

- **Link Layer Services**
  - Framing (header encapsulation), link access, reliable service (optional), flow control, error detection or and correction
  - Link layer functionalities mostly implemented in adaptor cards (NIC or networking interface card) such as Ethernet card and 802.11 (Wi-Fi) card
- **MAC address vs. IP address**
  - Each adapter card has a **6-byte** physical address (MAC address), which is used to identify the interface for transmission. This is a flat address, where each manufacturer is assigned a fixed prefix, which in turn ensures no two adaptor cards have the same address.
  - **IP address** is a logical address (hierarchical) primarily for routing, which is divided into a subnet part (network address) and a host ID within a network. These two parts is combined to a single IP address.
  - Destination address is used to determine the route by table lookup, i.e., determine the next hop to forward a packet or more precisely the outgoing interface within a router or host.
  - Recall the Internet is a packet switched network, the packet is stored and forwarded hop by hop. For the actual hop by hop transmission, the next hop MAC address is needed to form link level frames for actual transmission.
  - **Address Resolution Protocol** or **ARP** is used to translate a target IP address into a target MAC address in a local area network. The key feature is to take advantage of the broadcast nature in the local area network, i.e., ARP query is broadcasted. In case this is a point-to-point connection, a node will directly request the MAC address of the other node.
- **Random Access Protocols**
  - The most common medium access protocols used in local area networks are random access protocols, in particular CSMA/CD (Ethernet).
  - Slotted ALOHA protocol is one of the first random access protocols designed, where in each slot a node transmits a packet with a probability  $p$ . The simple performance study shows that the maximum utilization (throughout) is about 37%. Unslotted ALOHA achieves about half of this throughout at 18%.
  - CDMA/CD protocol improves over the ALOHA in two aspects, 1) it listen to the channel (Carrier Sense) before transmission, 2) it continues monitoring the channel after transmission. When there is a collision detected (CD), it will abort the transmission.
  - Assuming the maximum distance between two nodes in the Ethernet is  $D$ , speed of light is  $R$ , the maximum frame length is  $L$  and transmission rate (link bandwidth) is  $B$ . The maximum amount of time that a node has to wait after a transmission is  $2D/R$  (a roundtrip delay). For CSMA/CD protocol to work, it usually requires that  $L/B > 2D/R$ , transmission time much bigger than the propagation delay.

- **Switch**

- A switch can do intelligent filtering based on the destination MAC address. It maintain a switch table, when a packet comes, it check whether the destination MAC address is in the table to see if it can directly forward the packet to one single outgoing port. If there is no entry in the table, it simply forward to all outgoing ports except the one it receives the packet (exactly like a hub).
- A switch has self-learning capability, as it can record the interface that it receives a packet, by checking the source MAC address, it can build a record in the switch table, record (MAC address, Interface, TTL). Noticing for this to work, it mandates that a packet can not arrives from more than one incoming port, that is, the topology must be a tree (with no loop).

- **Switch vs. Router**

- Both use store-and-forward. In practice, both use an address extracted from a packet header as an index for table lookup to locate the outgoing link
- There is significant difference underneath the surface. Routers maintain routing (forwarding) table by running routing algorithms, which can determine the network topology (an arbitrary mesh topology). While switches perform filtering with self-learning algorithm to maintain the switching table. This cannot scale to large network, does not figure out the network topology and require a tree topology.
- Routers are based on IP (logical and hierarchical) address and switches utilize MAC (physical and flat) addresses.