计算机网络

5.

Packets, Frames, and Addressing

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第1课 传输介质	第2课 局域通信	第3课 远程通信	第4课 差错控制	第5-7课 局域网
第8-9课 广域网 技术	第10课 协议分层	第11课 互联网络 协议	第12课 支持协议 技术	第13课 可靠与不 可靠传输
第14课 Internet 路由	第15课 客户端与 服务器	第16课 套接字	第17-19课 应用层协 议	

第5课
分组、交换、网卡、编址、广(多)播

第6课
以太网帧格式、网络拓扑、无线网络

第7课
布线、拓扑、接口硬件

PART II Packet Transmission

Ch 13 Local Area Networks: Packets, Frames, and Addressing

局域网：分组、帧与编址

分组交换机

怎么分组，怎么交换

7.1 Introduction

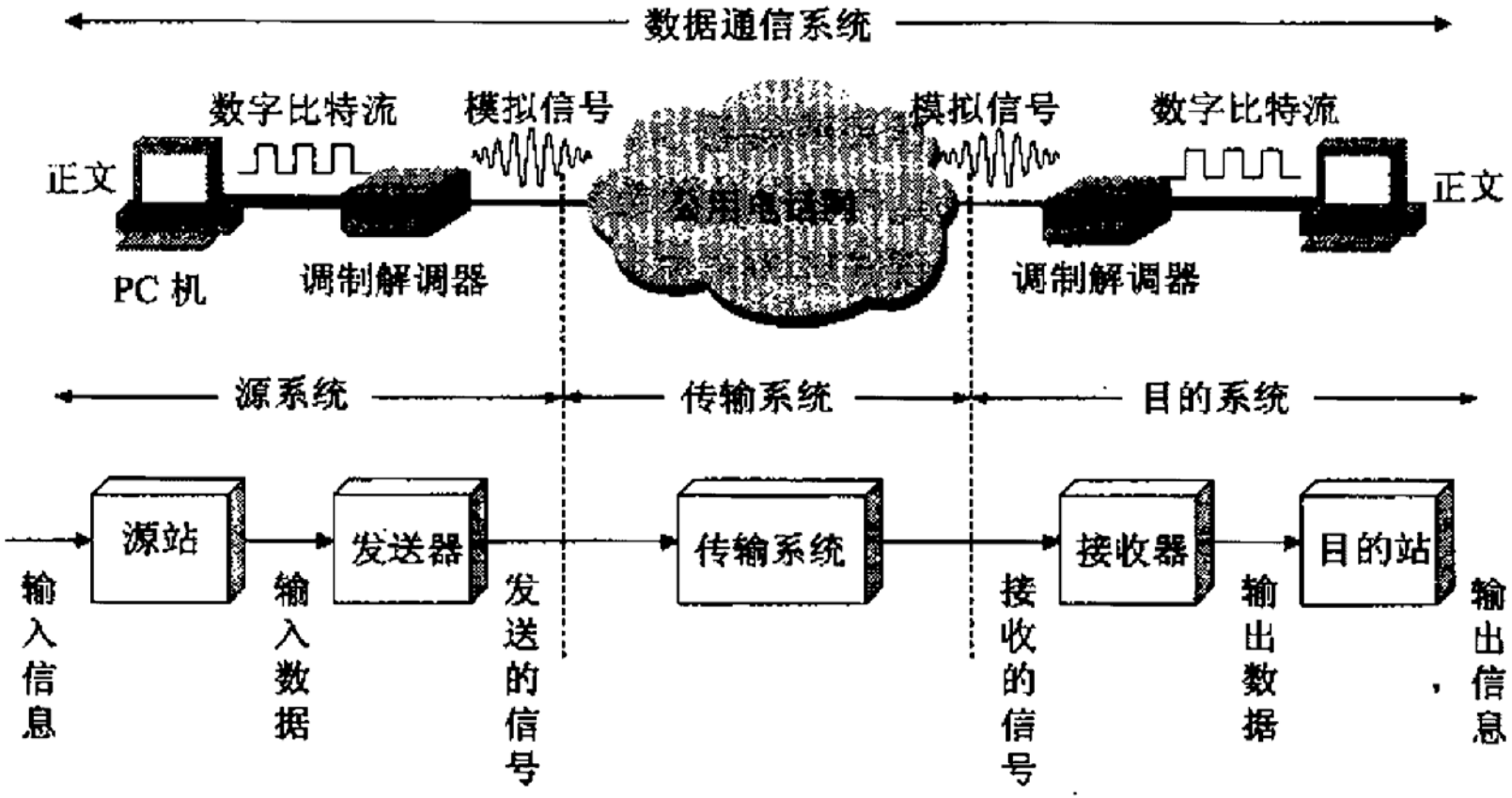


图 3-1　数据通信系统的模型

13.2 Circuit Switching

- **Circuit switching (线路交换)**
  - 指的是在发送方和接收方之间建立通路的交互机制
  - 收发方的路径与其他收发方是相互独立的
  - 类似于电话技术 (associated with telephone technology)

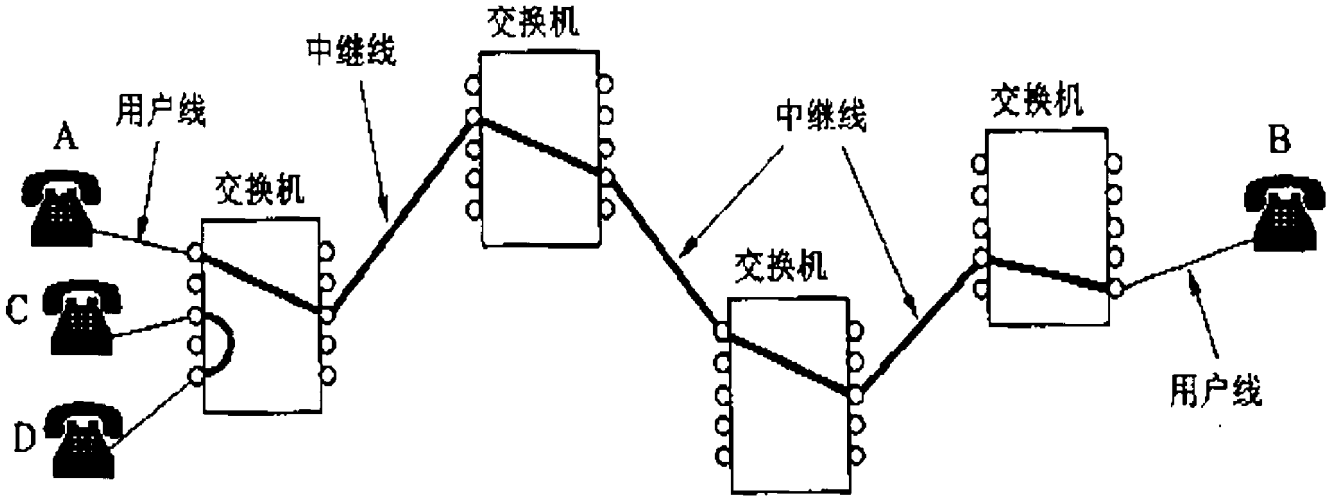


图 1-4　电路交换的示意图

13.2 Circuit Switching (线路交换)

- 线路交换 网络使用电子设备建立线路
  - **Instead of having each circuit correspond to a physical path**
    - **multiple circuits are multiplexed over shared media**
    - **and the result is known as a virtual circuit (虚拟通路)**

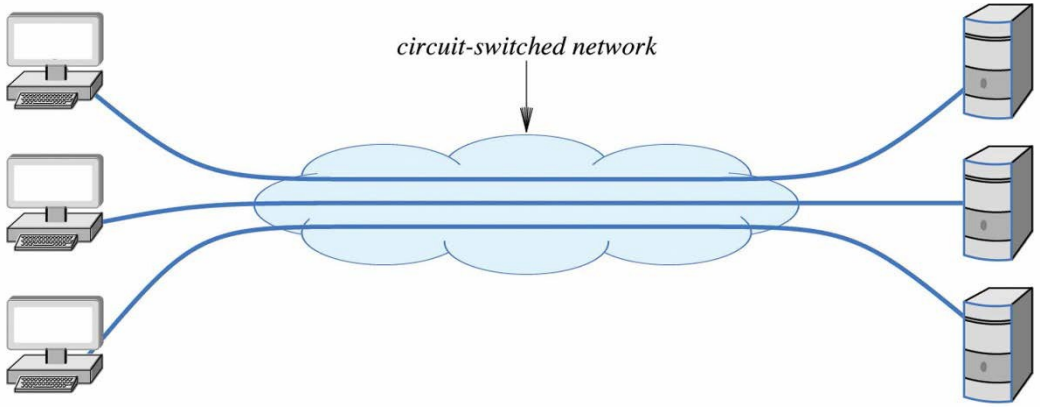


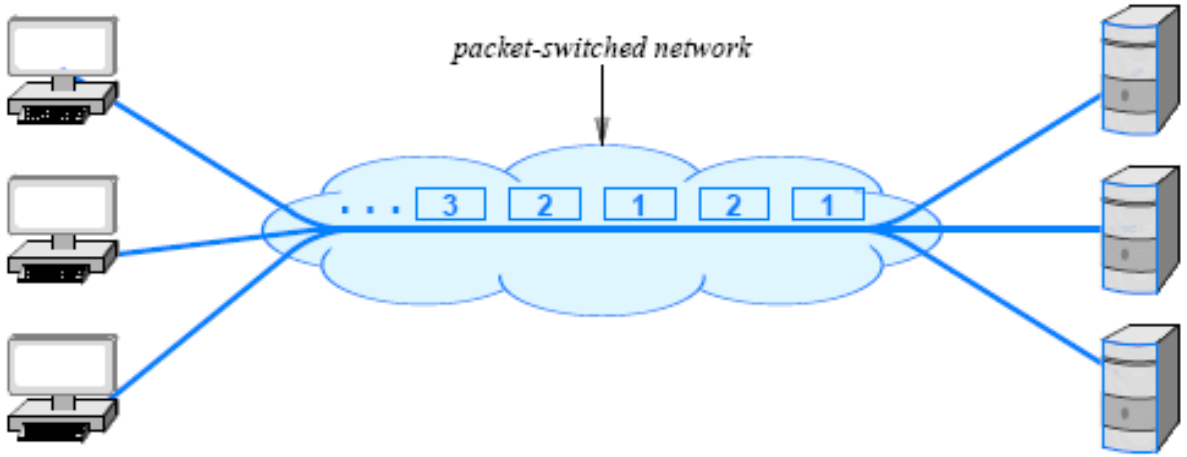
Figure 13.1 A circuit-switched network that provides a direct connection between each pair of communicating entities.

