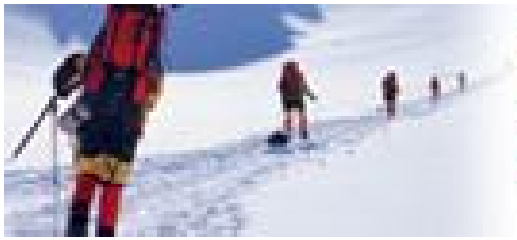


Data Communications and Networking Fourth Edition

Forouzan

# Chapter 23

# Process-to-Process Delivery: UDP, TCP, and SCTP

# 23-1 PROCESS-TO-PROCESS DELIVERY

***The transport layer is responsible for process-to-process delivery—the delivery of a packet, part of a message, from one process to another. Two processes communicate in a client/server relationship, as we will see later.***

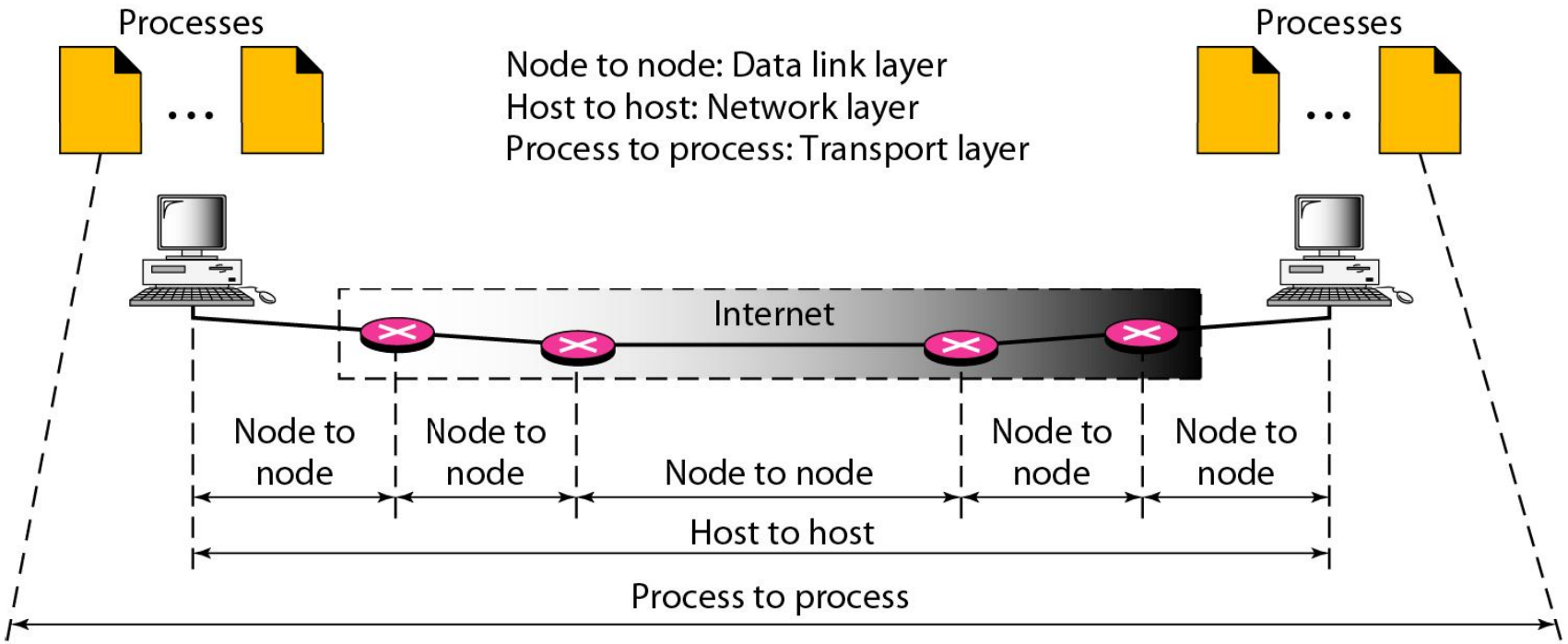
***Topics discussed in this section:***

**Client/Server Paradigm**
**Multiplexing and Demultiplexing**
**Connectionless Versus Connection-Oriented Service**
**Reliable Versus Unreliable**
**Three Protocols**

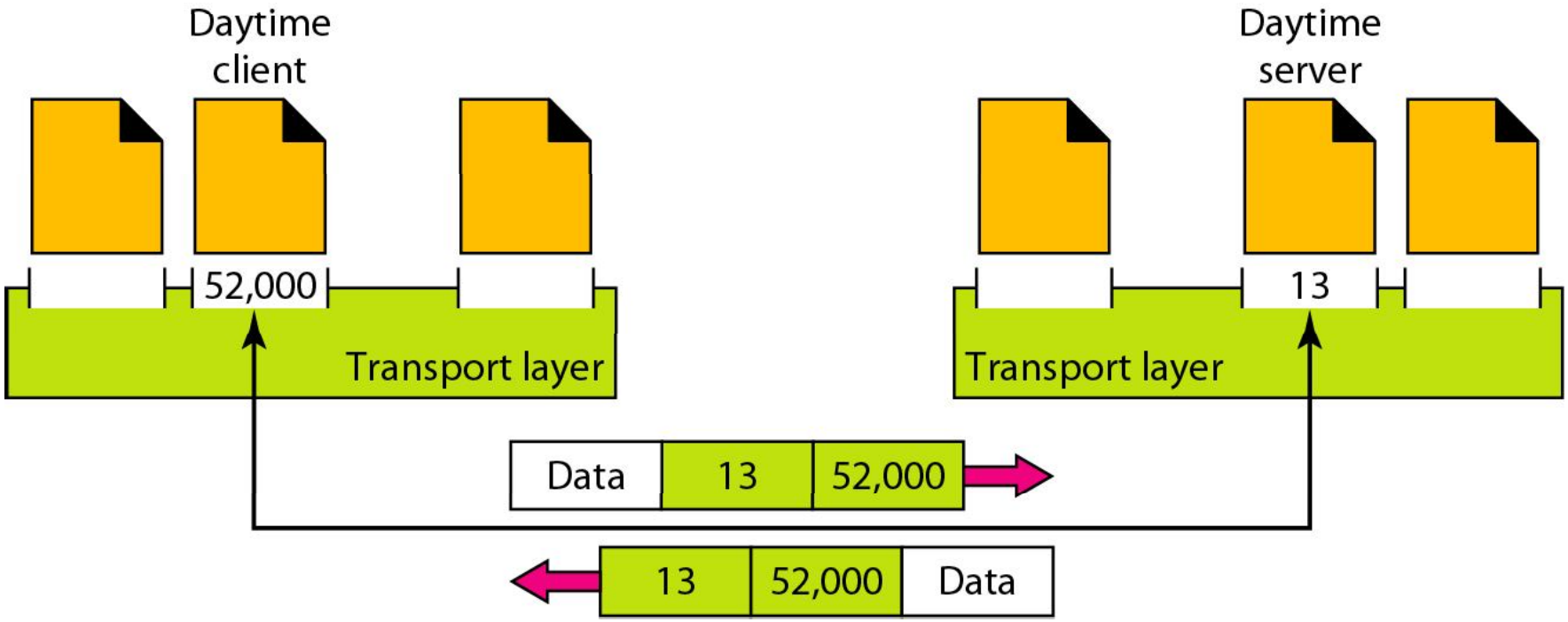
**Note**

**The transport layer is responsible for process-to-process delivery.**

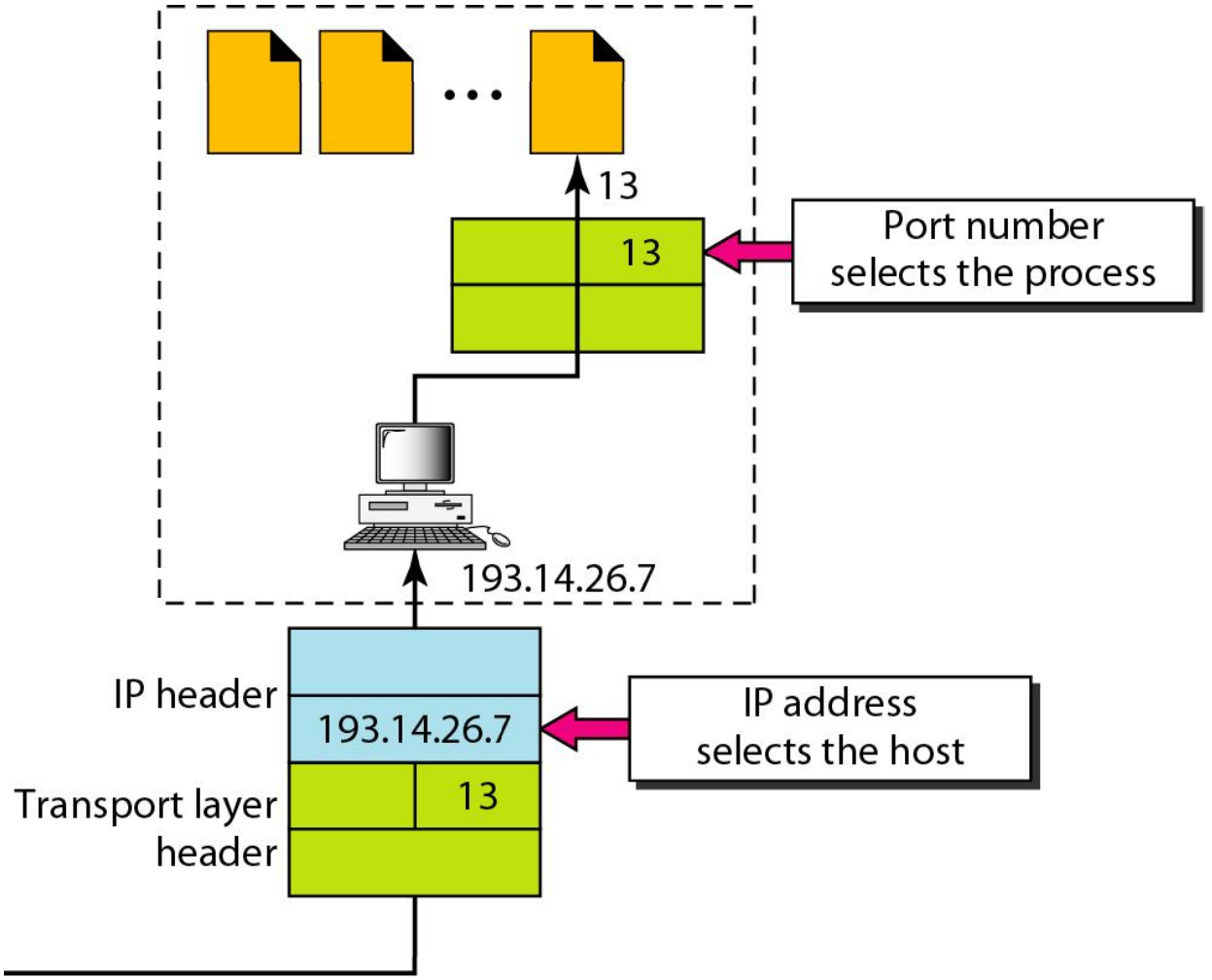
## Figure 23.1 *Types of data deliveries*



