ICMP

Need for ICMP

- Scenario 1: If a router must discard a datagram because:
  - it cannot find a router to the final destination
  - if the TTL field has a zero value?

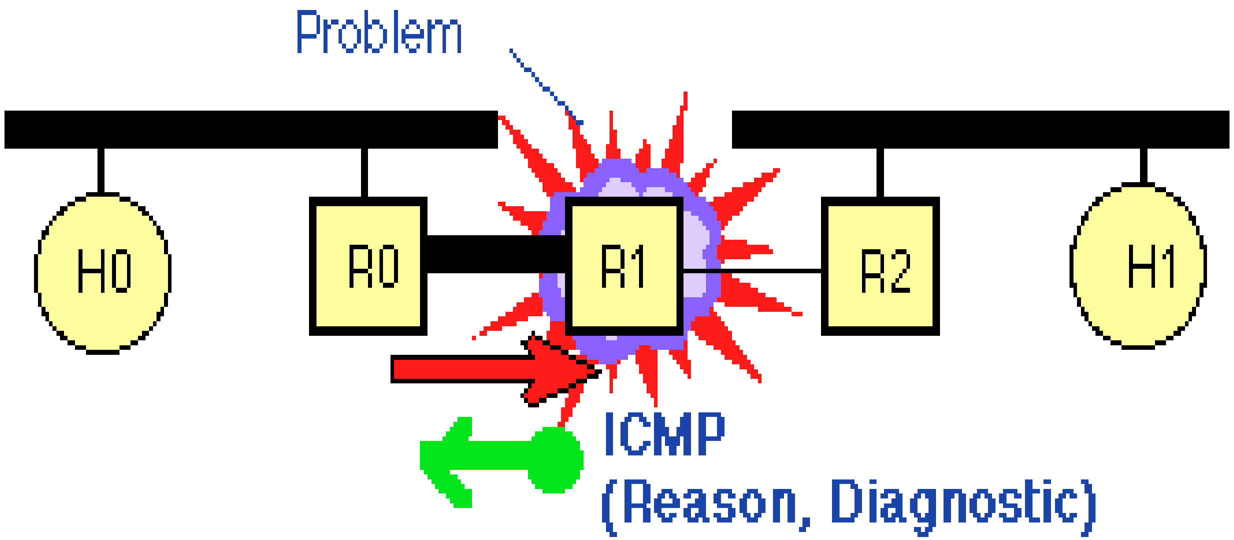
Need for ICMP

- Scenario 2: If a final destination host must discard all fragments of a datagram because:
  - it has not received all fragments in pre-determined time limit

Scenario 3: A host needs to determine if a router or another host is alive

Why ICMP?

IP Connectionless – does not have mechanism to report or correct error. ICMP compensates these deficiencies.



Need for ICMP

- The IP protocol has no error-reporting or error correcting mechanism
- IP protocol also lacks a mechanism for host and management queries
- ICMP has been designed to compensate for the above two deficiencies.
- Serves as companion to IP protocol

Figure 9.1 *Position of ICMP in the network layer*

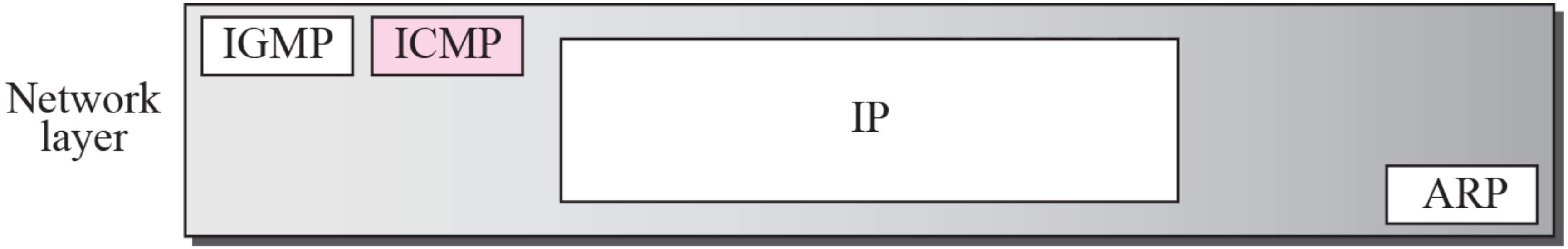
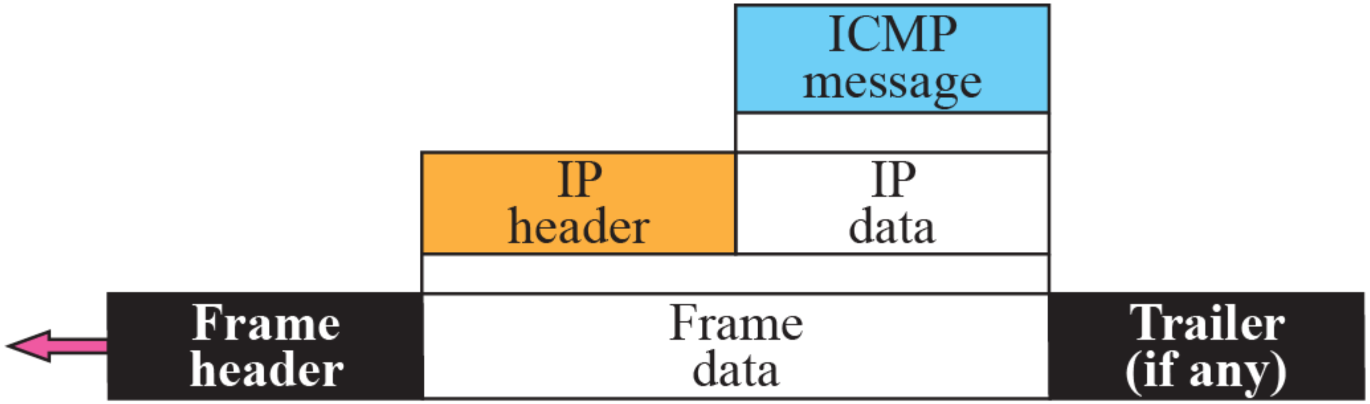


Figure 9.2 *ICMP encapsulation*



ICMP Messages

ICMP messages are divided into two broad categories:

- Error-reporting messages
  - The error-reporting messages report problems that a ***router or a host (destination)*** may encounter when it processes an IP packet.

- Query messages
  - The query messages, which occur in pairs, help ***a host or a network manager*** get specific information from a router or another host.

Table 9.1 *ICMP messages*

Category	*Type*	*Message*
Error-reporting messages	3	Destination unreachable
	4	Source quench
	11	Time exceeded
	12	Parameter problem
	5	Redirection
Query messages	8 or 0	Echo request or reply
	13 or 14	Timestamp request or reply

ICMP Parameter Message Format

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

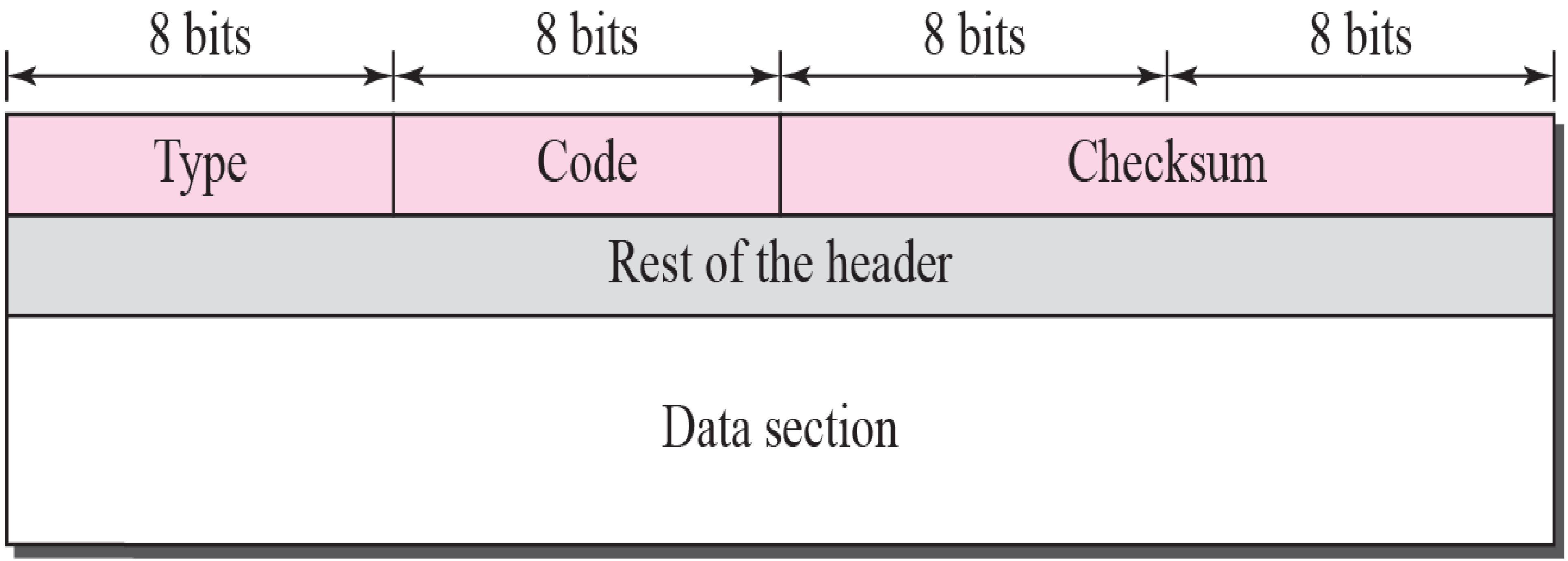
Type	**Code**	**Checksum**	
0	**1**	**2**	**3**
Pointer	**Unused**		
4	**5**	**6**	**7**
Internet Header + 8 bytes of Original Data Datagram			
8			