13.2 Circuit Switching

- **Three general properties:**
  - **Point-to-point communication**
  - **Separate steps for circuit creation, use, and termination**
  - **Performance equivalent to an isolated physical path**
- **交换线路使用三个步骤模拟拨打电话**
  - **建立线路：a circuit is established between two parties**
  - **线路交互：the two parties use the circuit to communicate**
  - **终止使用：the two parties terminate use**

13.3 Packet Switching

- A packet switching system uses statistical multiplexing
  - multiple sources compete for the use of shared media
- It requires a sender to divide each message into blocks of data that are known as packets (分组)
- 特点
  - 异步
  - 无需建立
  - 性能各异



13.3 Packet Switching

- 优点：To provide communication among N computers
  - 线路交换：at least N/2 independent paths
  - 分组交换：only requires one path that is shared

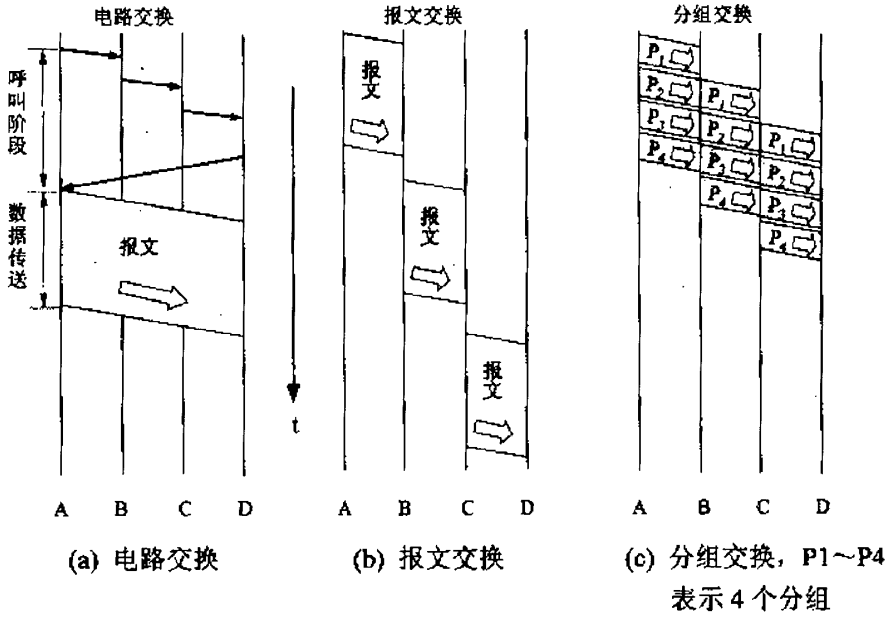


图 1-7　3 种交换的比较

分组交换

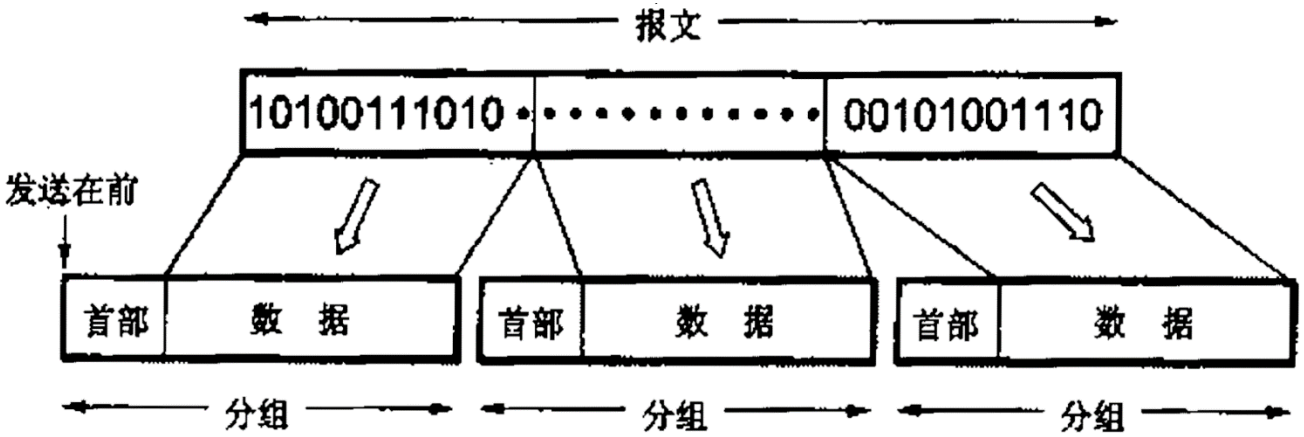
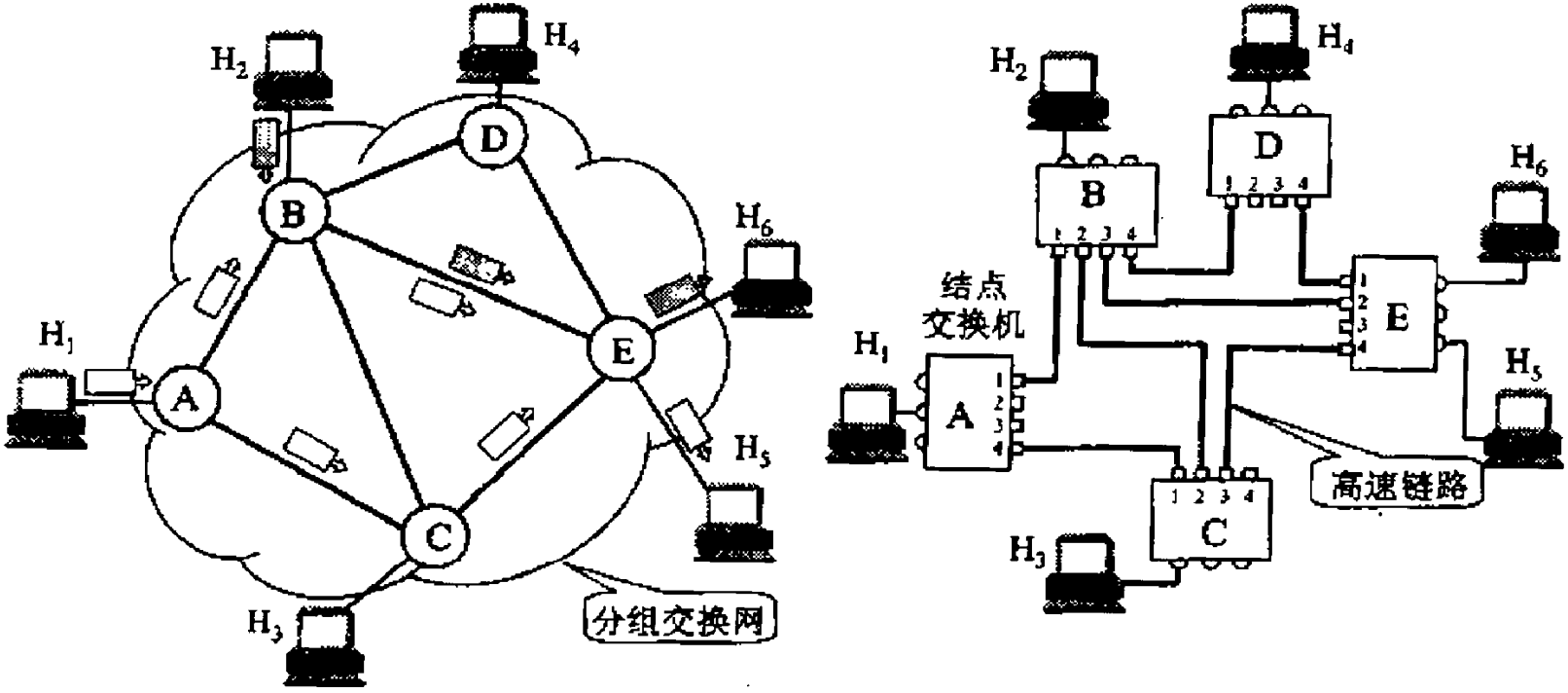


图 1-5 分组的概念

表 1-1 分组交换的优点

优点	所采用的手段
高效	在分组传输的过程中动态分配传输带宽
灵活	每个结点均有智能，可根据情况决定路由和对数据做必要的处理
迅速	以分组作为传送单位，在每个结点存储转发；网络使用高速链路
可靠	完善的网络协议；分布式多路由的通信子网

分组交换



(a) 通信子网和主机　　(b) 结点交换机的两组端口

图 1-6　分组交换网的示意图

7.2 The Concept of Packets

- **The network system divides data into small blocks called packets, which it sends individually.**
  - **Computer networks are often called packet networks or packet switching networks because they use packet technology.**
- **为何分组**
  - **收发双方需要协调传输**
  - **多个电脑共用底层硬件**

Figure 7.1 An illustration of one reason computer networks use packets. While one pair of computers communicate, others must wait.

