Ethernet Overview

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Foreword

- In 1973, Dr. Robert Metcalfe developed an Ethernet lab prototype system, which ran at a speed of 2.94 megabits per second (3 Mbps). After more than 40 years of development, Ethernet has become a LAN standard, and the speed of the Ethernet has reached an astonishing 100,000 Mbps.

Objectives

- Upon completion of this course, you will be able to:
  - Learn about the development history of Ethernet.
  - Understand Ethernet standards.
  - Understand the working principles of hubs and L2 switches.

Contents

1. Ethernet Technology Development

2. Working Principles of the Ethernet

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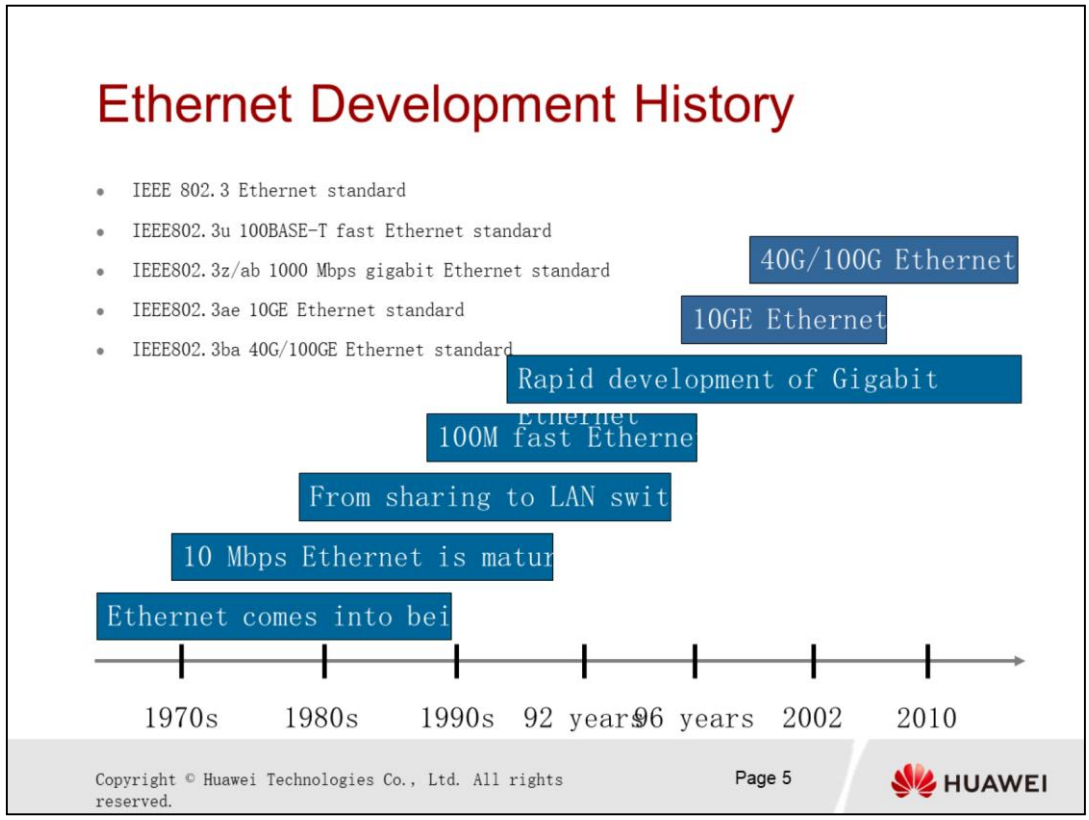
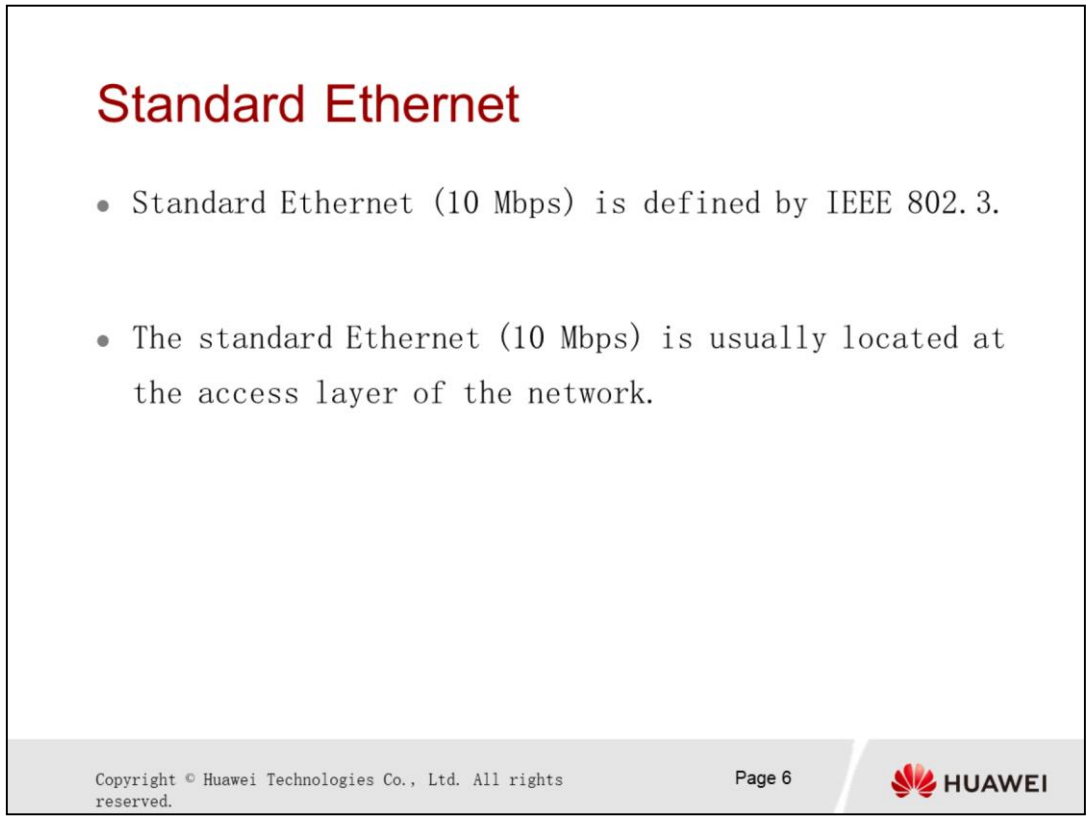


- Brief history of Ethernet development:
- In 1973, Xerox, a company in Palo Alto Californian, proposed and implemented the original Ethernet. Dr. Robert Metcalfe was recognized as the father of Ethernet, and his lab prototype system ran at a speed of 2.94 megabits per second (3 Mbps).
- In 1980, Digital Equipment Corporation, Intel, and Xerox jointly launched the 10 Mbps DIX Ethernet standard [DIX80]. IEEE 802.3 standards are formulated based on this original Ethernet technology.
- In 1995, IEEE officially passed the 802.3u Fast Ethernet standard.
- In 1998, the IEEE802.3z gigabit Ethernet standard was officially released.
- In 1999, the IEEE802.3ab standard, that is, the 1000BASE-T standard, was released.
- On July 18, 2002, IEEE passed the 802.3ae (10 Gbps Ethernet), also known as the 10GE Ethernet. It includes three physical interface standards: 10GBASE-R, 10GBASE-W, and 10GBASE-LX4.
- In March 2004, IEEE approved the 10G Ethernet standard 802.3ak for copper cables. The new standard will be implemented as 10GBASE-CX4 to provide a 10 Gbps rate on dual-axis cables.

