

Chapter 3 - Fundamentals of LANs

Ethernet – refers to standards that define physical and data link layer for LAN. Variables for Ethernet Standards are : Speed, type of cable, length of cable etc.

IEEE – Institute of Electrical and Electronics Engineers

IEEE separates the Ethernet Data link layer functions into two sub layers:

802.3 Media Access Control (MAC) sublayer (Lower layer)

802.2 Logical Link Control (LLC) sublayer (Higher Layer)

Common Name	Speed	Alternate Name	IEEE Standard	Cable type, Maximum Length
Ethernet	10 Mbps	10BASE-T	IEEE 802.3	Copper, 100 m
Fast Ethernet	100 Mbps	100BASE-TX	IEEE 802.3u	Copper, 100 m
Gigabit Ethernet	1000 Mbps	1000BASE-SX 1000BASE-LX	IEEE 802.3z	Fibre, 500 m (SX) 5 km (LX)
Gigabit Ethernet	1000 Mbps	1000BASE-T	IEEE 802.3ab	Copper, 100 m

Alternate Name always list speed in Mbps

T – in the alternate name means twisted pair (UTP)

Functions of LAN : File sharing, Printer sharing, File transfer and gaming

10BASE2 and 10BASE5 – early Ethernets, consisted of series of co-axial cables connecting computer and their NIC. Sending computer sends electrical signals through the bus (collection of cables forming electrical circuit).

CSMA/CD – Carrier Sense Multiple Access with Collision Detection , ensures that only one devices sends traffic in Ethernet at one time. Avoids collision and takes action when collision occurs. Algorithm:-

A device that wants to send a frame waits until LAN is silent, ie no frame is currently being send, before attempting to send an electrical signal

If a collision still occurs, the devices that caused the collision wait a random amount of time and try again

CSMA/CD : Carrier Sense Multiple Access with Collision detection, a device access mechanism in which devices ready to transmit data first check the channel for a carrier. If no carrier is sensed for a specific period of time, a device can transmit. If two devices

transmit at once, a collision occurs and is detected by all colliding devices. This collision subsequently delays re-transmission from those devices for a random length of time.

10BASE2 – maximum cable length 185m

10BASE5 – maximum cable length 500 m

Attenuation :- weakening of electrical signals as it traverse farther through a cable

Repeaters – connects multiple cable segments, receive electrical signal on one cable, interpret the bits as 1s and 0s and generates brand new, clean, strong electrical signal out the other cable. But does not interpret the meaning of the electrical signal (bits) and is a Layer 1 device.

Repeater does not simply amplify the signal, because amplifying the signal might also amplify any noise picked up along the way, but it re-generates brand new electrical signals.

Ethernet Hubs : hubs are essentially repeaters but with multiple physical ports, it re-generates the electrical signals that comes in one port and sends to every other ports and creates an electrical bus.

- Original Ethernet LANs created an electrical bus to which devices were connected
- 10BASE5 and 10BASE2 repeaters extended the length of the LAN by cleaning up the electrical signals and repeating it – a layer 1 function – without interpreting the meaning of the signals.
- Hubs are repeaters that provide a centralised connection point for the UTP, cabling, but still creates a single electrical bus shared by various devices, just like 10BASE2 and 10BASE5.
- Because collision could occur in any of these cases, Ethernet defines CSMA/CD algorithm, which tells devices how to avoid collision and also action to take when it occurs.

Ethernet UTP Cabling

10BASE-T (Ethernet) , 100BASE-T (fast Ethernet – FE) , 1000BASE-T (gigabit ethernet – GE) use UTP (unshielded twisted pair) cabling

UTP cables – two pairs or four pairs of wires.

RJ-45 connectors – connect to end points of utp cables and has pins (8) to which each of the coloured wires are connected to. RJ-45 connectors are inserted into RJ-45 ports in computers of switches.

