Data Communications and Networking Fourth Edition

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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*

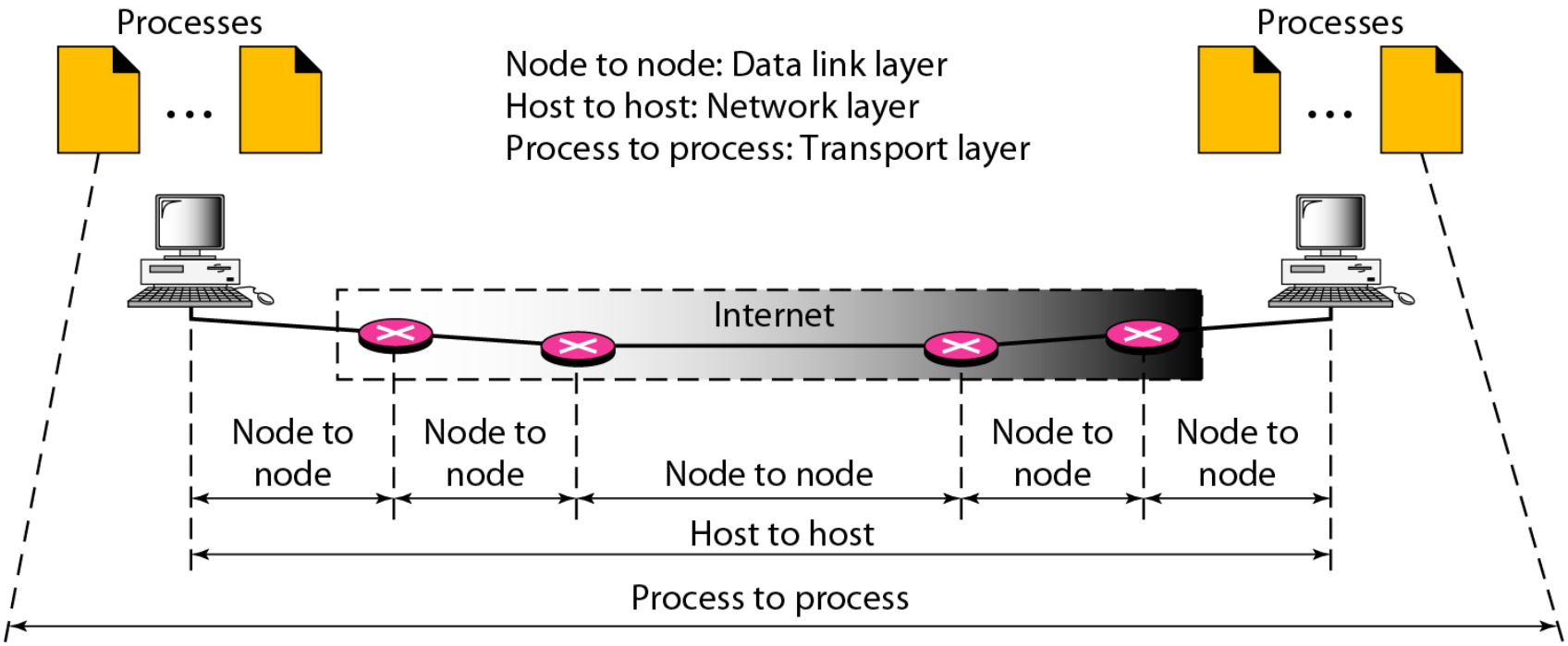


Figure 23.2 *Port numbers*

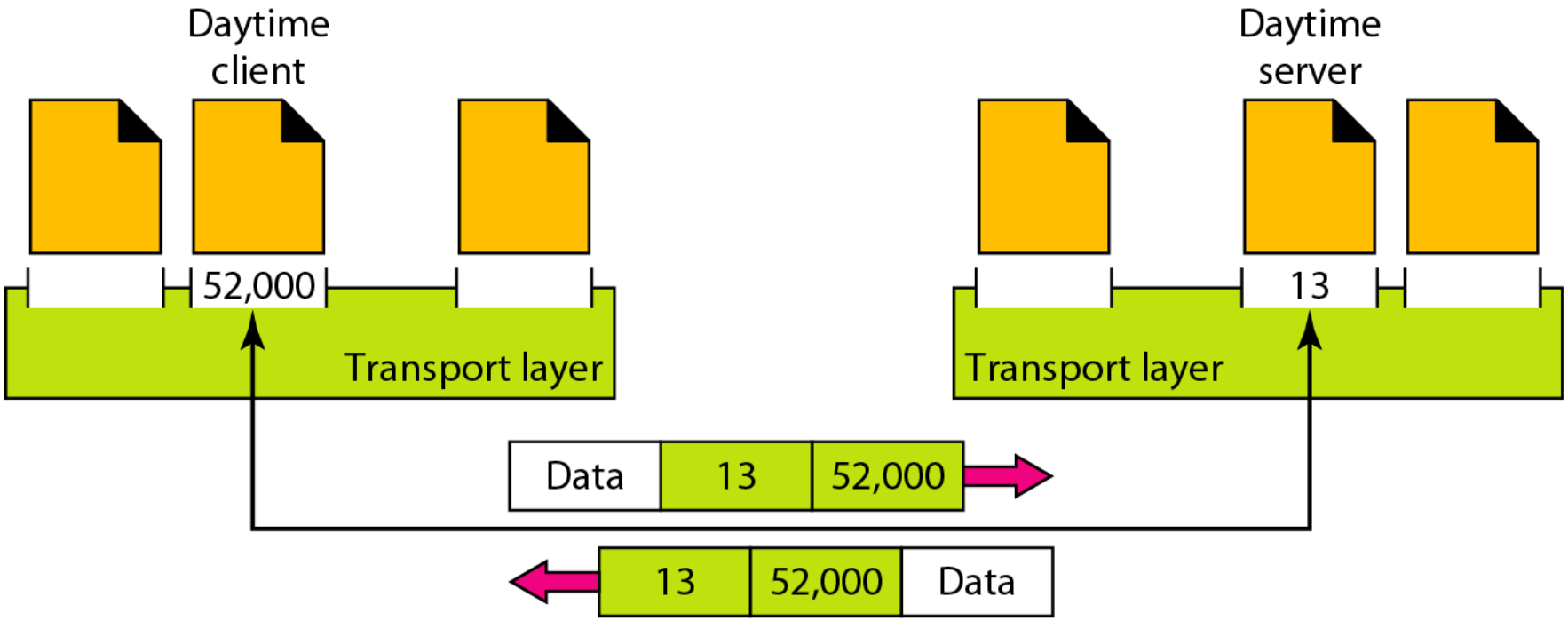


Figure 23.3 *IP addresses versus port numbers*

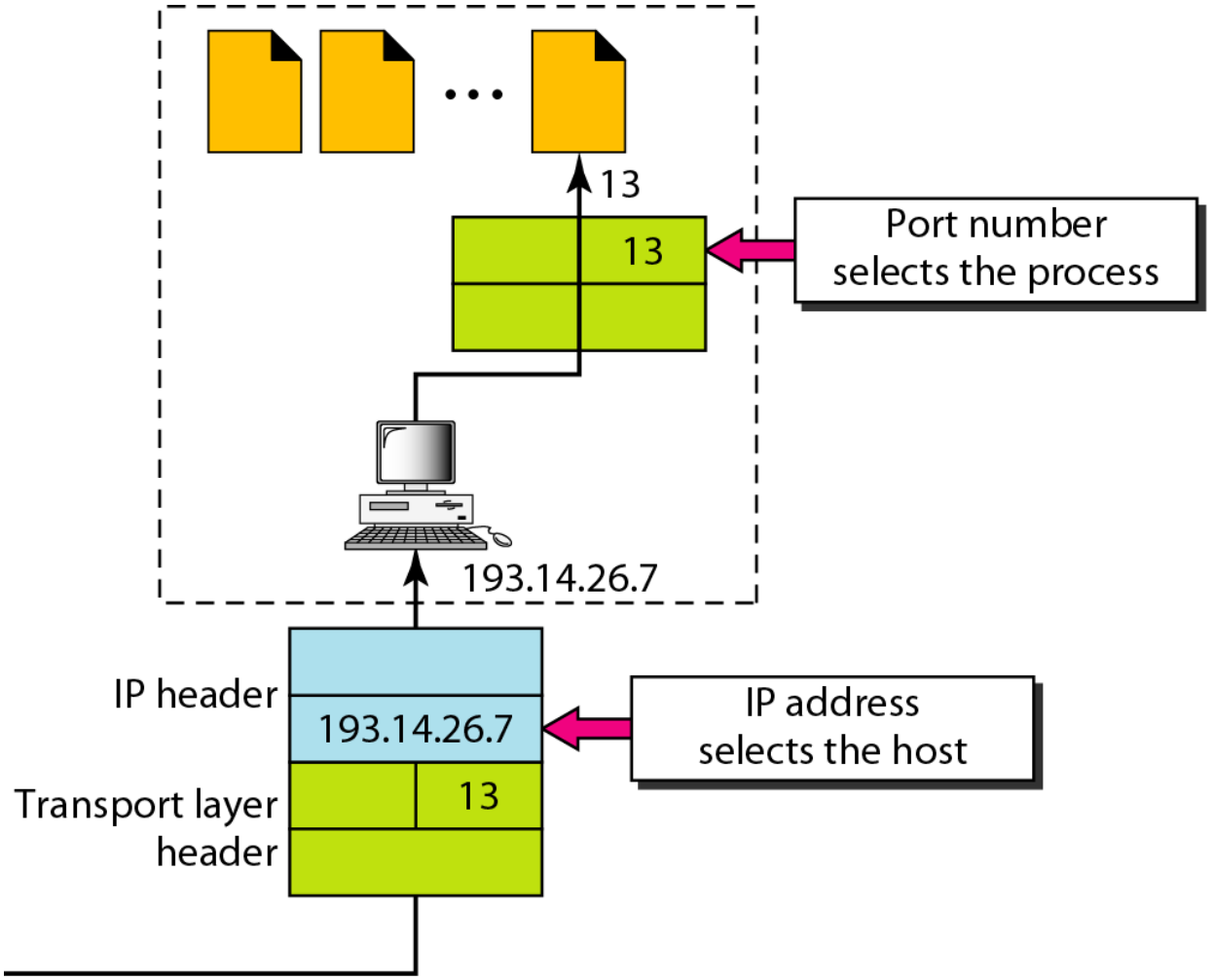
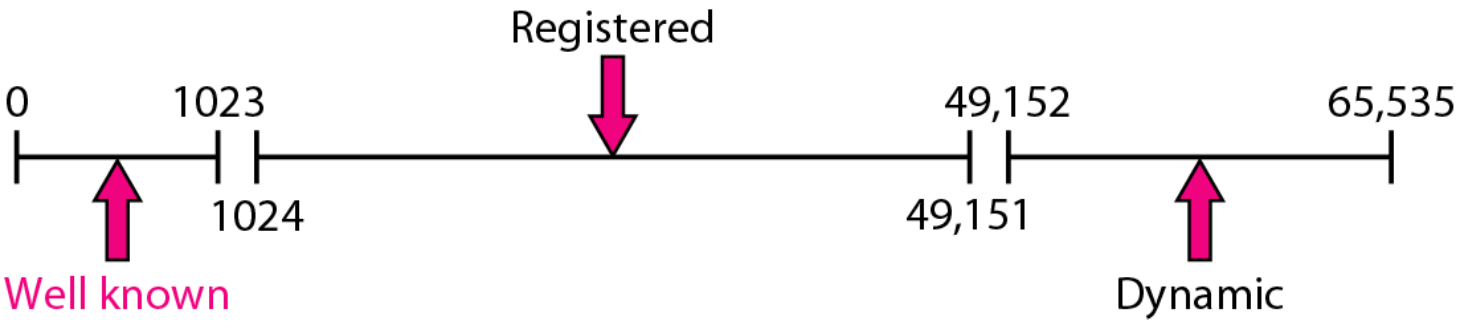
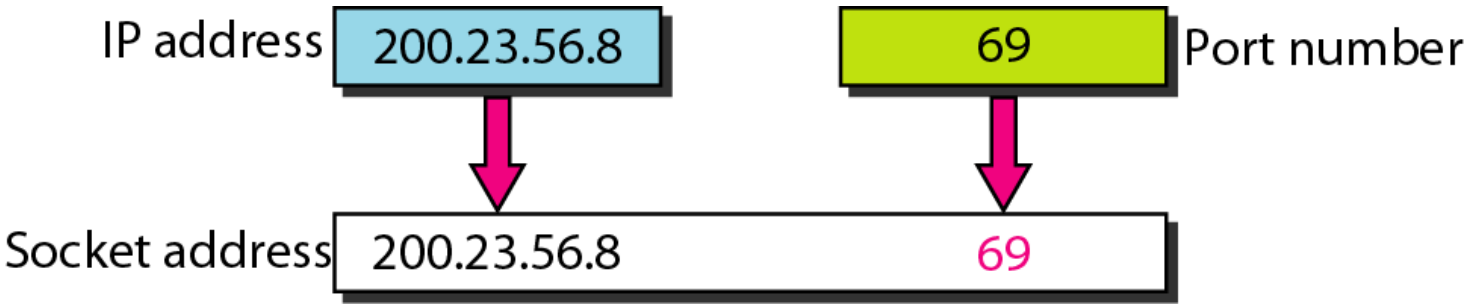


Figure 23.4 **IANA** (Internet Assigned Number Authority) ranges



- ✓ **Well-known ports.** The ports ranging from 0 to 1023 are assigned and controlled by IANA.
- ✓ **Registered ports**. They **can only be registered** with IANA to prevent duplication.
- ✓ **Dynamic ports**. They can be used by any process. These are the temporary ports.

Figure 23.5 *Socket address*



- ✓ Process-to-process delivery needs two identifiers, IP address and the port number, at each end to make a connection.
- ✓ **Socket address:** combination of an IP address and a port number.
- ✓ Client socket address defines the client process uniquely just as the server socket address defines the server process uniquely.