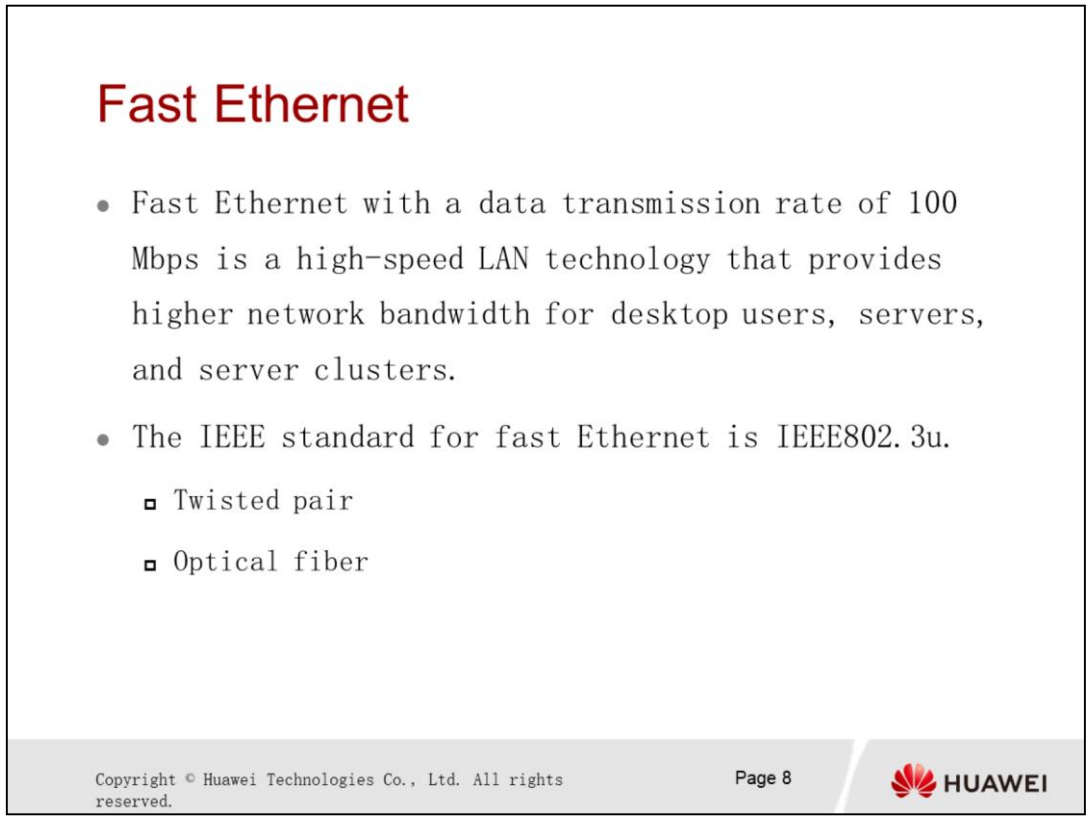


- The 10 Mbps Ethernet is usually located at the access layer of the network. The new-generation multimedia, image, and database products can easily overwhelm the Ethernet bandwidth of the 10 Mbps.

802.3 Cable Overview

Technical Standards	Cable Type	Transmission Distance
10BASE-5	Thick coaxial cable	500 m
10BASE-2	Thin coaxial cable	200 m
10BASE-T	Twisted pair	100 m

- In addition to coaxial cables and twisted pairs, IEEE 802.3 cables also include optical fiber 10BASE-F. The 10BASE-F has been used at the initial stage, and the transmission distance can reach about 2 km.

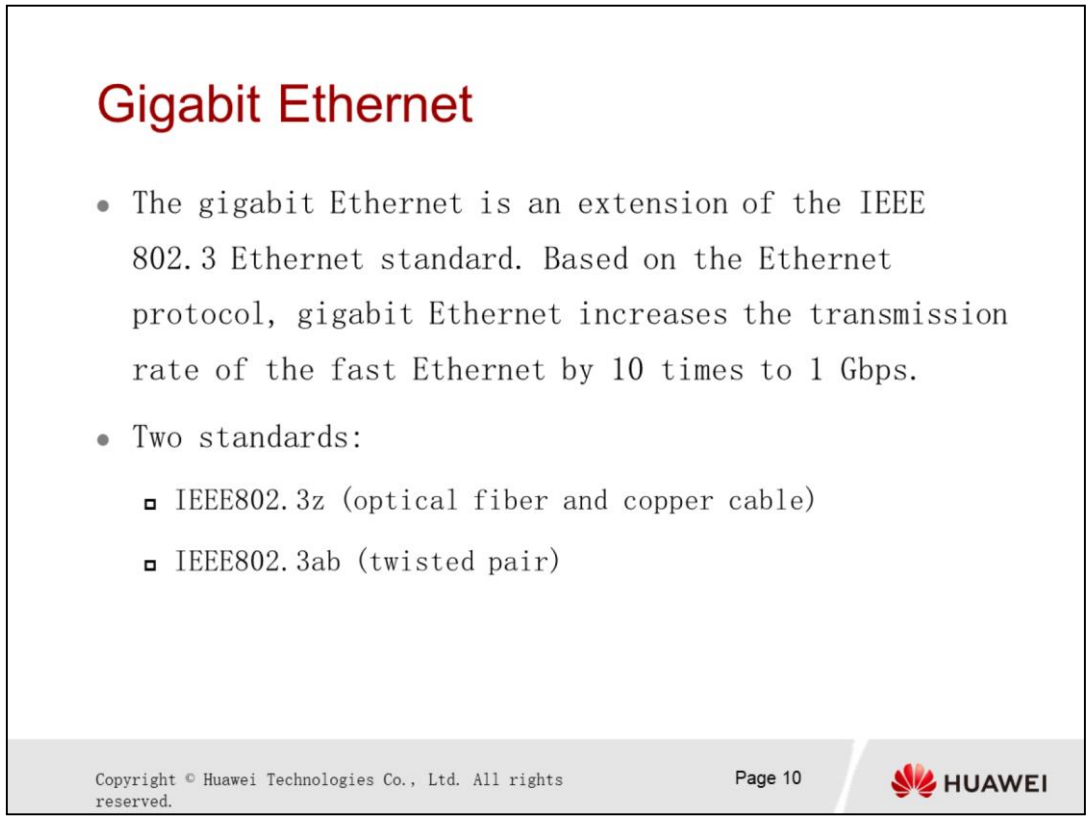


- The standard Ethernet rate is too low to meet the requirements of network data transmission in the modern age.
- Therefore, IEEE defined a fast Ethernet with a data transmission rate of 100 Mbps. The standard is IEEE802.3u, and the transmission medium mainly includes optical fibers and twisted pairs.

Fast Ethernet Cables

Technical Standards	Cable Type	Transmission distance
100BaseTX	EIA/TIA5 (UTP) unshielded twisted pair (2 pairs)	100 m
100BaseT4	EIA/TIA3, 4, and 5 (UTP) unshielded twisted pair (4 pairs)	100 m
100BaseFX	Multi-mode optical fiber (MMF)	550 m to 2 km
	Single-mode optical fiber (SMF)	> 2 km

- The fast Ethernet working in full-duplex mode can transmit and receive data at the rate of 100 Mbps at the same time. The channels for transmitting and receiving data are independent of each other. In this way, no conflict occurs and the communication efficiency of the network is improved.
- EIA/TIA: Electronic Industry Alliance/Telecommunications Industry Association



- The Gigabit Ethernet is an extension of the IEEE 802.3 Ethernet standard. Based on the Ethernet protocol, the Gigabit Ethernet increases the transmission rate of the fast Ethernet by 10 times to 1 Gbps.
- Gigabit Ethernet has two standards: IEEE802.3z (optical fiber and copper cable) and IEEE802.3ab (twisted pair)

Gigabit Ethernet Cables

Technical Standards	Cable Type	Transmission distance
1000BaseT	Copper EIA/TIA5 (UTP) unshielded twisted pair (4 pairs)	100 m
1000BaseCX	Copper shielded twisted pair	25 m
1000BaseSX	Multi-mode optical fiber, 50/62.5 um optical fiber, using laser with the wavelength of 850 nm	550 m/275 m
1000BaseLX	Single-mode optical fiber, 9 um optical fiber, using laser with the wavelength of 1300 nm	2 - 15 km

- IEEE802.3ab defines the 1000BaseT cable standards. 1000BaseT is a gigabit Ethernet technology that uses Cat. 5 UTP as network transmission media. The longest effective distance can reach 100 m, the same as 100BASETX. This technology can be used to achieve smooth upgrade from 100 Mbps to 1000 Mbps in the existing fast Ethernet system.
- IEEE802.3z defines 3 types of cable standards:
  - The 1000BaseCX uses a special type of shielded copper cable with high-quality balanced twisted pairs. The longest effective distance is 25 m, and a 9-core type-D connector is used to connect the cable.
  - 1000BaseSX is a network medium technology that uses short-wave laser as the signal source. The laser transmitter with the wavelength of 770 - 860nm (usually 800 nm) configured on the transceiver does not support single-mode optical fibers and can only drive multi-mode optical fibers.
  - 1000BaseLX is a network medium technology that uses long-wave laser as signal source. The laser transmitter with the wavelength of 1270 - 1355 nm (usually 1300 nm) configured on the transceiver can drive both multi-mode and single-mode optical fibers.