7.3 Packets and TDM

- **A network that permits many sources to take turns accessing a shared communication resource is providing a form of time-division multiplexing.**

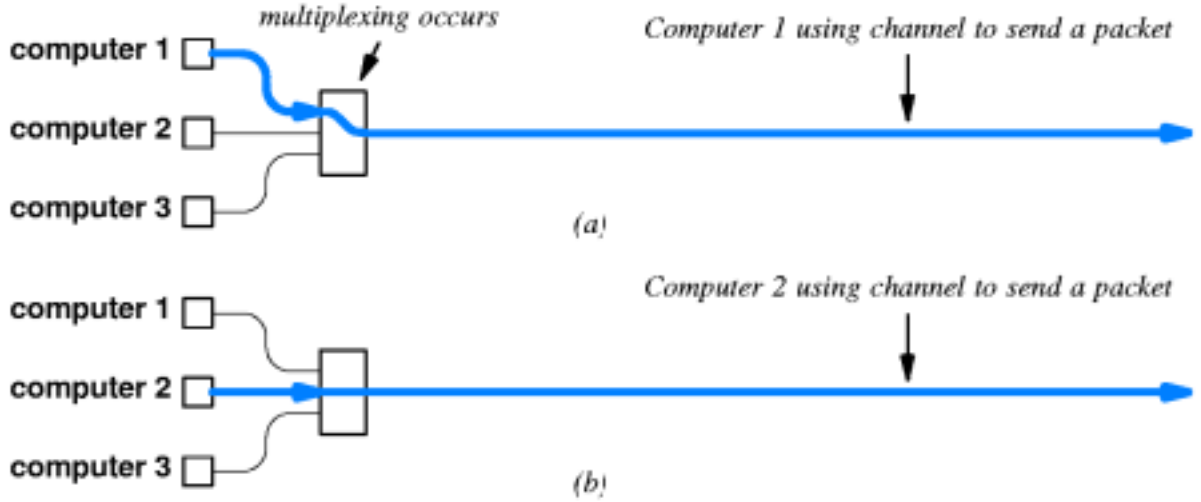


Figure 7.2 Illustration of multiplexing with packets. The sources take turns using the shared communication channel. (a) Computer *1* uses the resource to send a packet, and then (b) computer *2* uses the resource to send a packet.

7.4 Packets and Hardware Frames

- **Packet (分组)**
  - **refers to the general concept of a small block of data**
    - **there is no universal agreement on the exact format of packet.**
  - **具体硬件技术定义其格式及如何发送**
- **Frame (帧)**
  - **to denote the definition of a packet used with a specific type of network.**

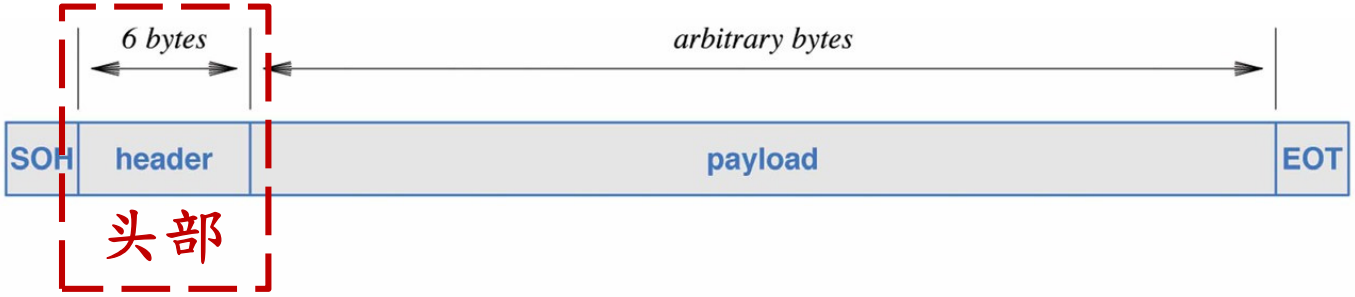


Figure 13.11 An example frame format that uses SOH and EOT characters to delineate a frame.

从双方到多方

RS-232：不需要共享介质

13.9 Packet Identification, Demultiplexing, MAC Addresses

- **Demultiplexing (解复用) to refer to the separation of a combination back into separate information streams**
  - **Demultiplexing uses an identifier known as an address**
    - **Each packet that travels across the shared medium is intended for a specific recipient**
      - **and only the intended recipient should process the packet**
- **IEEE has created a standard for addressing**
  - **Each computer is assigned a unique address**
    - **and each packet contains the address of the intended recipient**

9.1 Introduction

- **Physically, any signal sent across a shared network reaches all attached stations (所有连接的工作站).**
- **At a given station, the network interface hardware detects the electrical signal and extracts (提取) a copy of the frame.**
  - **Communication does not usually involve all stations.**
  - **Most communication occurs because an application program on one computer sends data directly to an application program on another.**

9.2 Specifying A Recipient

- Most LAN technologies use an addressing scheme to provide direct communication.
- Each station on the LAN is assigned a unique numeric value called a physical address (物理地址), hardware address (硬件地址), or media access address (MAC).
- A frame sent across a LAN contains the address of the sending computer, called a **source address**, and the address of the intended recipient, called the **destination address**.

9.3 How LAN Hardware Uses Addresses to Filter Packets

- LAN硬件完全与CPU、内存分离
  - 完全处理共享介质的收发细节，无需借助CPU
- LAN接口硬件使用物理地址防止收到LAN所有数据包
  - 一旦获得完整帧，接口硬件将其目的地址与该站的物理地址比较。

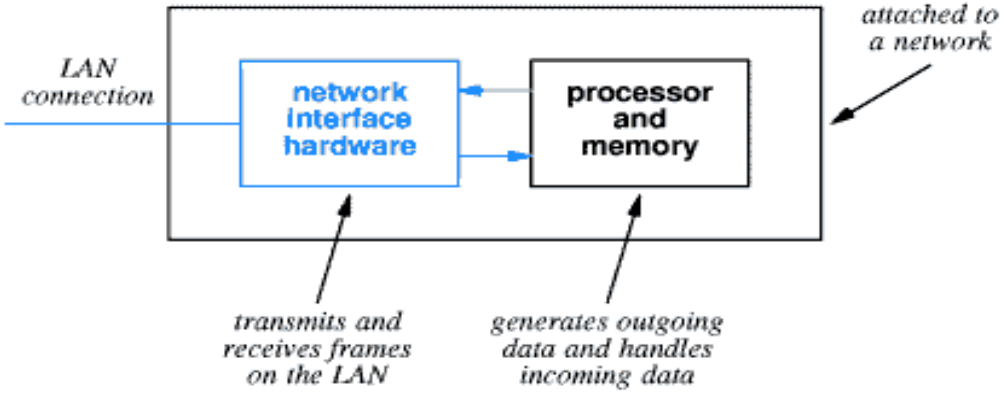


Figure 9.1 Organization of the hardware in a computer attached to a LAN. Because it is powerful and independent, the network interface hardware does not use the CPU when transmitting or receiving bits of a frame.

Network Interface Card

网卡

网卡

- 网卡的任务：
  - 检测帧是否存在
  - 有效性检验
  - 判断是否接收
- CPU的任务
  - 判断是否传给上层处理
- 分层处理的目的：减少CPU的负荷

网卡

- 数据包过滤是通信接收方的动作
- 通过检测数据的标识，对符合接收条件的：
  - 复制帧
  - 中断CPU，将复制后的帧交给CPU
  - 继续等待下一个帧
- 对不符合接收条件的：放弃接收，继续等待下一个帧

Media Access Control Address

MAC地址

如何识别收发双方

IEEE Addressing

- In the IEEE addressing scheme, each address consists of 48 bits: Media Access Control (MAC) address
  - often use the term Ethernet address (以太网地址)
- IEEE allocates a unique address for each piece of interface
  - Each Network Interface Card (NIC) contains a unique IEEE address assigned when the device was manufactured

IEEE Addressing

- **IEEE assigns a block of addresses to each vendor**
  - **allows the vendor to assign a unique value to each device**
  - **there is a 3-byte Organizationally Unique ID (OUI)**
    - **OUI identifies the equipment vendor**
    - **a 3-byte block that identifies a particular NIC**