Figure 23.6 *Multiplexing and demultiplexing*

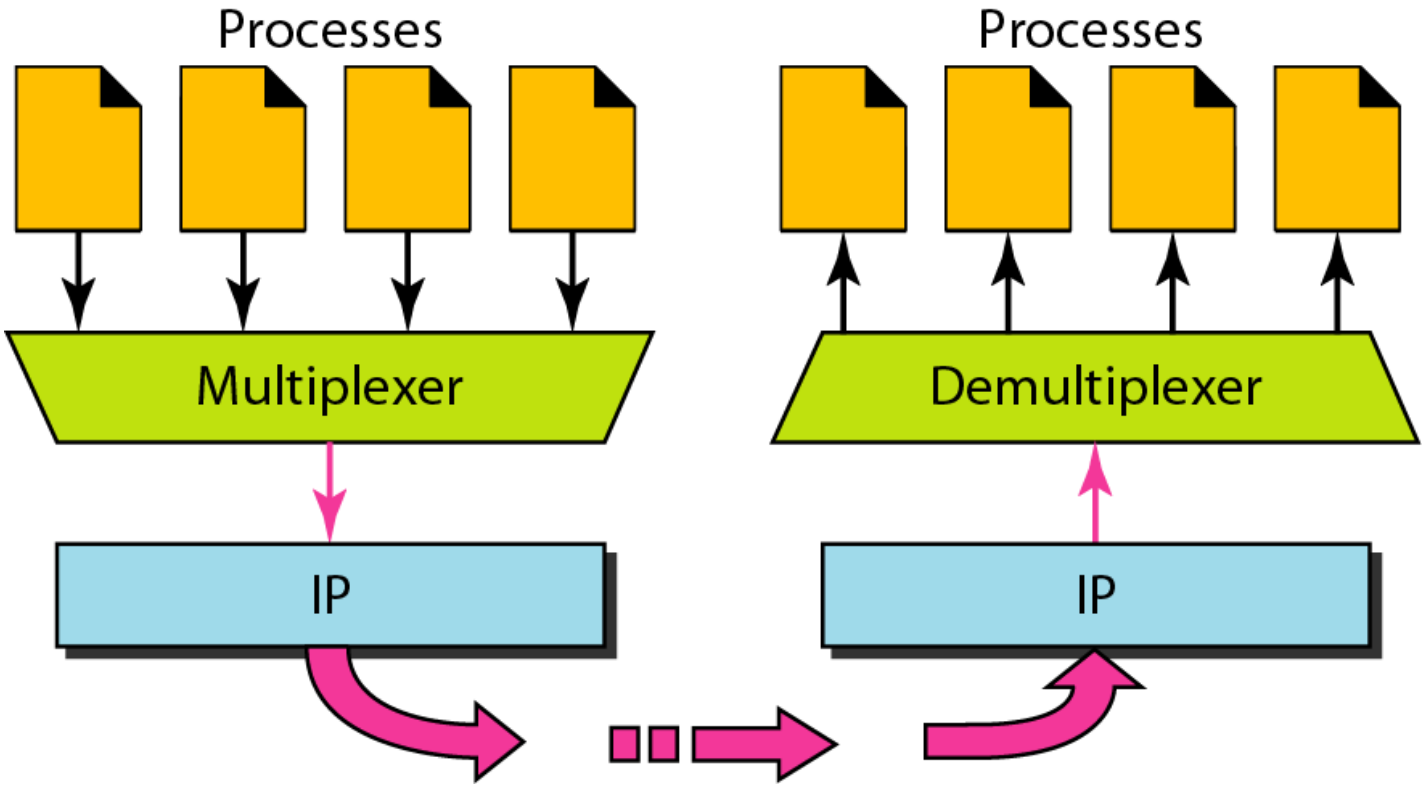


Figure 23.7 *Error control*

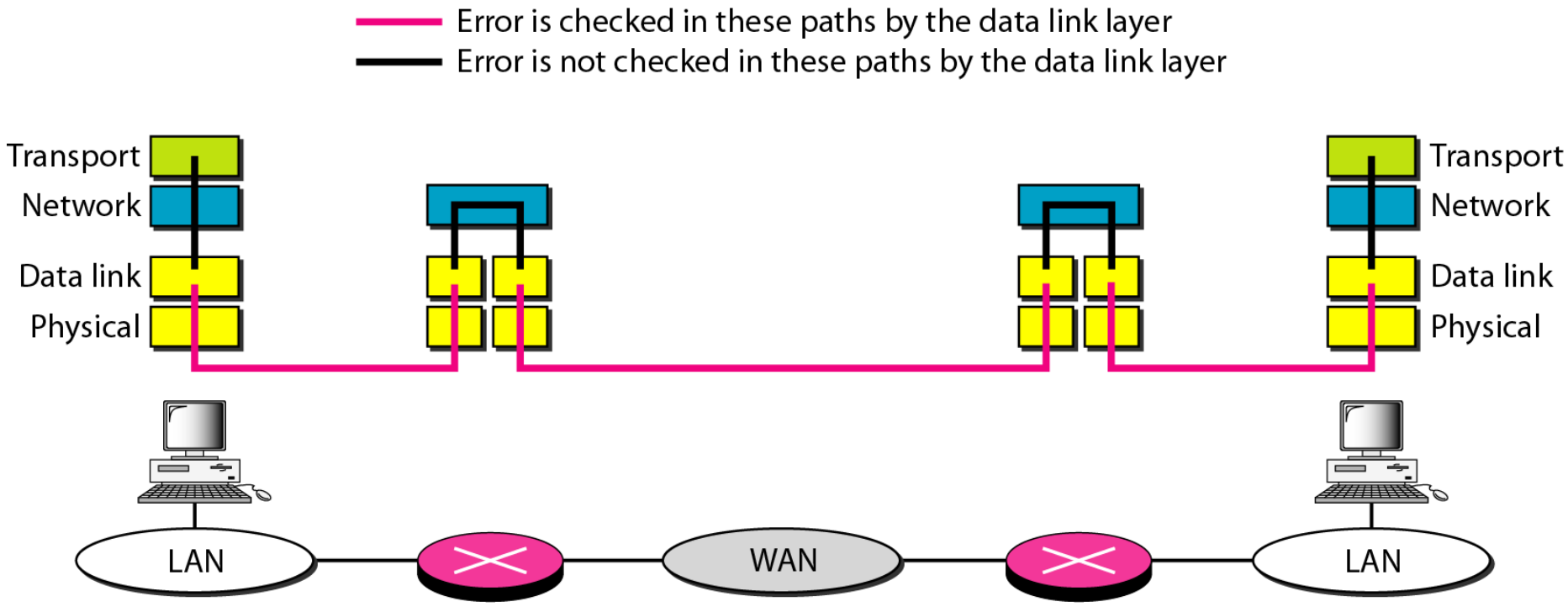
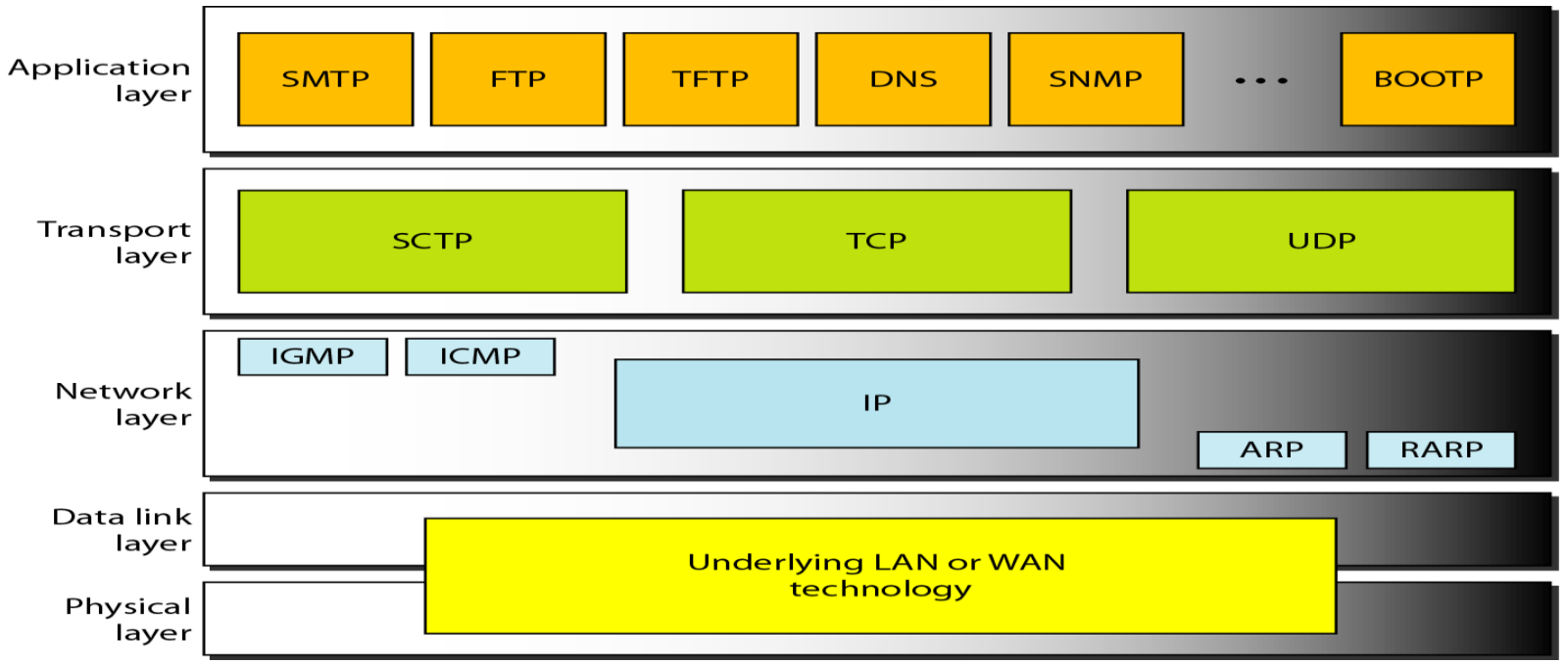


Figure 23.8 *Position of UDP, TCP, and SCTP in TCP/IP suite*



- ✓ The User Datagram Protocol (UDP) is called a **connectionless, unreliable** transport protocol.
- ✓ Transmission Control Protocol (TCP) is called a connection-oriented and reliable transport protocol/services provided to IP.
- ✓ Stream Control Transmission Protocol (SCTP) is a protocol that ensures reliable, in-sequence transmission of data.

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)

netstat –an

- ✓ To display network statistics and active connections.

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.