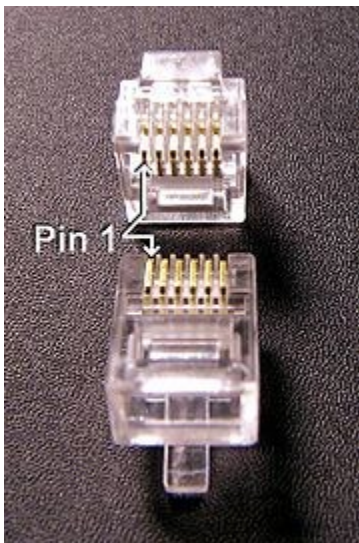
RJ11 – commonly used for telephone cables in North America

RJ11 is a [physical interface](#) often used for terminating [telephone](#) wires. It is probably the most familiar of the [registered jacks](#), being used for single line [POTS](#) telephone jacks in most homes across the world.

RJ14 is similar, but for two lines, and **RJ25** is for three lines. [RJ61](#) is a similar registered jack for four lines. The telephone line cord and its plug are more often a true RJ11 with only two conductors.

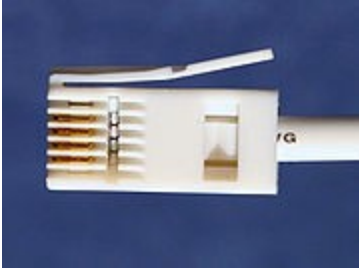
Phone generates analog signals at the rate of 0 – 4000 Hz, and the DSL modem uses frequencies higher than 4000 Hz, so that the phone and the DSL signals interfere very much, still need to use a filter.

The DSLAM directs (multiplexes) the analog voice signals – frequency range between 0 Hz and 4000 Hz, to a voice switch.



Two views of an RJ25 6P6C crimp-on style connector. .

RJ11 is a [physical interface](#) often used for terminating [telephone](#) wires. It is probably the most familiar of the [registered jacks](#), being used for single line [POTS](#) telephone jacks in



BS6312 431A plug; colloquially, a **British Telecom plug**. Used in NZ.

Cisco switches use GBIC (gigabit interface converter) or Small form Pluggables (SFP) so that a switch can use a variety of cable connectors, types of cabling and support different cable lengths.

Cisco switches can easily alternate between 1000BASE-T GBIC and 1000BASE-LX interface cards depending on the situation, like if the cabling needs to cover a longer distance.

Twisted pair copper wire cancels out the magnetic field when transmitting electricity. By twisting together wires in the same pair, with the current running in opposite directions on each wire, the magnetic field created by one wire mostly cancels out the magnetic field created by the other wire.

Networking devices create an electric circuit using twisted wire pairs and vary the signals as defined by the encoding scheme, to send bits over wire pairs.

Encoding schemes define how the electrical signal should vary, over time, to mean either a binary 0 or 1.

Twisted Pair : Transmission medium consisting of two insulated wires, with wires twisted around each other in a spiral. An electrical circuit flows over the wire pair, with the current in opposite directions on each wire, which significantly reduces the interference between two wires.

UTP Cabling Pinouts for 10BASE-T and 100BASE-TX

Telecommunications Industry Association (TIA) and Electronics Industry Alliance (EIA) define the standards for UTP cabling, color coding for wires and standard pinouts on the cable.

Two EIA/TIA pinout standards are T568A and T568B.

T568A pinout standard

RJ-45

pair 3 3 2 1 1 2 4 4
pins 1 2 3 4 5 6 7 8

Pinouts

- 1- G/W
- 2- Green
- 3- O/W
- 4- Blue
- 5- B/W
- 6- Orange
- 7- Brown/W
- 8- Brown

Pair 1	Pair 2	Pair 3	Pair 4
Blue/Blue W	Orange W/ Orange	Green W/Green	Brown W / Brown

T568B pinout standard

RJ-45

pair 2 2 3 1 1 3 4 4
pins 1 2 3 4 5 6 7 8

Pinouts

- 1- O/W
- 2- Orange
- 3- G/W
- 4- Blue
- 5- B/W
- 6- Green
- 7- Brown/W
- 8- Brown

Pair 1	Pair 2	Pair 3	Pair 4
Blue/Blue W	O W/Orange	Green W/Green	Brown W / Brown

Pinout : Documentation and Implementation of which wires inside a cable connect to each pin positions in side any connector

UTP cable requires two pairs of wire for 10BASE-T and 100BASE-TX and four pairs of wire for 1000BASE-T.