Contents

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2. Working Principles of the Ethernet

- Shared Ethernet
- Working Principles of Layer 2 Switches

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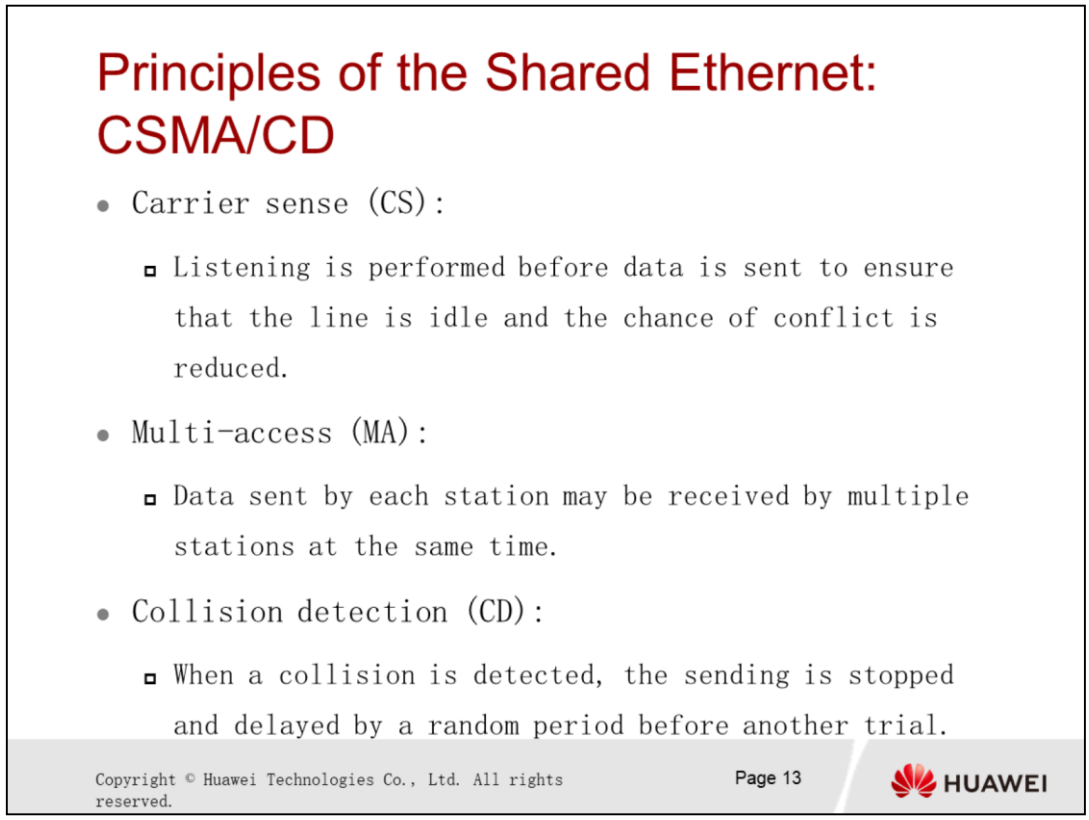
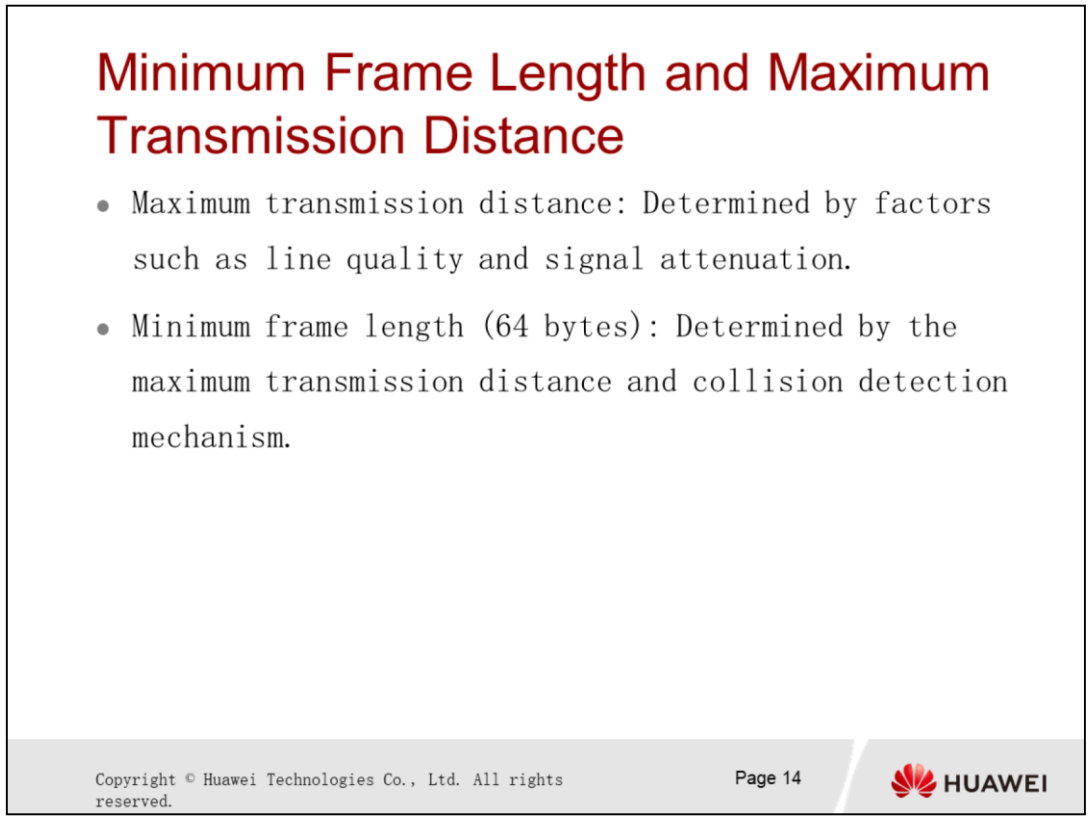
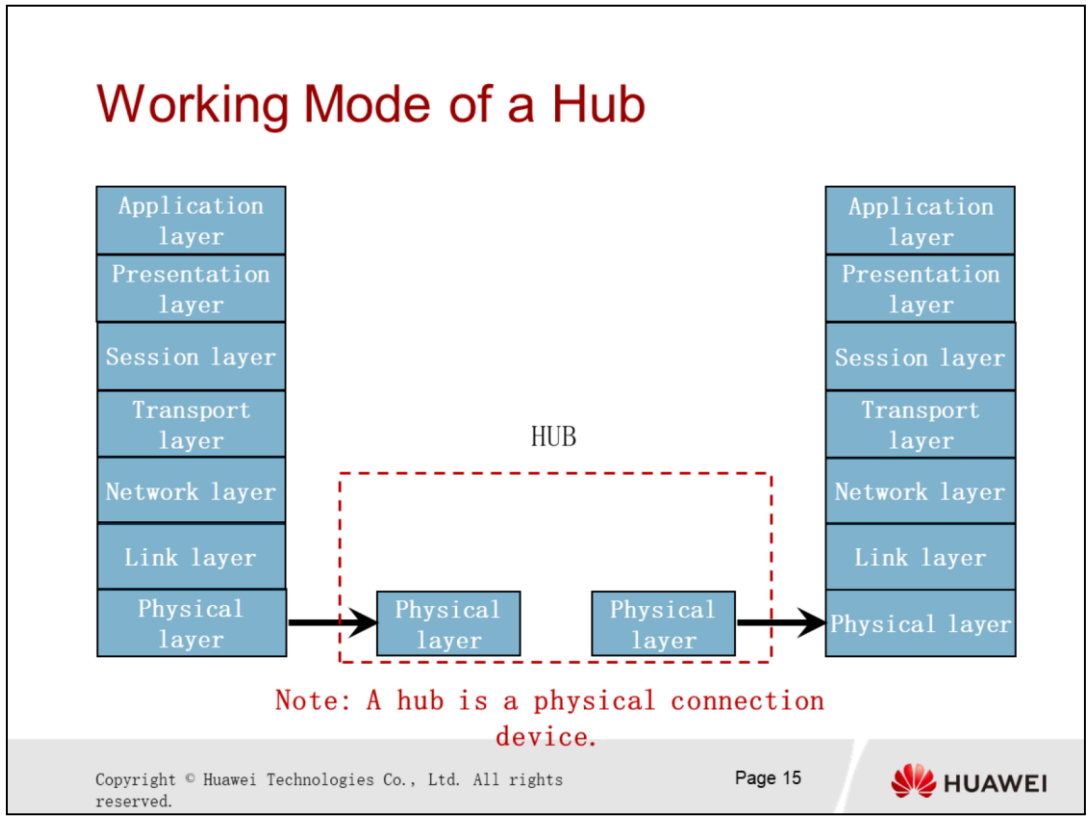