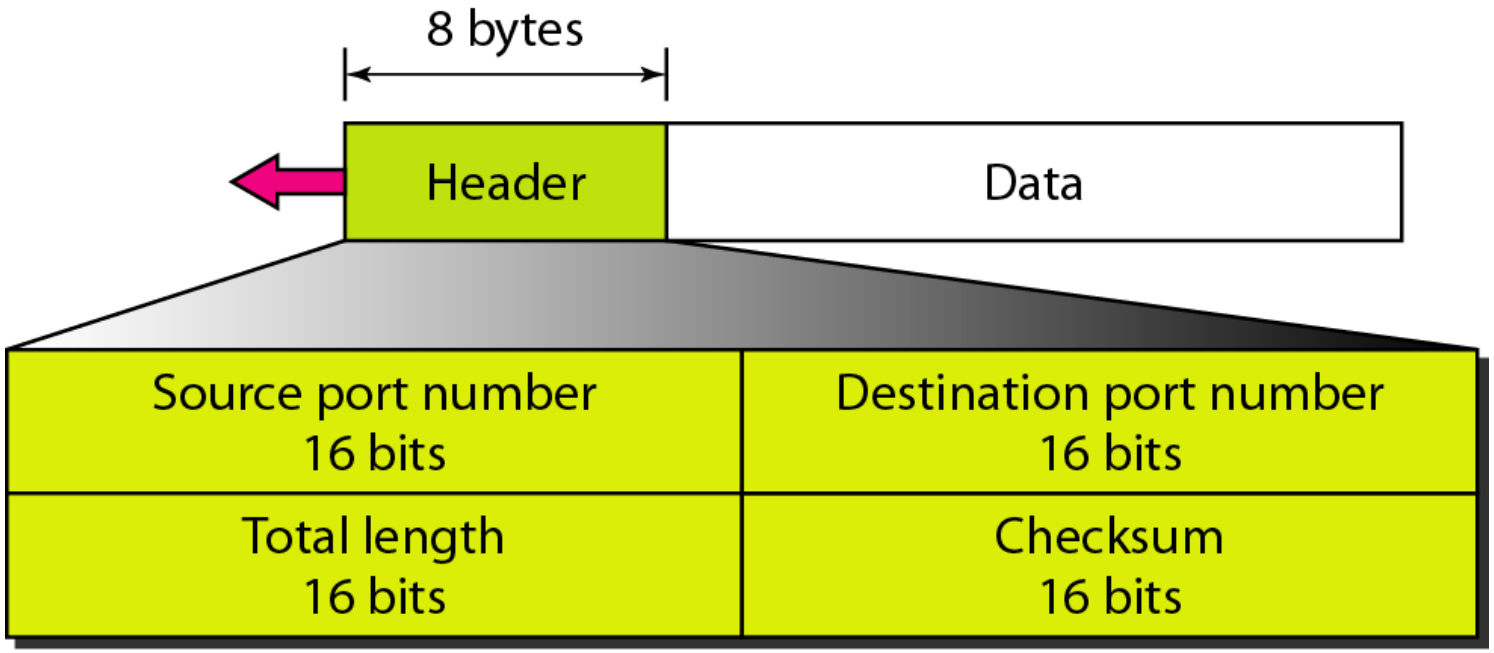
```
$ grep    ftp    /etc/services
ftp         21/tcp
ftp         21/udp
```

Example 23.1 (continued)

SNMP uses two port numbers (161 and 162), each for a different purpose.

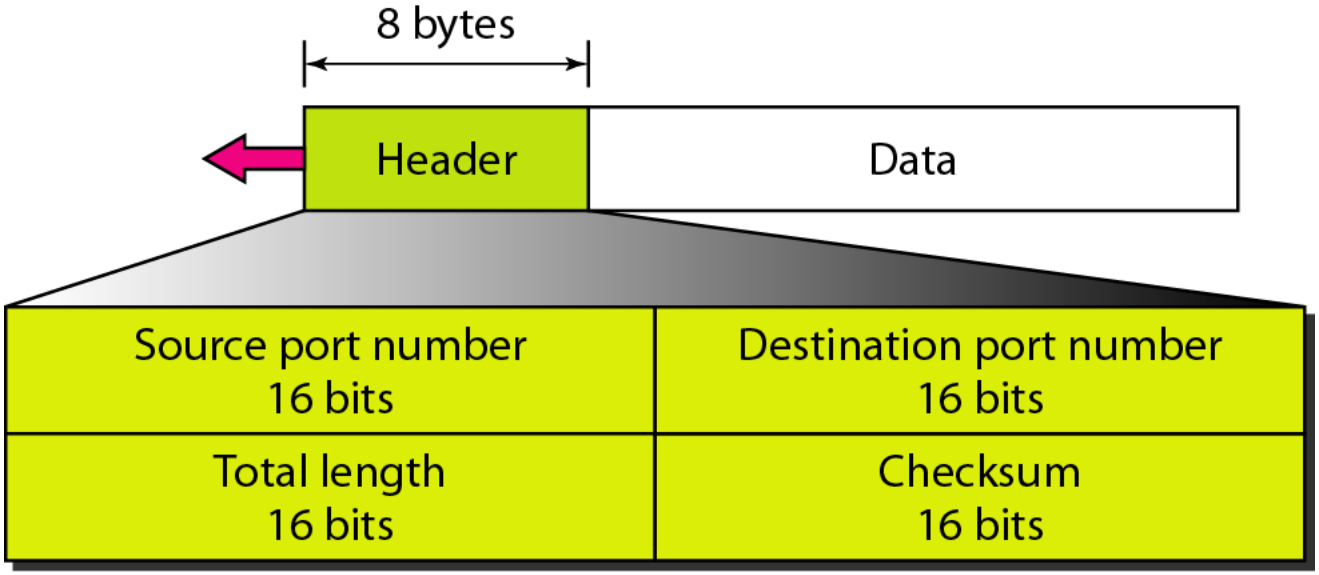
```
$ grep      snmp /etc/services
snmp            161/tcp         #Simple Net  Mgmt Proto
snmp            161/udp         #Simple Net  Mgmt Proto
snmptrap        162/udp         #Traps for SNMP
```

Figure 23.9 *User datagram format*



- ✓ **Fixed-size header of 8 bytes**
- ✓ **Source port number**:
  - ✓ used by the **process running** on the source host is 16 bits long (**0 – 65535**).
  - ✓ is a temporary port number requested by the process and chosen by the UDP

