

Chapter 7

Internet Control Message Protocol

ICMP

■ IP

- Lack of error control
- Lack of assistance mechanism

■ ICMP

- A companion to the IP
- Provide error reporting for IP
- Provide assistance mechanism for other layers
(TCP/UDP and application)

Error Reporting & Error Correction

- IP传输过程中出现差错是不可避免的
 - IP分组传输出现差错时，会产生相应的ICMP报文
 - 通过ICMP报文提供差错报告
- ICMP差错报告只能送给IP分组的源站，协议只提供了差错处理建议
 - 出错点可能不是当前的路由器
 - 源站可能无法确定差错源，需要与网络管理员一起协作处理

Internet Control Message Protocol

- RFC792: Internet Control Message Protocol, 1981
- RFC1256: ICMP Router Discovery Messages, 1991

Application Layer

Transport Layer

**Network
Layer**

ICMP

IGMP

IP

ARP

RARP

**Network
Access
Layer**

LANs

MANs

WANs

Message delivery and Encapsulation

- ICMP在IP之上实现，逻辑上与IP同在网络层
 - Connectionless communication
 - 直接送达目的站点，沿途路由器不能获知ICMP报文内容

**ICMP
message**

- Encapsulation
Protocol = 1



7.1 Types of Messages

ICMP messages

```
graph TD; A[ICMP messages] --> B[Error-reporting  
差错报告]; A --> C[Query  
测试查询]; B -.-> D[To report problems that a router or a destination host may encounter when it processes an IP packet]; C -.-> E[To help a host or a network manager get specific information from a router or another host];
```

Error-reporting
差错报告

To report problems that a router or a destination host may encounter when it processes an IP packet

Query
测试查询

To help a host or a network manager get specific information from a router or another host

过时:

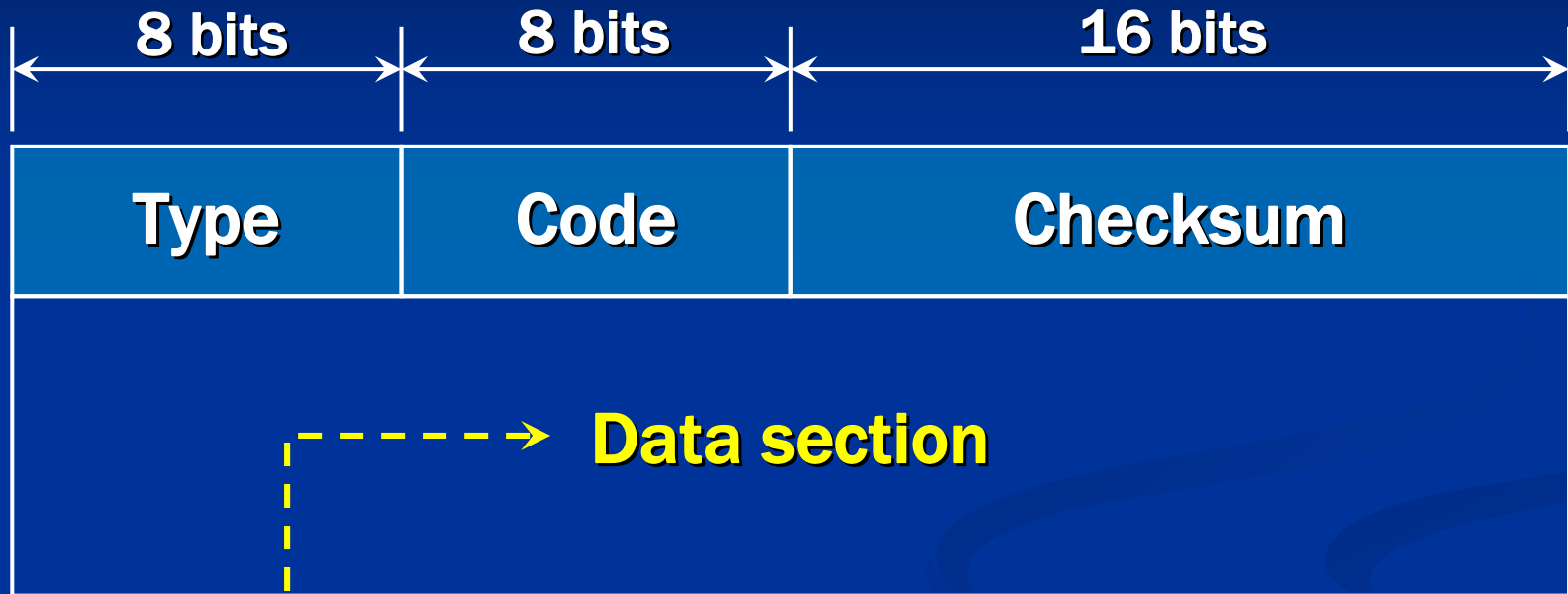
15 Information request

16 Information response

Types

| Category | Type | Message | Reason |
|--------------------------|----------|--------------------------------------|-----------------------------|
| Error-reporting messages | 3 | Destination unreachable | Unreachable |
| | 4 | Source quench | Congestion |
| | 11 | Time exceeded | Too long route |
| | 12 | Parameter problem | Format error |
| | 5 | Redirection | Route changed |
| Query messages | 8 or 0 | Echo request or reply | Reachability |
| | 13 or 14 | Timestamp request or reply | Synchronization |
| | 17 or 18 | Address mask request or reply | Mask maintenance |
| | 10 or 9 | Router solicitation or advertisement | Coincidence between routers |

7.2 Message Format



- 差错报文：引起差错的原始分组的一部分（首部 + 数据部分的前8个字节）
- 查询报文：基于查询类型的额外信息

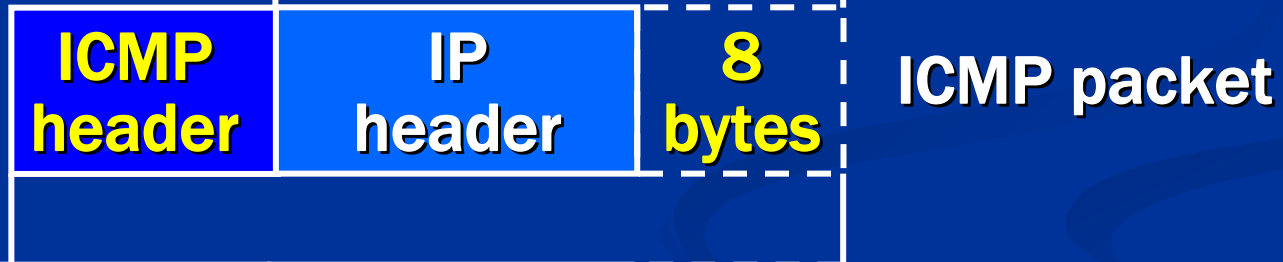
7.3 Error Reporting



- ICMP just simply report errors
- ICMP always reports error messages to the original source
- ICMP error message will **NOT** be generated for:
 - A datagram carrying an ICMP error message
 - A fragmented datagram that is **NOT** the first fragment
 - A datagram having a multicast address
 - A datagram having a special address such as 127.0.0.0 or 0.0.0.0

Contents of Data Field for Error Messages

Received datagram



Provide information about TCP and UDP

1 Destination Unreachable

- When a router cannot route a datagram or a host cannot deliver a datagram
 - The datagram is discarded
 - The router or the host sends a destination unreachable message back to the source

不可达的原因

| Type = 3 | Code = 0~12 | Checksum |
|----------|-------------|-----------------------------------|
| | | 0x00000000 |
| | | IP header + 8 bytes IP data |

A router cannot detect all problems that prevent the delivery of a packet

供源站分析错误

Destination Unreachable Codes

| Code | Description | Code | Description |
|------|-------------|------|--------------|
| 0 | 网络不可达 | 7 | 目的主机未知 |
| 1 | 主机不可达 | 8 | 源主机被隔离 |
| 2 | 协议不可达 | 9 | 与目的网络的通信被禁止 |
| 3 | 端口不可达 | 10 | 与目的主机的通信被禁止 |
| 4 | 需要分片，但DF=1 | 11 | 对指定TOS，网络不可达 |
| 5 | 源路由失败 | 12 | 对指定TOS，主机不可达 |
| 6 | 目的网络未知 | | |