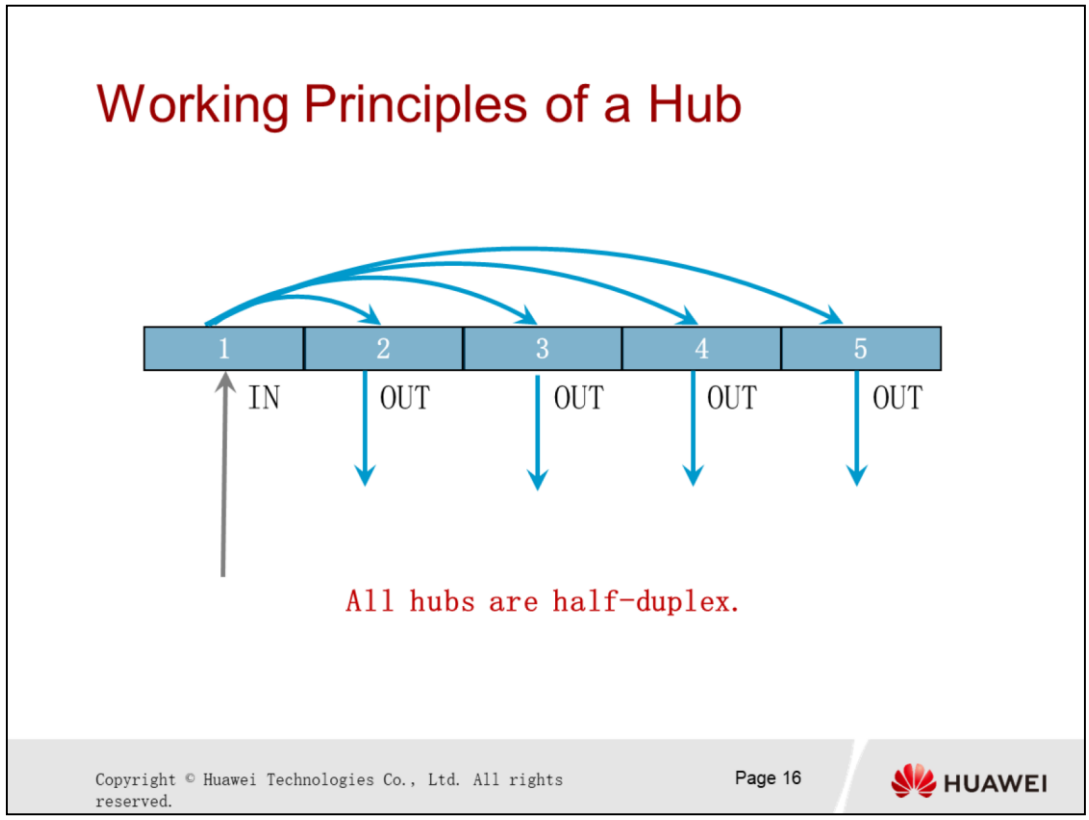
- Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is a method for implementing multipoint communication using shared media. The basic rules are as follows:
  - (1). If the medium is idle, send data. Otherwise, go to (2).
  - (2) If the medium is busy, keep listening to the channel until the channel is idle, and then send data immediately.
  - (3) If a collision is detected, that is, the swing of the voltage on the line exceeds twice the normal value, a short jamming signal is sent, so that all stations know that a collision occurs and stop sending data.
  - (4) After the jamming signal is sent, wait for a random period of time, try to send data again, and return to (1) to start again.



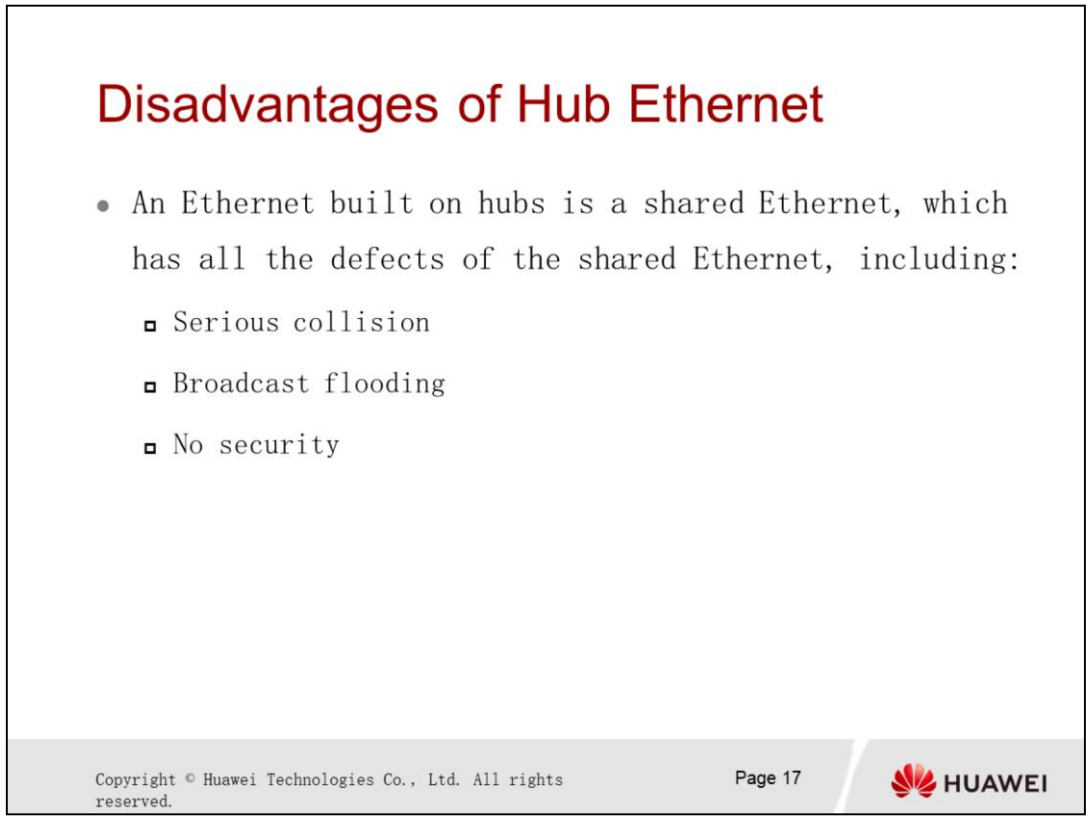
- Due to the limitation of the CSMA/CD algorithm, the frame length of a 10M half-duplex Ethernet frame cannot be less than 64 bytes.



- During the transition from shared Ethernet to switched Ethernet, there are 2 types of network devices: Repeaters and hubs.
- After the network range is expanded, signals may be distorted during transmission, resulting in bit errors. The function of a repeater is to recover distorted signals and amplify the signals.
- Hubs and repeaters are connection devices at the physical layer.



- Hub is an Ethernet device that works based on the CSMA/CD mechanism. Its working principle is simple: The data frames (be it unicast or broadcast) received from any port are all forwarded to any other ports except the source port.
- Therefore, the hub and repeater only change the physical topology of the Ethernet. The logical structure of the Ethernet is still the bus topology.
- A hub does not use the MAC address, and only replicates and forwards data.