Figure 23.9 *User datagram format*

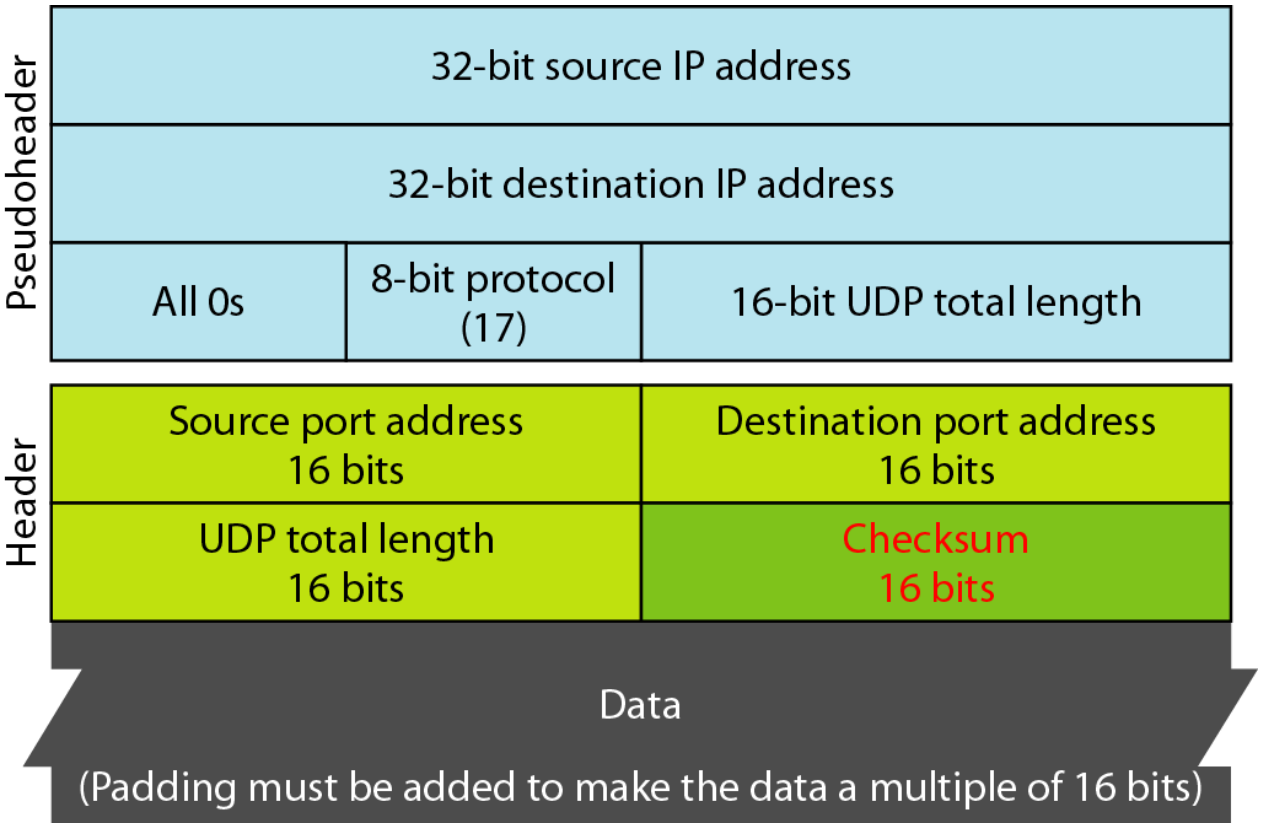


- ✓ **Destination port number**:
  - ✓ used by the process running on the destination host is 16 bits long (0 – 65535).
- ✓ **Length**:
  - ✓ 16-bit field, defines the **total length**, header plus data.
  - ✓ Total length of **0 to 65,535** bytes. However, the total length needs to be much less because a UDP user datagram is stored in an IP datagram with a limit of 65,535 bytes
- ✓ **Checksum.** This field is used to detect errors over the entire user datagram (header plus data).

Note

UDP length
= IP length – IP header's length

Figure 23.10 *Pseudoheader for checksum calculation*



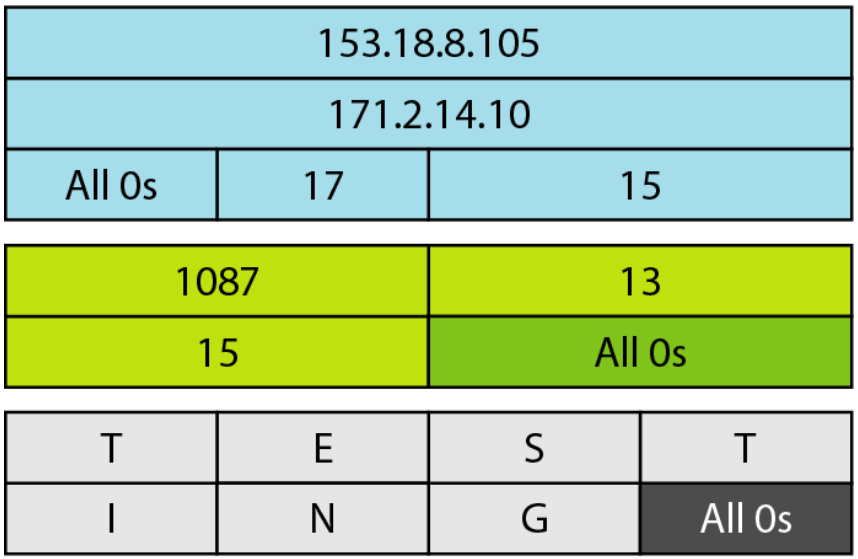
- ✓ The checksum includes three sections:
  - ✓ a ***pseudoheader***,
  - ✓ the ***UDP header***, and
  - ✓ the ***data*** coming from the application layer.

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*



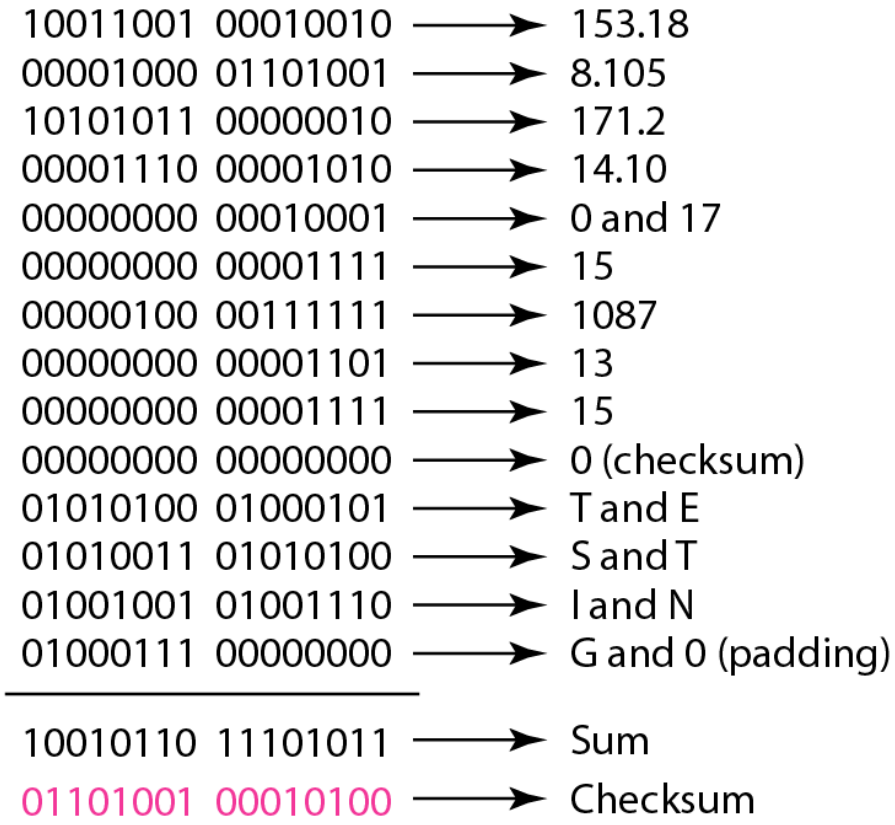
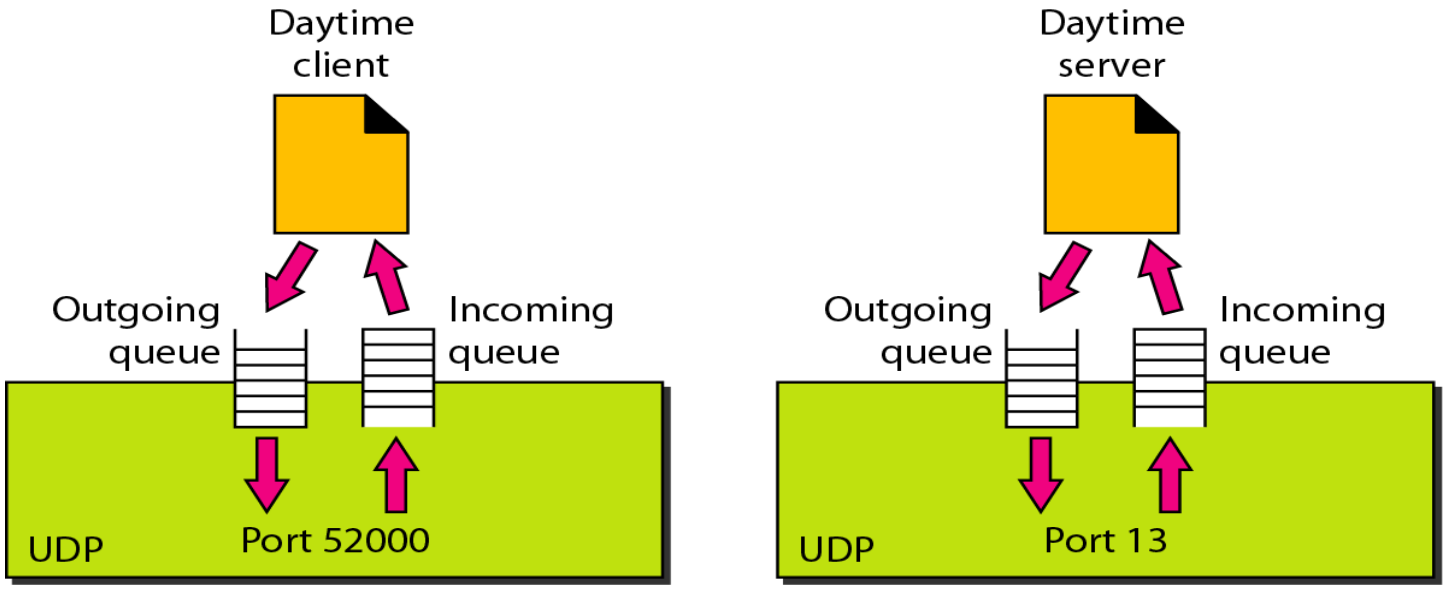


Figure 23.12 *Queues in UDP*



- ✓ Each client uses one port with an outgoing and an incoming queue for all communications.
- ✓ Queue Overflow: If the outgoing or incoming queue overflows, messages are dropped, and an ICMP "port unreachable" message may be sent to the sender.
- ✓ Lifecycle: Queues exist only while the process is running and are destroyed when the process terminates

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.