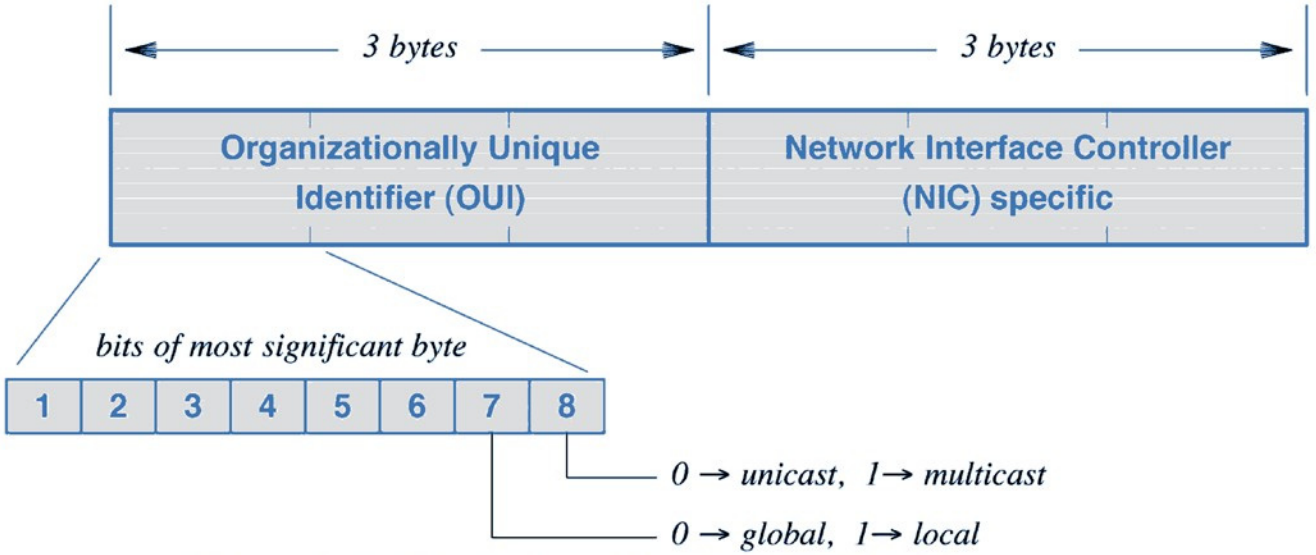


Figure 13.8 The division of a 48-bit IEEE MAC address.

9.4 Format of A Physical Address

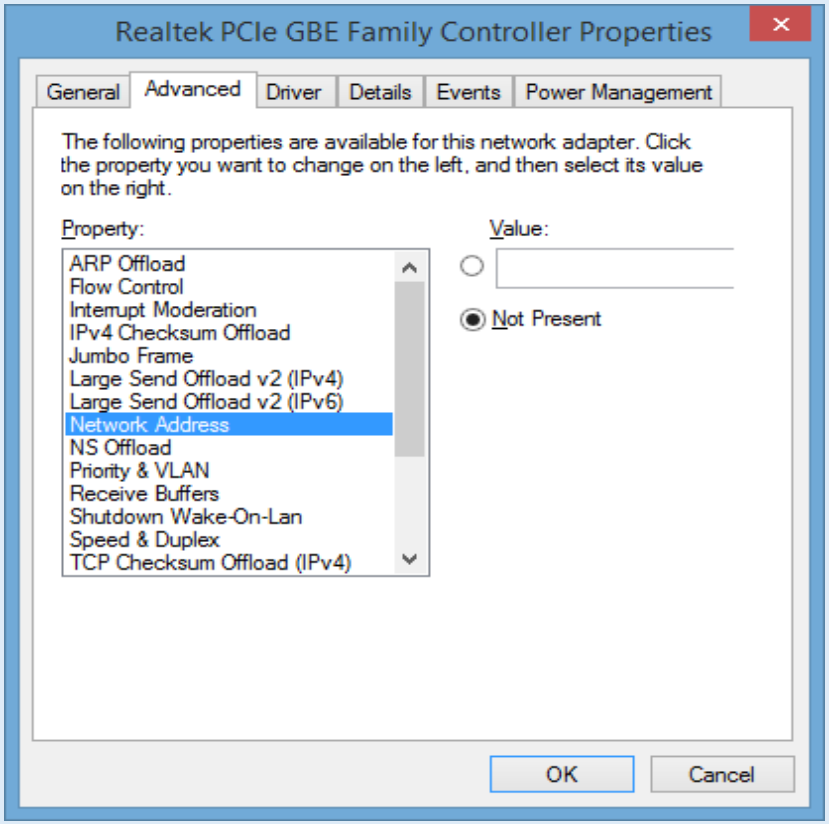
- 物理地址 (Physical Address)
  - 必须是所在局域网内的唯一标识
  - 局域网内要对物理地址提供检索的功能
- Three broad categories:
  - Static address（静态地址）
    - 出厂前由生产厂家一次性配置完成
    - 全球唯一硬件标识，不会出现地址冲突
    - 一次生成，永久使用
    - 地址较长，查询慢

9.4 Format of A Physical Address

- **Three broad categories:**
  - **Configurable address（可配置地址）**
    - 系统出厂后，用户动态分配，保持局域网内唯一
    - 地址短，查询快
    - 地址可以永久有效，也可以随需求改变
  - **Dynamic address（动态地址）**
    - 每当系统启动的时候动态分配，局域网内唯一
    - 地址短，查询快
    - 有可能出现地址冲突
    - 地址动态改变，不利于地址映射表的维护

思考题

MAC地址能不能改



13.10 Unicast, Broadcast, and Multicast Addresses

- IEEE address format reserves a bit to distinguish between unicast and multicast
  - but does not provide a way to designate a broadcast address
  - specifies a broadcast address consists of 48 bits with all 1s
    - Thus, a broadcast address has the multicast bit set
  - Broadcast can be viewed as a special form of multicast
    - Each multicast address corresponds to a group of computers
    - Broadcast address corresponds to a group that includes all computers on the network

13.11 Broadcast, Multicast, and Efficient Multi-Point Delivery

- **Broadcast and multicast addresses are useful in LANs**
  - **because they permit efficient delivery to many computers**
- **To understand the efficiency**
  - **recall that a LAN transmits packets over a shared medium**
- **In a typical LAN**
  - **each computer on the LAN monitors the shared medium**
  - **extracts a copy of each packet**
  - **and then examines the address in the packet**
  - **determine whether the packet should be processed or ignored**

Algorithm

Algorithm 13.1

Purpose:

Handle a packet that has arrived over a LAN

Method:

```
Extract destination address, D, from the packet;
if (D matches "my address") {
    accept and process the packet;
} else if (D matches the broadcast address) {
    accept and process the packet;
} else if (D matches one of the multicast addresses for a
  multicast group of which I am a member) {
    accept and process the packet;
} else {
    ignore the packet;
}
```

Algorithm 13.1 Packet processing algorithm used in a LAN.

9.5 Broadcasting 广播

- **Broadcasting was originally applied to radio and television transmission.**
- **The network designers define a special, reserved address known as a broadcast address (广播地址).**
- **The hardware interface on a computer is built to recognize the special broadcast address as well as the station's physical address.**

9.5 Broadcasting 广播

- 当一台计算机需要向多台计算机广播信息时，若使用单播技术，必须向每一台计算机分别发送数据，将造成网络负载的成倍增长。
- 采用广播实现方式，发送方按照一个广播地址向共享介质发送数据帧，网上所有设备的网卡分别进行数据帧的拷贝，并交给CPU处理。需要接收数据帧的设备由CPU完成向上层的传递，不需要数据帧的设备由CPU丢弃该数据帧
  - 通过广播，实现了一对多的数据通信，比单点传输方式减少了负载，但所有计算机CPU都要决定接收还是丢弃数据帧，这样增加了无关设备的CPU负载。

9.6 Multicasting 组播

- A restricted form (限制形式) of broadcasting known as **multicasting**.
- A network interface does not automatically forward multicast frame to the CPU.
- The interface hardware must be programmed with specification of which multicast frame to accept and which to reject.
- The **interface hardware makes the decision** and only accepts those frames that match the specification.

9.7 Multicast Addressing 组播编址

- When the computer boots, the interface is programmed to recognize only the computer's address and broadcast address.
- If an application on the computer wishes to receive multicast frame, the application must inform the network interface which multicast address to use.
- The interface adds the address to the set it will recognize, and begins accepting frame sent to that address.

9.8 Identifying Packet Contents

- A receiver cannot use data in the packet to determine what the packet contains.
  - Each frame contains additional information that specifies the type of the contents.
- Two methods to identify the contents of a frame.
  - Explicit frame type (显式帧类型)
    - The bits of a frame used to identify the contents are called the frame type field (帧类型域), and the frame is ·self- identifying (自标识).
  - Implicit frame type (隐式帧类型)
    - 双方协商决定

帧与成帧

Frame & Framing

13.12 Frames and Framing

- Chapter 9 introduces the concept of framing
  - – in synchronous communication systems it is used as a mechanism that allows a receiver to know where a message begins and ends
- In more general terms, framing refers to the structure added to a sequence of bits or bytes that allows a sender and receiver to agree on the exact format of the message

13.12 Frames and Framing

- In a packet-switched network, each frame corresponds to a packet
- A frame consists of two conceptual parts:
  - Header that contains metadata, such as an address
    - contains information used to process the frame
  - Payload that contains the data being sent
    - contains the message being sent
    - and is usually much larger than the frame header

13.12 Frames and Framing

- A message is opaque (不透明的)
  - that the network only examines the frame header
  - the payload can contain an arbitrary sequence of bytes that are only meaningful to the sender and receiver
- Some tech.'s delineate each frame by sending a short prelude before the frame and a short postlude after it

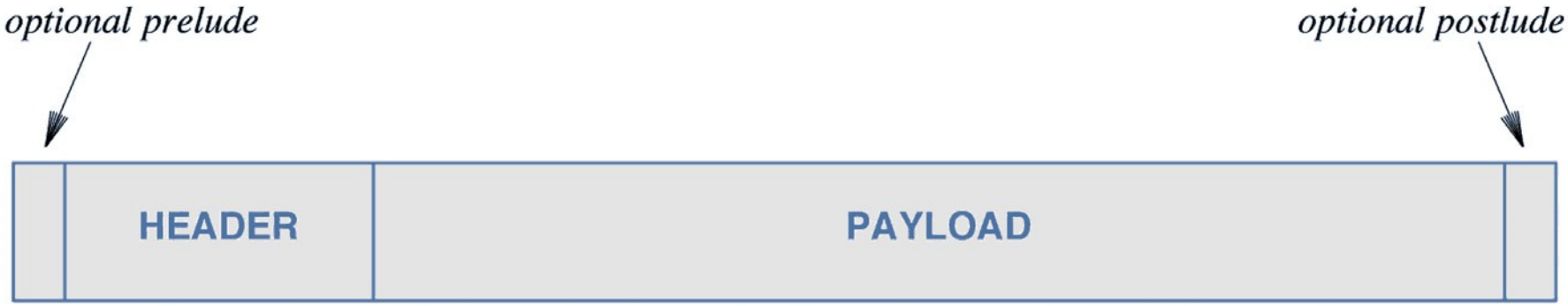


Figure 13.10 Typical structure of a frame in a packet-switched network.