- From the above contents, we can know an Ethernet built using hubs and repeaters is a shared Ethernet. A shared Ethernet has the following disadvantages:
  - Serious collision
  - Broadcast flooding
  - No security

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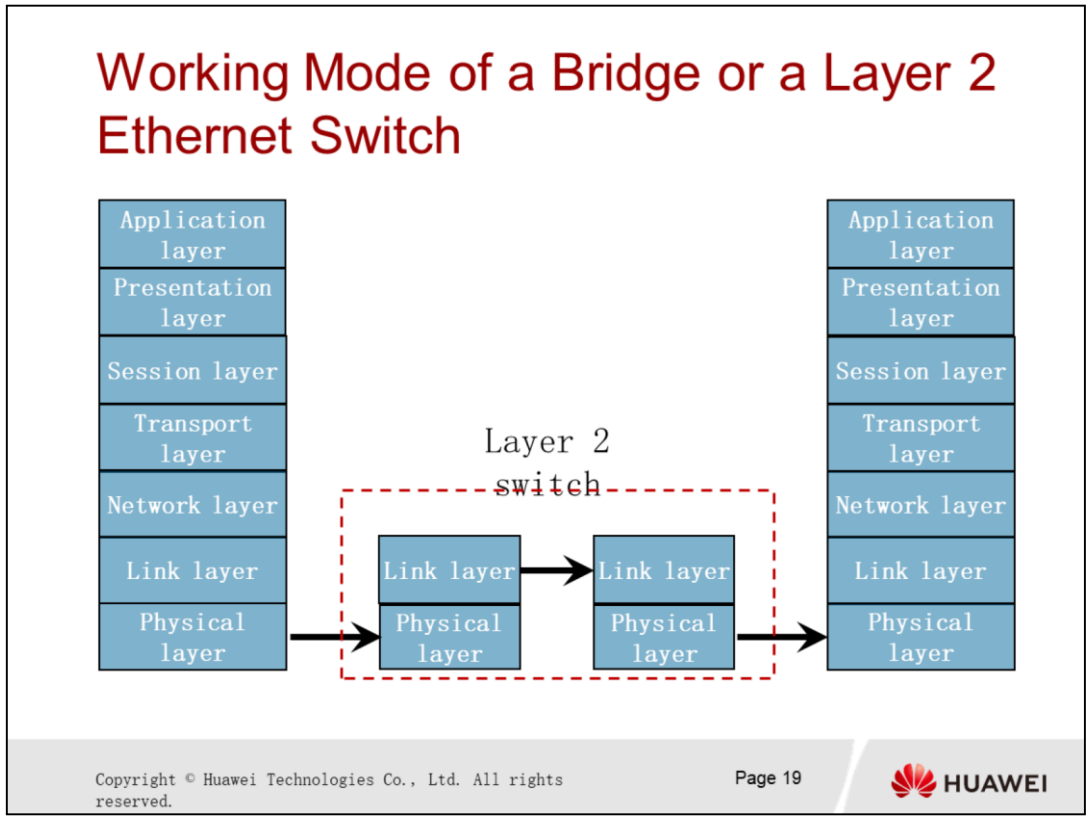
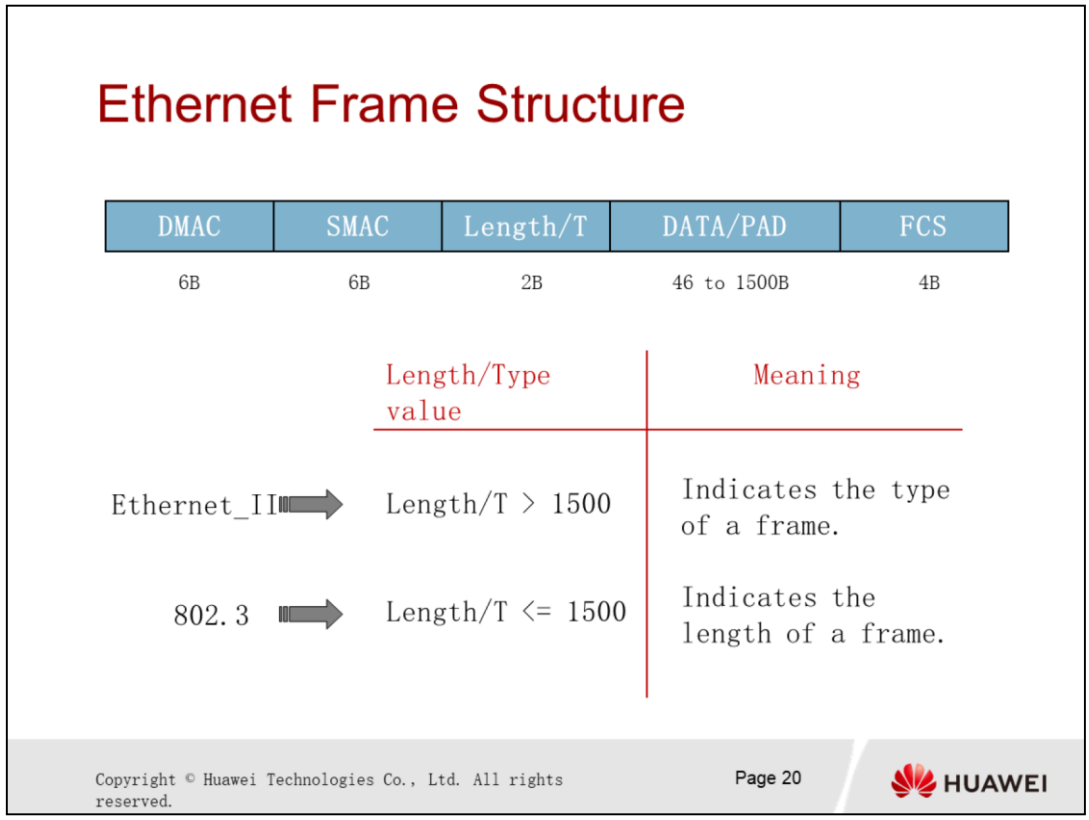
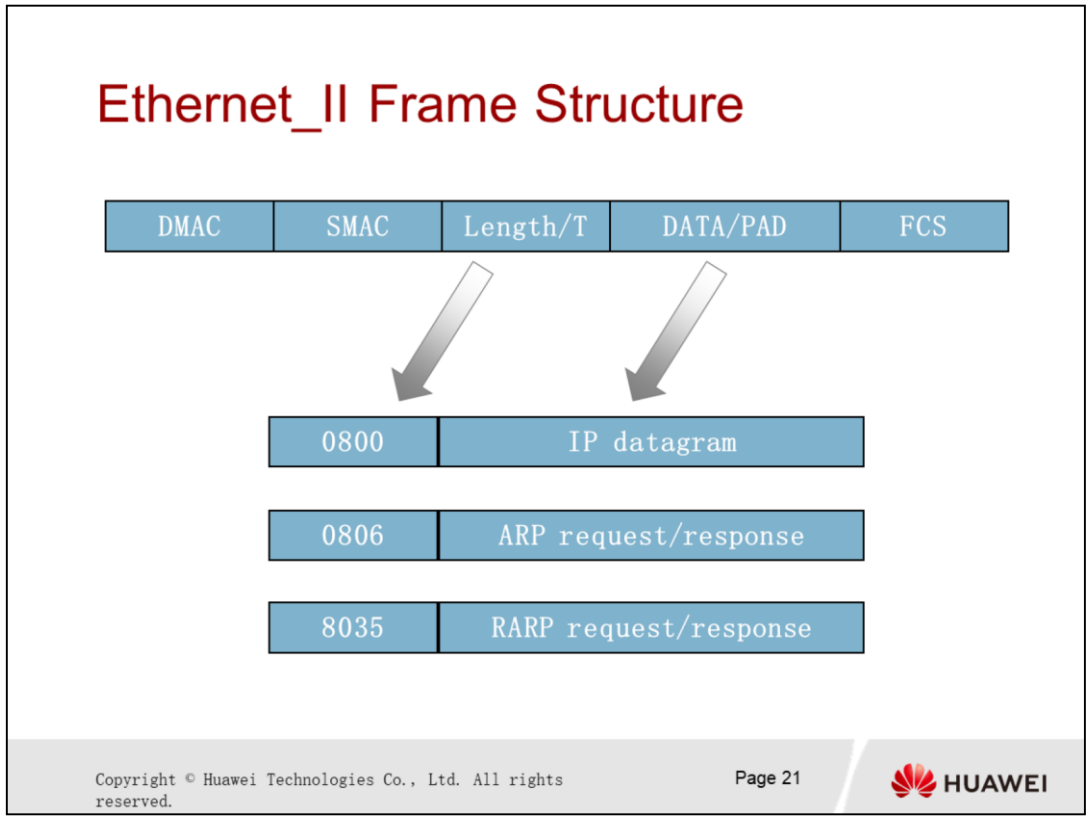