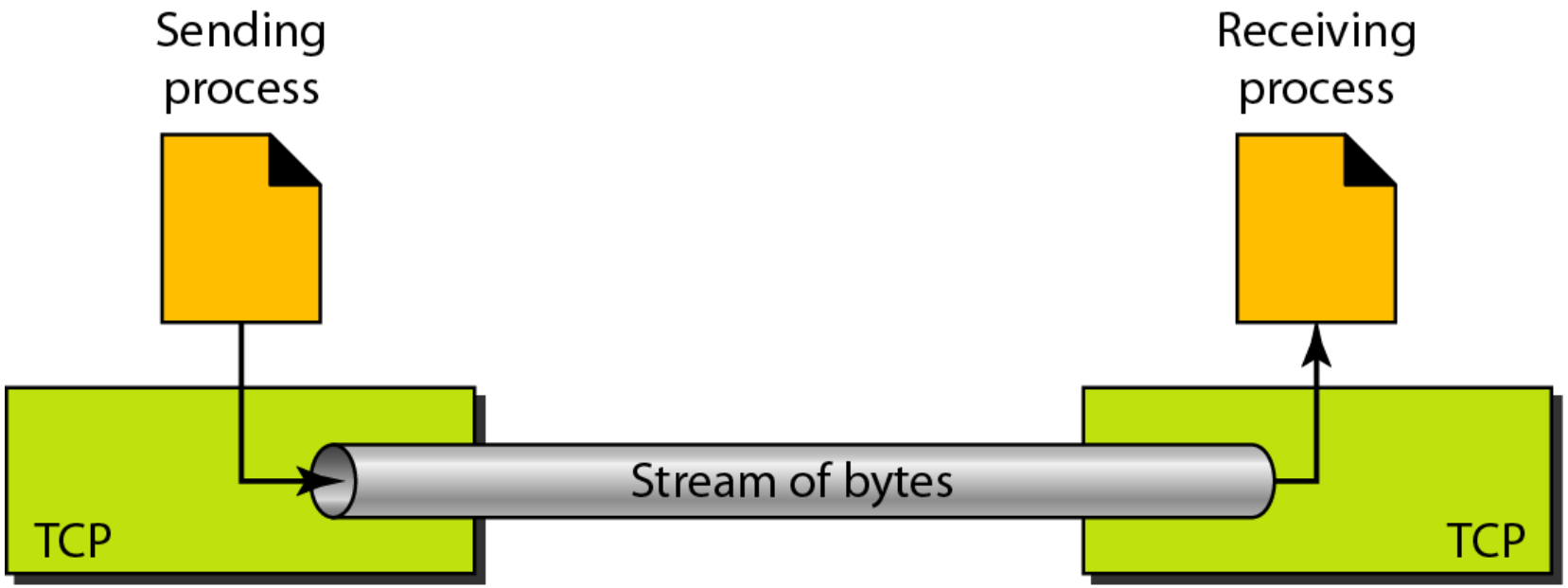
Topics discussed in this section:

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

Table 23.2 *Well-known ports used by TCP*

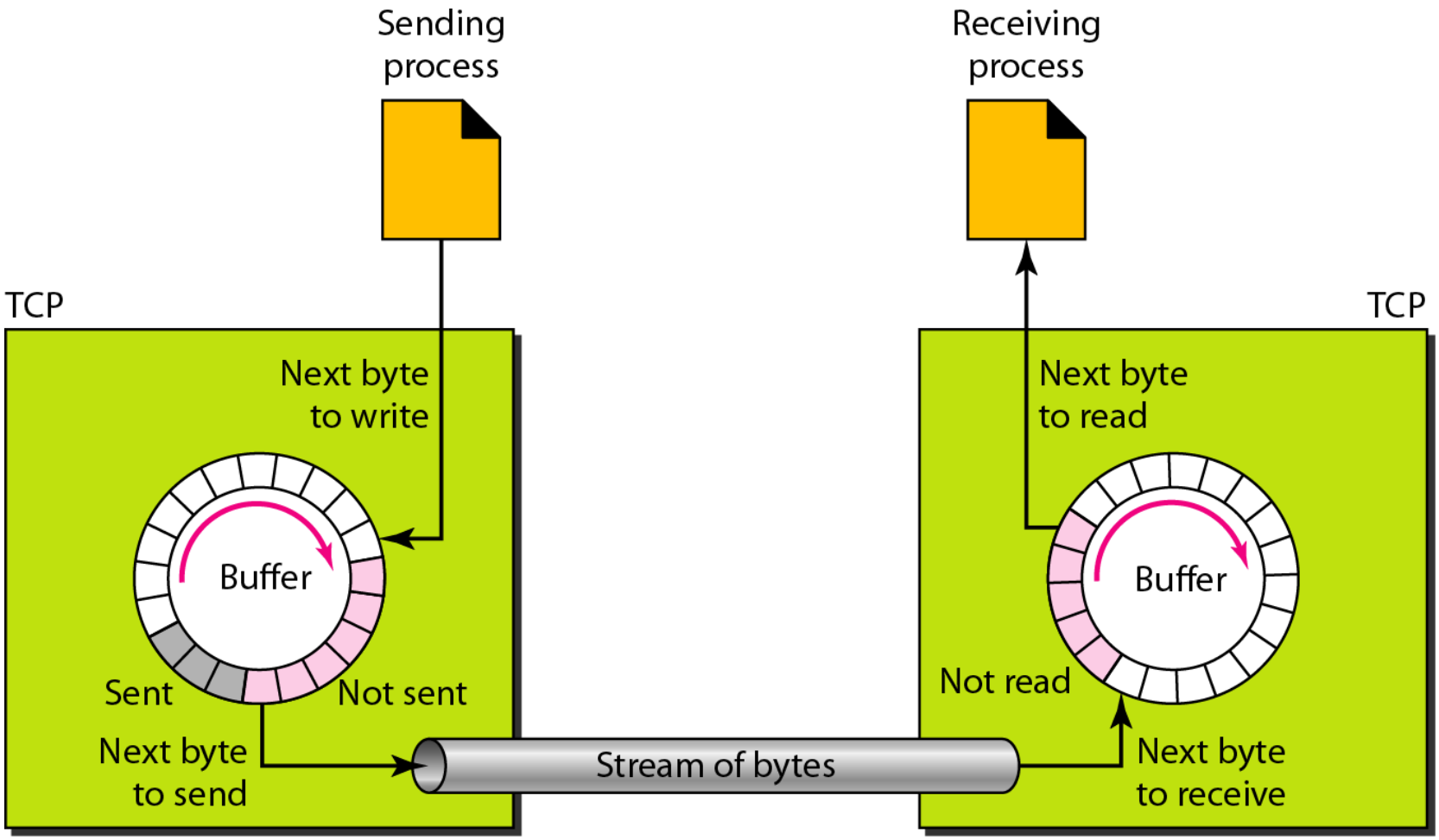
Port	*Protocol*	*Description*
7	Echo	Echoes a received datagram back to the sender
9	Discard	Discards any datagram that is received
11	Users	Active users
13	Daytime	Returns the date and the time
17	Quote	Returns a quote of the day
19	Chargen	Returns a string of characters
20	FTP, Data	File Transfer Protocol (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*