13.12 Frames and Framing

- Assume that a packet header consists of 6 bytes
  - the payload consists of an arbitrary number of bytes
- We can use ASCII character set
  - Start Of Header (SOH) marks the beginning of a frame
  - End Of Transmission (EOT) marks the end

Figure 13.11 An example frame format that uses SOH and EOT characters to delineate a frame.

7.5 Byte Stuffing 字节填充

- 网络允许传输任意字节，因此需要对帧进行定界
  - 如何区分正常数据和定界？
- 回顾C语言的转义字符\r \n，右斜杠：\\
- 字节填充(data stuffing)：插入额外的比特或字节

Byte In Payload	Sequence Sent
SOH	ESC A
EOT	ESC B
ESC	ESC C

Figure 13.12 An example of byte stuffing that maps each special character into a 2-character sequence.

7.5 Byte Stuffing 字节填充

- **The term byte stuffing and character stuffing refer to data stuffing used with character-oriented hardware, and bit stuffing refers to data stuffing used with bit-oriented hardware. For example:**

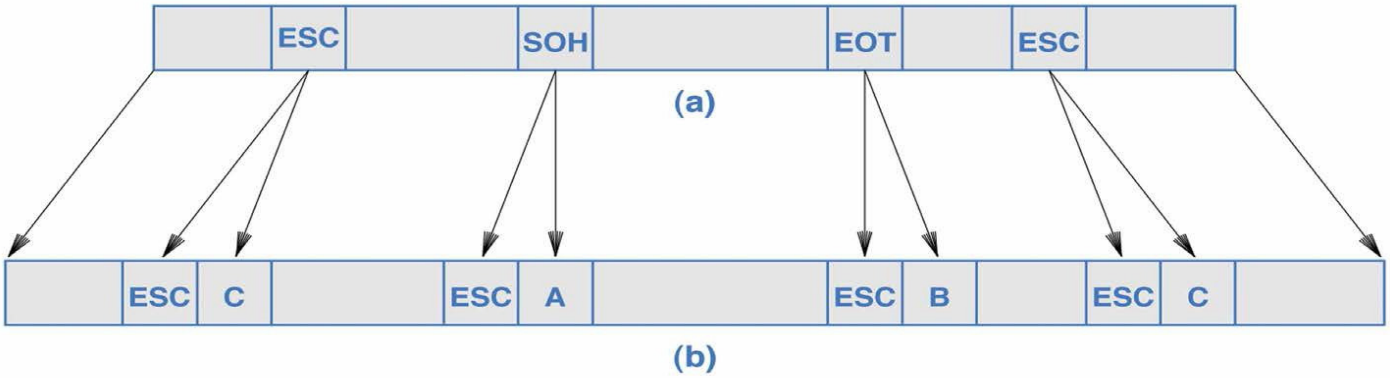


Figure 13.13 Illustration of (a) original data, and (b) a version after byte-stuffing has been performed.

- 字符填充

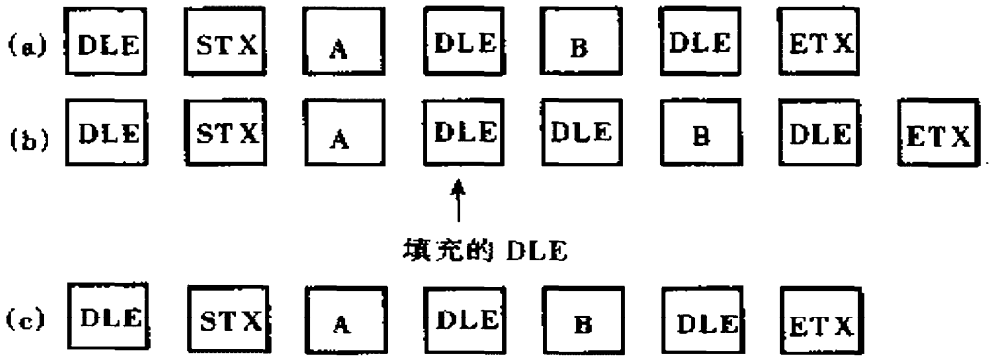


图 3-4 (a) 网络层发出的数据；(b) 经数据链路层填充后的数据；(c) 数据传送给接收方的网络层。

- 位填充

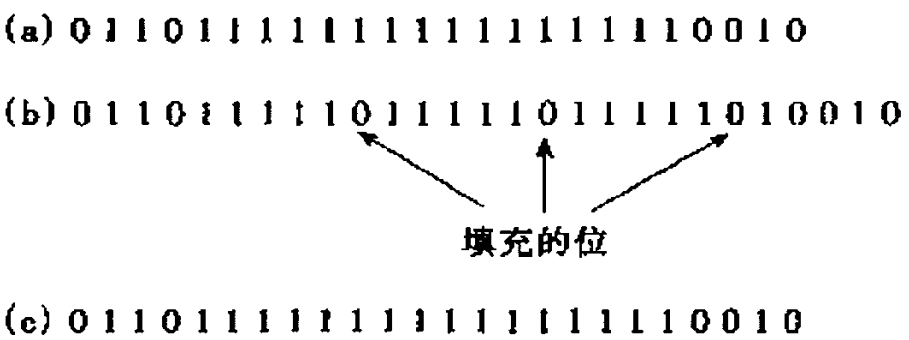


图 3-5 位填充

(a) 原始数据；(b) 线上数据；(c) 删除填充位后接收方存储器内的数据。

位填充

用这种方法成帧的主要缺点是要完全依赖于 8 位字符，特别是 ASCII 字符。随着网络的发展，这种在帧中嵌入字符的机制所带来的弊端变得越来越明显。于是，一种允许任意长短字符的新技术发展起来。

这种新技术允许数据帧包含任意个数的比特，而且也允许每个字符的编码包含任意个数的比特。它的工作方式如下：每一帧使用一个特殊的位模式，即 01111110 作为开始和结束标志(flag)字节。当发送方的数据链路层在数据中遇到 5 个连续的 1 时，它自动在其后插入一个 0 到输出比特流中。这种位填充技术类似于字符填充技术，后者是在数据中的 DLE 之前填充一个 DLE 到输出字符流中。

当接收方看到 5 个连续的 1 后面跟着一个 0 时，自动将此 0 删去。**位填充(bit stuffing)**技术和字符填充技术一样，对通信双方计算机的网络层来说都是完全透明的。如果用户数据包含着位模式 01111110，则将以 011111010 的形式传送出去，但是仍然以 01111110 的形式存放在接收方的存储器中。图 3-5 给出了一个位填充的例子。

采用位填充技术，两帧间的边界就可以通过位模式唯一地识别。因此，如果接收方失去同步，它只需在输入流中扫描标志序列，即可重新获得同步。因为这些标志序列只能是帧界，而决不应该在数据中。

帧格式

9.10 An Example Frame Format

- An Ethernet frame begins with a header that contains three fields.
- The 64-bit preamble contains alternating 1s and 0s
- The first two fields of the header contain physical addresses (48-bit static addressing scheme).
- The third field of the header consists of a 16-bit Ethernet frame type.

Digital-Intel-Xerox (DIX)

- **The DIX Ethernet standard specifies the value that can be used in the header fields and their meanings.**
  - **The address with all 48 bits set to 1 is reserved for broadcast, other addresses that start with a 1 bit are used for multicast.**

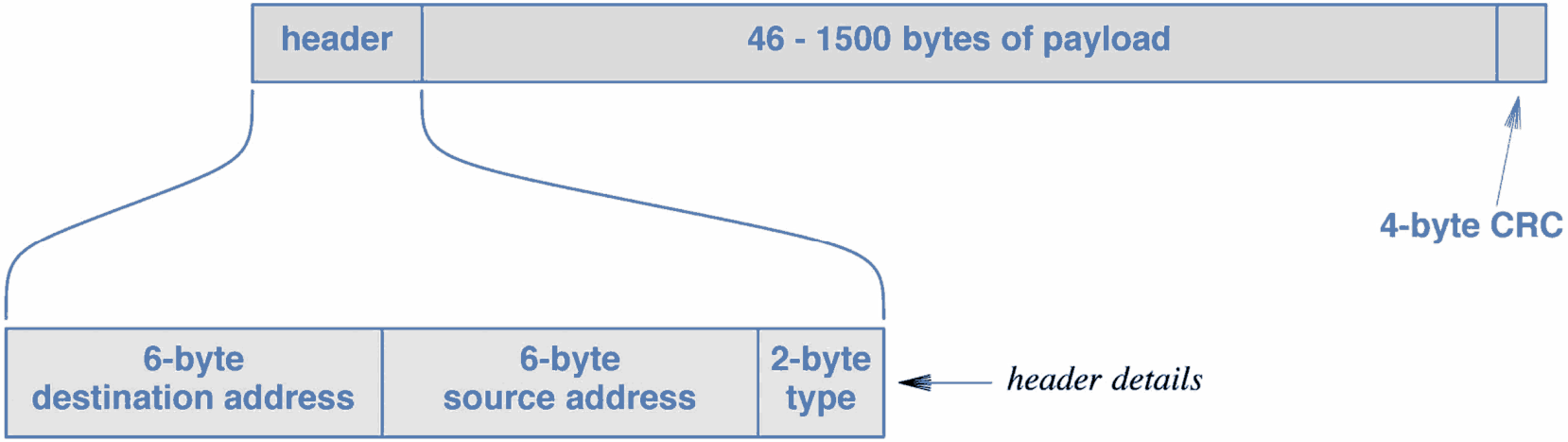


Figure 15.1 Illustration of the Ethernet frame format and header details.