Type	Code	Meaning
0	0	Echo Reply
3	0	Net Unreachable
	1	Host Unreachable
	2	Protocol Unreachable
	3	Port Unreachable
	4	Frag needed and DF set
	5	Source route failed
	6	Dest network unknown
	7	Dest host unknown
	8	Source host isolated
	9	Network admin prohibited
	10	Host admin prohibited
	11	Network unreachable for TOS
	12	Host unreachable for TOS
	13	Communication admin prohibited
4	0	Source Quench (Slow down/Shut up)

Type	Code	Meaning
5	0	Redirect datagram for the network
	1	Redirect datagram for the host
	2	Redirect datagram for the TOS & Network
	3	Redirect datagram for the TOS & Host
8	0	Echo
9	0	Router advertisement
10	0	Router selection
11	0	Time To Live exceeded in transit
	1	Fragment reassemble time exceeded
12	0	Pointer indicates the error (Parameter Problem)
	1	Missing a required option (Parameter Problem)
	2	Bad length (Parameter Problem)
13	0	Time Stamp
14	0	Time Stamp Reply
15	0	Information Request
16	0	Informaiton Reply
17	0	Address Mask Request
18	0	Address Mask Reply
30	0	Traceroute (Tracert)

Figure 9.3 *General format of ICMP messages*

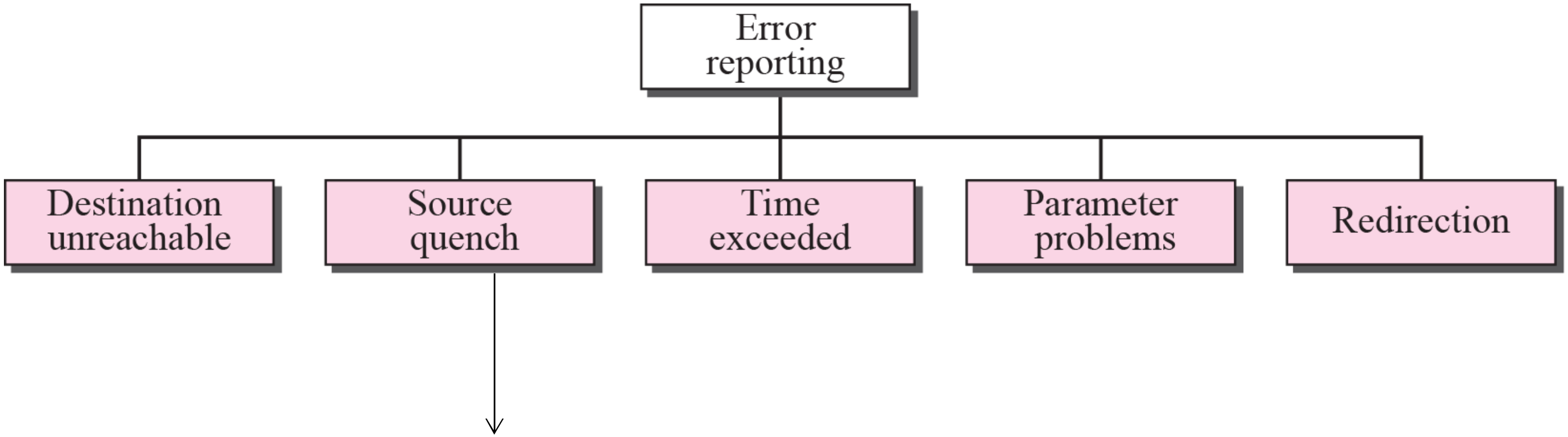
ICMP has 8 byte header,
Variable size data section



Note

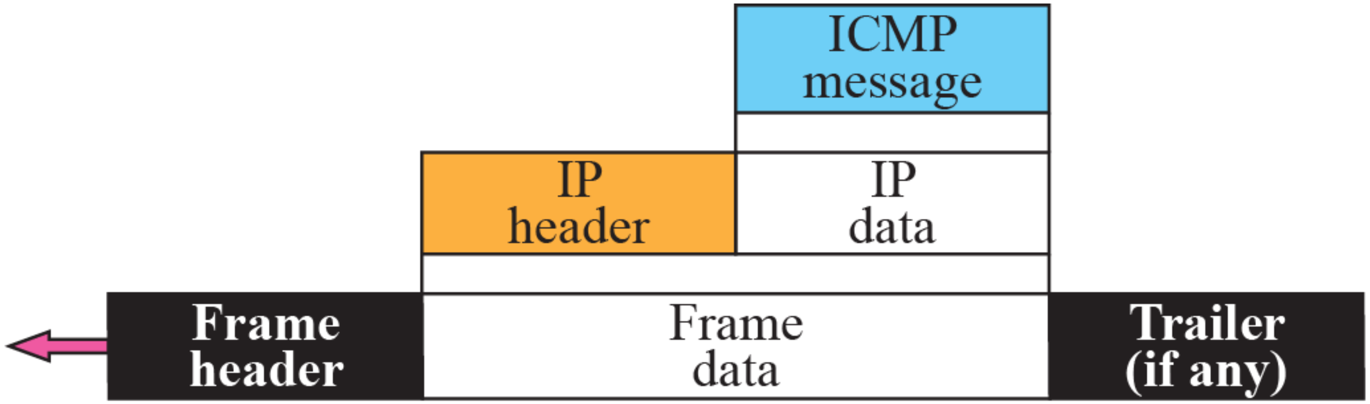
ICMP always reports error messages to the original source.

Figure 9.4 *Error-reporting messages*



Source quench: Deprecated
Others: Active

Figure 9.2 *ICMP encapsulation - RECALL*



ICMP – Data section

- Error messages – carries information for **finding original packet** that had error