2 Source Quench

- The lack of flow control for IP → congestion
 - 主机产生的数据量可能比网络快
 - 不适当的路由使流量过分集中，超过信道容量
 - 路由器的转发性能低
- 路由器或主机因拥塞丢弃IP分组时，向源站发送ICMP源抑制报文，通知源站放慢分组的发送

| Type = 4 | Code = 0 | Checksum |
|-----------------------------------|----------|----------|
| 0x00000000 | | |
| IP header + 8 bytes IP data | | |

The Solution of the Congestion

- 发送队列缓冲：缓解短暂的突发数据
- 丢弃报文，产生源抑制ICMP报文给源站
 - 丢弃算法 —— QoS
 - 源站减缓发送速率
 - 源站没有收到源抑制报文后逐步提高发送速率
- 源抑制报文的拥塞控制能力
 - 只能解决因主机问题造成的拥塞
 - 对因路由或路由器问题造成的拥塞不起作用

3 Time Exceeded

- 路由器或主机因分组超时而丢弃IP分组时，向源站发送ICMP超时报文

Code = 0 —— 路由器检测到分组的TTL值为0

Code = 1 —— 目的站在规定时间内没有收到所有分片

| Type = 11 | Code = 0,1 | Checksum |
|-----------------------------------|------------|----------|
| 0x00000000 | | |
| IP header + 8 bytes IP data | | |

4 Parameter Problem

- 路由器或主机因首部字段格式或取值错误而丢弃报文时，向源站发送ICMP参数问题

Code = 0 —— 首部字段错误，指针字段指向错误字节
Code = 1 —— 缺少所需的选项部分，指针字段无效

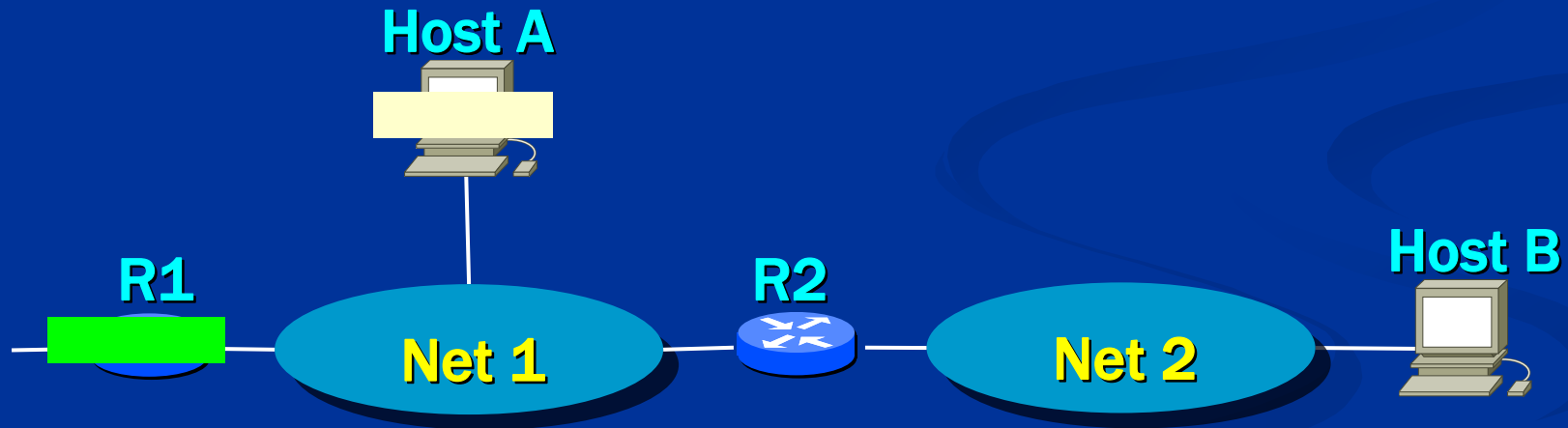
| | | |
|-----------------------------------|------------|----------|
| Type = 12 | Code = 0,1 | Checksum |
| Pointer | 0x00000000 | |
| IP header + 8 bytes IP data | | |

5 Redirection

■ 重定向

| | |
|-----------|------|
| Net 1 | 直接交付 |
| Net 2 | R2 |
| Net 1 | 直接交付 |
| 0.0.0.0/0 | R1 |

A want to send datagrams to B, but it doesn't know R2 is the better choice. What will it do?