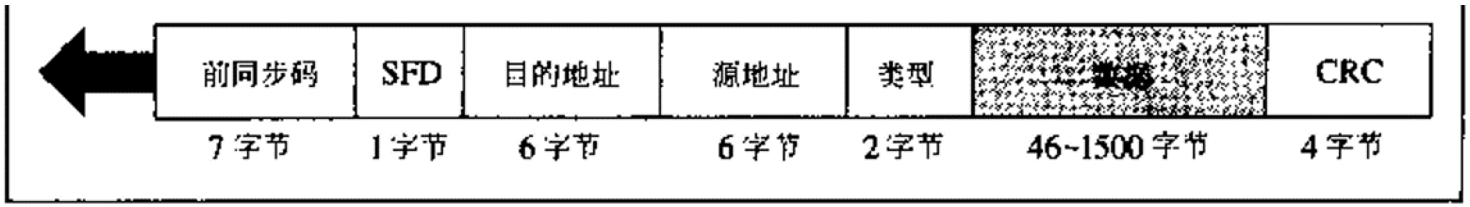


图 3.10　以太网的格式

以太网定义的帧共有 7 个字段：

- **前同步码**。这个字段有 7 个字节(56 比特)的交替出现的 0 和 1，其作用就是提醒接收系统有帧到来，以及使到来的帧与计时器同步。
- **帧首定界符(SFD)**。这里用 1 字节(10101011)作为标志，并指出帧的开始。
- **目的地址**。6 字节的目的物理地址。
- **源地址**。6 字节的源物理地址。
- **类型**。这个字段定义了封装在帧中的数据类型。
- **数据**。这个字段包含从上层来的数据。数据长度必须在 46 到 1500 字节之间。如果上层协议产生的数据长度小于 46 字节，则应将其填补到 46 字节。若数据长度超过 1500 字节，上层就必须将其进行分片。
- **循环冗余检验(CRC)**。这是一个 4 字节的字段用作差错检测，它使用 CRC-32

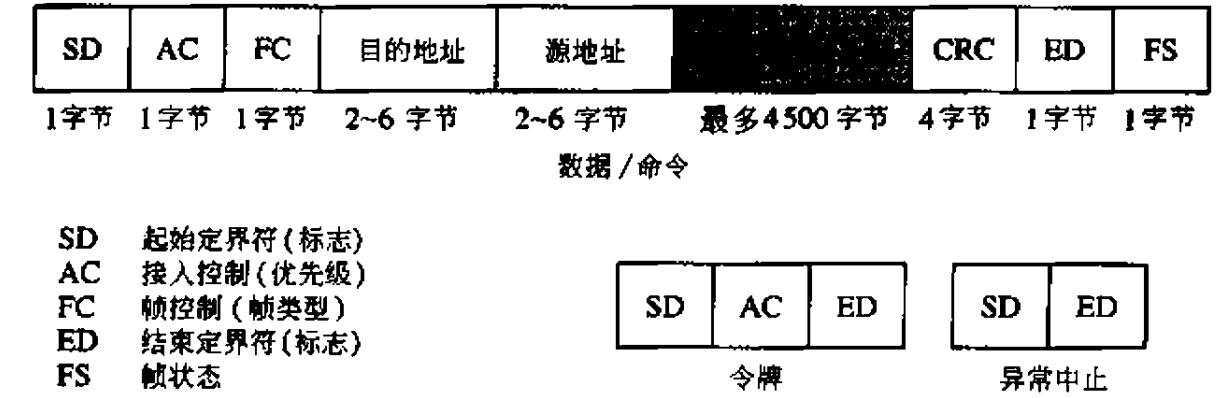


图 3.15 令牌环的帧格式

- **目的地址(DA)**。这个可变长度(2 至 6 字节)字段是下一站的物理地址。
- **源地址(SA)**。这个可变长度(2 至 6 字节)字段是前一站的物理地址。
- **数据**。这个字段是数据。数据可多到 4500 字节。
- **CRC**。这个字节为 4 字节长,包含 CRC-32 检错序列(见附录 D)。
- **结束定界符(ED)**。这个 1 字节字段指出发送器的数据结束,同时还包含更多的控制信息。
- **帧状态(FS)**。这个 FS 字段由接收器设置,指出帧已被读取,或由监督站设置,指出该帧已在环上转了一圈。

令牌帧,令牌帧包括三个字段:SD、AC 和 ED。

异常中止帧,异常中止帧只有两个字段:SD 和 ED。当出现一些问题时,监督站使用异常中止帧来中止令牌传递机制。

15.4 Ethernet Type Field and Demultiplexing

- The type field in an Ethernet frame provides multiplexing and demultiplexing
  - that allows a given computer to have multiple protocols operating simultaneously
- When a frame arrives at its destination
  - the receiver examines the type field, and it uses the value to determine which software module should process the frame

15.4 Ethernet Type Field and Demultiplexing

- **The protocols used on the Internet send IP datagrams and ARP messages over Ethernet**
  - **Each is assigned a unique Eth. type**

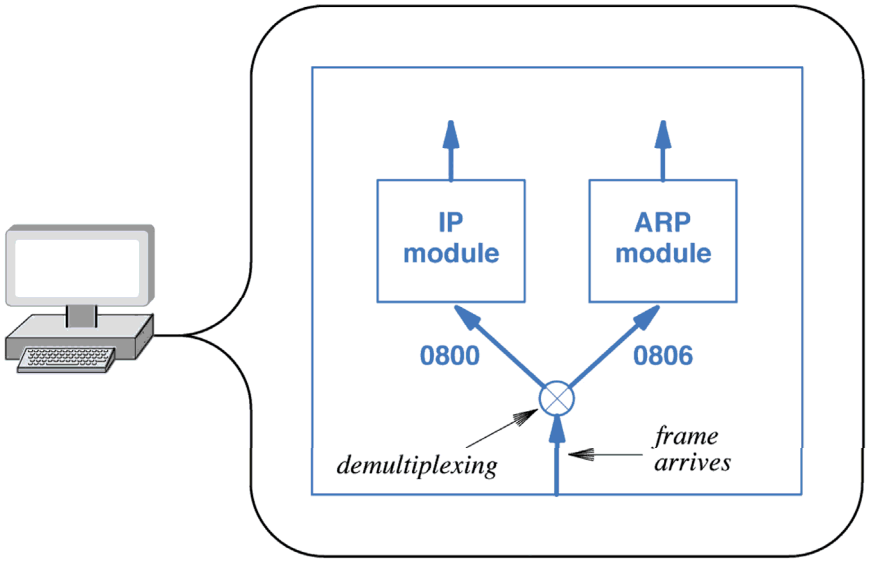


Figure 15.2 Illustration of using the frame type field for demultiplexing.

Value	Meaning
0000-05DC	Reserved for use with IEEE LLC/SNAP
0800	Internet IP Version 4
0805	CCITT X.25
0900	Ungermann-Bass Corporation network debugger
0BAD	Banyan Systems Corporation VINES
1000-100F	Berkeley UNIX Trailer encapsulation
6004	Digital Equipment Corporation LAT
6559	Frame Relay
8005	Hewlett Packard Corporation network probe
8008	AT&T Corporation
8014	Silicon Graphics Corporation network games
8035	Internet Reverse ARP
8038	Digital Equipment Corporation LANBridge
805C	Stanford University V Kernel
809B	Apple Computer Corporation AppleTalk
80C4-80C5	Banyan Systems Corporation
80D5	IBM Corporation SNA
80FF-8103	Wellfleet Communications
8137-8138	Novell Corporation IPX
818D	Motorola Corporation
FFFF	Reserved

15.5 IEEE's Version of Ethernet (802.3)

- IEEE developed a standard for Ethernet (1983) and attempted to redefine the Ethernet frame format
  - This IEEE working group is numbered 802.3
- 传统Ethernet与802.3 Ethernet区别于类型域的解释
  - 802.3 standard interprets the original type field as a packet length, and adds 8-byte header that contains the packet type
  - The extra header is known as a Logical Link Control / Sub-Network Attachment Point (LLC/SNAP) header; most professionals simply call it a SNAP header