- Query messages – extra information based on the **query**

Figure 9.5 Contents of data field for the error message

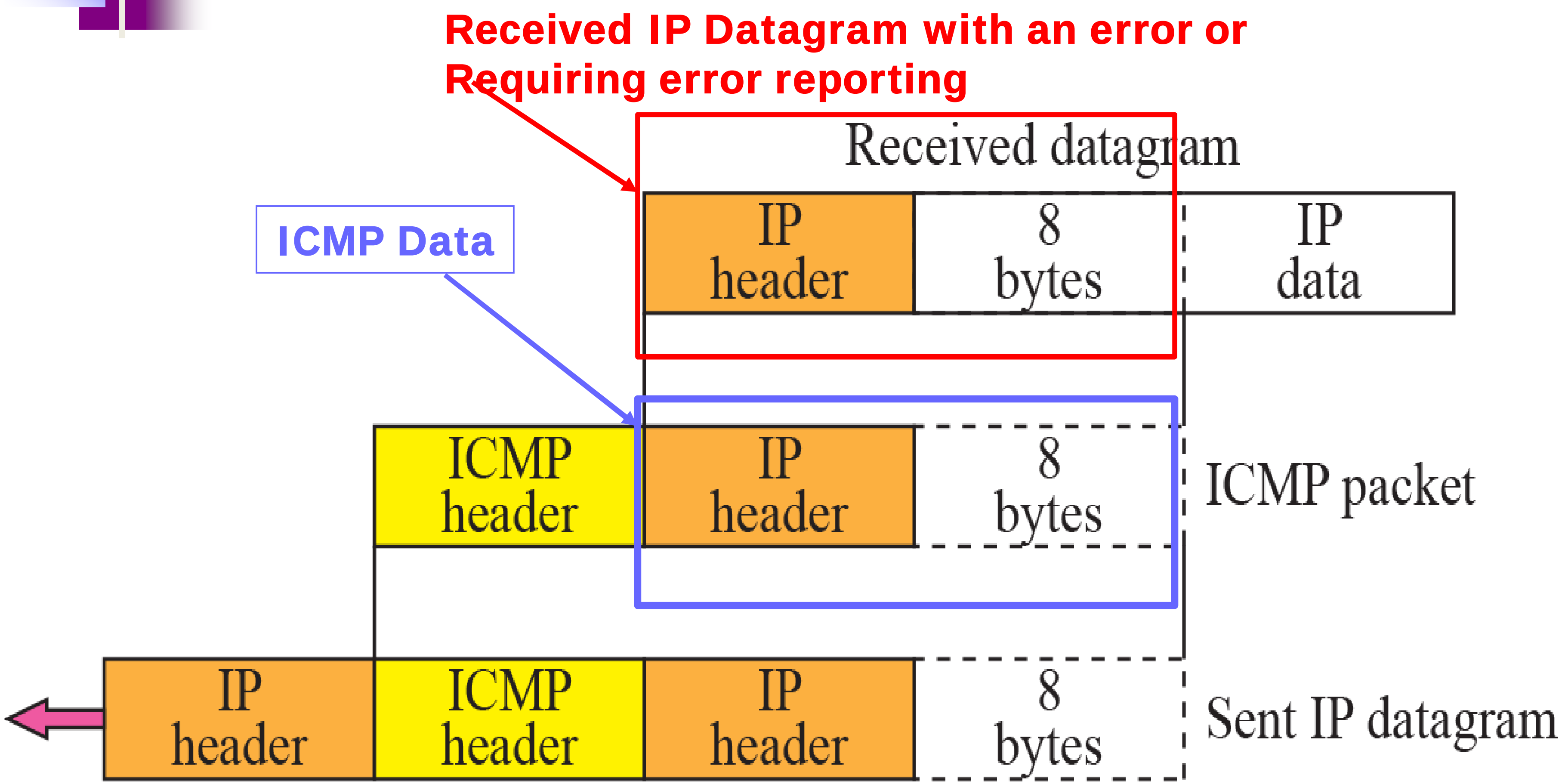
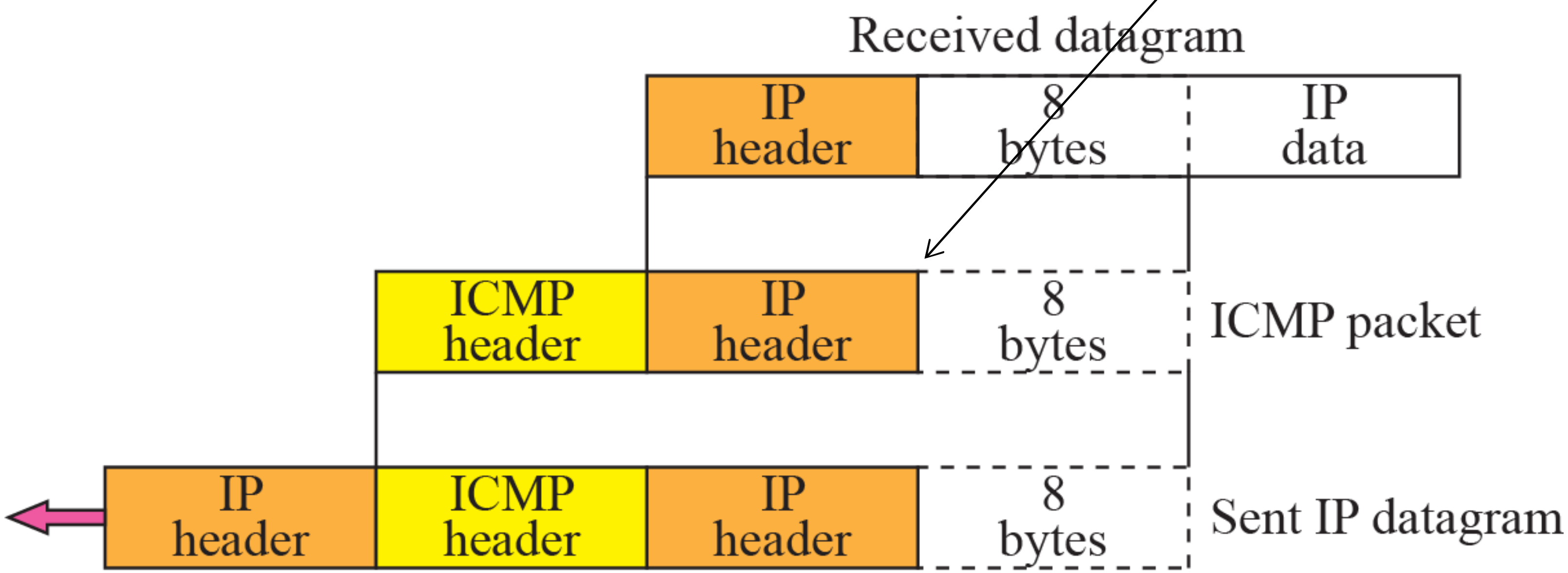


Figure 9.5 Contents of data field for the error message

Note: This format is only for error messages and NOT FOR QUERY MESSAGES

Q1] Can you answer why IP Header and 8 bytes of IP data is embedded in error message ?



Answer to Q1

- This ICMP error message is a response to original source
- A router in the network receives an IP datagram
- An error occurs and **router** generates an error message and sends the **ICMP Error message** back to original source so that source can understand the error scenario.

Why IP header inside ICMP error message?

➔ **gives error message information about the IP datagram itself**

Answer to Q1 (contd….)

Why 8 bytes of IP data?

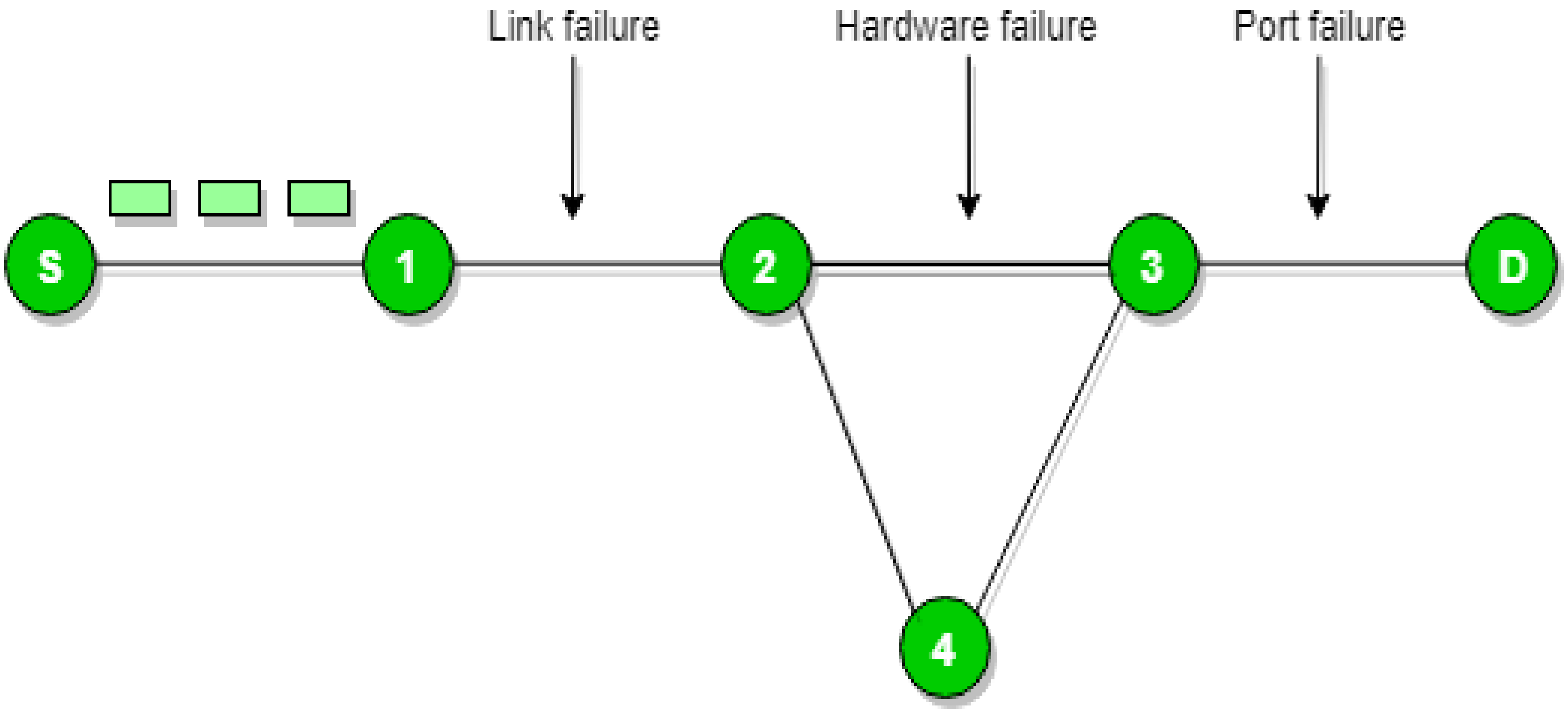
- First 8 bytes of IP data provide information about
  - **Port numbers (TCP/UDP)**
  - **Sequence Numbers (TCP)**
- This information is needed so the source can inform protocols (TCP/UDP in transport layer) in source, must receive this ICMP error message. So port information is necessary
- Hence to identify the source process, ICMP error message adds this information
- ICMP module forms ICMP error message and encapsulates in IP datagram

Destination unreachable message

Destination unreachable

- When a router cannot route a datagram or a host cannot deliver a datagram
  - The datagram is discarded
  - Router/host sends this error message
  - Back to the source that initiated the datagram

Destination unreachable



Destination unreachable - reasons

Reasons for discarding the datagram

- Network unreachable may be due to hardware failure
- Host unreachable
- **Code 3:** Port unreachable –application process not running
- Fragmentation required but DF flag not set
- **Code 2:** Protocol unreachable- UDP/TCP/OSPF may not be running
- Source routing cannot be accomplished
- Destination host/network unknown
- Network/host unreachable for specified type of service
- And many more reasons…..