Ethernet NIC send data using the wire pair connected to Pins 1 and 2. (pair 3, T568A standard)

Ethernet NIC receives data using the wire pair connected to Pins 3 and 6. (pair 2, T568A standard)

Hubs and switches send data using the wire pair connected to Pins 3 and 6. (pair 2, T568A standard)

Hubs and switches receives data using the wire pair connected to Pins 1 and 2. (pair 3, T568 standard)

Straight Through Cable : connects two devices (NIC and switch) which uses opposite pinout pairs to transmit and receive data.

Straight through cable connects wire at pin 1 on one end of the cable to pin 1 on other end of the cable, wire at pin 2 on one end of the cable to pin 2 on other end of the cable and so on.

But will not work for connecting two hubs/switches together as they use the same pins for send and receive.

A cable that swaps the wire pair in side the cable is called **Cross over cable**.

Cross over cable must be used to connect two switches as both the switches uses pair at pin 3,6 to transmit and pair at pins 1,2 to receive, the cable must swap or cross the pairs.

1 ---- 3
2 ---- 6
3 --- 1
6 --- 2

Devices on opposite end of the cable using same pair of pins to transmit need crossover cable, devices uses opposite pair of pins to transmit requires straight trough cables.

Crossover Cable : An Ethernet cable that swaps the wire pair used for transmission on one device to wire pair used for receiving on a device connected to the other end of the cable. In 10BSAE-T and 100BASE-TX networks, this cable swaps the wire pair at Pin 1,2 to Pins 3,6 on other end of the cable, and Pair at Pins 3,6 to Pins 1,2.

Straigh-through Cable : An Ethernet cable that connects wire on Pin 1 on one end of the cable to Pin 1 on other end of the cable, Pin 2 on one end to Pin 2 on other end and so on.

10BASE-T and 100BASE-TX pin pairs used

Devices that transmit on pin pair 1,2 and receives on 3,6	Devices that transmit on pin pair 3,6 and receives on 1,2
PC NICs	Hubs
Routers	Switches
Wireless Access Points (Ethernet Interface)	
Network Printers (directly connected to LAN)	

1000BASE-T requires 4 wire pairs also gigabit Ethernet transmit and receives on each of the four wire pairs simultaneously.

1000BASE-T straight through cables connect wire at pin 1 to pin 1 , pin 2 – pin 2 and so on.

1000BASE-T crossover cable crosses wire pairs between pins (1,2 and 3,6) and (4,5 and 7,8).

Auto-mdix is a cisco switch feature that notices wrong cabling pinouts, and re-adjusts the switch's logic and makes the cable work.

Hubs to Switches

Five steps of a hub creating electrical bus.

1. NIC sends a frame
2. NIC loops the send frame to its receive pair internally on the card
3. hub receives the electrical signals, interpret the signals as bits, so that it can clean up and repeat as strong signals
4. hubs internal wiring repeats the signal to all other ports, except the port the signals was received from
5. the hub repeats the signal to each receiver pair on all other devices

If two NIC send frames at same time, at step 4, the electrical signals would overlap, frames would collide, and either frames will be completely unintelligible, or full or errors.

CSMA/CD algorithm helps prevent the collision and also defines how to act when collision occurs, CSMA/CD algorithm work like this;

1. A device with a frame to send listens until Ethernet is not busy
2. when the Ethernet is not busy sender(s) begin(s) sending the frame
3. the sender(s) listen(s) to make sure that no collision occurred
4. if a collision occurs the devices that had been sending, each send a jamming signal to ensure that all stations recognizes the collision
5. after the jamming is complete, each sender randomizes a timer and waits that long before trying to resend the collided frame
6. when each random timer expires, the process start from step 1

Using a hub with CSMA/CD causes performance problems;

1. only one device can send at a given point in time
2. if a collision occurs, the sending devices waits for a ramdomized time before trying to re-send the collided frame

For devices connected to a hub, only one device can send at any one instant in time. As a result the devices connected to a hub share the bandwidth available through the hub. The logic of waiting for the LAN to be silent before sending, means that a device either send or receive at a given point in time, but not both , and this is called half duplex.