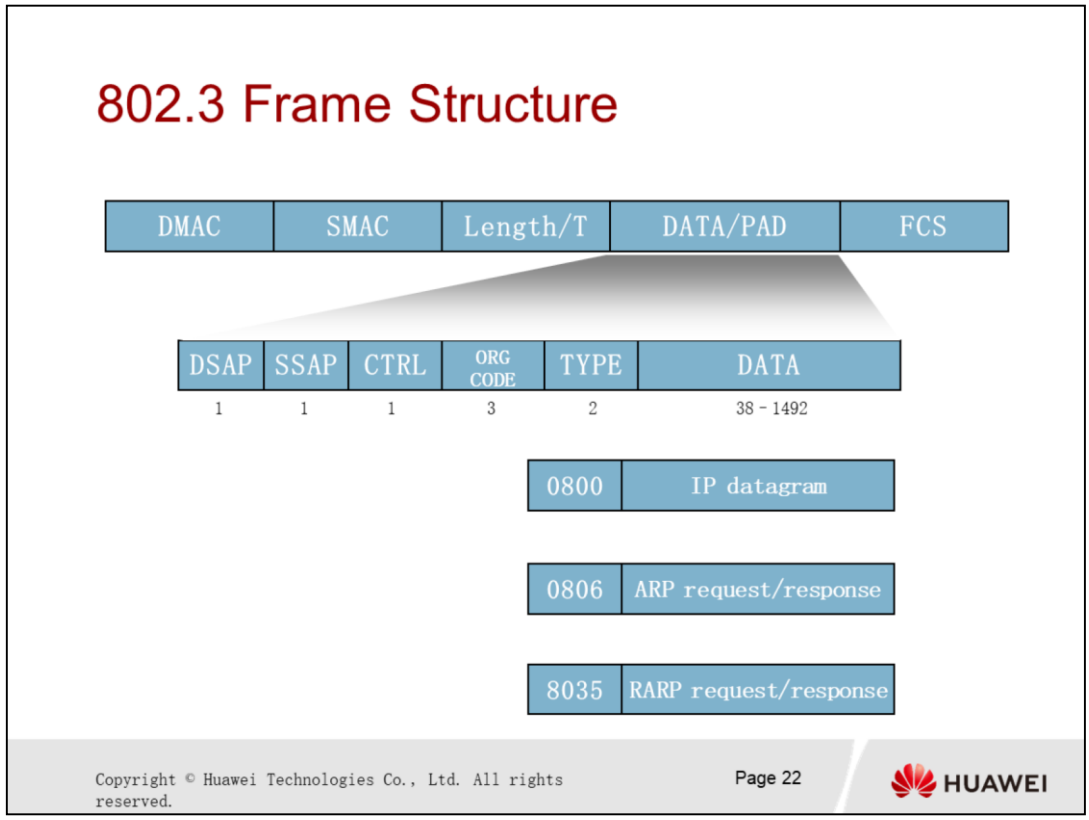
- A switch is a bridge device working at the data link layer of the Ethernet. It needs to implement the following basic functions:
  - MAC address learning
  - Forwarding and filtering



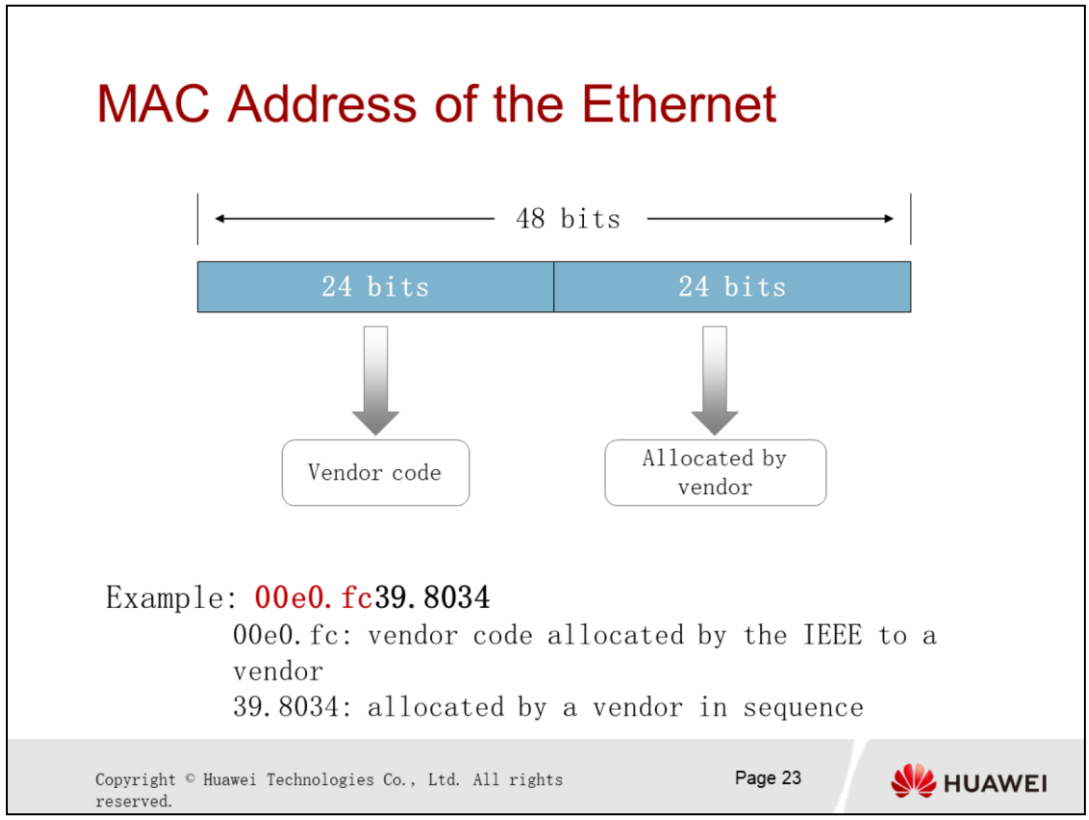
- In this figure, DMAC represents the MAC address of the destination terminal, SMAC represents the source MAC address, and the LENGTH/TYPE field has different meanings according to the value. If LENGHT/TYPE is greater than 1500, it indicates the type of the data frame (for example, the upper-layer protocol type). If LENGTH/TYPE is less 1500, it indicates the length of the data frame. DATA/PAD is specific data. The minimum length of an Ethernet data frame must be greater than or equal to 64 bytes (calculated according to the maximum distance in half-duplex mode). Therefore, if the data length plus the frame header is less than 64 bytes, the padding content needs to be added to the data part. FCS is a frame check field, which is used to determine whether an error occurs in a data frame.
- If the value of LENGTH/TYPE is greater than 1500, the MAC sub-layer can directly submit the data frame to the upper layer protocol according to the value of LENGTY/TYPE. In this case, it is unnecessary to implement the LLC sub-layer. This structure is the currently popular ETHERNET_II, and most computers support this structure. Note that in this structure, the data link layer may not implement the LLC sub-layer, but includes only one MAC sub-layer.
- If the value of LENGTH/TYPE is less than or equal to 1500, this structure is called ETHERNET_SNAP, which is a standard defined by the 802.3 Committee. Currently, it is not widely used.



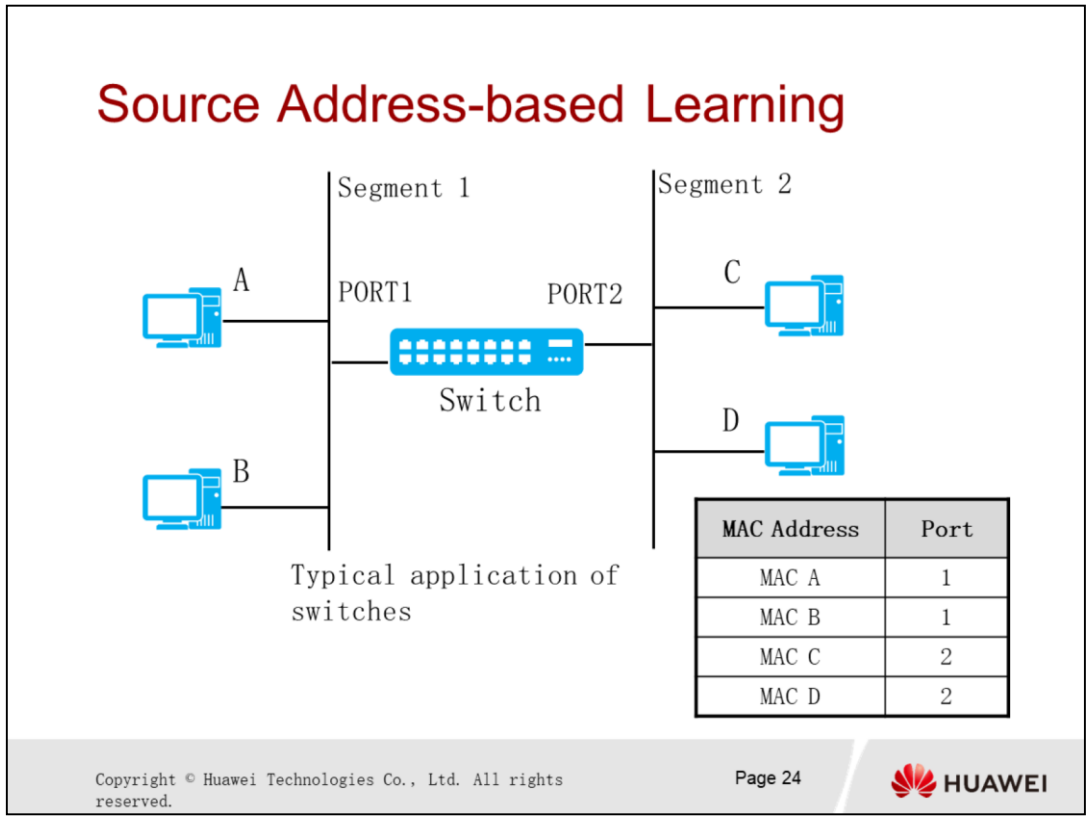
- If an Ethernet frame of the 0800 type is generated, it belongs to Ethernet_II (0x0800 is greater than 1500) and is an IP datagram (0800 indicates an IP datagram).
- Similarly, if the type is 0806, the data is the ARP request/response. If the type is 8035, the data is the RARP request/response.
- The problem is that the field indicates the frame length in the 802.3 frame structure. How to indicate the preceding packet types?