Figure 9.6 *Destination-unreachable format*

Type: 3	Code: 0 to 15	Checksum
Unused (All 0s)		
Part of the received IP datagram including IP header plus the first 8 bytes of datagram data		

Note

Destination-unreachable messages with codes 2 or 3 can be created only by the destination host.

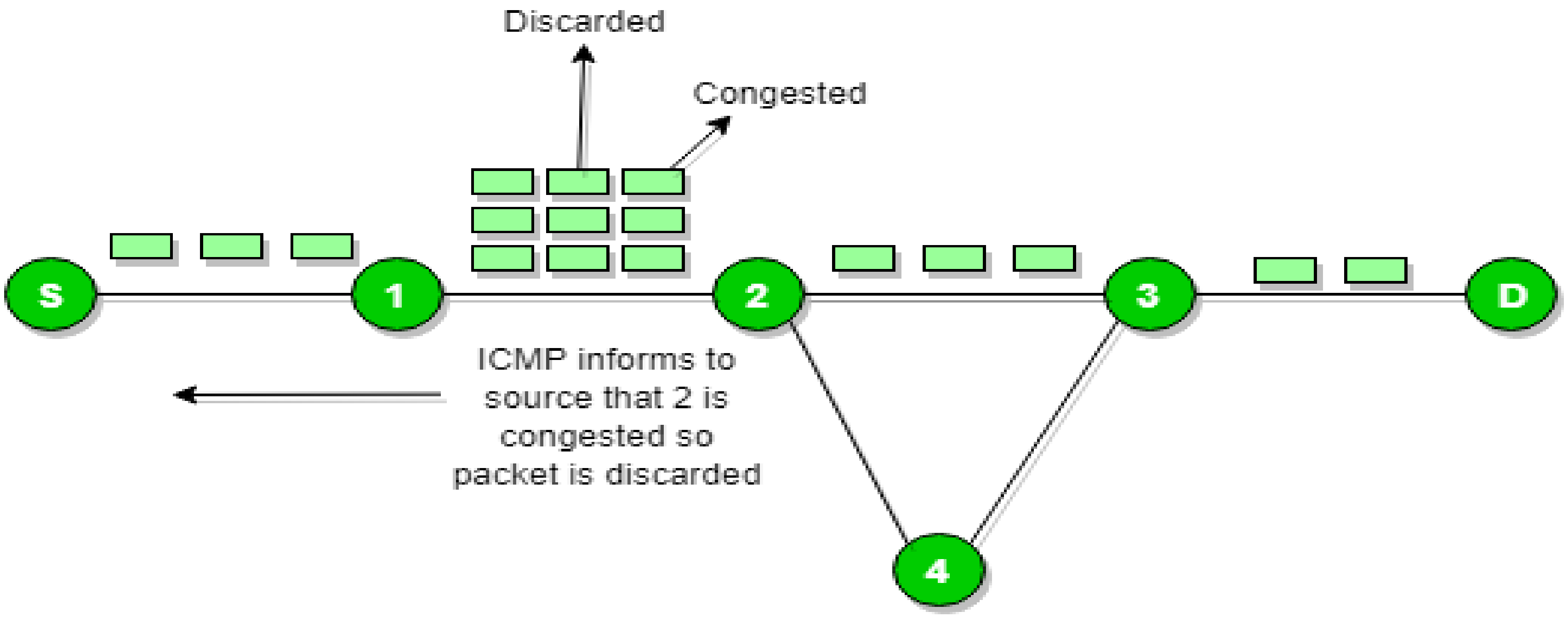
Other destination-unreachable messages can be created only by routers.

Note

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

Source Quench message

Source Quench



Note

There is no flow-control or congestion-control mechanism in the IP protocol.

Figure 9.7 *Source-quench format*

Type: 4	Code: 0	Checksum
Unused (All 0s)		
Part of the received IP datagram including IP header plus the first 8 bytes of datagram data		

Note

A source-quench message informs the source that a datagram has been discarded due to congestion in a router or the destination host.

The source must slow down the sending of datagrams until the congestion is relieved.

Note

One source-quench message is sent for each datagram that is discarded due to congestion.

Source Quench - deprecated

- SQ messages - may not be useful always
- Router or destination host has no clue which source is responsible for congestion
- It may drop datagram of a very slow host instead of dropping datagram from the source that has actually created the congestion

Time Exceeded message

Time exceeded message

- Two reasons for generating this ICMP error message

Note

Time Exceeded message -
ICMP Error message generation – Reason 1

Whenever a router decrements a datagram with a time-to-live value to zero, it discards the datagram and sends a time-exceeded message to the original source.

Note

Time Exceeded message -
ICMP Error message generation – Reason 2

When the final destination does not receive all of the fragments in a set time, it discards the received fragments and sends a time-exceeded message to the original source.

Time exceeded message :

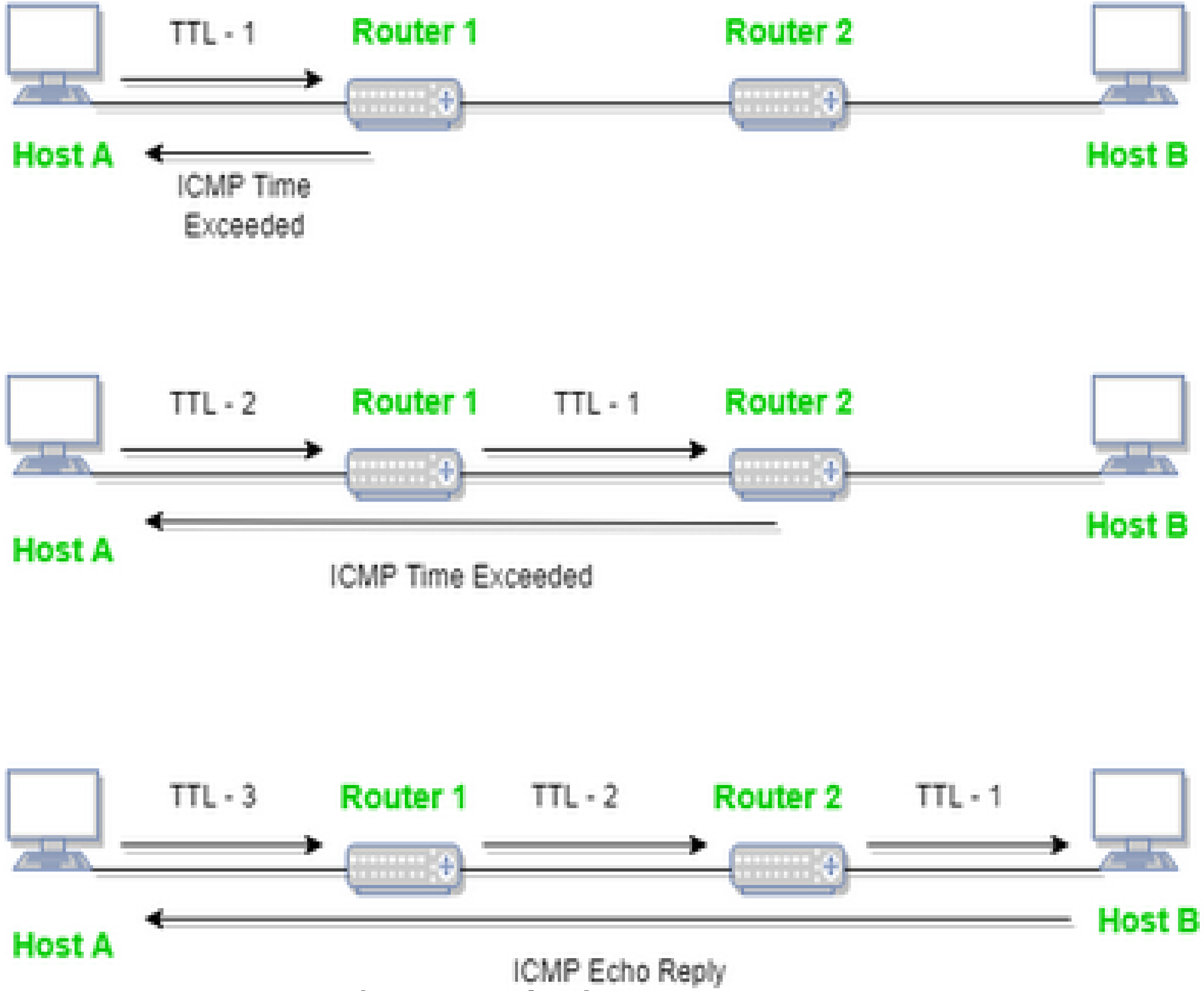
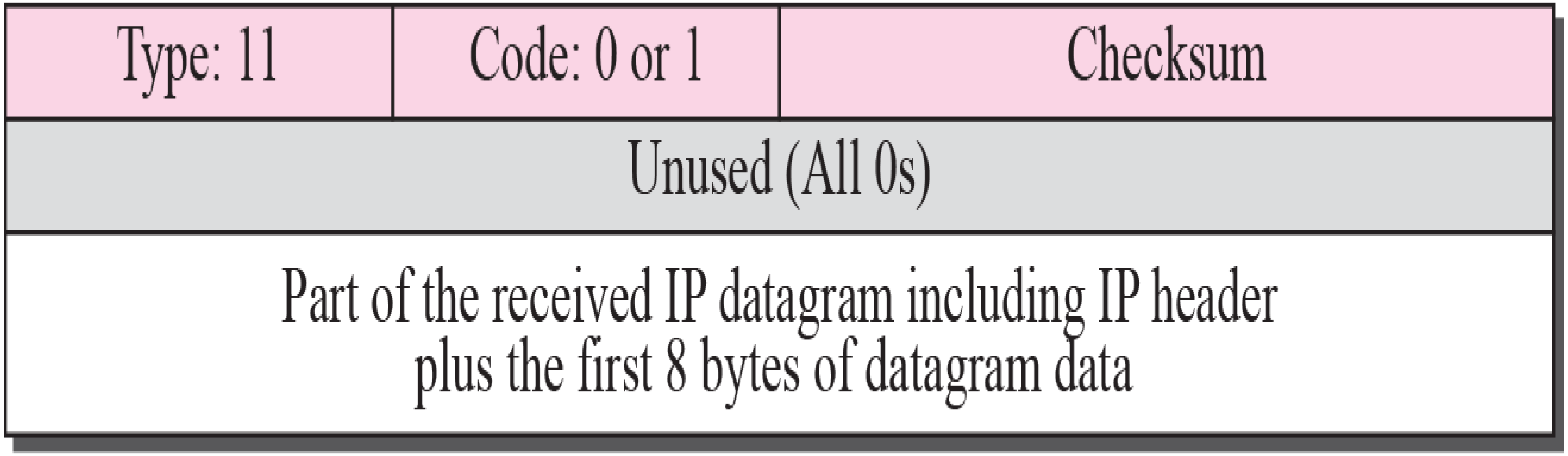