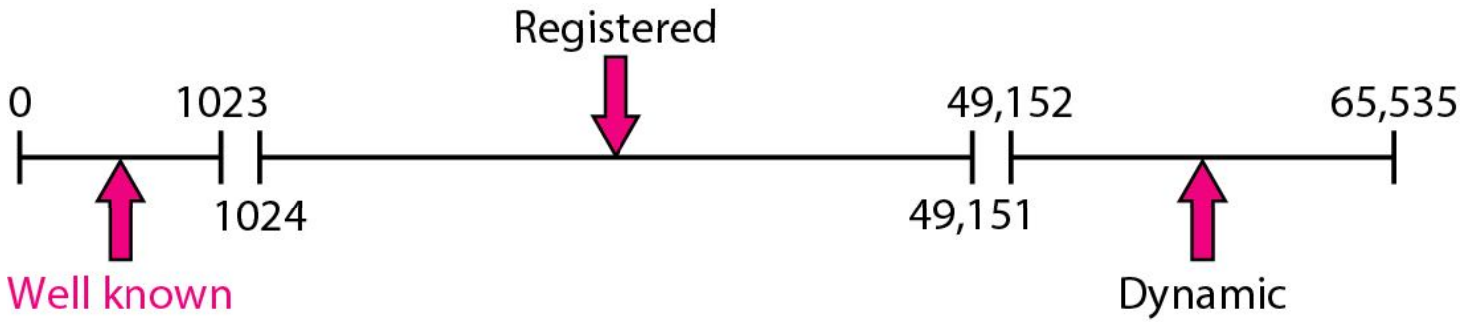
## Figure 23.2 *Port numbers*



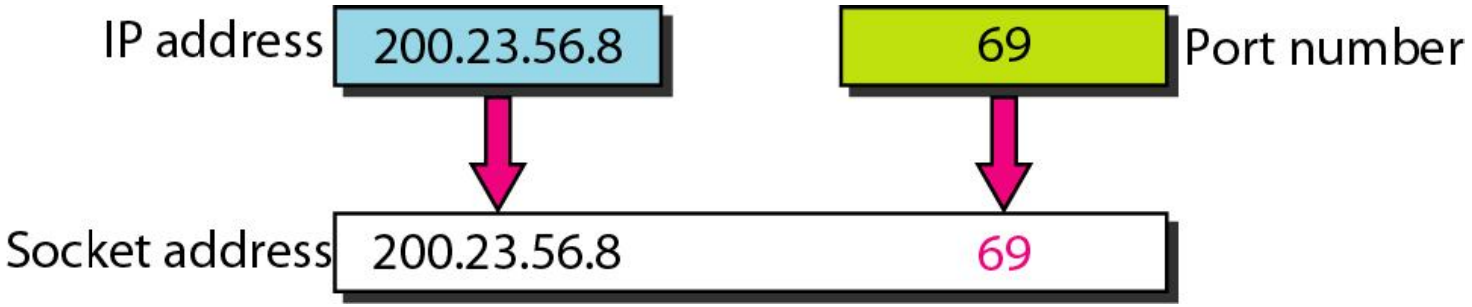
## Figure 23.3 *IP addresses versus port numbers*