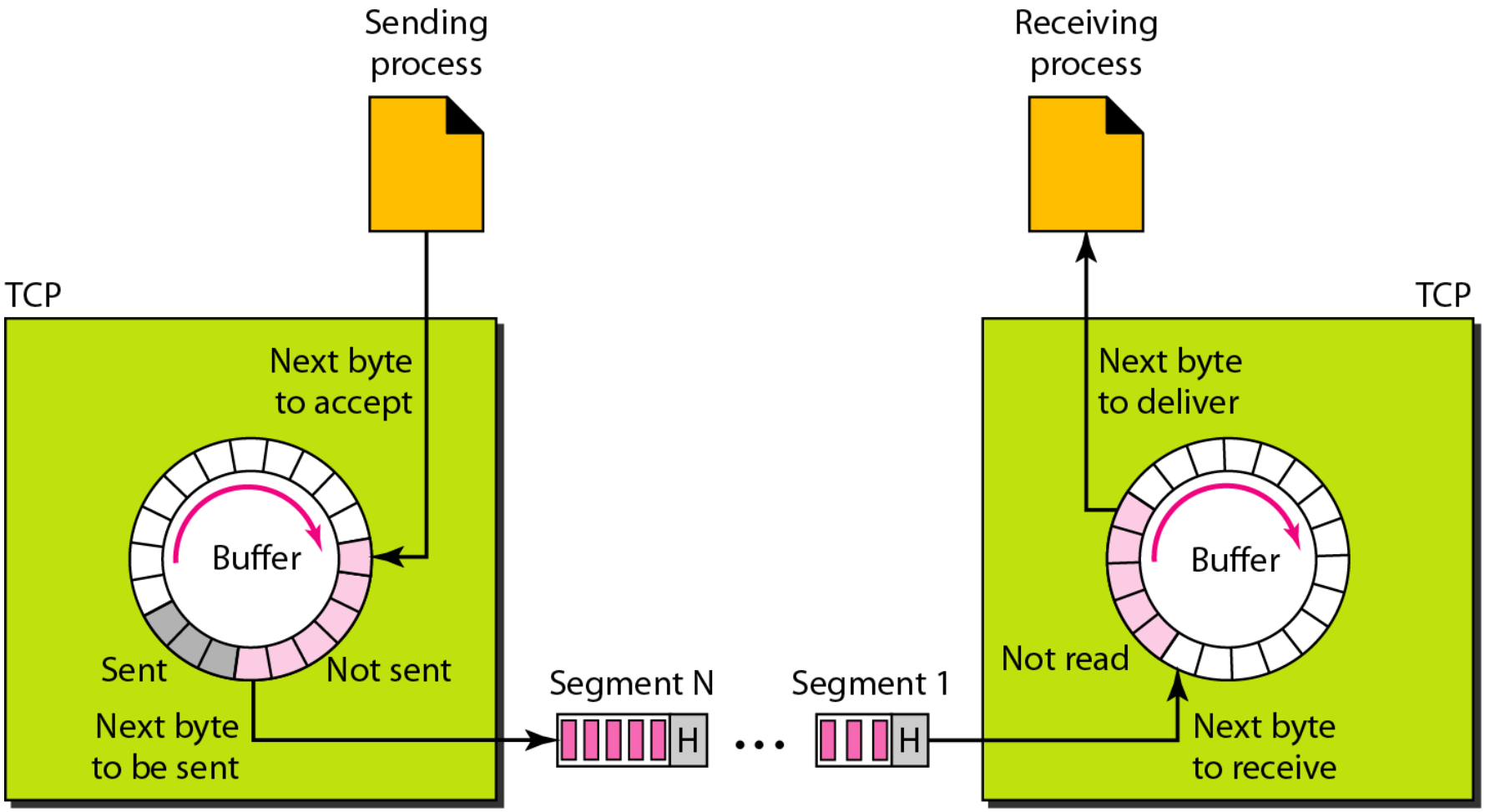
Connected by an imaginary "tube" that carries their data across the Internet

Figure 23.14 *Sending and receiving buffers*



*Sending and the receiving processes **may not** write or read data at the **same speed***

Figure 23.15 *TCP segments*



*Segments with **different byte sizes**.*

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)

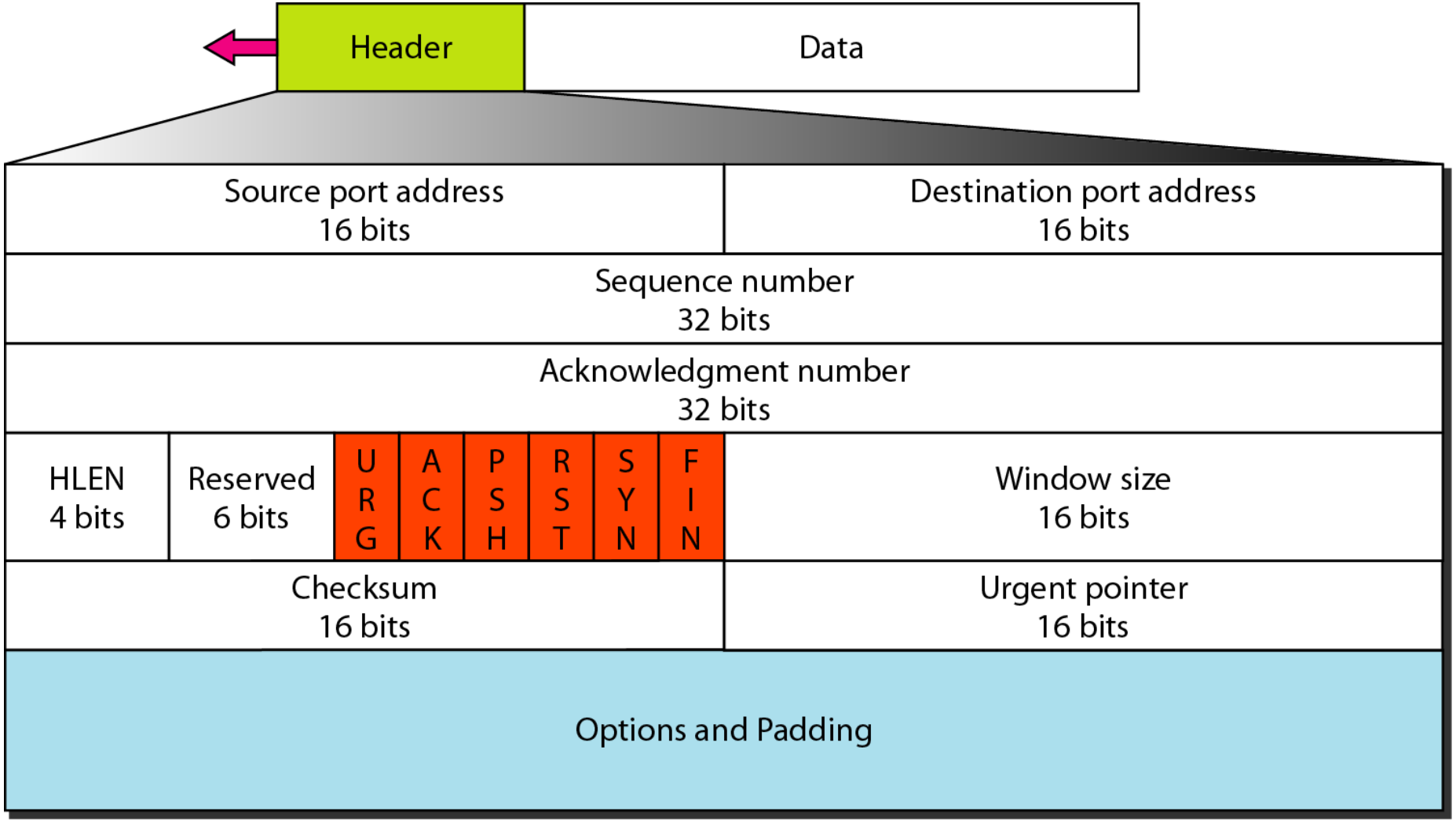
Note

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*

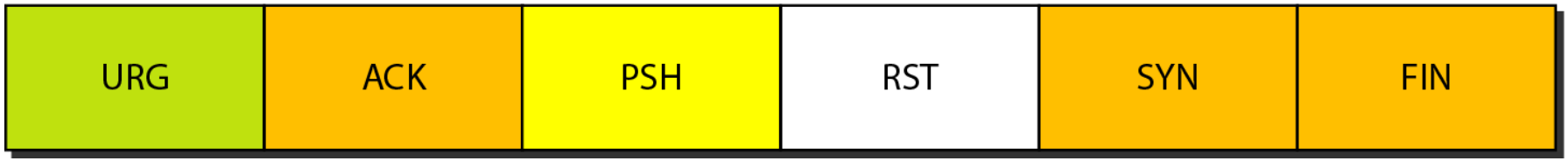


20-60 byte header;
HLEN: (size x 4), eg size=5, So 20 bytes hearder
The sender must obey the Receiving window (rwnd);
Checksum: same as in UDP

Urgent: the number of the last urgent byte in the data section of the segment.