 IP packet to B

 Redirection message

Format

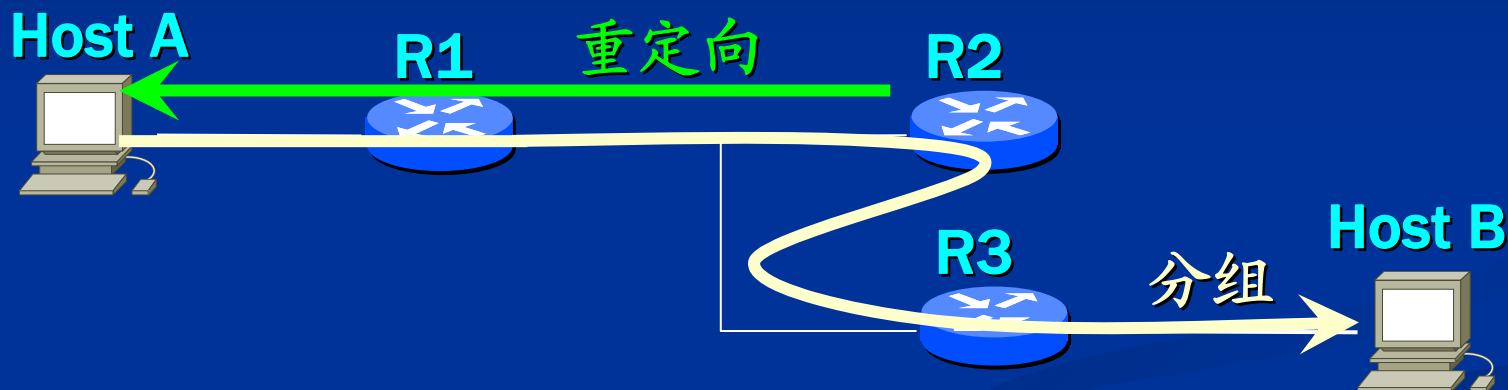
| Type = 5 | Code = 0~3 | Checksum |
|-----------------------------------|------------|----------|
| IP address of the target router | | |
| IP header + 8 bytes IP data | | |

| Code | Description |
|------|--------------------------------------|
| 0 | Network specific |
| 1 | Host specific |
| 2 | Network specific (specified service) |
| 3 | Host specific (specified service) |