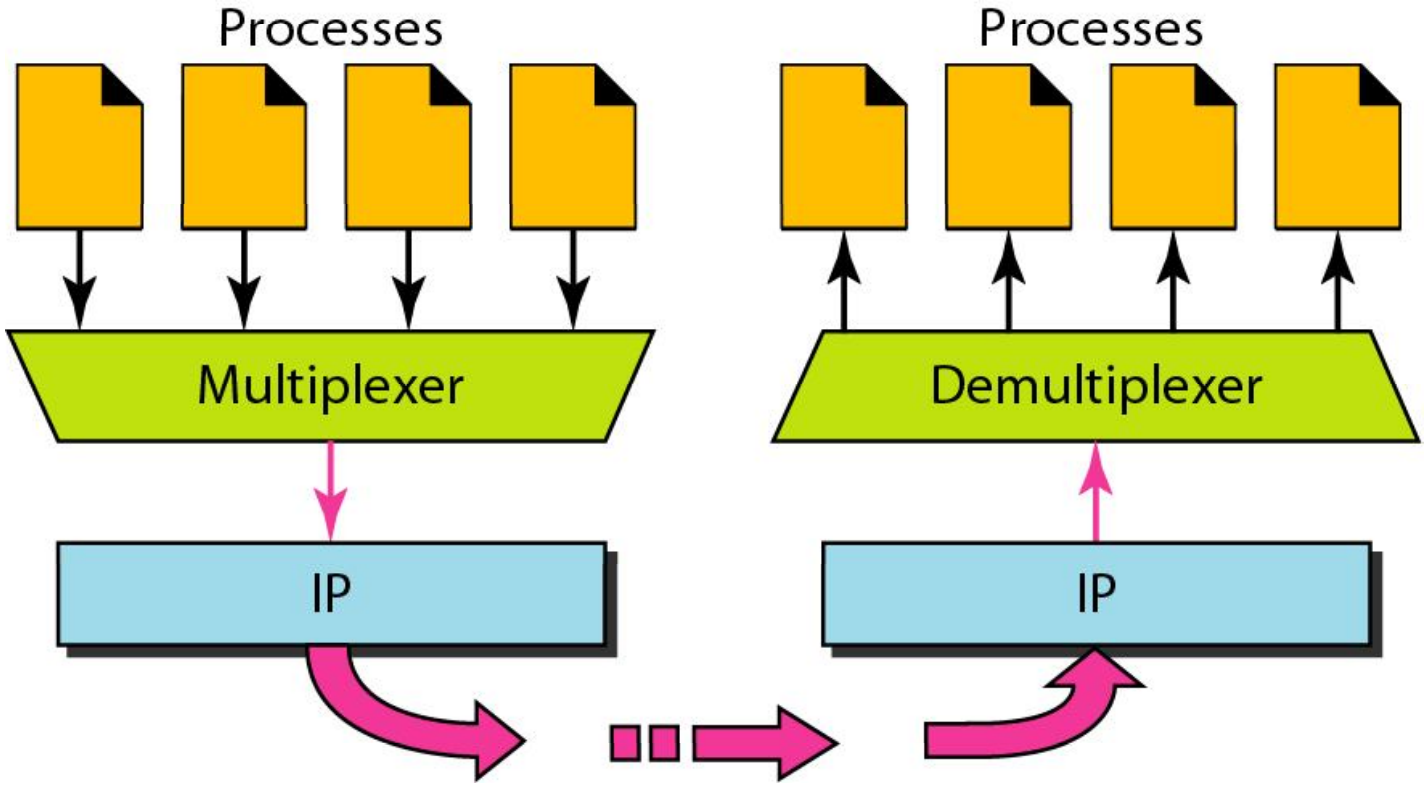
## Figure 23.4 *IANA ranges*



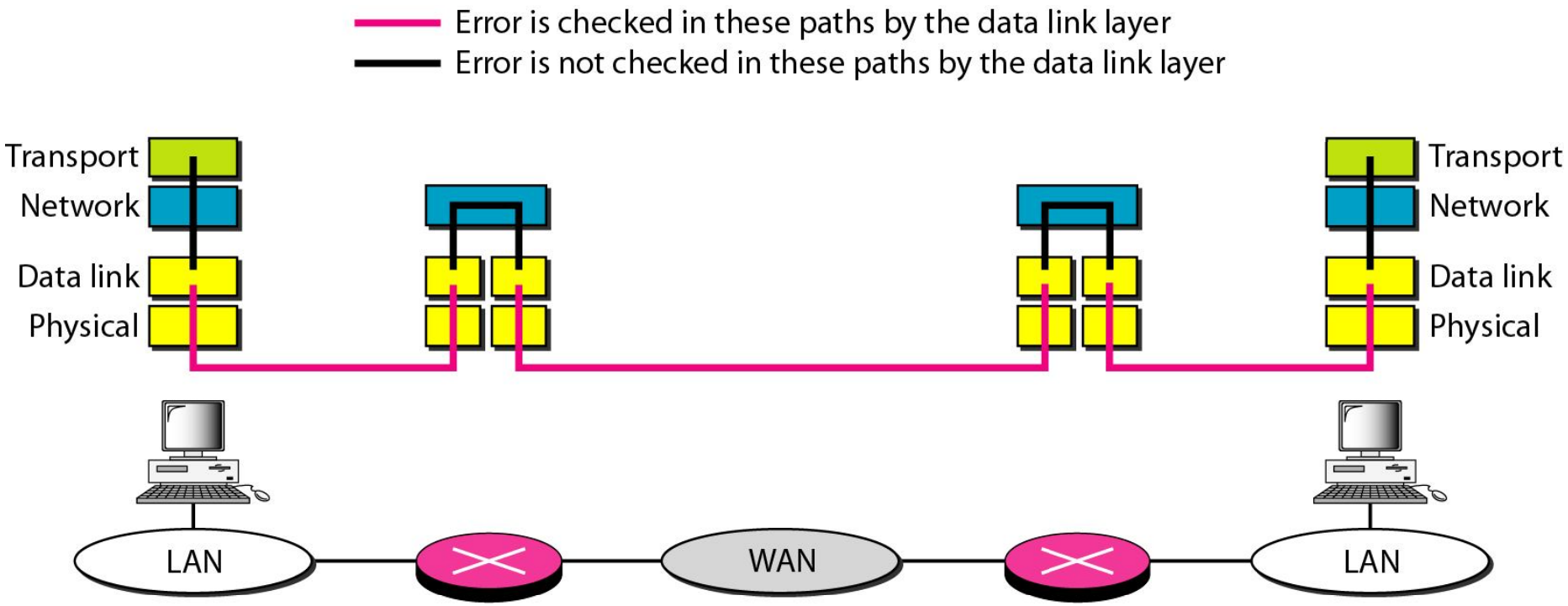
## Figure 23.5 *Socket address*



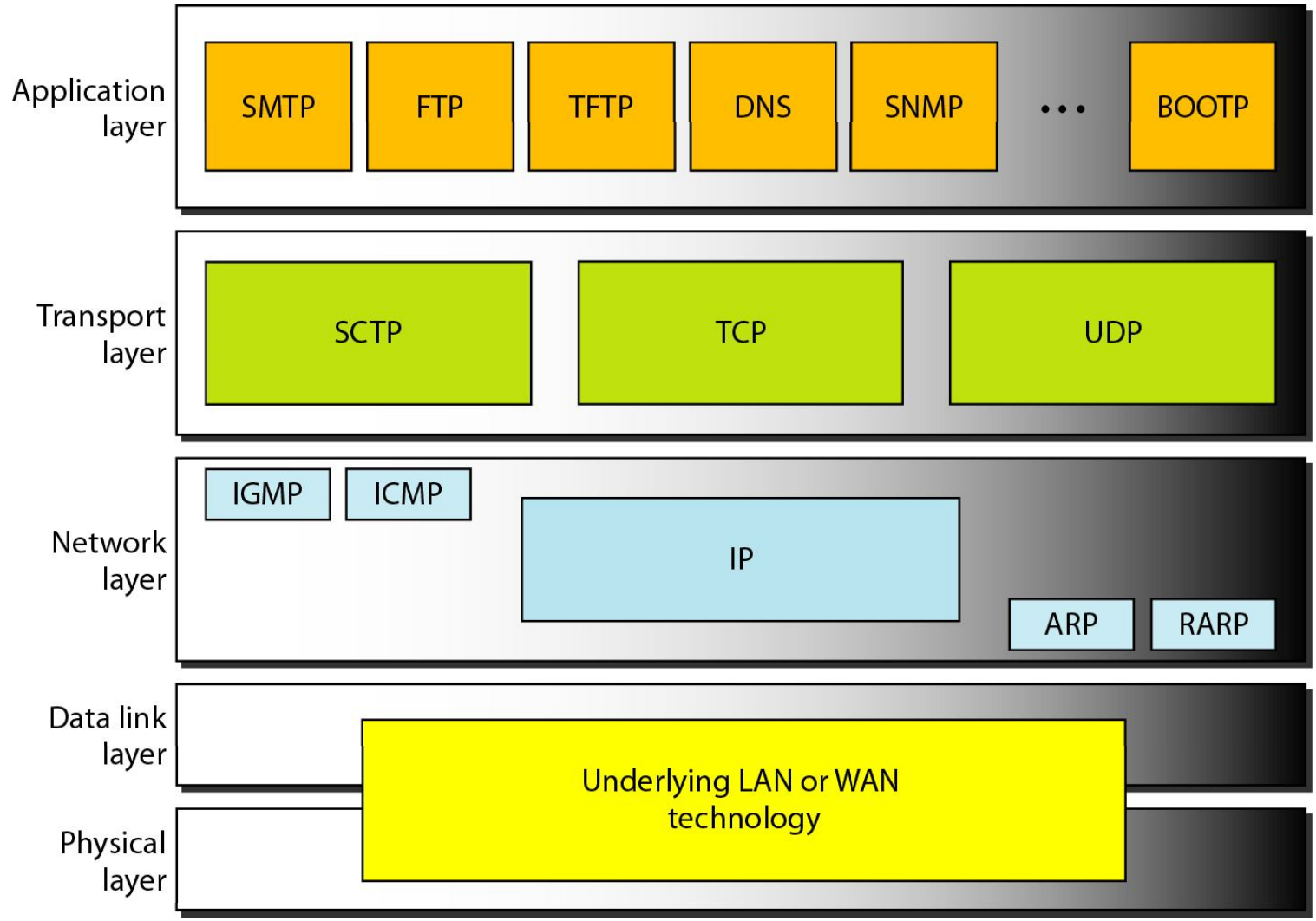
## Figure 23.6 *Multiplexing and demultiplexing*



## Figure 23.7 *Error control*



## Figure 23.8 *Position of UDP, TCP, and SCTP in TCP/IP suite*



# 23-2 USER DATAGRAM PROTOCOL (UDP)

***The User Datagram Protocol (UDP) is called a connectionless, unreliable transport protocol. It does not add anything to the services of IP except to provide process-to-process communication instead of host-to-host communication.***

***Topics discussed in this section:***

**Well-Known Ports for UDP**
**User Datagram**
**Checksum**
**UDP Operation**
**Use of UDP**

## Table 23.1 *Well-known ports used with UDP*

| *Port* | *Protocol* | *Description* |
|---|---|---|
| 7 | Echo | Echoes a received datagram back to the sender |
| 9 | Discard | Discards any datagram that is received |
| 11 | Users | Active users |
| 13 | Daytime | Returns the date and the time |
| 17 | Quote | Returns a quote of the day |
| 19 | Chargen | Returns a string of characters |
| 53 | Nameserver | Domain Name Service |
| 67 | BOOTPs | Server port to download bootstrap information |
| 68 | BOOTPc | Client port to download bootstrap information |
| 69 | TFTP | Trivial File Transfer Protocol |
| 111 | RPC | Remote Procedure Call |
| 123 | NTP | Network Time Protocol |
| 161 | SNMP | Simple Network Management Protocol |
| 162 | SNMP | Simple Network Management Protocol (trap) |

# Example 23.1

*In UNIX, the well-known ports are stored in a file called /etc/services. Each line in this file gives the name of the server and the well-known port number. We can use the grep utility to extract the line corresponding to the desired application. The following shows the port for FTP. Note that FTP can use port 21 with either UDP or TCP.*

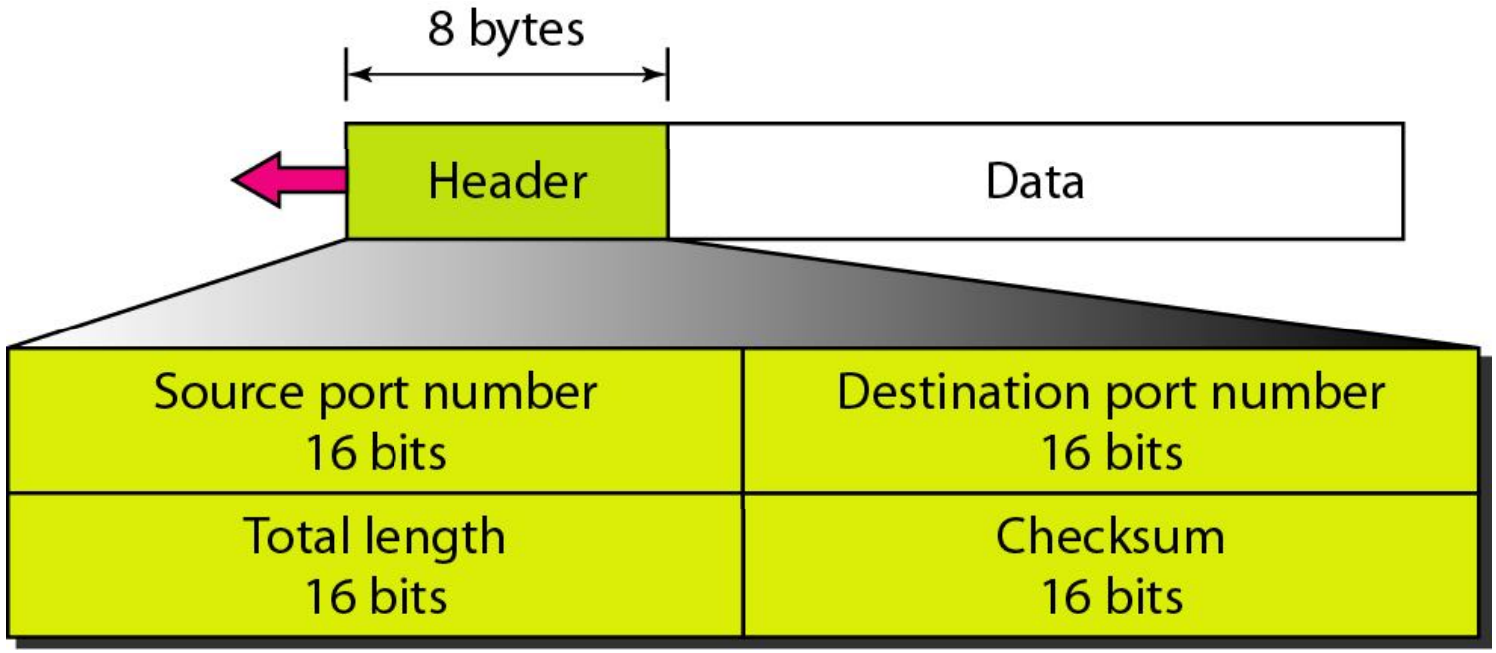
```
$ grep    ftp   /etc/services
ftp          21/tcp
ftp          21/udp
```

# Example 23.1 (continued)

***SNMP uses two port numbers (161 and 162), each for a different purpose, as we will see in Chapter 28.***

```
$ grep      snmp /etc/services
snmp            161/tcp         #Simple Net  Mgmt Proto
snmp            161/udp         #Simple Net  Mgmt Proto
snmptrap        162/udp         #Traps for SNMP
```