Figure 9.8 *Time-exceeded message format*



Note

In a time-exceeded message, code 0 is used only by routers to show that the value of the time-to-live field is zero.

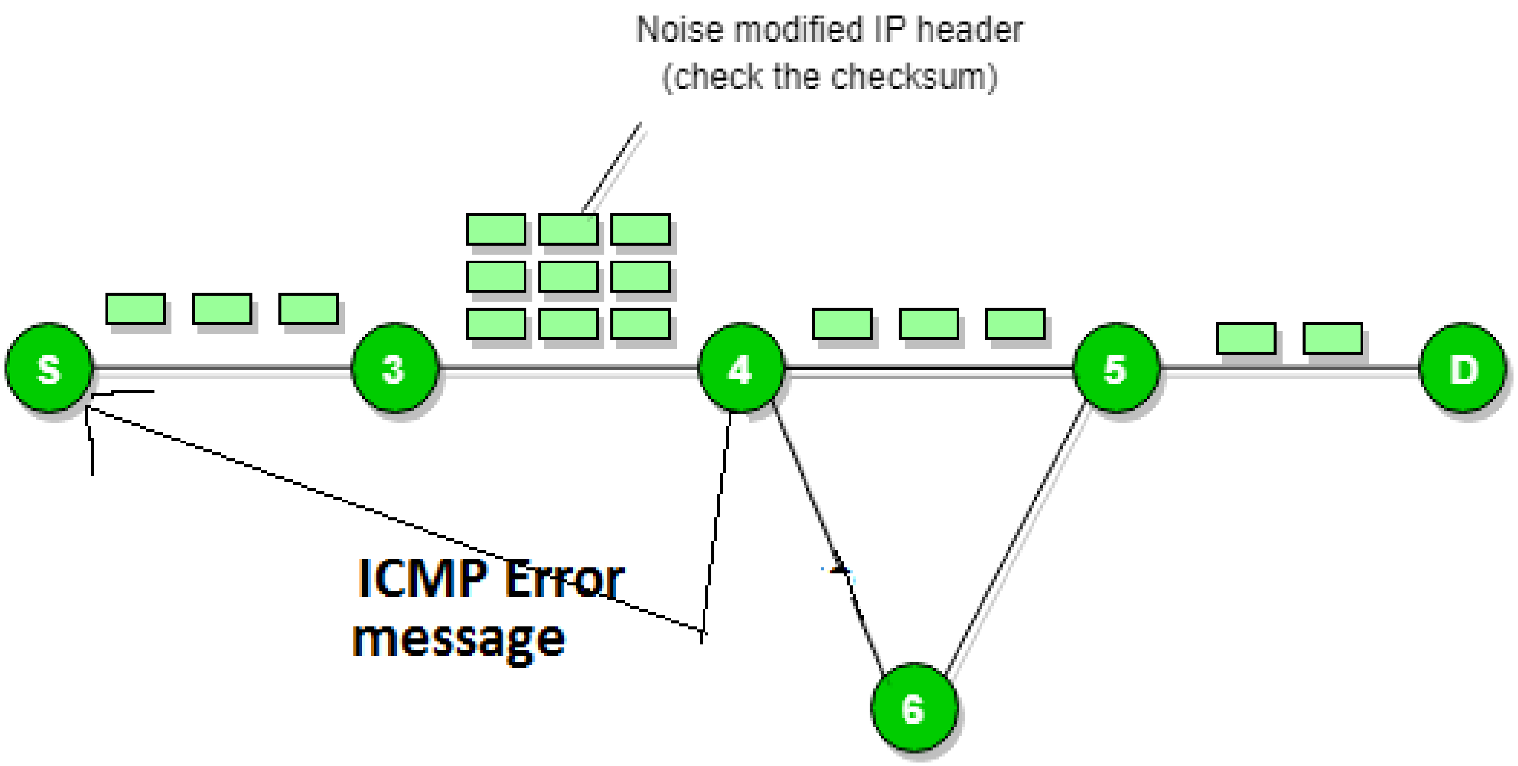
Code 1 is used only by the destination host to show that not all of the fragments have arrived within a set time.

Parameter problem message

Parameter Problem

- Two reasons for generating this ICMP error message
- **Reason 1:** Error or ambiguity in header field of IP datagram – code 0
- **Reason 2:** required part of an option messing – code 1

Parameter Problem



Note

A parameter-problem message can be created by a router or the destination host.

Figure 9.9 *Parameter-problem message format*

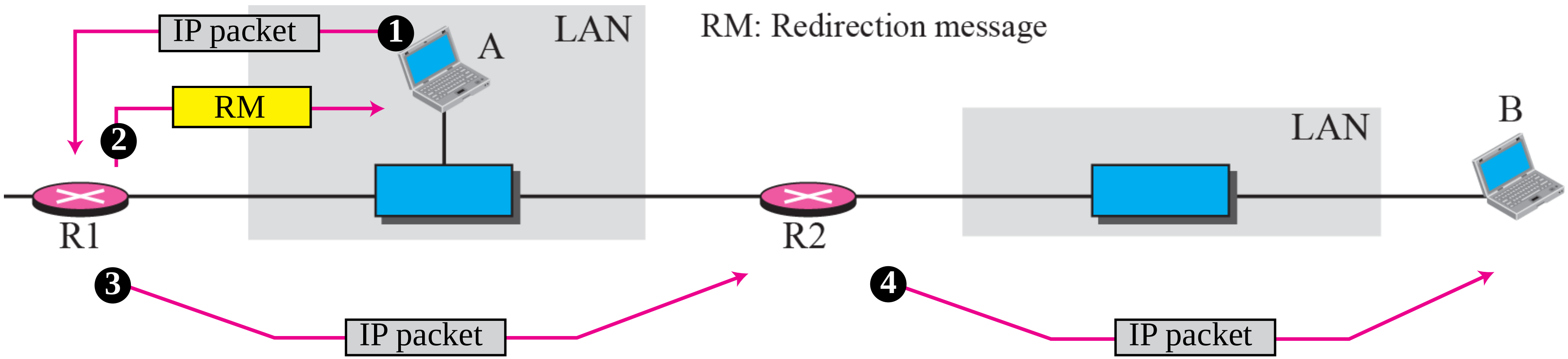
Type: 12	Code: 0 or 1	Checksum
Pointer	Unused (All 0s)	
Part of the received IP datagram including IP header plus the first 8 bytes of datagram data		

Redirection message

Redirection

- Not an error message. Provides additional information
- Routing tables maintained by routers are dynamic and accurate.
- Routing tables maintained by hosts are static (as hosts doesn't participate in routing process) and may not have accurate information.
- A host may send datagram to a wrong router R1.
- **Now R1 receives the datagram, but is able to forward the packet to next correct router R2.**
- **Also, R1 is benevolent and informs host that it (host) needs to update its routing table.**
- So ICMP redirection message is sent by R1 to host to help host to update routing table with correct entries.