- The 802.3 frame format is followed by a 3-byte 802.2 LLC and a 5-byte 802.2 SNAP. The values of the destination service access point (DSAP) and source service access point (SSAP) are both set to 0xAA. The value of the Ctrl field is set to 3. The subsequent 3 bytes (org codes) are set to 0. The subsequent two byte type fields are in the same format as Ethernet frames.

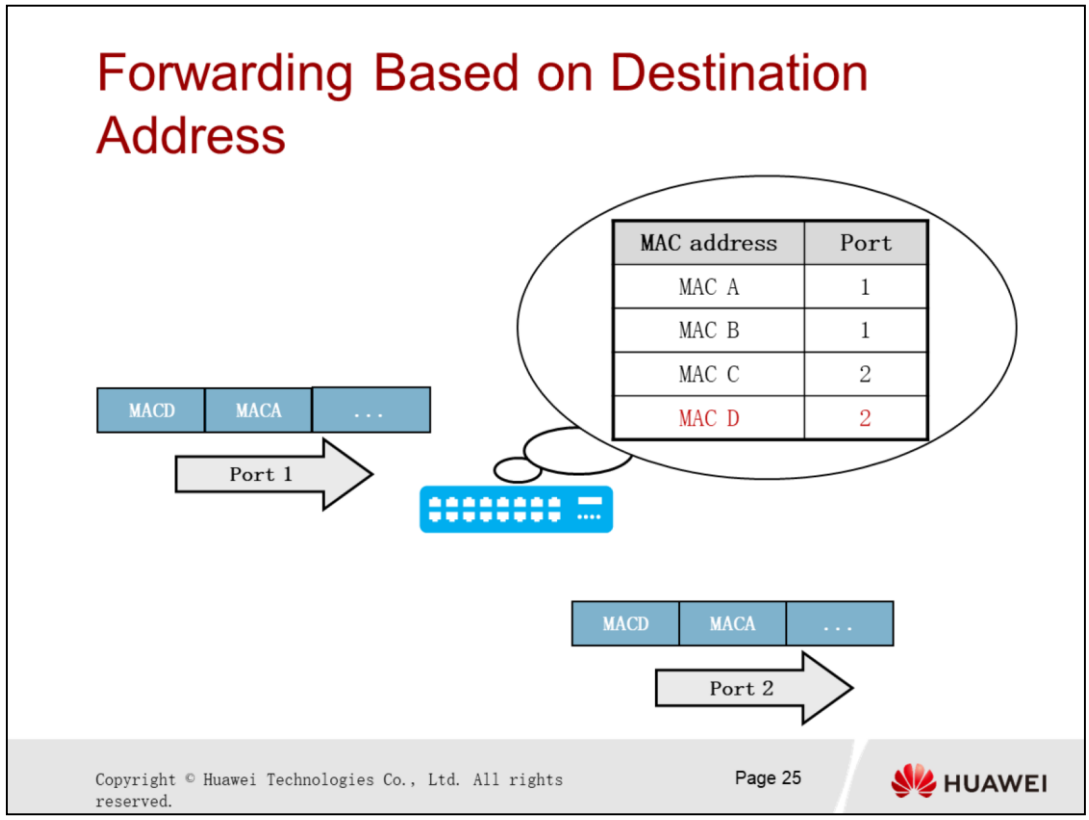


- A MAC address contains 48 bits, but it is usually represented as a 12-bit dotted hexadecimal number.
- MAC addresses are globally unique and managed and allocated by the IEEE.
- Each address consists of 2 parts: vendor code and serial number. The first 24 bits represent the vendor code, which is managed and allocated by the IEEE. The remaining 24 bits are allocated by each vendor.
- Special MAC address:
  - 1. If all 48 bits are 1, the address is a broadcast address.
  - 2. If the 8th bit is 1, the address is a multicast address.
- In a destination address, the 8th bit indicates whether a frame is to be sent to a single station or a group of stations. In the source address, the 8th bit must be 0. (because a frame cannot be sent from a group of stations). It is essential that the address of a station be uniquely determined. The destination of a frame must be clear.

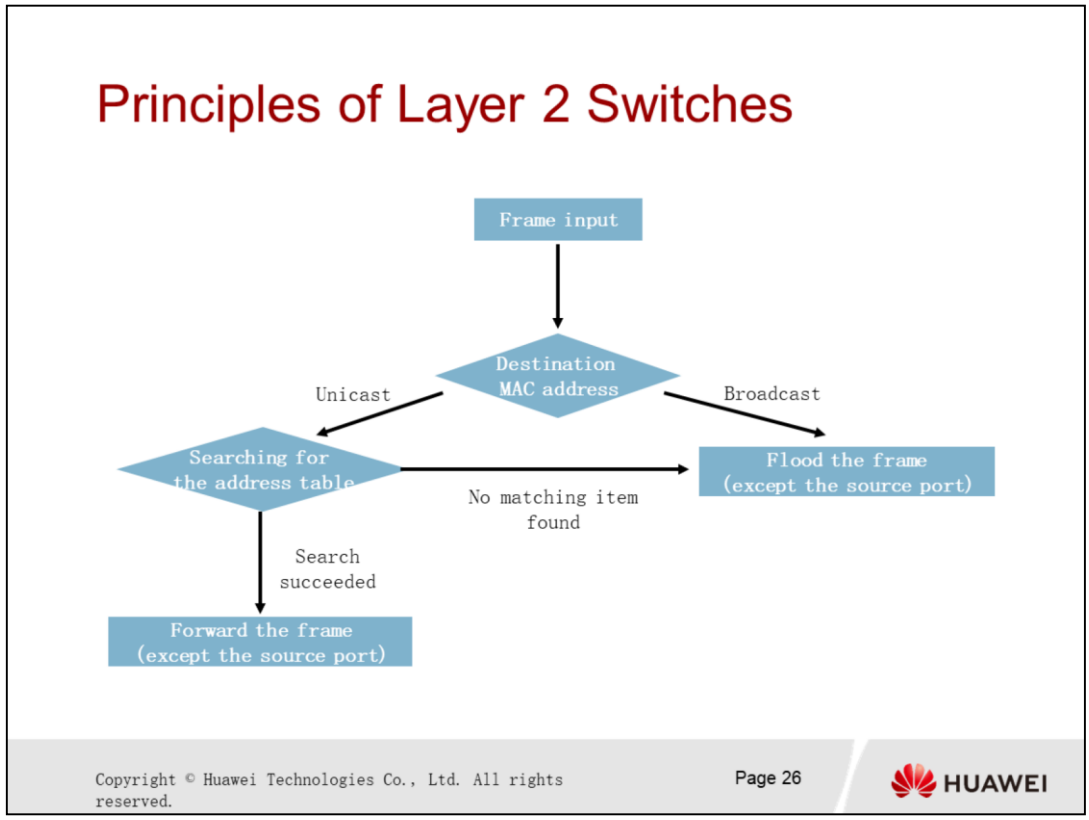


- First let's talk about the MAC address learning.
- A bridge forwards data frames based on the MAC address table. The MAC address table is learned by the bridge based on the source MAC address. The MAC address table of a common L2 switch is the mapping between the MAC address and switch ports.
- Here we need to emphasize that the bridge listens to the source address of the data frame, and each port of the switch listens to the source address of the received data frame.
- During initialization, the MAC address table of the switch is empty.
- The following is an example. After receiving a frame from port 1, the switch checks the destination MAC address and then the cached MAC address table on the switch. However, the MAC address table is empty. What will the switch do? The switch sends the data frame to all ports (except the port 1 which is the source port of the frame). The switch also checks the source MAC address of the frame and maps the MAC address of port 1 to the MAC address of site A. The source MAC address of the frame is the physical address of site A. In this way, each station establishes a mapping relationship with a directly connected port, so as to form a MAC address table.
- If a port is connected to a hub, one port corresponds to multiple MAC addresses. Each port on a switch corresponds to a collision domain.