15.5 IEEE's Version of Ethernet (802.3)

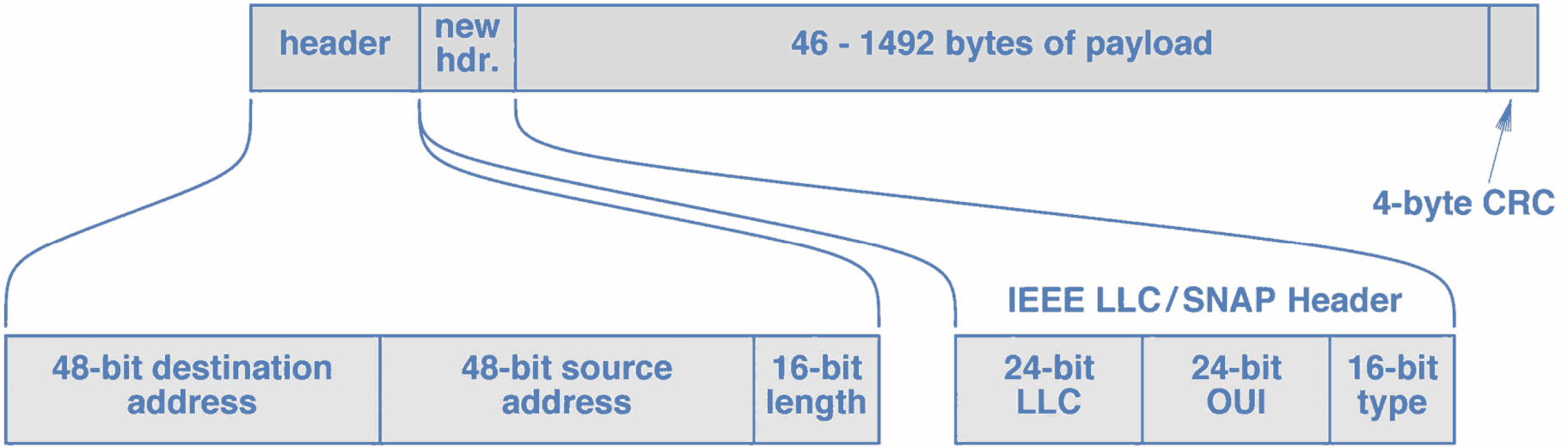


Figure 15.3 The IEEE 802.3 frame format with an LLC/SNAP header.

15.5 IEEE's Version of Ethernet (802.3)

- The overall frame size in 802.3 Ethernet remains the same as conventional Ethernet: 1514 bytes
  - IEEE reduced the max. payload from 1500 bytes to 1492
    - SNAP header occupies the first 8 bytes of the payload
- To keep the two versions of Ethernet compatible:
  - If bytes 13-14 of a frame is less than 1500
    - the field is interpreted as a packet length and the 802.3 standard applies
  - otherwise, the field is interpreted as a type field and the original Ethernet standard applies

15.6 LAN Connections and Network Interface Cards

- NIC appears to be an I/O device
  - it is connected in the same manner as a disk or video device
  - handles address recognition; CRC computation; frame recognition; sending/receiving frames
- consists of a circuit board with a plug on one side.
- Most computers come with a NIC already installed
- The NIC is independent from the rest of the computer
  - a user can replace the NIC without making other changes

- 可用的标识方式
  - 把传送的数据看作有效数据，发送和接收者通过其它协议约定传输的数据类型标识
  - 有效数据开始部分作为数据类型标识
- 应用层数据标识的问题
  - 类型标识值可能被重复使用，很难保持全局唯一

- 数据链路层标识
  - 全球唯一的标识的建立：IEEE802.2的LLC/SNAP
  - 在帧的有效数据头附加一个唯一标识
- 逻辑链路层控制(LLC)：3bytes
- 子网连接点：SNAP
  - 组织唯一标识(OUI)：3bytes，标准组织的编号
  - 组织内部唯一类型标识：2bytes

9.12 Network Analyzers, Physical Addresses, Frame Type

- A network analyzer or network monitor is a device that can be configured to count or display frame as they pass across a shared network.
- To read packets, analyzer software places the computer's network interface hardware into promiscuous mode (混合模式).
- An analyzer obtains a copy of each frame, then uses header fields such as the physical source address, physical destination address, or type information to determine how to process the frame.

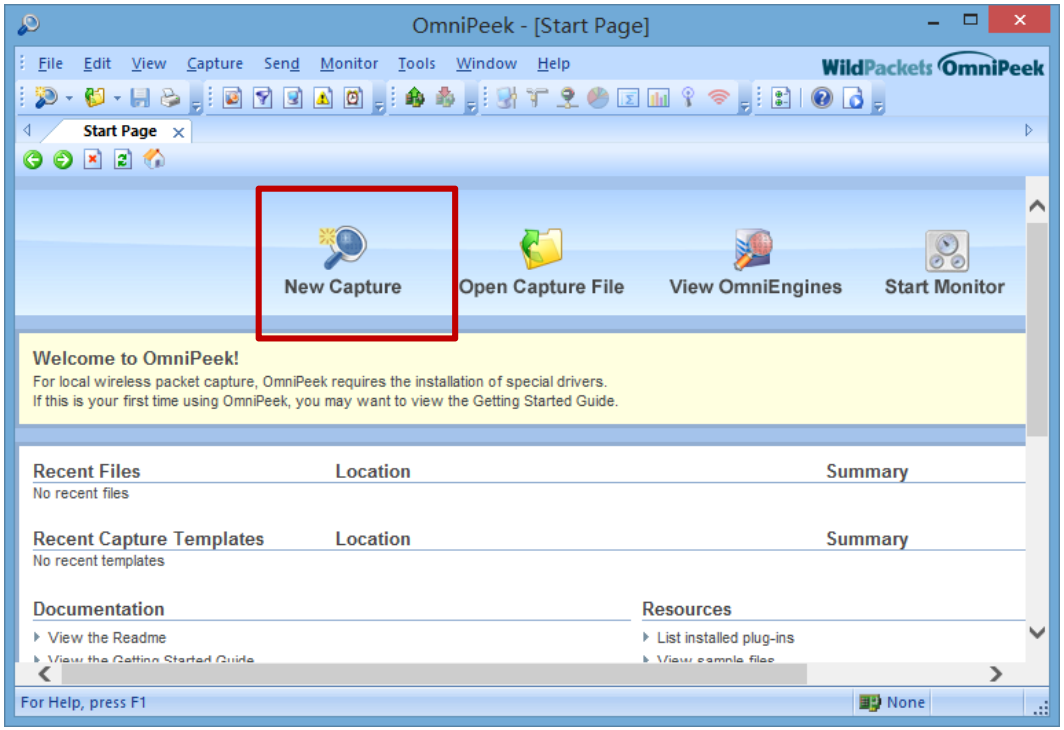
实践是检验真理的唯一标准

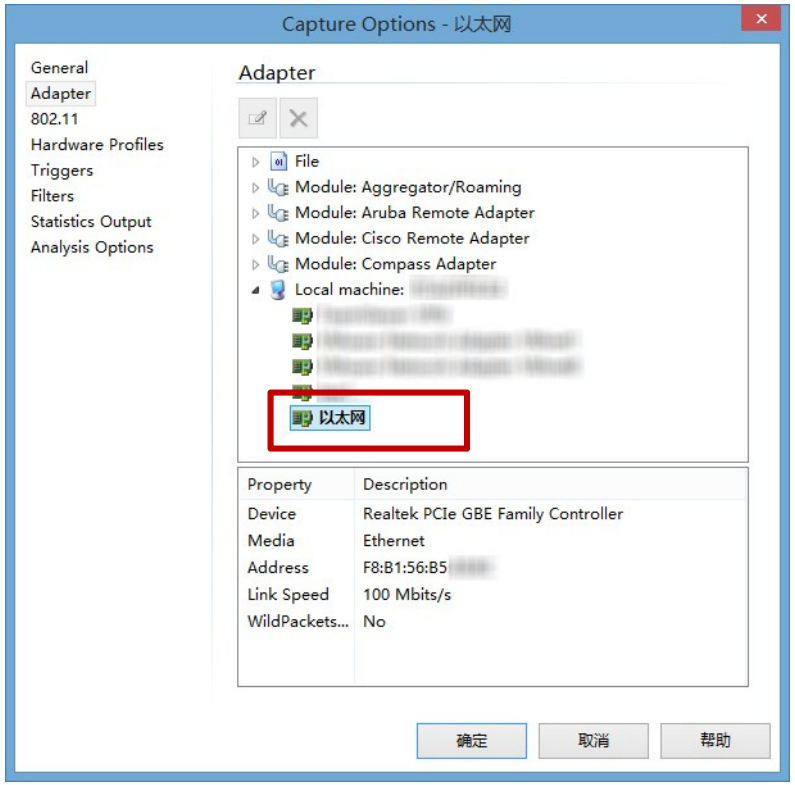
实验

- 请用Omnipeek监听本机的收发包，观察MAC地址
  - 在宿舍里（设宿舍内不用路由），PING不同室友的电脑（或QQ传文件），观察包的MAC地址
  - PING公网上的不同主机，观察包的MAC地址
  - 以上实验也可以在机房完成
  - Omnipeek程序在FTP上，用法请上网搜教程。
- 得到了什么结论？