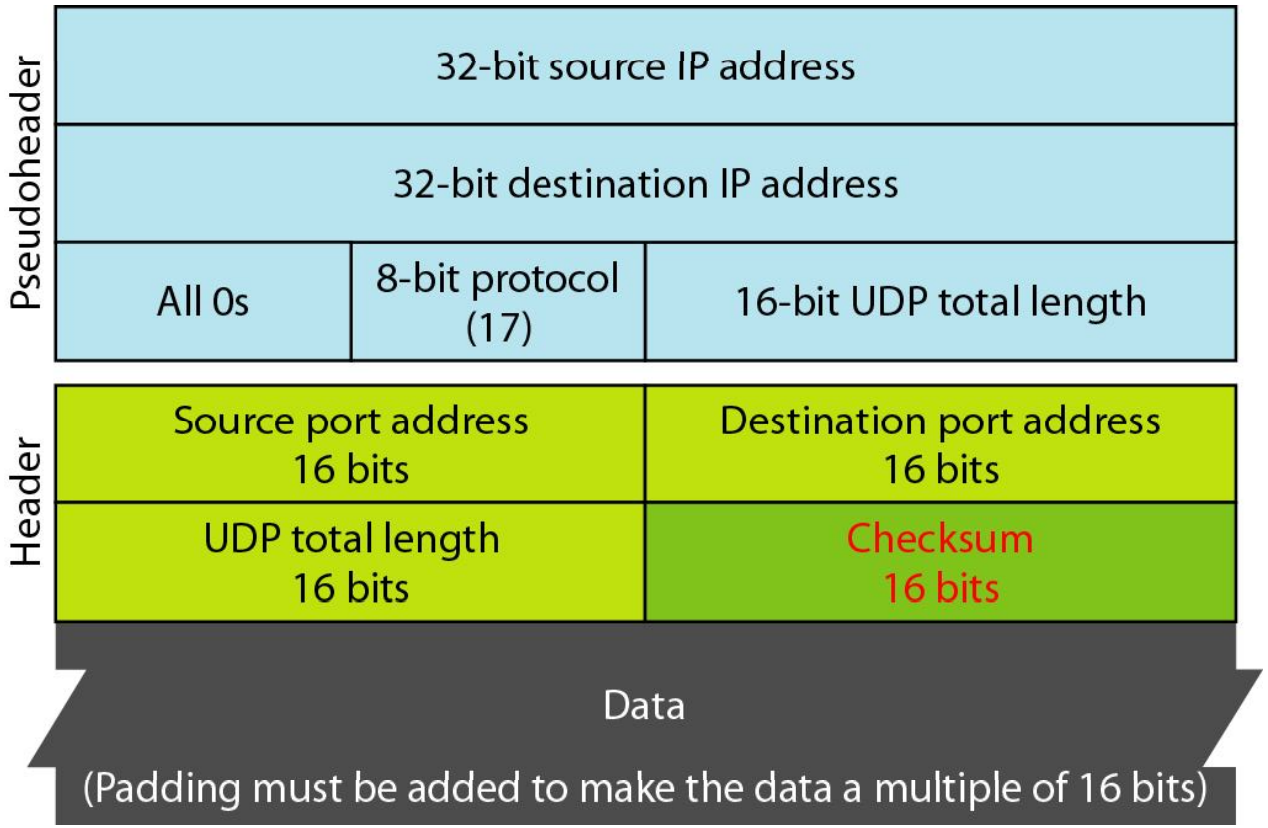
## Figure 23.9 *User datagram format*

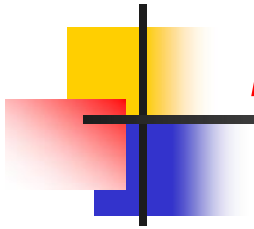


Note

**UDP length**
**= IP length – IP header's length**

## Figure 23.10 *Pseudoheader for checksum calculation*

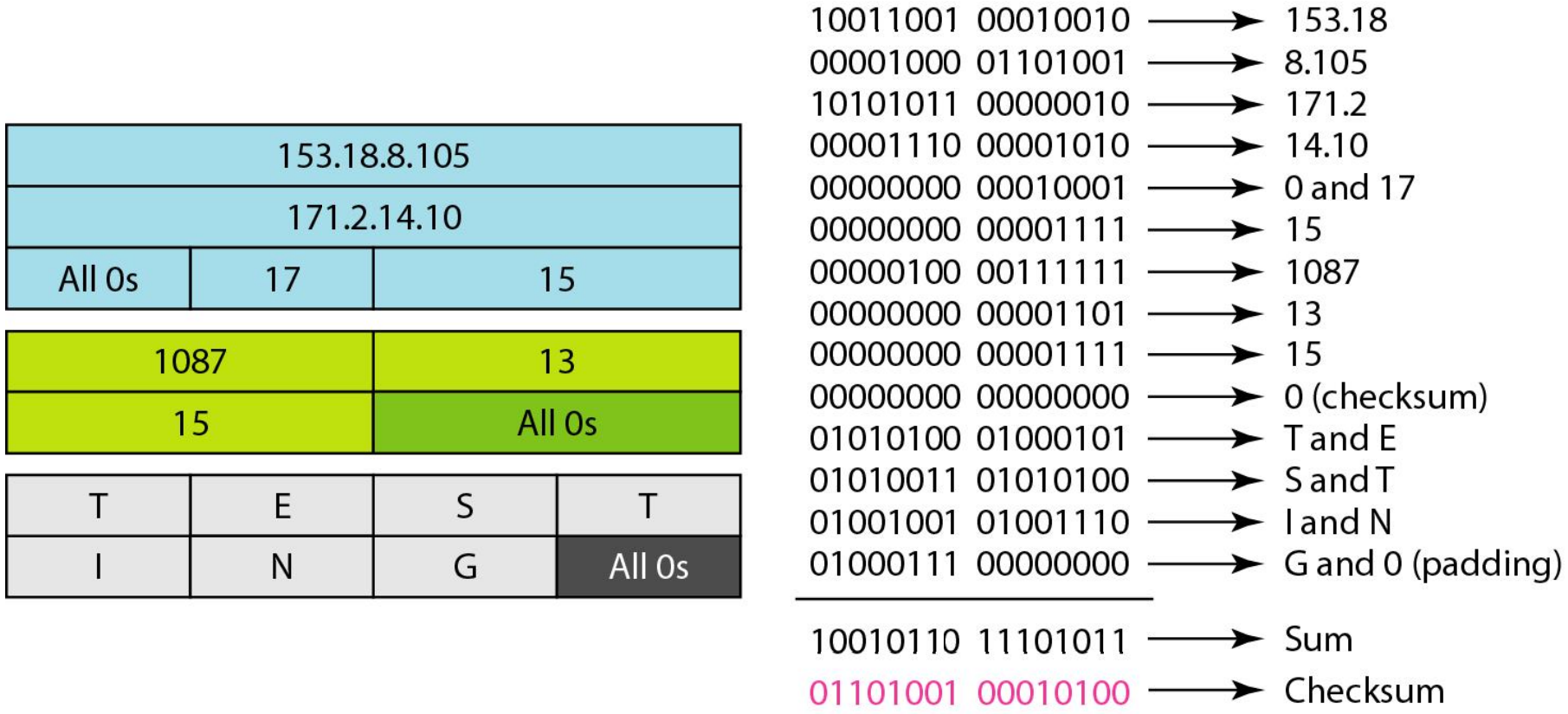




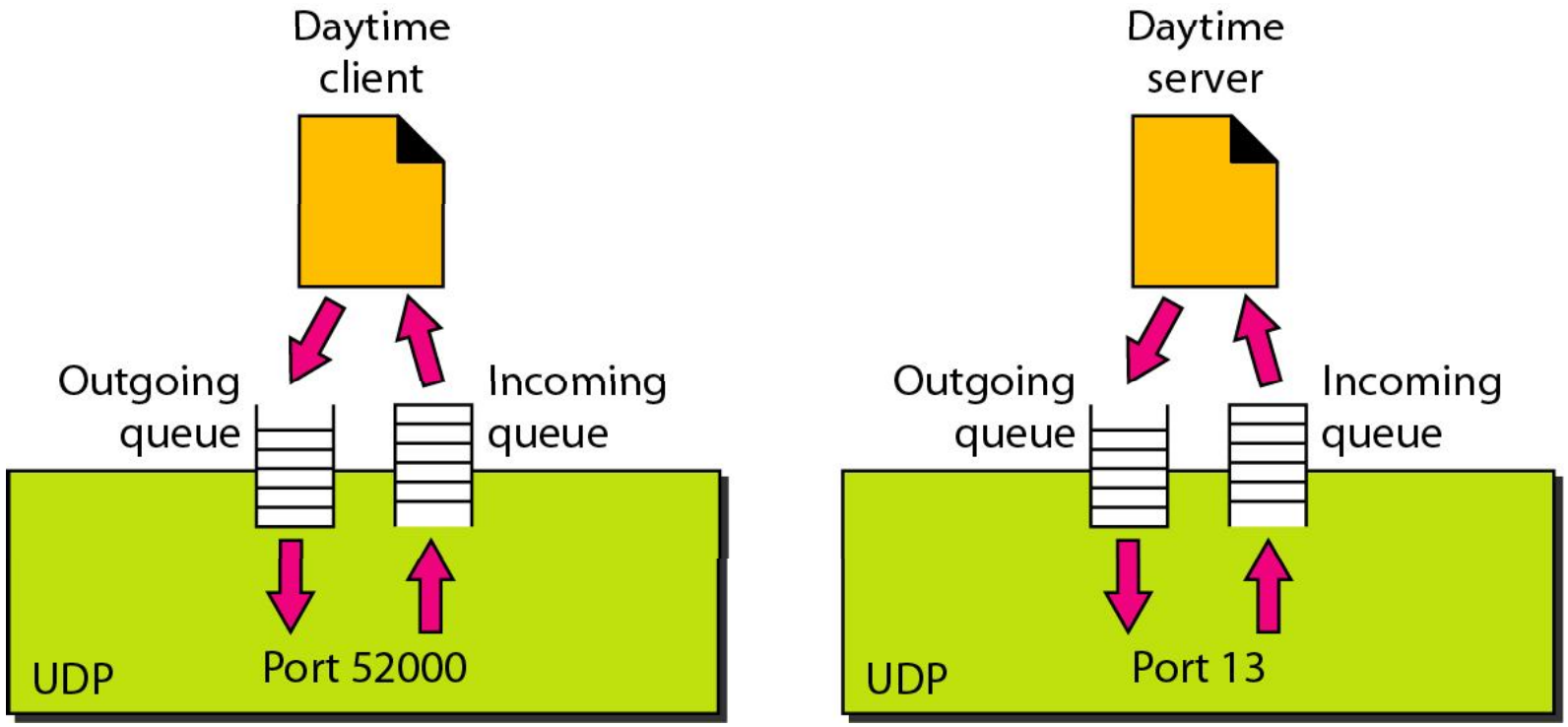
# Example 23.2

*Figure 23.11 shows the checksum calculation for a very small user datagram with only 7 bytes of data. Because the number of bytes of data is odd, padding is added for checksum calculation. The pseudoheader as well as the padding will be dropped when the user datagram is delivered to IP.*

## Figure 23.11 *Checksum calculation of a simple UDP user datagram*



## Figure 23.12 *Queues in UDP*



# 23-3 TCP

***TCP is a connection-oriented protocol; it creates a virtual connection between two TCPs to send data. In addition, TCP uses flow and error control mechanisms at the transport level.***