Collision domain : defines the set of devices whose frame could collide. All devices on a 10BASE2 and 10BASE5 network and any network using a HUB are said to be in the same collision domain.

Hubs : A LAN device providing a centralized connection point for LAN cabling, repeating any received electrical signals out all other ports, thereby creating a logical bus. Hubs do not interpret the electrical signals as a frame of bits, so Hubs are considered to be Layer 1 devices.

Switches:

1. Interprets the bits in the received frame, so that they can typically send the frame out the required one port, rather than all other ports
2. If the switch needs to forward multiple frame out the same port, the switch buffers the frames in memory, sending one at a time and thereby avoiding collision.

A switch is considered to be a layer 2 device as it need to look at the Ethernet header for address.

Single devices connected to switch ports does not share the bandwidth, ie a switch with 100Mbps port, has 100Mbps for each port.

Shared Ethernet : Ethernet using a hub or the original co-axial cabling LAN were the LAN bandwidth is shared among the devices, as each device has to take turn in using the LAN, because of the CSMA/CD algorithm.

Switched Ethernet : LANs with switches does not have to share the bandwidth between devices connected to a port. Ie a switch with 100 Mbps port has 100Mbps for each port.

A hub with 24, 100Mbps devices connected to it all share a theoretical total bandwidth of 100Mbps. However a switch with 24, 100 Mbps devices connected to it, support 100 Mbps on each of the 24 ports, or 2400 Mbps (2.4 Gbps) theoretical maximum bandwidth.

LAN switches with only one devices cabled to each port, can completely eliminate collision, which allows the use of full-duplex operation. Full-duplex means the Ethernet cards can send and receive concurrently. When full-duplex is implemented CSMA/CD will be disabled on devices at both end of the cable. And performance will be doubled by allowing simultaneous transmission in both directions.

Full Duplex : Any communication in which two communicating devices can send and receive data concurrently is said to have full duplex communication. In Ethernet LAN full duplex is allowed when the CSMA/CD is disabled on both the communicating devices.

Half Duplex : Any communication in which only one device can send data at a time. In Ethernet LAN normal results of CSMA/CD that enforces the rule that only one device should send at any point in time.

Ethernet Data-Link Protocols

Ethernet data-link protocols (small set) is same and applies to almost all of the variations of Ethernet from 10BASE5 up through to 10 Gbps Ethernet.

Ethernet LAN addressing identifies either a individual device (unicast) or a group of devices in LAN (broadcast and multicast). Ethernet LAN address is 6 bytes (48 bits) long, usually written as set of 4 digit hex (12 hex digits) values separated by dots.
0000.OC12.3456

Unicast Ethernet address identifies a single LAN card.

Ethernet card manufactures encodes MAC address into the card, usually in a ROM chip, first half identifies the manufactures and is assigned by IEEE and is called Organizationally Unique Identifier (OUI), second half is a unique number assigned by the manufacture for each card. It is also called Burned in address (BIA) , also called uiversally administered address (UAA).

Structure of unicast Ethernet address

	Organizationally Unique Identifier	Vendor Assigned NIC Cards, Interfaces
Size in bits	←-----24 Bits-----→	←-----24 Bits--- --→
Size in Hex Digits	←-----6 Hex -----→	←-----6 Hex --- --→
Example	←---00 60 2F -----→	←---3A 07 BC--- --→

Group address – represents more than one LAN interface cards:-

Broadcast addresses: represents all the devices on the LAN, and is represented by FFFF.FFFF.FFFF in hexadecimal notation.

Multicast address – allows a subset of devices on the lan to communicate. When IP multicasts over an Ethernet, the multicast MAC address used by IP follows the format, **0105.5exx.xxxx** where x can take any value.

LAN MAC Address terminology

LAN addressing term or feature	Description
MAC	Media Access Control 802.3 (Ethernet) defines the MAC sublayer of the IEEE Ethernet.
Ethernet Address, NIC Address, LAN address	Other terms for MAC address, and defines 6 bytes (48 bits) long address for LAN Interface cards.
Burned in address (BIA)	6 byte ling address assigned by the NIC vendor
Unicast address	MAC address representing a single LAN interface
Broadcast address	An address that means all devices that reside on this LAN right now
Multicast address	Implies to some subset of all the devices currently on the Ethernet LAN

Ethernet Framing : Defines how a string of binary numbers are interpreted, it defines the meaning behind the bits that are transmitted across a network.