缩小路由
由改变
的范围

思考

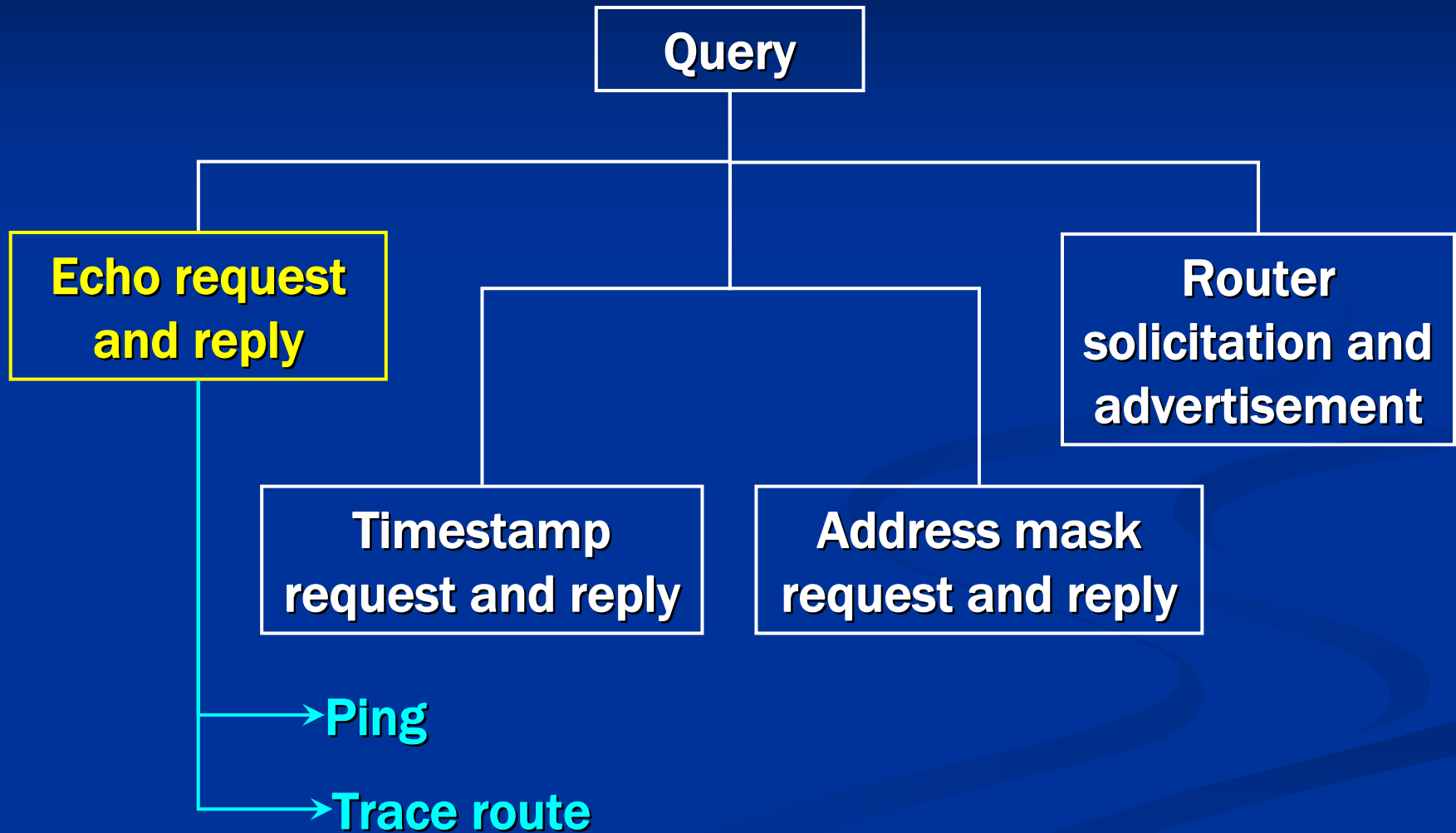
- 在以下情况中，重定向报文是否有用？



R2发出的重定向
报文应该送给谁？



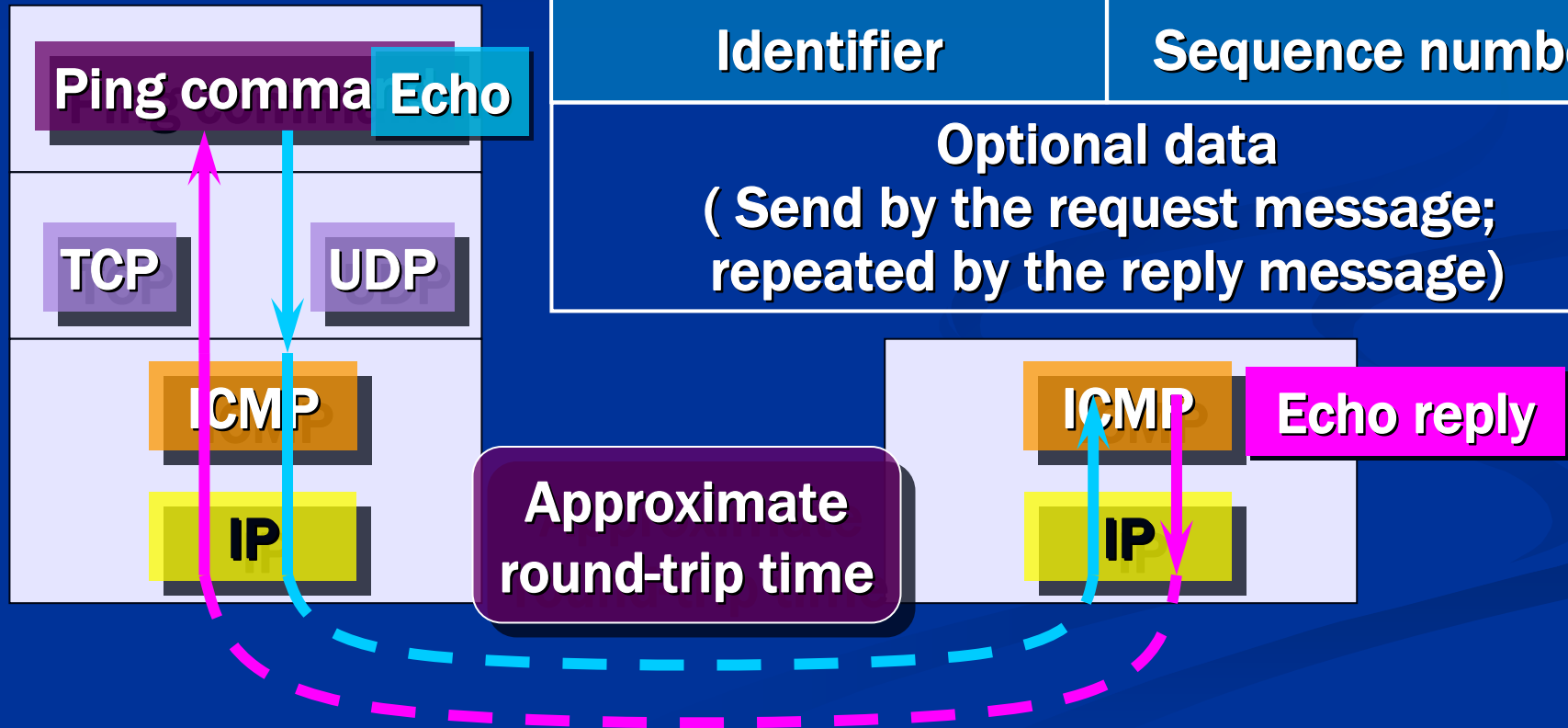
7.4 Query



1 Echo Request and Reply

- To test the reachability of a host

| | | |
|---|----------|-----------------|
| Type = 8,0 | Code = 0 | Checksum |
| Identifier | | Sequence number |
| Optional data (Send by the request message; repeated by the reply message) | | |



2 Timestamp Request and Reply

| | | |
|---|-----------------|------------------------|
| Type = 13, 14 | Code = 0 | Checksum |
| Identifier | | Sequence number |
| Original timestamp (filled by source) | | |
| Receive timestamp (filled by destination) | | |
| Transmit timestamp (filled by destination) | | |

- Used to calculate the round-trip time (ms)
 - 发时间 = 收时戳 - 初始时戳, 收时间 = 返回时间 - 发时戳
 - 往返时间 = 发时间 + 收时间
- Used to synchronize two clocks in two machines
- 由于路径、传输, 难以得到非常精确的时间

3 Mask Request and Reply

| | | |
|---------------|----------|-----------------|
| Type = 17, 18 | Code = 0 | Checksum |
| Identifier | | Sequence number |
| Mask | | |

■ 应用

- 供IP协议软件使用
- 主机知道路由器地址时，可以向路由器发送请求
- 不知道路由器时，可广播发送，路由器作应答

4 Route Solicitation and Advertisement

- 主机发送路由器询问报文，查询本网中的路由器

| | | |
|-------------------|-----------------|------------------------|
| Type = 10 | Code = 0 | Checksum |
| Identifier | | Sequence number |

- 路由器发送路由器通告报文，通告自己以及所知的本网中其他路由器的存在

| | | |
|-----------------------------|-----------------|------------------------|
| Type = 10 | Code = 0 | Checksum |
| Identifier | | Sequence number |
| Router address 1 | | |
| Address preference 1 | | |
| Router address 2 | | |
| Address preference 2 | | |
| | | |