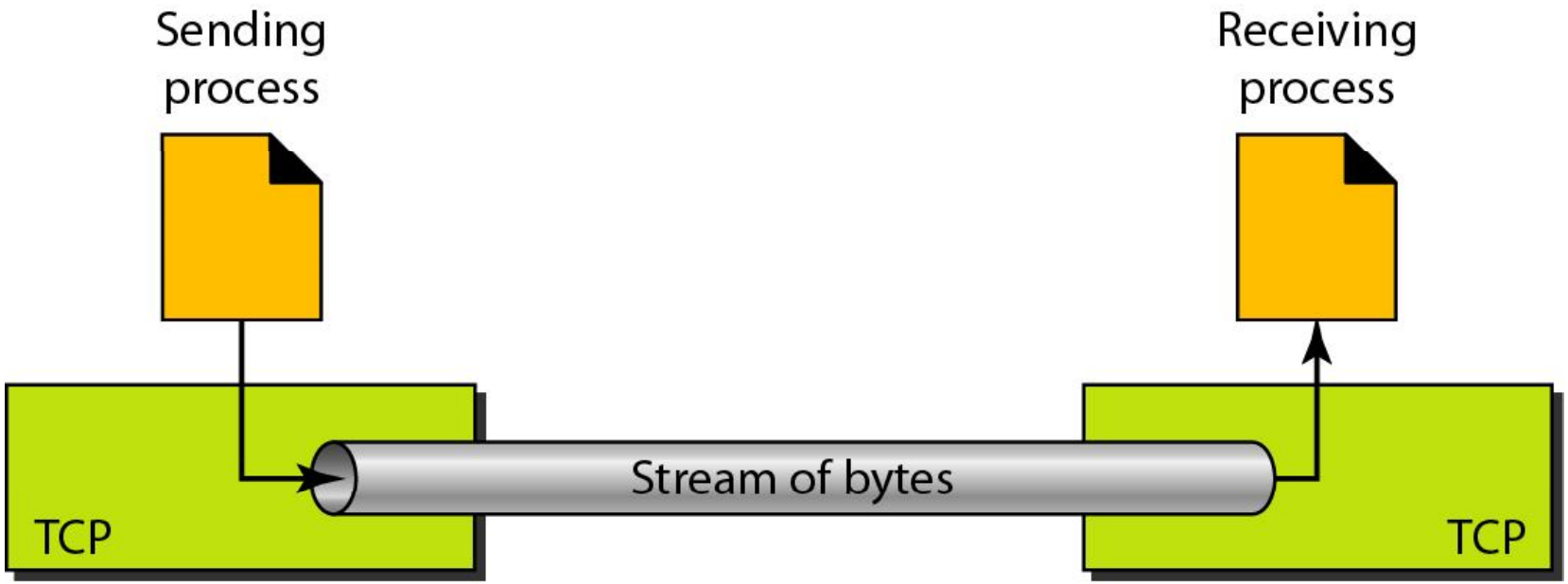
***Topics discussed in this section:***

**TCP Services**
**TCP Features**
**Segment**
**A TCP Connection**
**Flow Control**
**Error Control**

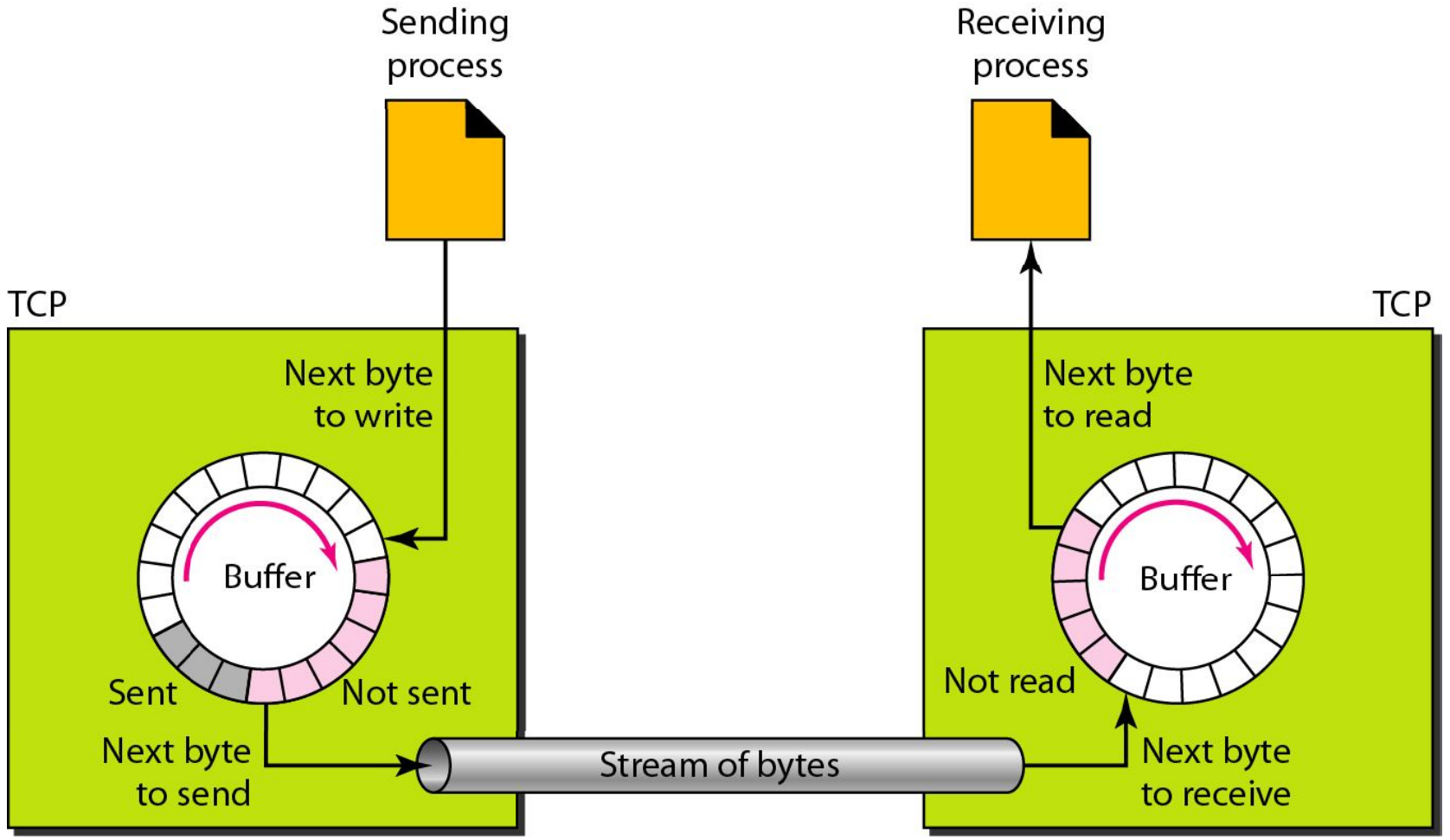
## Table 23.2 *Well-known ports used by TCP*

| *Port* | *Protocol* | *Description* |
|---|---|---|
| 7 | Echo | Echoes a received datagram back to the sender |
| 9 | Discard | Discards any datagram that is received |
| 11 | Users | Active users |
| 13 | Daytime | Returns the date and the time |
| 17 | Quote | Returns a quote of the day |
| 19 | Chargen | Returns a string of characters |
| 20 | FTP, Data | File Transfer Protocol (data connection) |
| 21 | FTP, Control | File Transfer Protocol (control connection) |
| 23 | TELNET | Terminal Network |
| 25 | SMTP | Simple Mail Transfer Protocol |
| 53 | DNS | Domain Name Server |
| 67 | BOOTP | Bootstrap Protocol |
| 79 | Finger | Finger |
| 80 | HTTP | Hypertext Transfer Protocol |
| 111 | RPC | Remote Procedure Call |

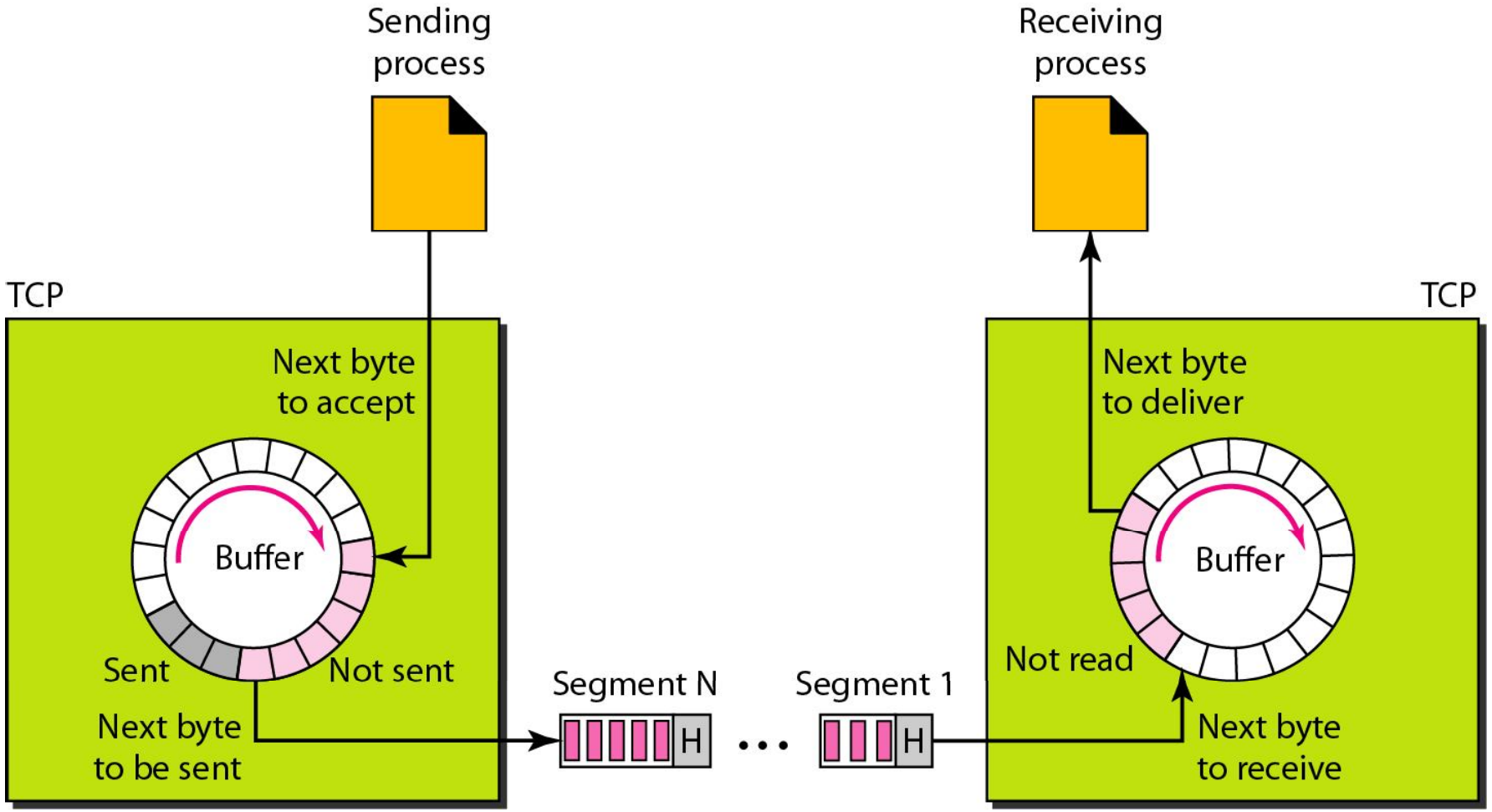
## Figure 23.13 *Stream delivery*



## Figure 23.14 *Sending and receiving buffers*



## Figure 23.15 *TCP segments*



**Note**

**The bytes of data being transferred in each connection are numbered by TCP. The numbering starts with a randomly generated number.**

# Example 23.3

***The following shows the sequence number for each segment:***

| | | |
|---|---|---|
| Segment 1 | → | Sequence Number: 10,001 (range: 10,001 to 11,000) |
| Segment 2 | → | Sequence Number: 11,001 (range: 11,001 to 12,000) |
| Segment 3 | → | Sequence Number: 12,001 (range: 12,001 to 13,000) |
| Segment 4 | → | Sequence Number: 13,001 (range: 13,001 to 14,000) |
| Segment 5 | → | Sequence Number: 14,001 (range: 14,001 to 15,000) |

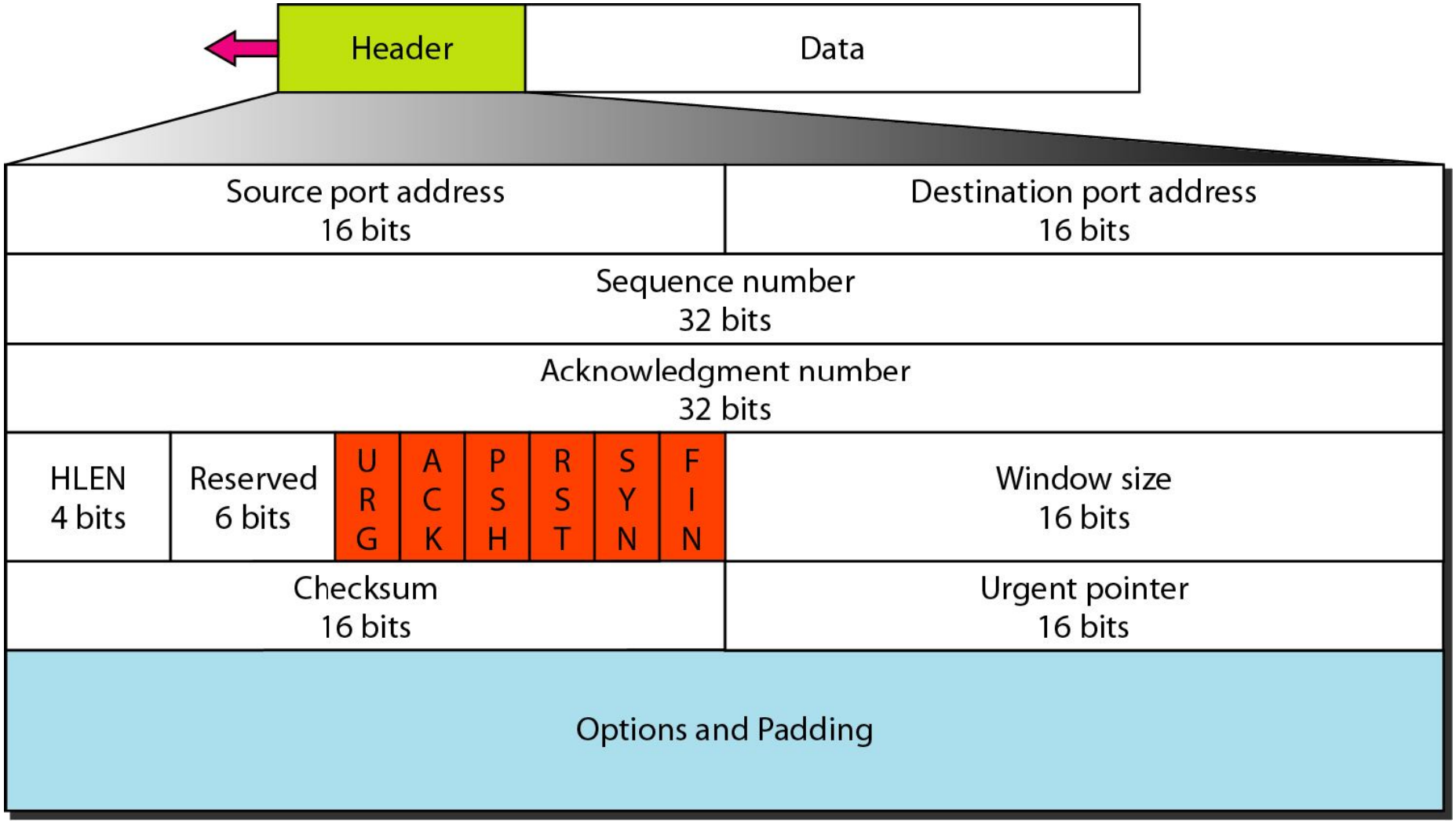
**Note**

**The value in the sequence number field of a segment defines the number of the first data byte contained in that segment.**