Ethernet Frame (IEEE 802.3 revised 1997).

Preamble	SFD	Destination	Source	Length/type	Data and Pad	FCS	
7	1	6	6	2	46-1500	4	(Bytes)

IEEE 802.3 Ethernet header and trailer fields

Field	Field Length	Description
Preamble	7	Synchronization
Start frame delimiter (SFD)	1	Signifies the next byte begins the destination MAC field
Destination	6	Destination MAC
Source	6	Source MAC
Length	2	Length of the data field of the frame (either length or type is present not both)
Type	2	Type of protocol listed inside the frame (either length or type is present not both)
Data and pad	46-1500	Holds data from higher layer L3 PDU (generally) mostly IP Packet
Frame check sequence (FCS)	4	Provides a method for the receiving NIC to determine if the frame experienced transmission errors

The IEEE 802.3 specification limit the data portion of the 802.3 frame to maximum of 1500 Bytes. The data field was designed to hold the layer 3 IP Packet. The term Maximum Transmission Unit (MTU) refers to the maximum layer 3 packet that can be send over a medium. Because Layer 3 IP Packet resides inside the data portion of an Ethernet frame, 1500 bytes is the largest **IP MTU** that can be send over an Ethernet.

Layer 3 protocols like IBM SNA, Novel Netware, AppleTalk, TCP/IP could be transmitted over Ethernet LAN. (layer 2 ethernet frame).

Type field in the Ethernet frame header identifies the Layer 3 protocol used, eg . IP packet means 0800 (decimal 2048) value in the type field.

When length/type field in the Ethernet frame header is used to represent the length of entire Ethernet frame (hex value less than 0600 decimal 1536), in such cases Ethernet frame adds two additional headers after the 802.3 Ethernet header but before he L3 Header:-

1. an IEEE 802.2 Logical Link Control (LLC) header
2. an IEEE subnetwork access protocol (SNAP) header

LLC Header
DSAP SSAP CTL
1 1 1 (Bytes)

SNAP Header

OUI	Type	
3	2	(Bytes)

Preamble	SFD	Destination	Source	Length/type	LLC Header	SNAP Header	Data and Pad	FCS	
7	1	6	6	2	3	5	46-1500	4	(Bytes)

Length/Type field will have value less than 1536, meaning it represents the length of the entire Ethernet frame.

Protocol Type Field : A field in a LAN header that identifies the type of header that follows (Layer 3 PDU) the LAN header, Includes the DIX Ethernet Type Field, IEEE 802.2 DSAP field, and the SNAP protocol type field.

Error Recovery

Ethernet Frame Check sequence is the only field in the Ethernet frame trailer, allows the devices receiving the frame to detect if the bits have changed during transmission. FCS error detection does not mean error recovery.

To detect an error the sending device calculates a complex mathematical function with the frame contents as input and puts the results into the frames 4 Bytes FCS field. The receiving device does the same math on the frame, if its calculation matches the FCS field in the frame, no errors occurred. If the results doesn't match an error has occurred and the frame is discarded, Ethernet does not do any thing for error recovery, it takes no action for re-sending the frame, but is taken care by protocols like TCP.

1000BASE-T : A name for IEEE Gigabit Ethernet standard that uses four pair copper cabling, a speed of 1000 Mbps (1 Gbps) and a maximum cable length of 100 meters.

100BASE-TX : A name for the IEEE fast Ethernet standard that uses two pair copper cabling, a speed of 100 Mbps and a maximum cable length of 100 meters

10BASE –T : The 10 Mbps baseband Ethernet specification using two pairs of twisted pair cabling. (Category 3,4, or 5). One pair transmit and other pair receives data. 10BASE T which is part of the IEEE 802.3 specification, has a distance limit of approximately 100 meters.

Please go toDo I know this Already –QUIZ. – Chapter 3. :- Page 42.