Figure 9.10 *Redirection concept*



Note

A host usually starts with a small routing table that is gradually augmented and updated.

One of the tools to accomplish this is the redirection message.

Figure 9.11 *Redirection message format*

Type: 5	Code: 0 to 3	Checksum
IP address of the target router		
Part of the received IP datagram including IP header plus the first 8 bytes of datagram data		

Note

A redirection message is sent from a router to a host on the same local network.

ICMP Query messages

Query messages

- Echo request/Reply
- Timestamp Request/Reply

Echo request/Reply

- Designed for diagnostic purposes

- Network managers utilize this pair of messages to identify network problems

Note

An echo-request message can be sent by a host or router.

An echo-reply message is sent by the host or router that receives an echo-request message.

Note

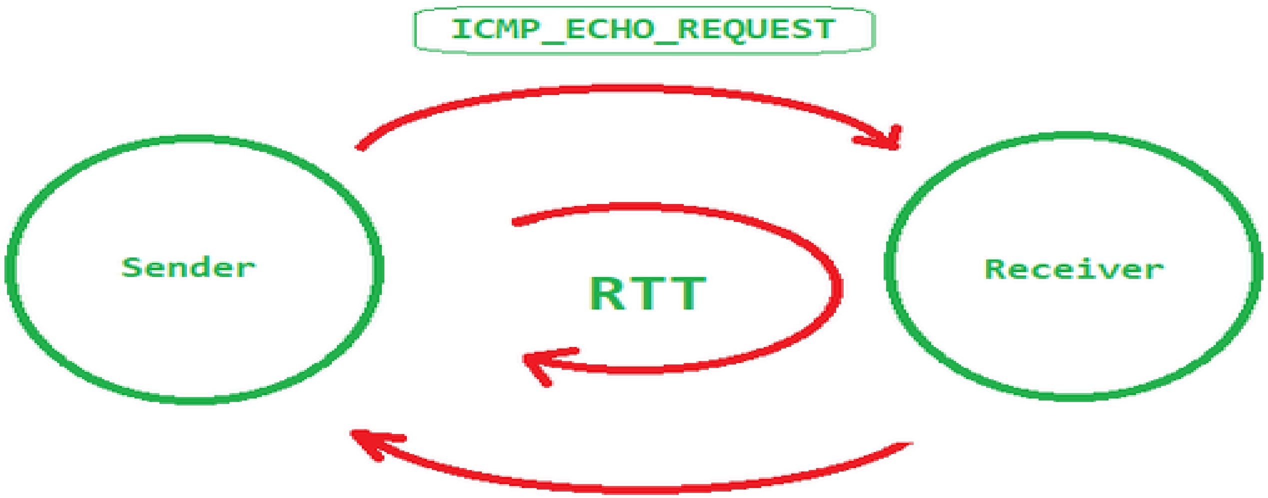
Echo-request and echo-reply messages can be used by network managers to check the operation of the IP protocol.

Note

Echo-request and echo-reply messages can test the reachability of a host.

This is usually done by invoking the ping command.

Echo request/Reply



- ❑ **Designed for diagnostic purposes**
- ❑ **Network managers utilize these pair of messages to identify network problems.**
- ❑ **Used to determine if two systems can communicate with each other (eg., PING Network utility)**

Ping command

- **Round Trip Time (RTT)** is the length of the time it takes for a **data packet to be sent to a destination plus the time it takes for an acknowledgment of that packet to be received back at the origin**.

- The RTT between a network and server can be determined by using the ping command.

Figure 9.12 *Echo-request and echo-reply message*

Often same as Process ID

Type 8: Echo request
Type 0: Echo reply

Type: 8 or 0	Code: 0	Checksum
Identifier		Sequence number
Optional data Sent by the request message; repeated by the reply message		

Timestamp Request/Reply

Timestamp Request/Reply

- Timestamp-request and timestamp-reply messages can be used to calculate the round-trip time between a source and a destination machine

- It can be used to synchronize clocks in two machines

Figure 9.13 *Timestamp-request and timestamp-reply message format*

Type 13: request
Type 14: reply

Type: 13 or 14	Code: 0	Checksum
Identifier		Sequence number
Original timestamp		
Receive timestamp		
Transmit timestamp		

Round Trip Time needed for an IP datagram to travel between two hosts can be computed using this message.

Returned time: Time of receiving 'Response packet' at source

Sending time = receive timestamp – original timestamp
Receiving time = returned time – transmit timestamp
Round-Trip time = sending time + receiving time

Accuracy of RTT calculation

- Sending time = receive timestamp – original timestamp
- Receiving time = returned time – transmit timestamp
- Round-Trip time = sending time + receiving time

- **Sending time and receiving time** – requires both source and destination clocks to be synchronized to be accurate

- **RTT** – Accurate even **if two clocks are not synchronized** since each clock contributes twice to RTT calculation, thus cancelling any difference in synchronization

Note

Timestamp-request and timestamp-reply messages can be used to calculate the round-trip time between a source and a destination machine even if their clocks are not synchronized.

Note

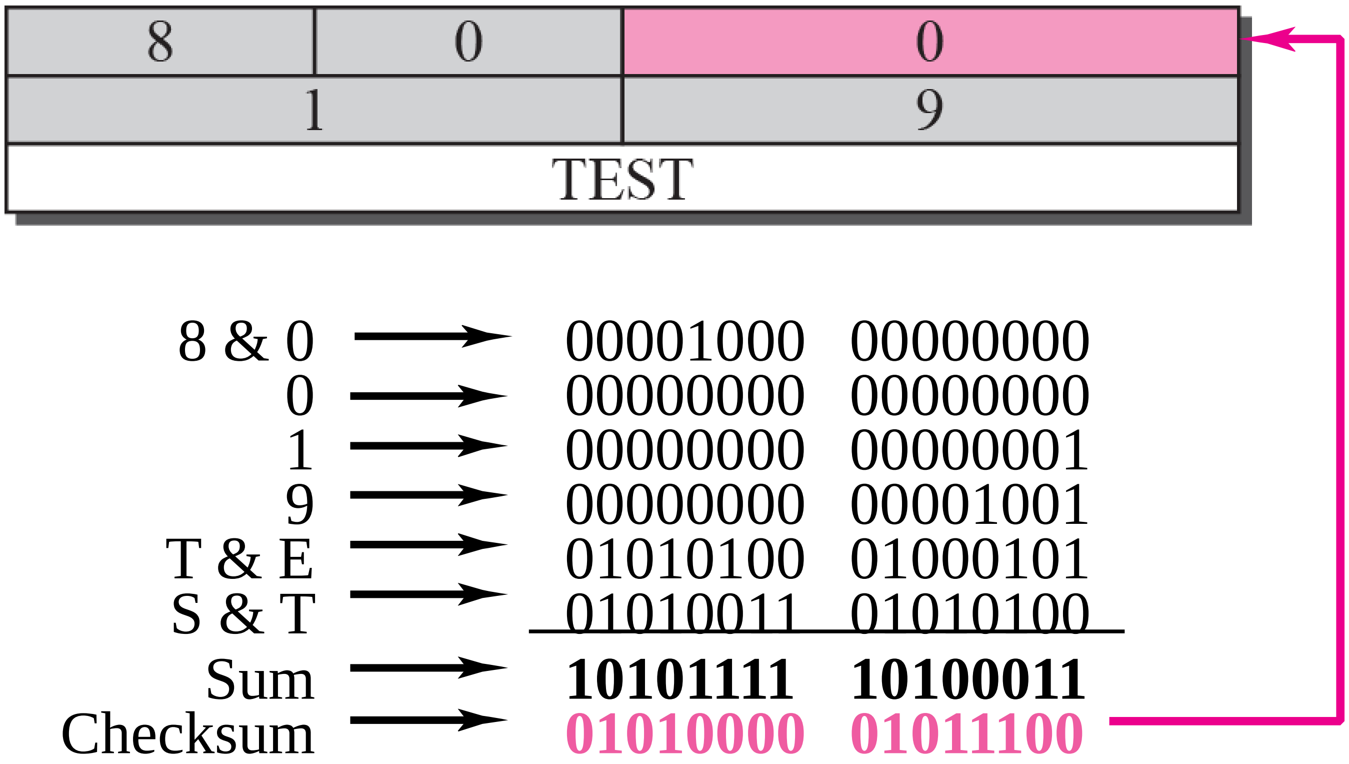
The timestamp-request and timestamp-reply messages can be used to synchronize two clocks in two machines if the exact one-way time duration is known.