Note

**The value of the acknowledgment field in a segment defines the number of the next byte a party expects to receive. The acknowledgment number is cumulative.**

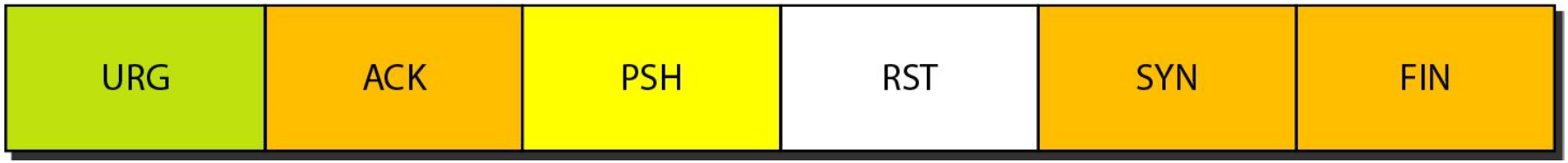
## Figure 23.16 *TCP segment format*



## Figure 23.17 *Control field*

URG: Urgent pointer is valid
ACK: Acknowledgment is valid
PSH: Request for push

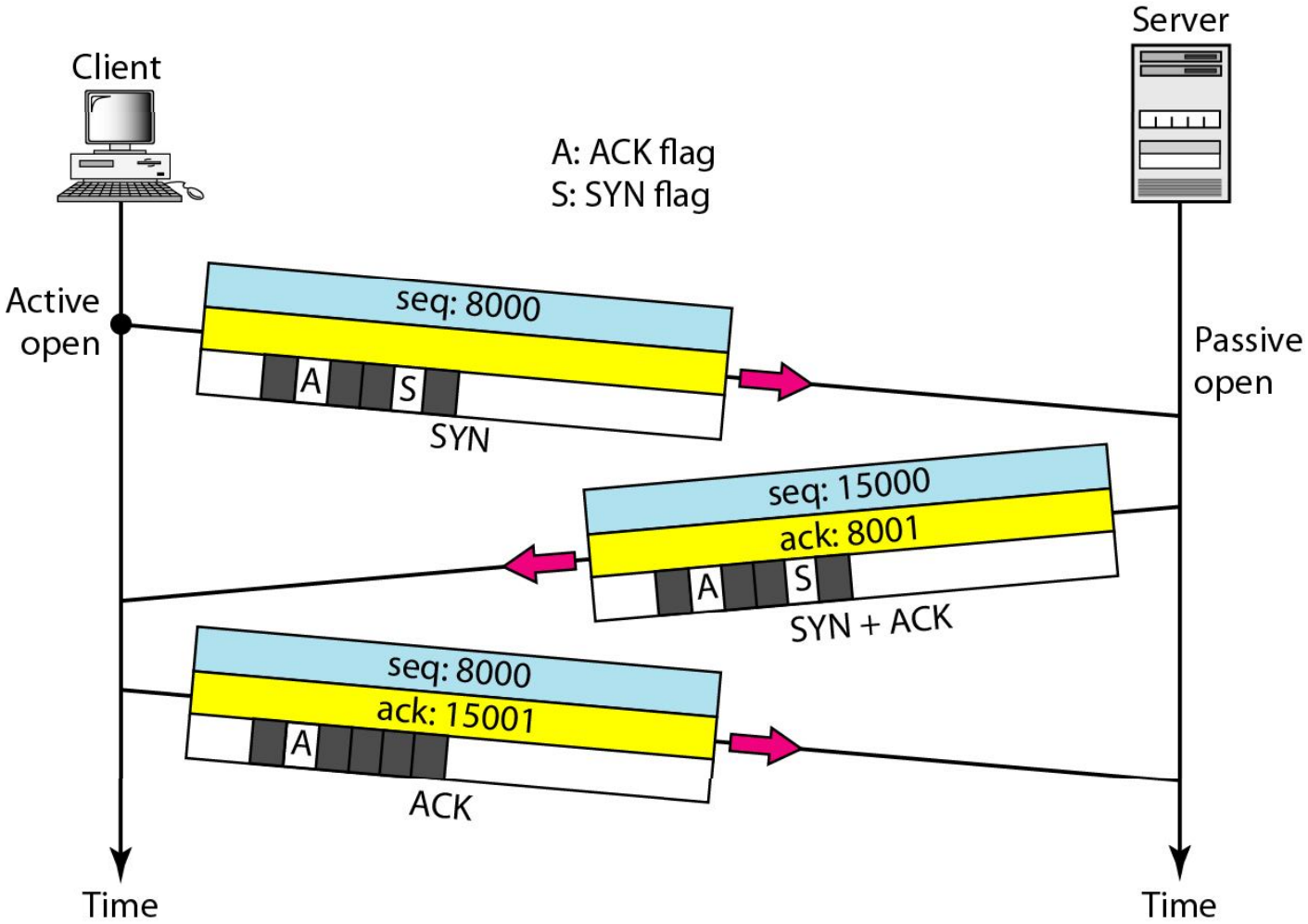
RST: Reset the connection
SYN: Synchronize sequence numbers
FIN: Terminate the connection



## Table 23.3 *Description of flags in the control field*

| *Flag* | *Description* |
|---|---|
| URG | The value of the urgent pointer field is valid. |
| ACK | The value of the acknowledgment field is valid. |
| PSH | Push the data. |
| RST | Reset the connection. |
| SYN | Synchronize sequence numbers during connection. |
| FIN | Terminate the connection. |