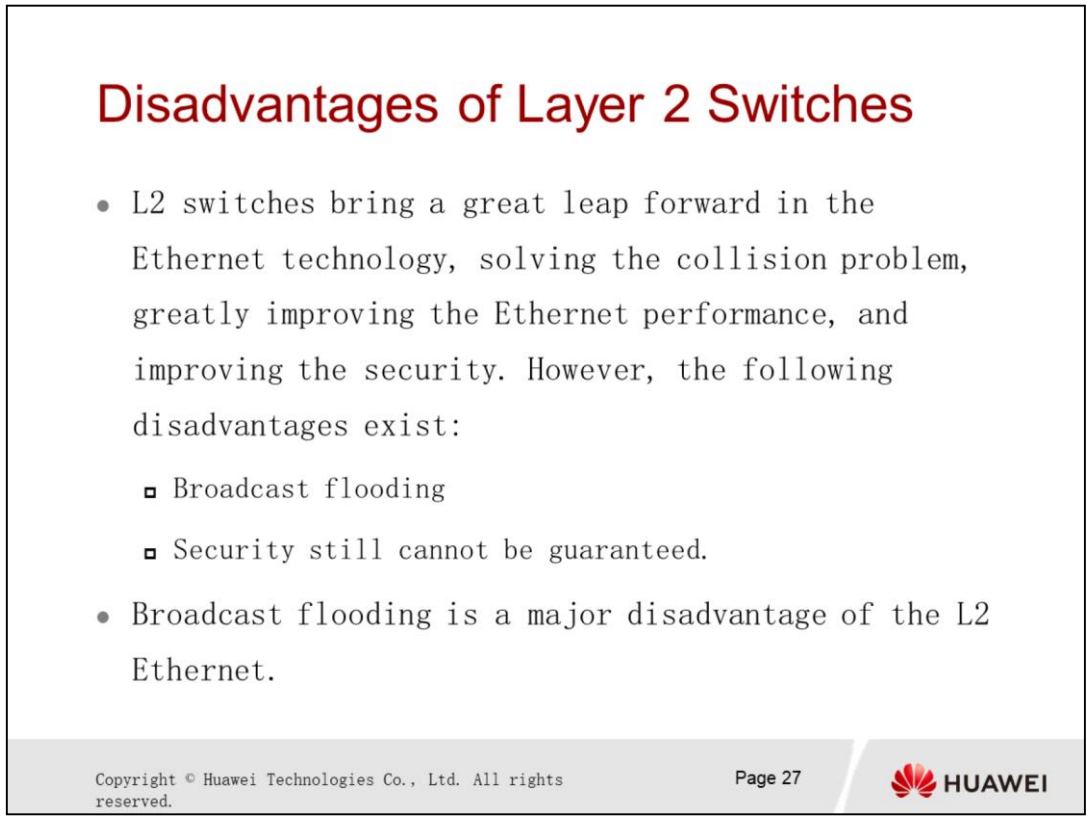
- Note: In the case of multicast, an address entry is established through protocols such as IGMP snooping instead of learning.



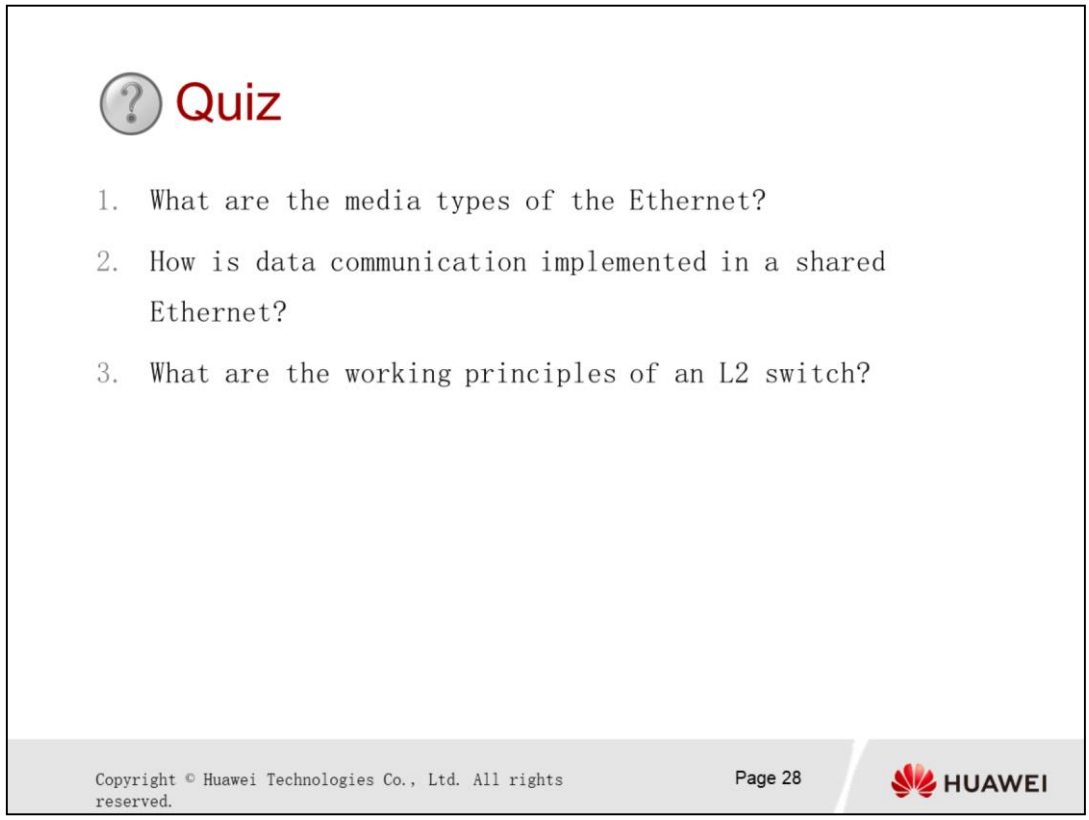
- The second basic function of a switch is forwarding packets based on destination addresses.
  - The switch queries the MAC forwarding table and forwards packets accordingly. If a destination address of a packet does not exist in the table, the switch forwards the packet in broadcast mode.
  - The address table is maintained using the automatic address learning and aging mechanism.
  - Generally, the frame format is not modified (the frame format needs to be modified and a tag must be added in a VLAN).



- Receive all data frames on a network segment.
- Use the source MAC address in the received data frame to establish the MAC address table (source address self-learning) and use the address aging mechanism to maintain the address table.
- Search the MAC address table for the destination MAC address of a data frame. If the destination MAC address is found, send the data frame to the corresponding port (excluding the source port). If no destination MAC address is found, send data to all ports (excluding the source port).
- Forward broadcast and multicast frames to all ports (excluding the source port).



- An L2 switch solves the collision problems in a shared Ethernet, but it still has the problem of broadcast flooding.



- Reference answer:
  - 1. Including coaxial cables, twisted-pair cables, and optical fibers.
  - 2. Carrier Sense Multiple Access/Collision Detection (CSMA/CD) is an effective means of multi-point communication through a shared medium. Listening is performed before data is sent to ensure that the line is idle and the chance of collision is reduced. Data sent by each station may be received by multiple stations at the same time. In addition, when a collision is detected, the sending is stopped and retried after a random period of time.
  - 3. An l2 switch is a device working at the data link layer and needs to perform the following functions: learning source MAC addresses and forwarding packets based on destination MAC addresses.

Summary

- Development history and standards of Ethernet
- Working principles of the shared Ethernet
- Working principles of layer 2 Ethernet

Thank You

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