Example 9.1

Figure 9.14 shows an example of checksum calculation for a simple echo-request message (see Figure 9.12). We randomly chose the identifier to be 1 and the sequence number to be 9. The message is divided into 16-bit (2-byte) words. The words are added together and the sum is complemented. Now the sender can put this value in the checksum field.

Checksum computed on ICMP header and data

Figure 9.14 *Example of checksum calculation*



9-3 DEBUGGING TOOLS

There are several tools that can be used in the Internet for debugging. We can find if a host or router is alive and running. We can trace the route of a packet. We introduce two tools that use ICMP for debugging: ping and traceroute. We will introduce more tools in future chapters after we have discussed the corresponding protocols.

Topics Discussed in the Section

- ✓ **Ping**
- ✓ **Traceroute**

Example 9.2

We use the ping program to test the server fhda.edu. The result is shown below:

```
$ ping fhda.edu
PING fhda.edu (153.18.8.1)    56 (84)  bytes of data.
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=0    ttl=62    time=1.91 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=1    ttl=62    time=2.04 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=2    ttl=62    time=1.90 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=3    ttl=62    time=1.97 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=4    ttl=62    time=1.93 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=5    ttl=62    time=2.00 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=6    ttl=62    time=1.94 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=7    ttl=62    time=1.94 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=8    ttl=62    time=1.97 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=9    ttl=62    time=1.89 ms
64 bytes from tiptoe.fhda.edu (153.18.8.1): icmp_seq=10   ttl=62    time=1.98 ms

--- fhda.edu ping statistics ---
11 packets transmitted, 11 received, 0% packet loss, time 10103 ms
rtt min/avg/max = 1.899/1.955/2.041 ms
```

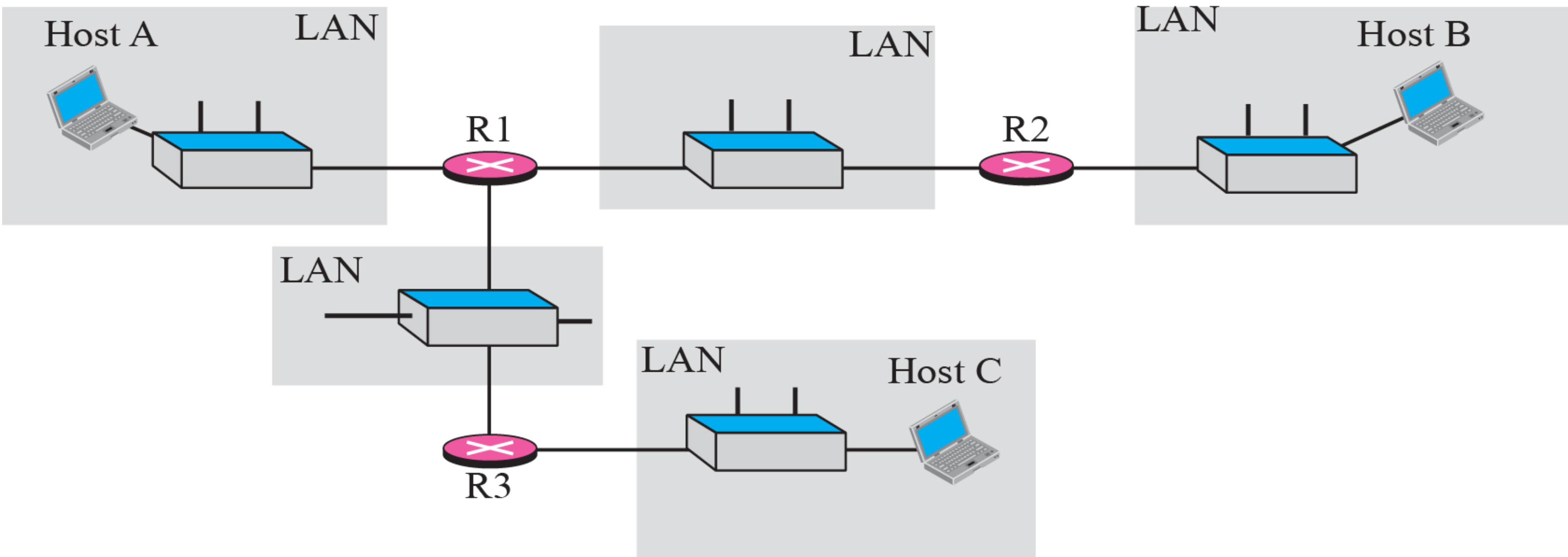
Example 9.3

For the second example, we want to know if the adelphia.net mail server is alive and running. The result is shown below: Note that in this case, we sent 14 packets, but only 13 have been returned. We may have interrupted the program before the last packet, with sequence number 13, was returned.

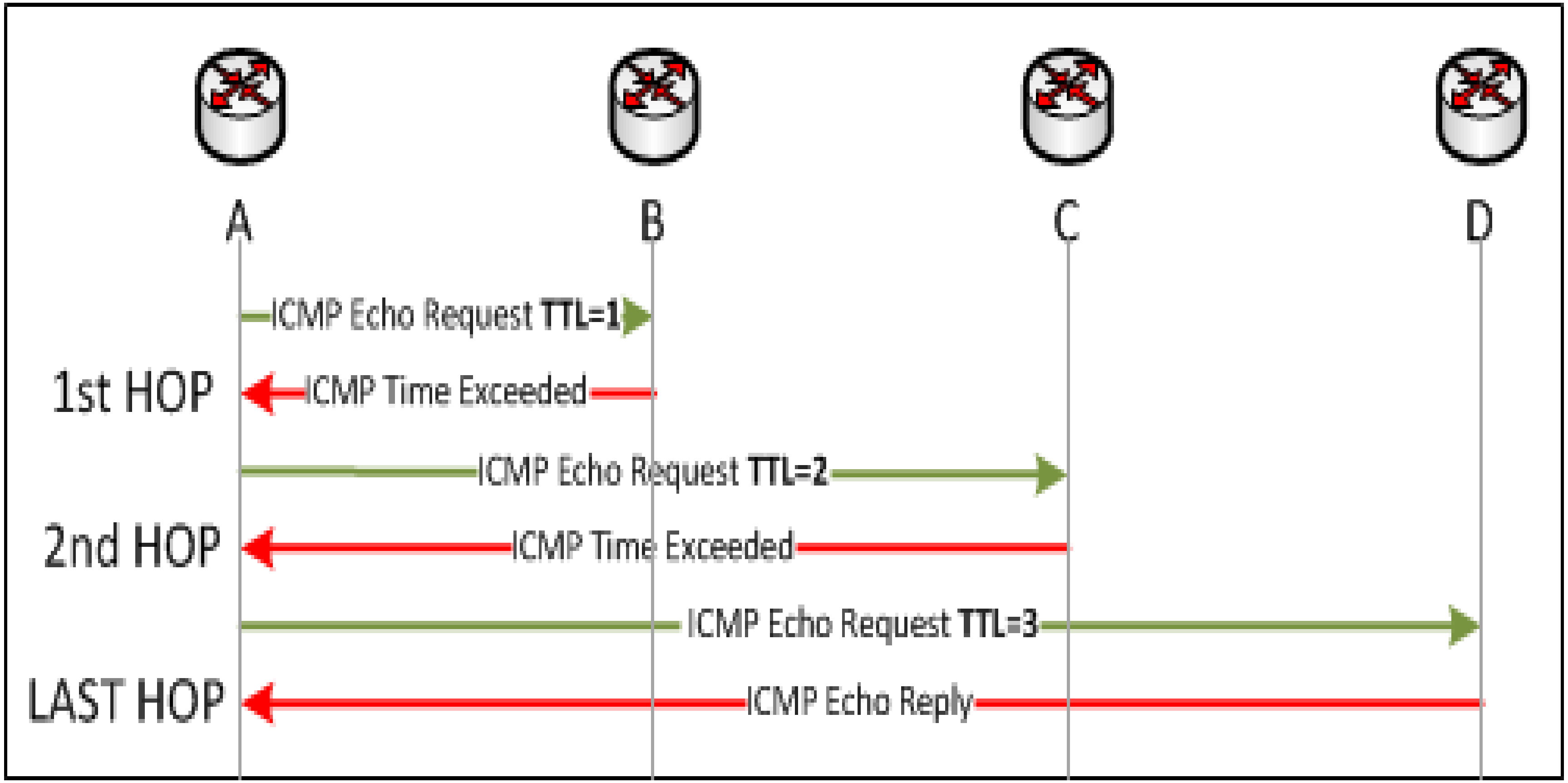
```
$ ping mail.adelphia.net
PING mail.adelphia.net (68.168.78.100) 56(84) bytes of data.
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=0   ttl=48   time=85.4 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=1   ttl=48   time=84.6 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=2   ttl=48   time=84.9 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=3   ttl=48   time=84.3 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=4   ttl=48   time=84.5 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=5   ttl=48   time=84.7 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=6   ttl=48   time=84.6 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=7   ttl=48   time=84.7 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=8   ttl=48   time=84.4 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=9   ttl=48   time=84.2 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=10  ttl=48   time=84.9 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=11  ttl=48   time=84.6 ms
64 bytes from mail.adelphia.net (68.168.78.100): icmp_seq=12  ttl=48   time=84.5 ms

--- mail.adelphia.net ping statistics ---
14 packets transmitted, 13 received, 7% packet loss, time 13129 ms
rtt min/avg/max/mdev = 84.207/84.694/85.469
```