## Figure 23.18 *Connection establishment using three-way handshaking*



Note

**A SYN segment cannot carry data, but it consumes one sequence number.**

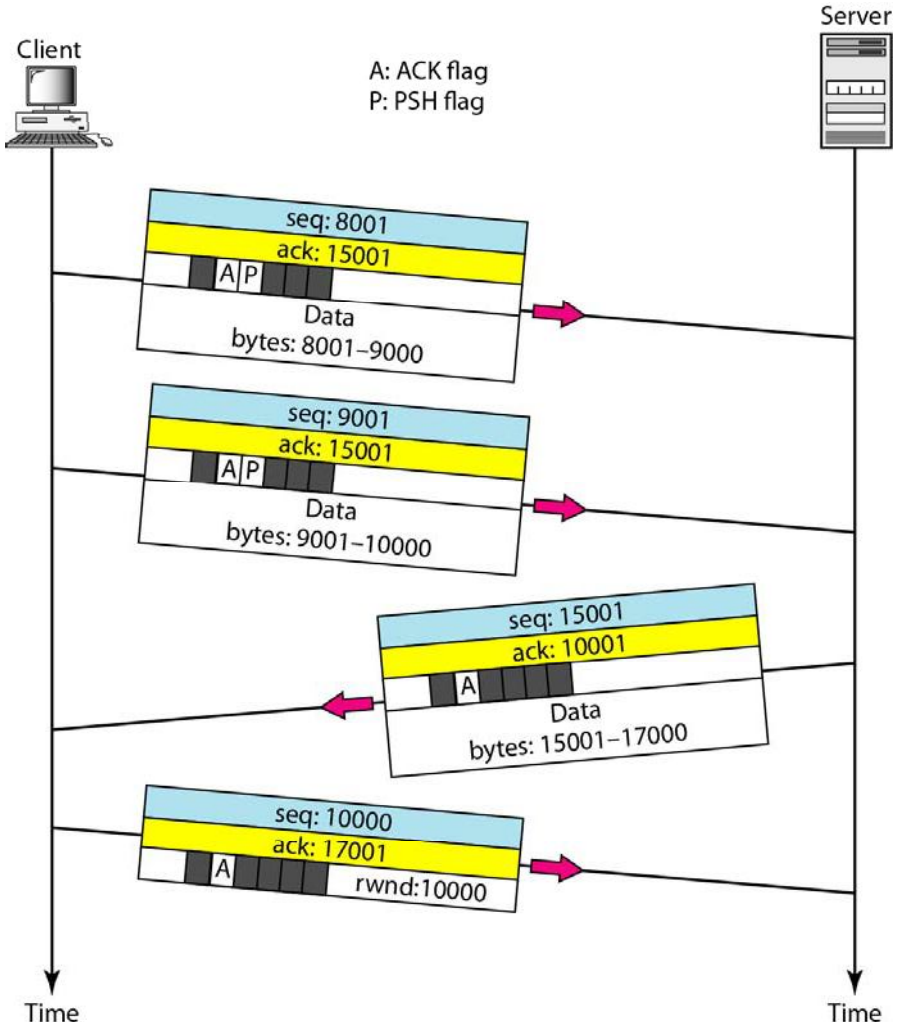
**Note**

**A SYN + ACK segment cannot carry data, but does consume one sequence number.**

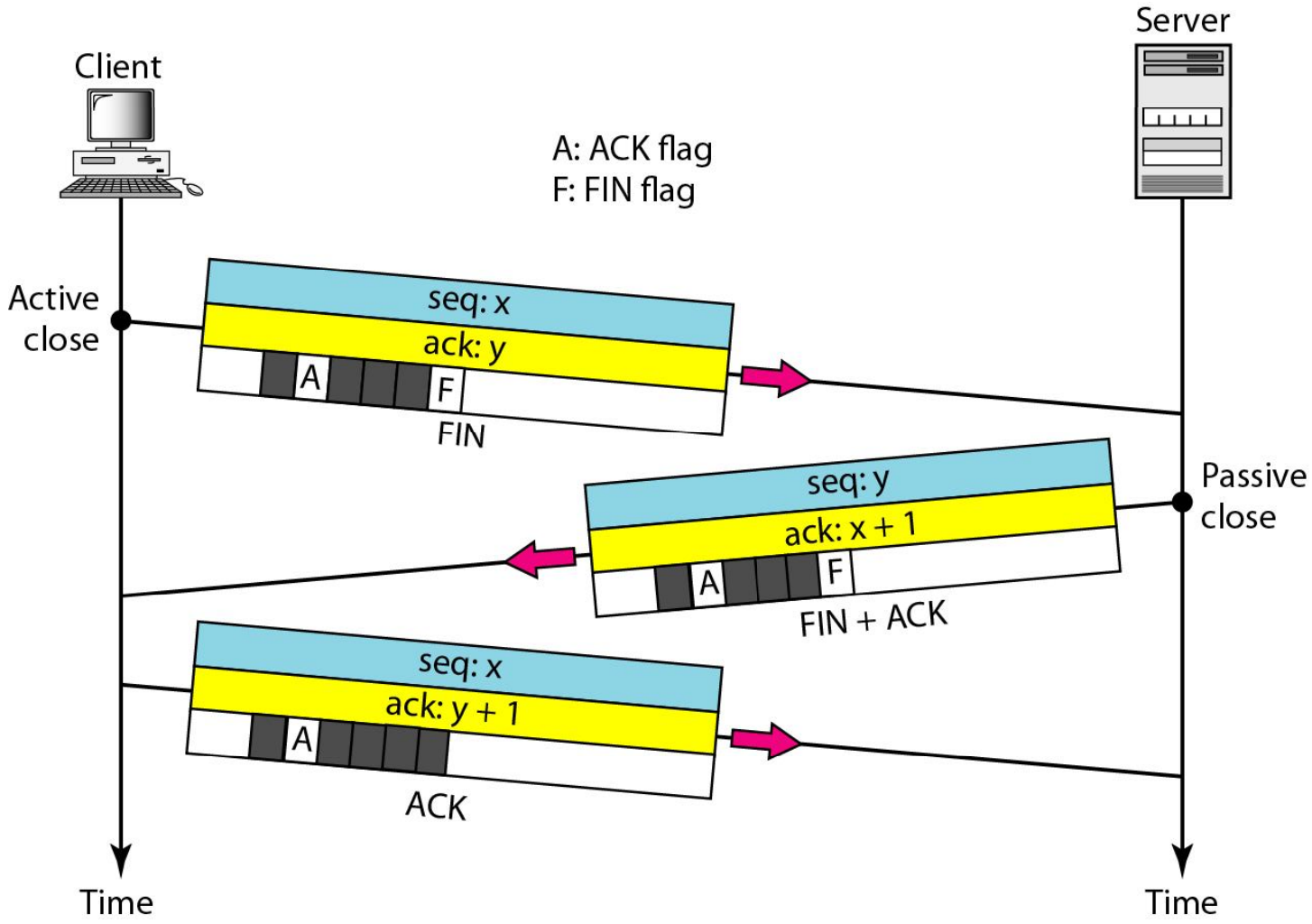
**Note**

**An ACK segment, if carrying no data, consumes no sequence number.**

## Figure 23.19 *Data transfer*



## Figure 23.20 *Connection termination using three-way handshaking*



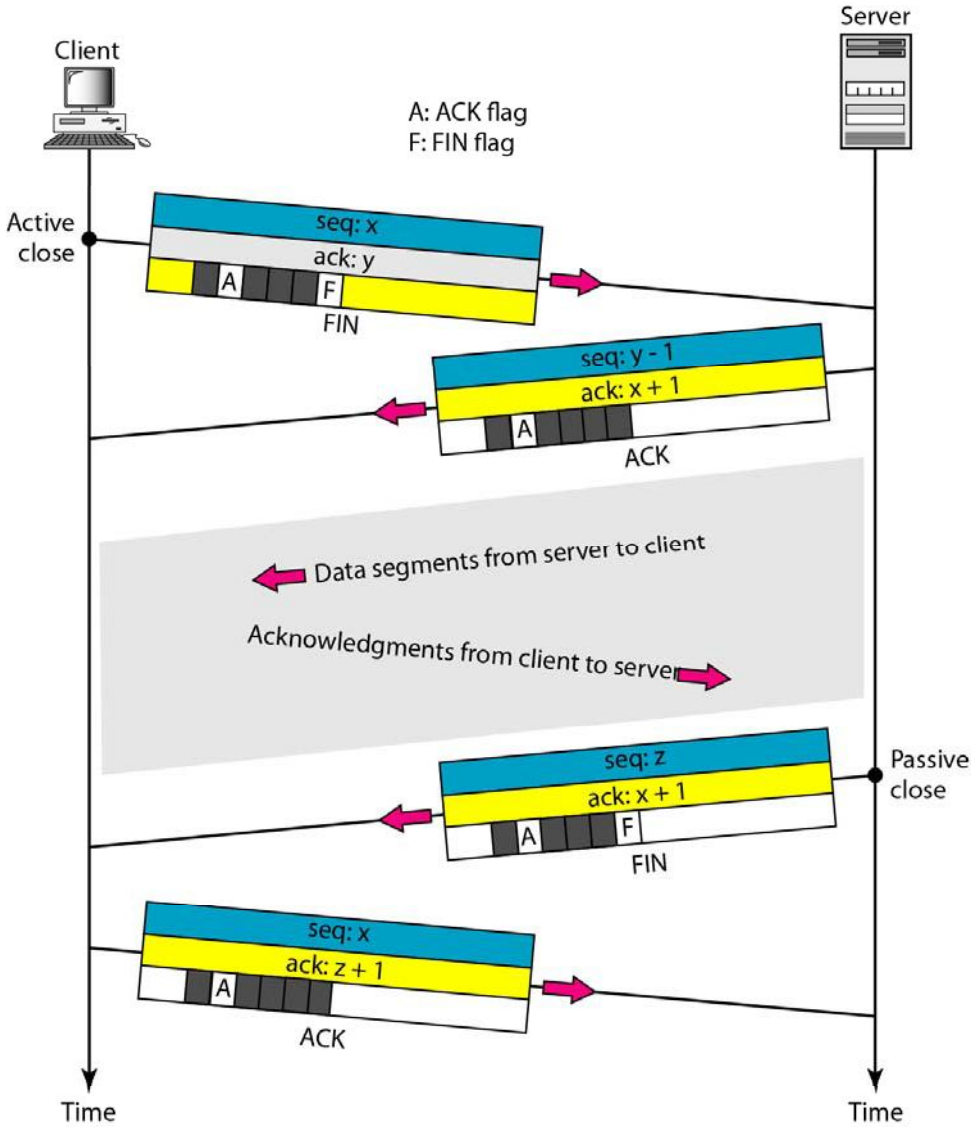
**Note**

**The FIN segment consumes one sequence number if it does not carry data.**

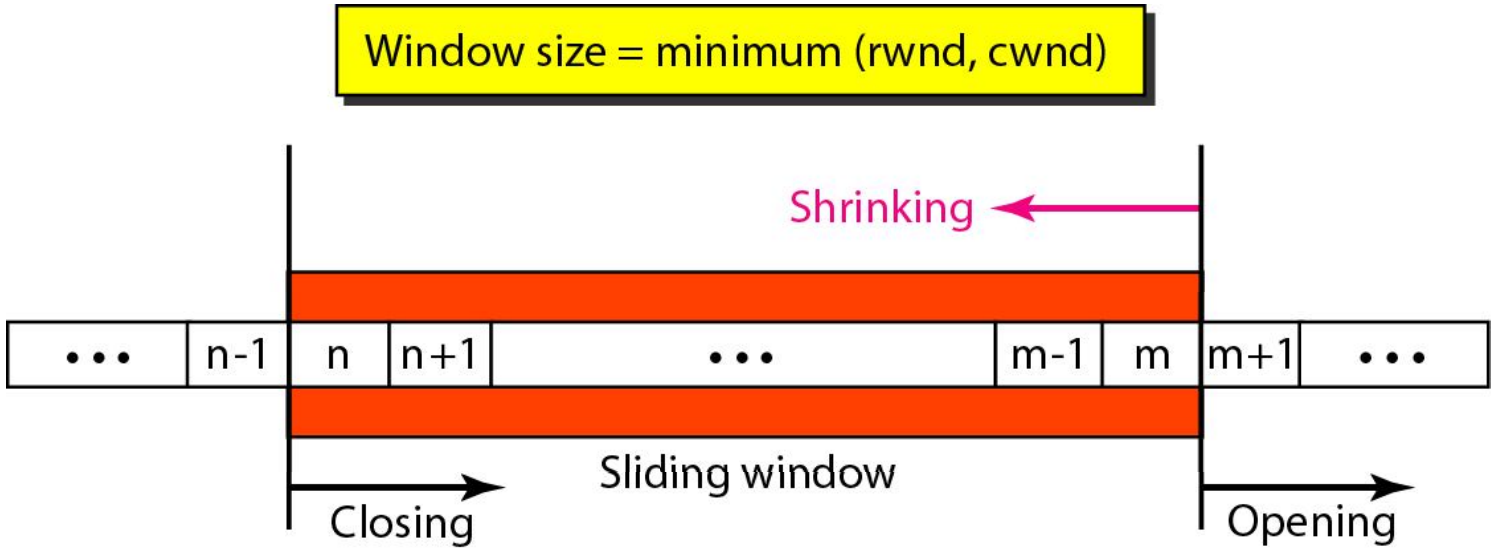
**Note**

**The FIN + ACK segment consumes one sequence number if it does not carry data.**

# Figure 23.21 *Half-close*

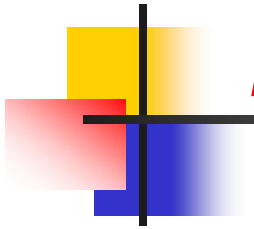


## Figure 23.22 *Sliding window*



**Note**

**A sliding window is used to make transmission more efficient as well as to control the flow of data so that the destination does not become overwhelmed with data.**
**TCP sliding windows are byte-oriented.**

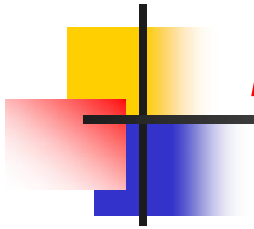


# Example 23.4

***What is the value of the receiver window (rwnd) for host A if the receiver, host B, has a buffer size of 5000 bytes and 1000 bytes of received and unprocessed data?***

***Solution***

***The value of rwnd = 5000 − 1000 = 4000. Host B can receive only 4000 bytes of data before overflowing its buffer. Host B advertises this value in its next segment to A.***

