplex.**
- **Ethernet breaks the 10M barrier, on copper wires**
- **1995 100BaseTX standardised**
- **FDDI priced out even with a copper variant**

Ethernet Another Competitor

- **ATM - Asynchronous Transfer Mode**
  - **In early 90's ATM came out of the Telcos as the ultimate comms protocol for unifying voice and data. Held out great promise, but complexity and slow development meant it fell flat on its face by the late 90's**
  - **Retains a foothold by being the carrier protocol for ADSL broadband services.**

Ethernet Even Faster

- **1998 1000BaseSX/LX/CX**
  - **Gigabit over Fibre Optics - technology delayed because of stupid decision to retain the concept of shared media, collisions and all that stuff.**
- **1999 1000BaseT**
  - **Gigabit over copper, despite people saying impossible**
- **2002 10Gigabit Ethernet**
  - **This time collisions and shared media are out the window.**

Ethernet And Now Everywhere

- **2000s**
  - **Token Ring legacy and Obsolete**
  - **FDDI legacy and obsolete**
  - **ATM toe hold role in ADSL**
- **Ethernet**
  - **Everywhere in the LAN, and becoming a de facto standard for WAN connections, but not in a form envisaged originally. Ethernet had to evolve for world domination.**

Ethernet References 1

- **Good Ethernet wiring etc page....**
  www.d-m.com/documents/network/networks.html
- **Bob Spurgeon's Ethernet pages at.....**
  http://www.ethermanage.com/ethernet/ethernet.html
- **Ethernet Interoperability Lab.**
  http://www.iol.unh.edu/training/ethernet.html
- **PDF of Evolution of Ethernet Presentation.....**
  ftp://ftp.iol.unh.edu/pub/gec/training/ethernet_evolution.pdf
- **Ethernet Performance and other papers**
  http://www.ethermanage.com/ethernet/papers.html

Ethernet References 2

- **1995 Ethernet tutorial**
  http://pclt.cis.yale.edu/pclt/COMM/ETHER.HTM
- **Optical Communications and Networking Timeline**
  http://www.infozoic.com/Timeline.htm
- **The History of Computers timeline**
  http://inventors.about.com/library/blcoindex.htm