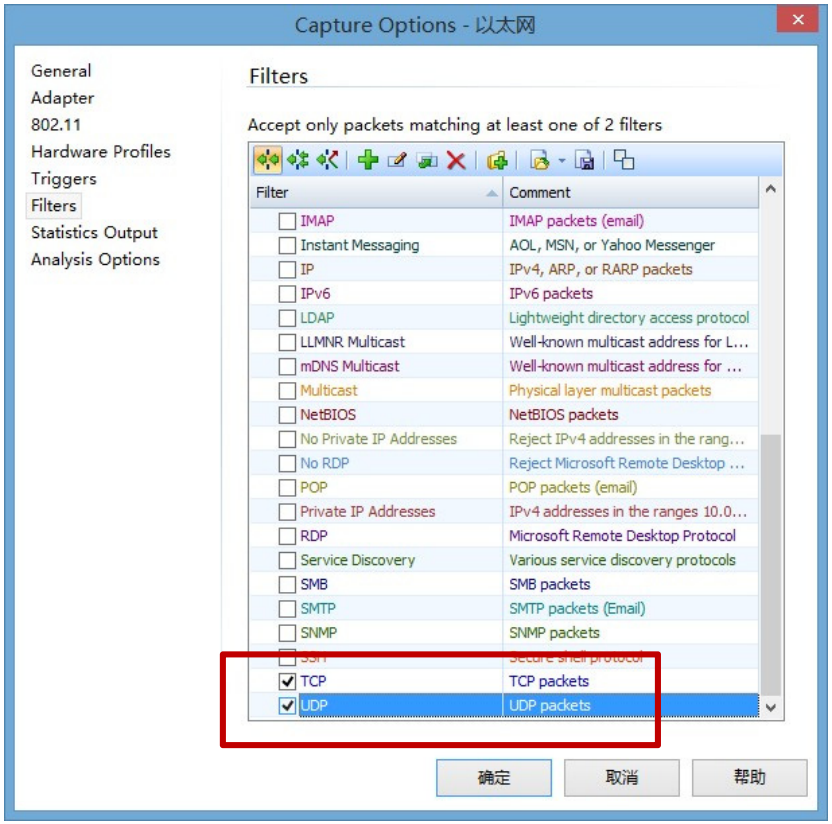
Omnipeek 7.5教程

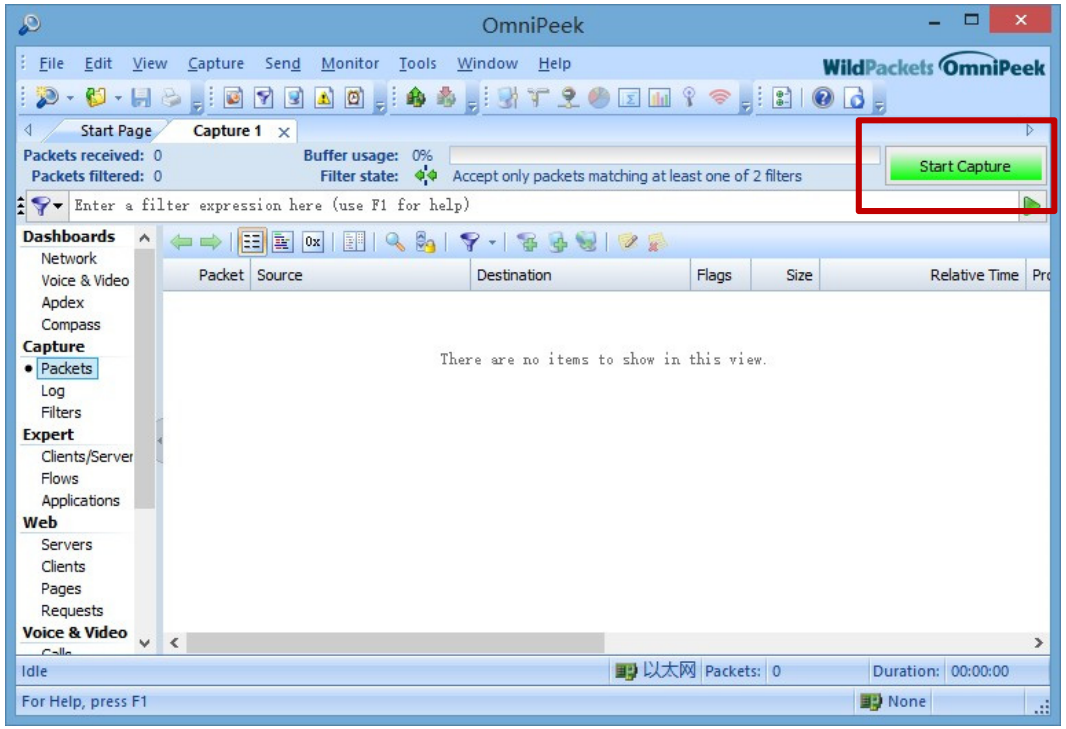
- 下载地址：
  - FTP://XXXX/教学课件/林/计算机网络实验课/tools/



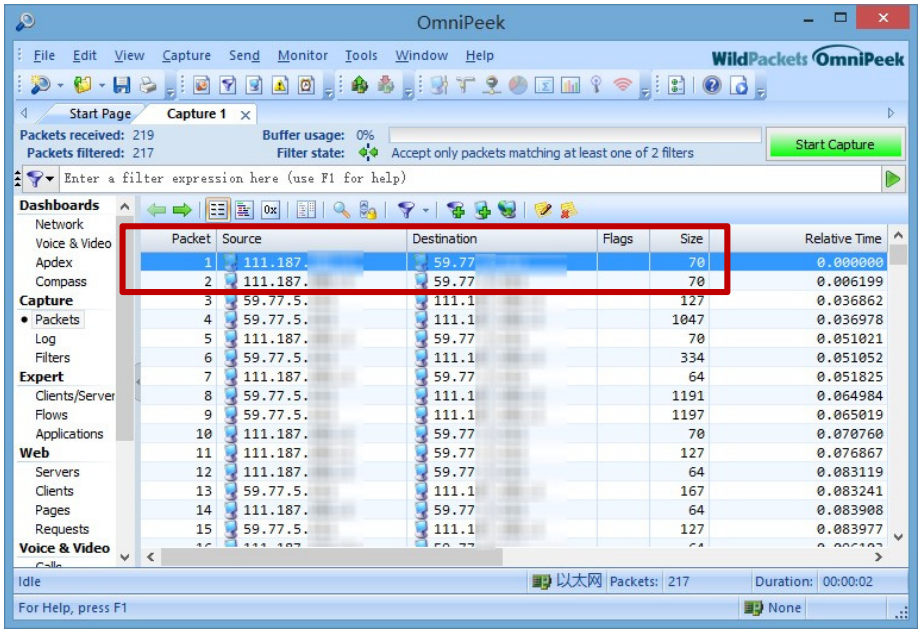


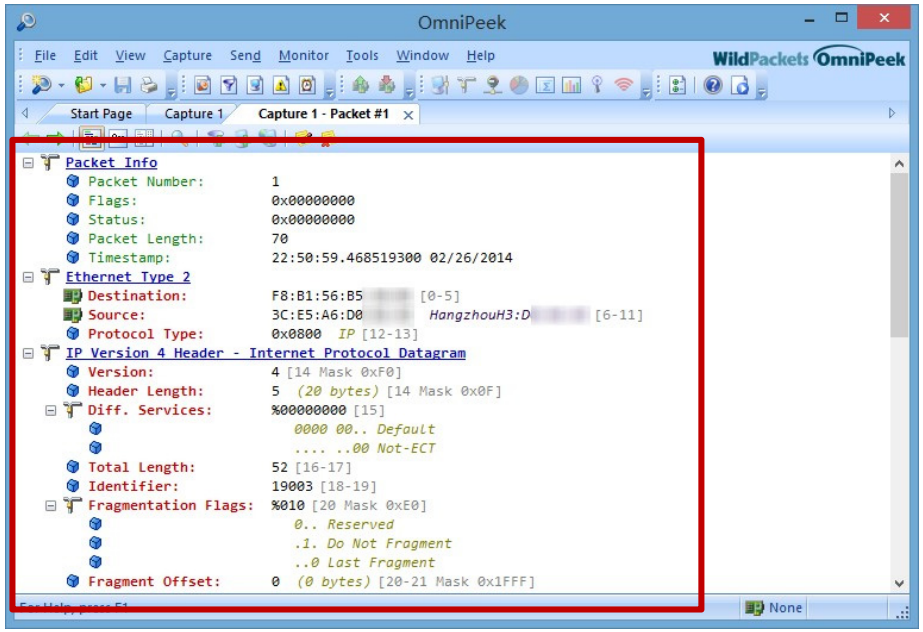
Omnipeek 7.5教程





Omnipeek 7.5教程





监听结果节选

```
Packet #1
Ethernet Type 2
  Destination:              FF:FF:FF:FF:FF:FF   Ethernet Broadcast  [0-5]
  Source:                   00:0C:29:37:5A:1B   VMware:37:5A:1B  [6-11]
  Protocol Type:            0x0800   IP  [12-13]
IP Version 4 Header - Internet Protocol Datagram
  Version:                  4   [14 Mask 0xF0]
  Protocol:                 17   UDP  [23]
  Source IP Address:        0.0.0.0   [26-29]
  Dest. IP Address:         255.255.255.255   IP Broadcast  [30-33]
UDP - User Datagram Protocol
  Source Port:              68   bootpc  [34-35]
  Destination Port:         67   bootps  [36-37]
BootP - Bootstrap Protocol
  IP Address Known By Client:    0.0.0.0   IP Address Not Known By Client  [54-57]
  Client IP Addr Given By Srvr:  0.0.0.0   [58-61]
  Server IP Address:             0.0.0.0   [62-65]
  Gateway IP Address:            0.0.0.0   [66-69]
  Client Hardware Addr:          00:0C:29:37:5A:1B   VMware:37:5A:1B  [70-75]
DHCP - Dynamic Host Configuration Protocol
Requested IP Address
  Address:                  192.168.7.132   [296-299]

Host Name Address
  String:                   WIN-KG9CLM76UIA   [302-316]
```

计算机网络

5.

THANK YOU.

厦门大学软件学院

黄炜 助理教授