7.5 ping程序

- Ping(Packet InterNet Groper, 简称ping)程序用来测试两个站点之间在IP层的连通性, 它使用了ICMP回送请求报文和回送应答报文。

7.6 ICMP软件包

- Input module
- Output module

Input module

Receive : an ICMP packet from the IP layer

1. If (the type is any of the three request type)
 1. Create a reply
 2. Send the reply
2. If (the type is a router solicitation)
 1. If (station is a router)
 1. Create a router advertisement
 2. Send the advertisement
3. If (the type is one of the three reply messages or router advertisement)
 1. Extract information in the data section of the packet
 2. Deliver extracted information to the process that requested it
4. If (the type defines a redirection) modify the routing table
5. If (the type defines an error message other than a redirection)
 1. Inform the appropriate source protocol about the situation
6. return

Output module

Receive: a demand

1. If (the demand defines an error message)
 1. If (the demand is from IP)
 1. If (the demand is forbidden) return
 2. If (the type defines a redirection message)
 1. If (the station is not a router) return
 3. Create the error message using the type, the code, and the IP packet
2. If (the demand defines a request or solicitation)
 1. Create a request or solicitation message
3. Send the message
4. return

Summary of ICMP

- ICMP tries to solve problems in IP transmission
- An ICMP message is encapsulated in an IP datagram
- ICMP error messages are reported only to the source
- The source does not always know how to solve the reported errors
- ICMP is widely used, in spite of its limited ability to control and manage networks

Summary

■ ARP

- 作用、分组格式
- 操作
 - 何时发送、送给谁
 - 发送方式（单播、广播）
 - 发送内容（ARP分组各字段的具体取值，以及封装该分组的以太帧中各字段的具体取值）
- Proxy ARP、Gratuitous ARP

■ RARP

- 作用、操作、缺陷

Summary

■ ICMP

- 作用、通信方式

■ ICMP报文

- 封装：直接封装在IP分组中
- 类型：差错报告（传输特点）、测试查询
- 作用、特点

Summary

- ICMP发送5种类型的差错报文和4对查询报文，用来支持不可靠的和无连接的IP
- ICMP封装成IP数据报
- 当数据报无法交付时，就用终点不可达差错报文发送给源主机
- 源点抑制差错报文是用来减轻拥塞程度的
- 超时报文通知源主机：（1）生存时间字段值已下降到零，或（2）在预定时间内报文中的一些分片未能到达
- 参数问题报文通知主机，在数据报的首部字段中出现了问题
- 发送改变路由报文可使主机中的路由表更加有效
- 回送请求和回送回答报文用来测试两个系统之间的连通性
- 时间戳请求和回答能够确定两个系统之间的往返时间或两个系统之间的时间差
- 地址掩码请求和地址掩码回答报文用来得到子网掩码
- 路由器询问和路由器通告报文允许主机更新其路由表

- 某计算机将时间戳请求发送给另一个计算机。它在3:46:07AM收到相应的时间戳回答。原始时间戳、接收时间戳以及发送时间戳分别为13 560 000、13 562 000和13 564 000。试问发送时间是多少？接收时间是多少？往返时间是多少？发送端与接收端时钟之差是多少？

- Original timestamp:13 560 000(03:46:00AM)
- Receive timestamp:13 562 000(03:46:02AM)
- Transmit timestamp:13 564 000(03:46:04AM)
- Return time:03:46:07AM(13 567 000)
- 发送时间: 03:46:00AM
- 接收时间: 03:46:02AM
- 往返时间=发时间+收时间
=(receive time-original time)+(return time-transmit time)
=(13 562 000- 13 560 000)+ (13 567 000- 13 564 000)
=5000 milliseconds

$$\begin{aligned}\text{Time difference} &= \text{receive timestamp} - \\ &\quad (\text{original timestamp field} + \text{one-way time duration}) \\ &= 13\,562\,000 - (13\,560\,000 + 5000/2) \\ &= -500\end{aligned}$$

取绝对值，时间差为500milliseconds(0.5s)