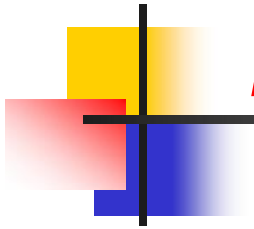


# Example 23.5

***What is the size of the window for host A if the value of rwnd is 3000 bytes and the value of cwnd is 3500 bytes?***

***Solution***

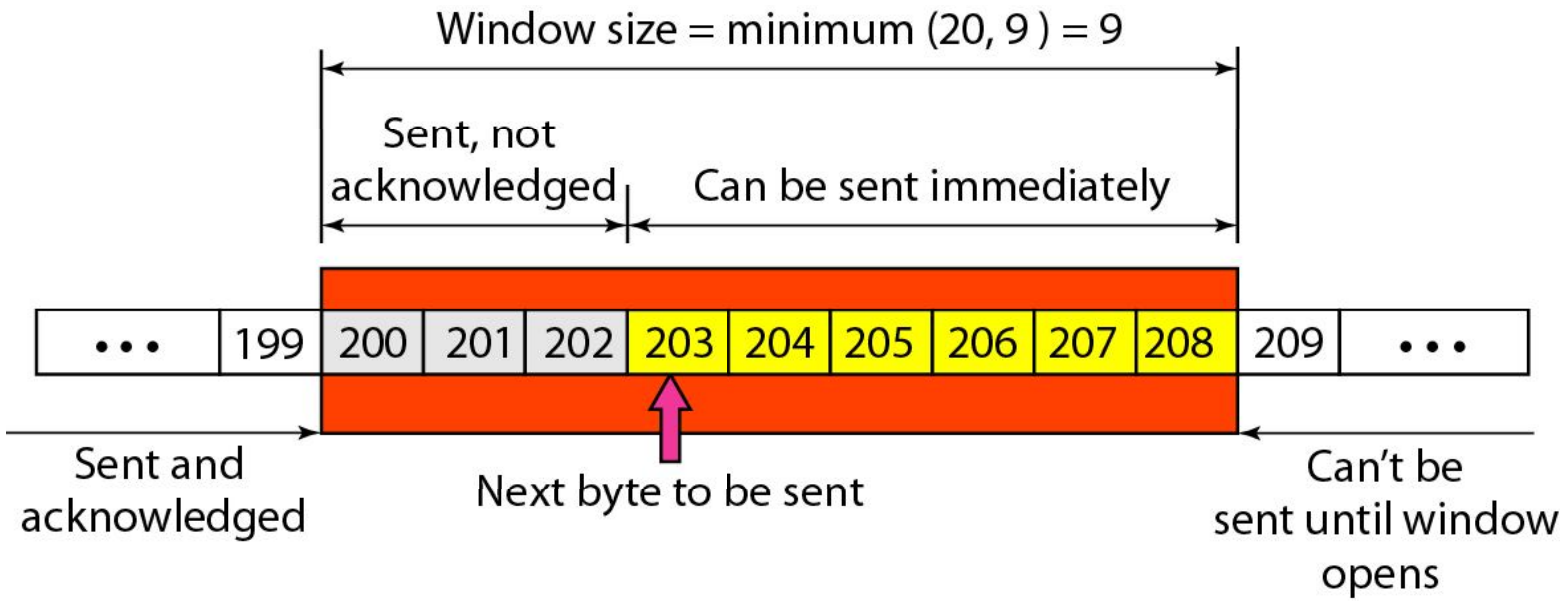
***The size of the window is the smaller of rwnd and cwnd, which is 3000 bytes.***



# Example 23.6

*Figure 23.23 shows an unrealistic example of a sliding window. The sender has sent bytes up to 202. We assume that cwnd is 20 (in reality this value is thousands of bytes). The receiver has sent an acknowledgment number of 200 with an rwnd of 9 bytes (in reality this value is thousands of bytes). The size of the sender window is the minimum of rwnd and cwnd, or 9 bytes. Bytes 200 to 202 are sent, but not acknowledged. Bytes 203 to 208 can be sent without worrying about acknowledgment. Bytes 209 and above cannot be sent.*

## Figure 23.23 *Example 23.6*



Note

## Some points about TCP sliding windows:

- The size of the window is the lesser of rwnd and cwnd.
- The source does not have to send a full window's worth of data.
- The window can be opened or closed by the receiver, but should not be shrunk.
- The destination can send an acknowledgment at any time as long as it does not result in a shrinking window.
- The receiver can temporarily shut down the window; the sender, however, can always send a segment of 1 byte after the window is shut down.

**Note**

**ACK segments do not consume sequence numbers and are not acknowledged.**

**Note**

**In modern implementations, a retransmission occurs if the retransmission timer expires or three duplicate ACK segments have arrived.**

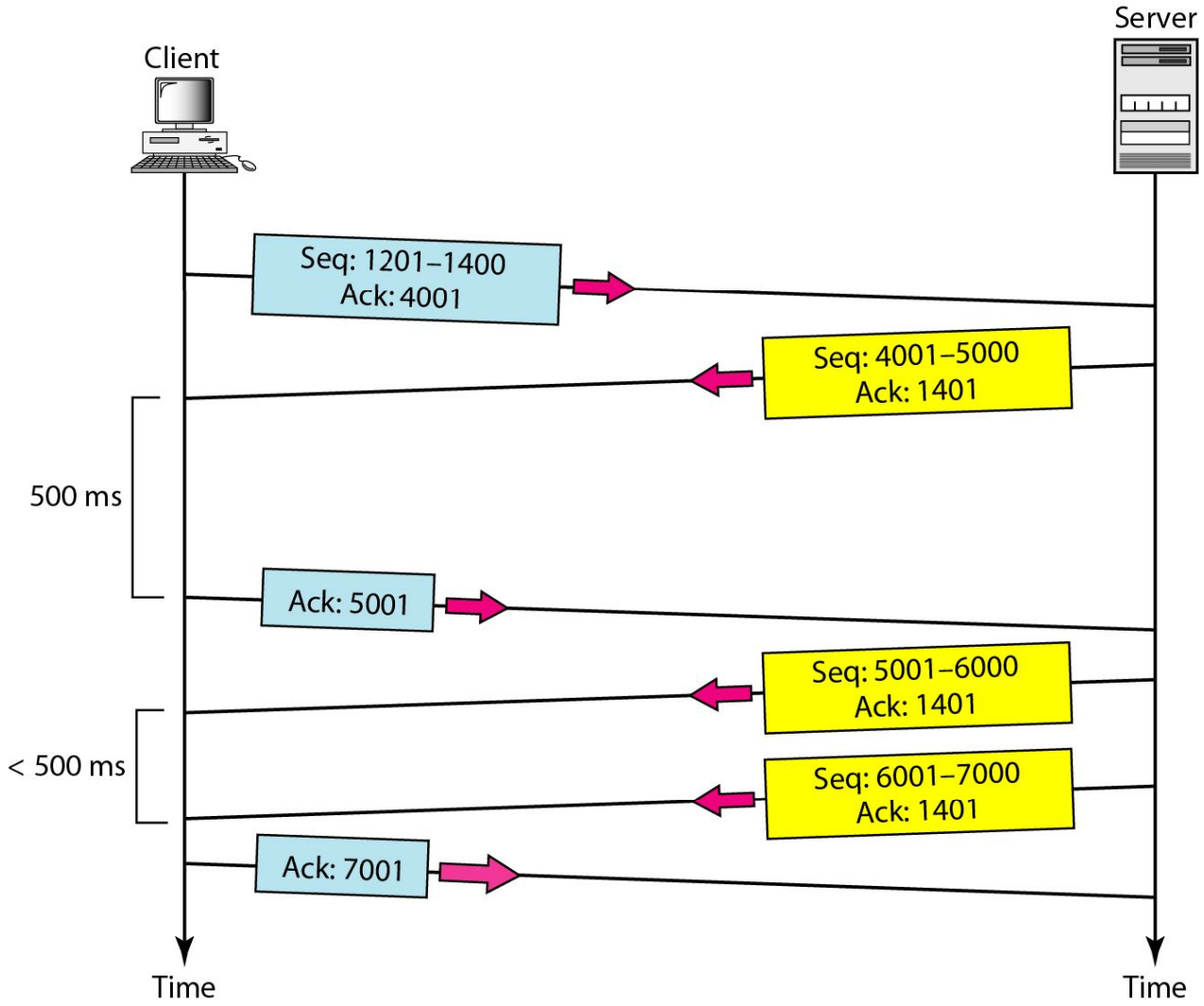
Note

**No retransmission timer is set for an ACK segment.**

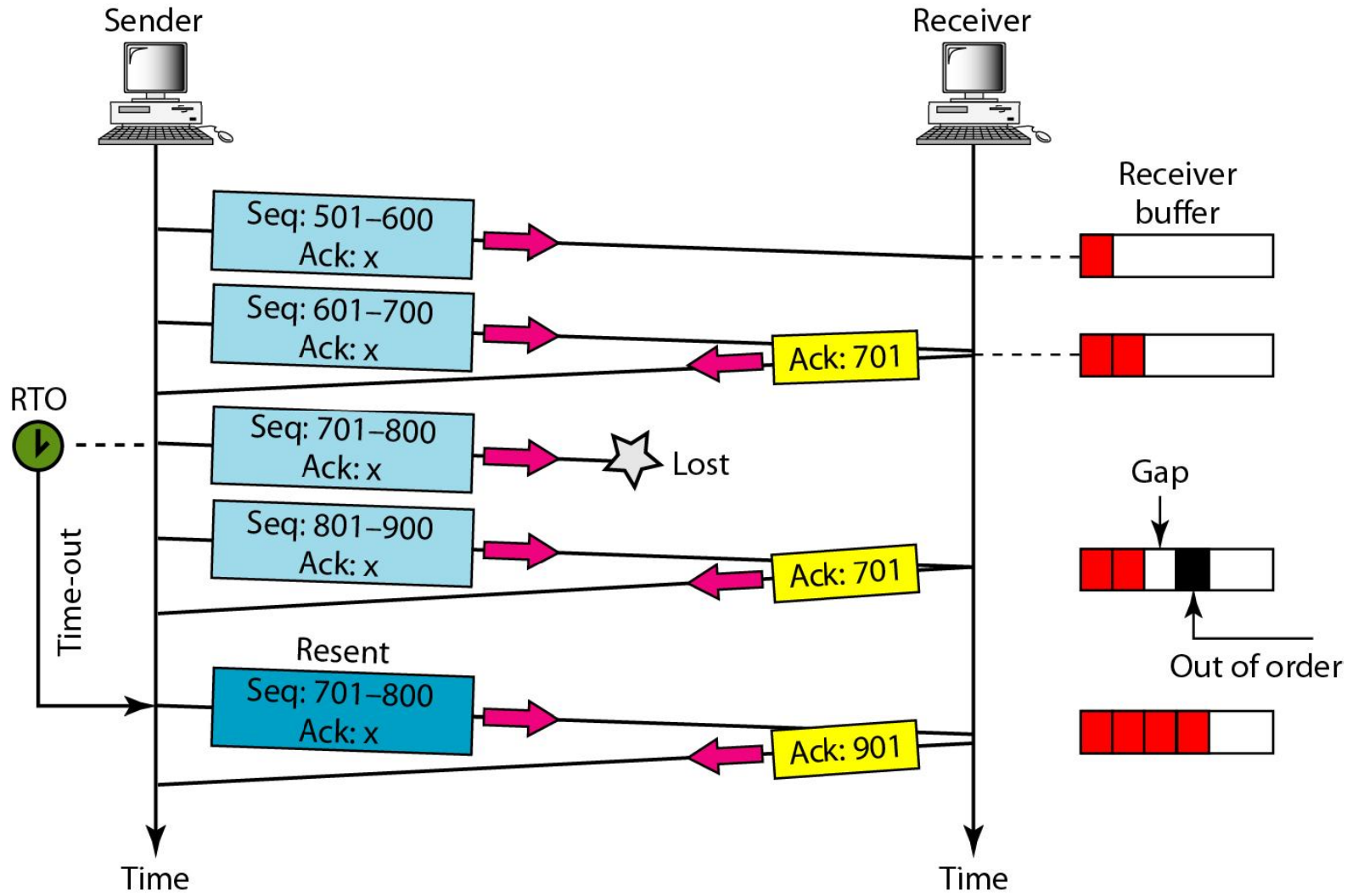
**Note**

**Data may arrive out of order and be temporarily stored by the receiving TCP, but TCP guarantees that no out-of-order segment is delivered to the process.**

## Figure 23.24 *Normal operation*



## Figure 23.25 *Lost segment*



Note

**The receiver TCP delivers only ordered data to the process.**

## Figure 23.26 *Fast retransmission*