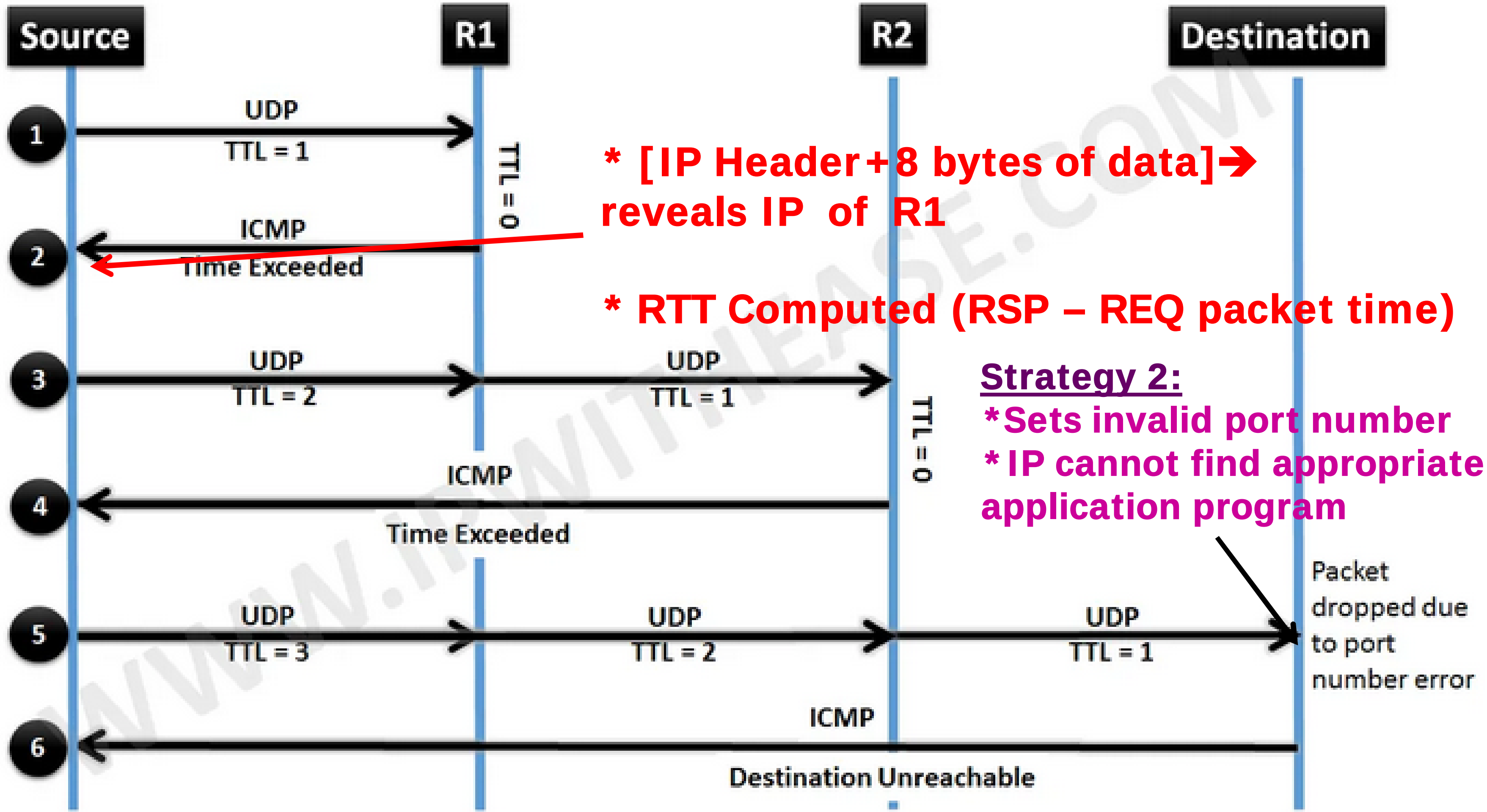
Figure 9.15 *The traceroute program operation*



Traceroute Implementation
Method -1 “tracert” utility in windows



Traceroute Implementation
Method -2



*** Each set of communication happens 3 times i.e. Set 1&2 , Set 3 &4 and Set 5&6

Example 9.4

We use the traceroute program to find the route from the computer voyager.deanza.edu to the server fhda.edu. The following shows the result.

```
$ traceroute fhda.edu
traceroute to fhda.edu       (153.18.8.1), 30 hops max, 38 byte packets
1  Dcore.fhda.edu       (153.18.31.25)   0.995 ms   0.899 ms   0.878 ms
2  Dbackup.fhda.edu     (153.18.251.4)   1.039 ms   1.064 ms   1.083 ms
3  tiptoe.fhda.edu      (153.18.8.1)     1.797 ms   1.642 ms   1.757 ms
```

Example 9.5

In this example, we trace a longer route, the route to xerox.com. The following is a partial listing.

```
$ traceroute xerox.com
```

traceroute to xerox.com (13.1.64.93), 30 hops max, 38 byte packets

1	Dcore.fhda.edu	(153.18.31.254)	0.622 ms	0.891 ms	0.875 ms
2	Ddmz.fhda.edu	(153.18.251.40)	2.132 ms	2.266 ms	2.094 ms
3	Cinic.fhda.edu	(153.18.253.126)	2.110 ms	2.145 ms	1.763 ms
4	cenic.net	(137.164.32.140)	3.069 ms	2.875 ms	2.930 ms
5	cenic.net	(137.164.22.31)	4.205 ms	4.870 ms	4.197 ms
6	cenic.net	(137.164.22.167)	4.250 ms	4.159 ms	4.078 ms
7	cogentco.com	(38.112.6.225)	5.062 ms	4.825 ms	5.020 ms
8	cogentco.com	(66.28.4.69)	6.070 ms	6.207 ms	5.653 ms
9	cogentco.com	(66.28.4.94)	6.070 ms	5.928 ms	5.499 ms

Example 9.6

An interesting point is that a host can send a traceroute packet to itself. This can be done by specifying the host as the destination. The packet goes to the loopback address as we expect.

```
$ traceroute voyager.deanza.edu
traceroute to voyager.deanza.edu   (127.0.0.1), 30 hops max, 38 byte packets
1  voyager          (127.0.0.1)          0.178 ms          0.086 ms          0.055 ms
```

Example 9.7

Finally, we use the traceroute program to find the route between fhda.edu and mhhe.com (McGraw-Hill server). We notice that we cannot find the whole route. When traceroute does not receive a response within 5 seconds, it prints an asterisk to signify a problem (not the case in this example), and then tries the next hop.

```
$ traceroute mhhe.com
traceroute to mhhe.com (198.45.24.104), 30 hops max, 38 byte packets
1   Dcore.fhda.edu       (153.18.31.254)      1.025 ms    0.892 ms    0.880 ms
2   Ddmz.fhda.edu        (153.18.251.40)      2.141 ms    2.159 ms    2.103 ms
3   Cinic.fhda.edu       (153.18.253.126)     2.159 ms    2.050 ms    1.992 ms
4   cenic.net            (137.164.32.140)     3.220 ms    2.929 ms    2.943 ms
5   cenic.net            (137.164.22.59)      3.217 ms    2.998 ms    2.755 ms
6   SanJose1.net         (209.247.159.109)   10.653 ms   10.639 ms   10.618 ms
7   SanJose2.net         (64.159.2.1)        10.804 ms   10.798 ms   10.634 ms
8   Denver1.Level3.net   (64.159.1.114)      43.404 ms   43.367 ms   43.414 ms
9   Denver2.Level3.net   (4.68.112.162)      43.533 ms   43.290 ms   43.347 ms
10  unknown              (64.156.40.134)     55.509 ms   55.462 ms   55.647 ms
11  mcleodusa1.net       (64.198.100.2)      60.961 ms   55.681 ms   55.461 ms
12  mcleodusa2.net       (64.198.101.202)    55.692 ms   55.617 ms   55.505 ms
13  mcleodusa3.net       (64.198.101.142)    56.059 ms   55.623 ms   56.333 ms
14  mcleodusa4.net       (209.253.101.178)  297.199 ms  192.790 ms  250.594 ms
15  eppg.com             (198.45.24.246)     71.213 ms   70.536 ms   70.663 ms
16  ...                  ...                 ...         ...         ...
```