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



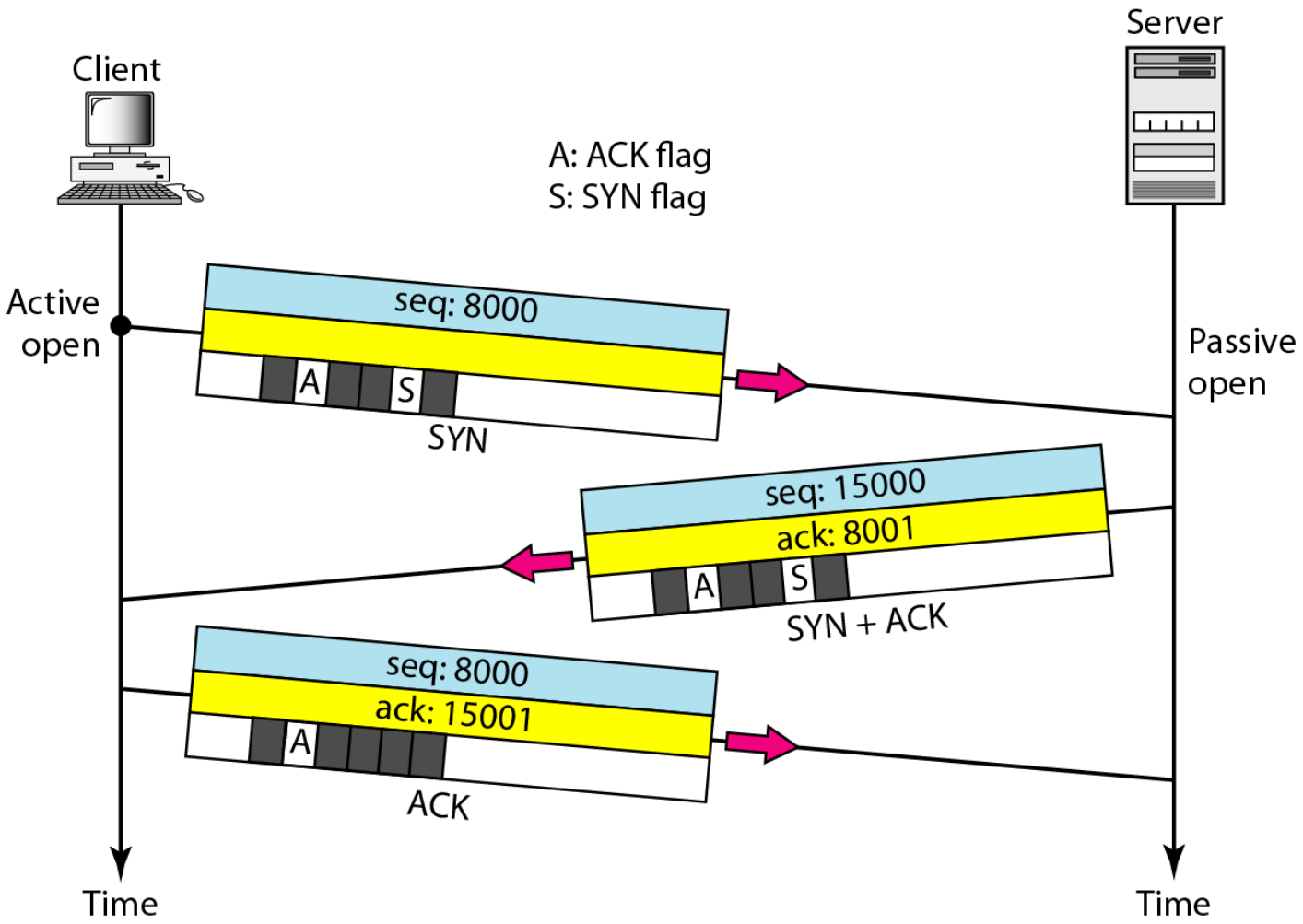
Flag	*Description*
URG	The value of the urgent pointer field is valid.
ACK	The value of the acknowledgment field is valid.
PSH	Push the data.
RST	Reset the connection.
SYN	Synchronize sequence numbers during connection.
FIN	Terminate the connection.

Table 23.3 *Description of flags in the control field*

TCP is Connection-Oriented

- ✓ A connection-oriented transport protocol establishes a virtual path between the source and destination.
- ✓ Connection-oriented transmission requires three phases:
    1. connection establishment,
    2. data transfer, and
    3. connection termination.
- ✓ TCP transmits data in full-duplex mode (each party must initialize communication and get approval)

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*

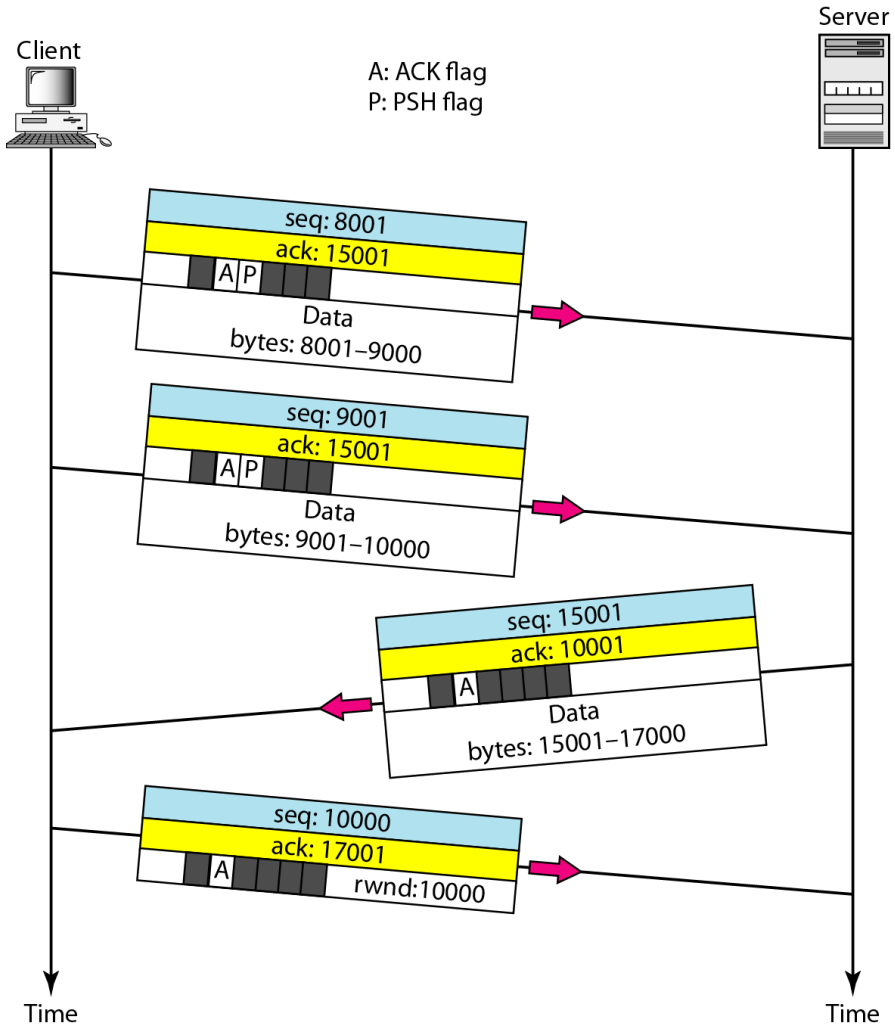
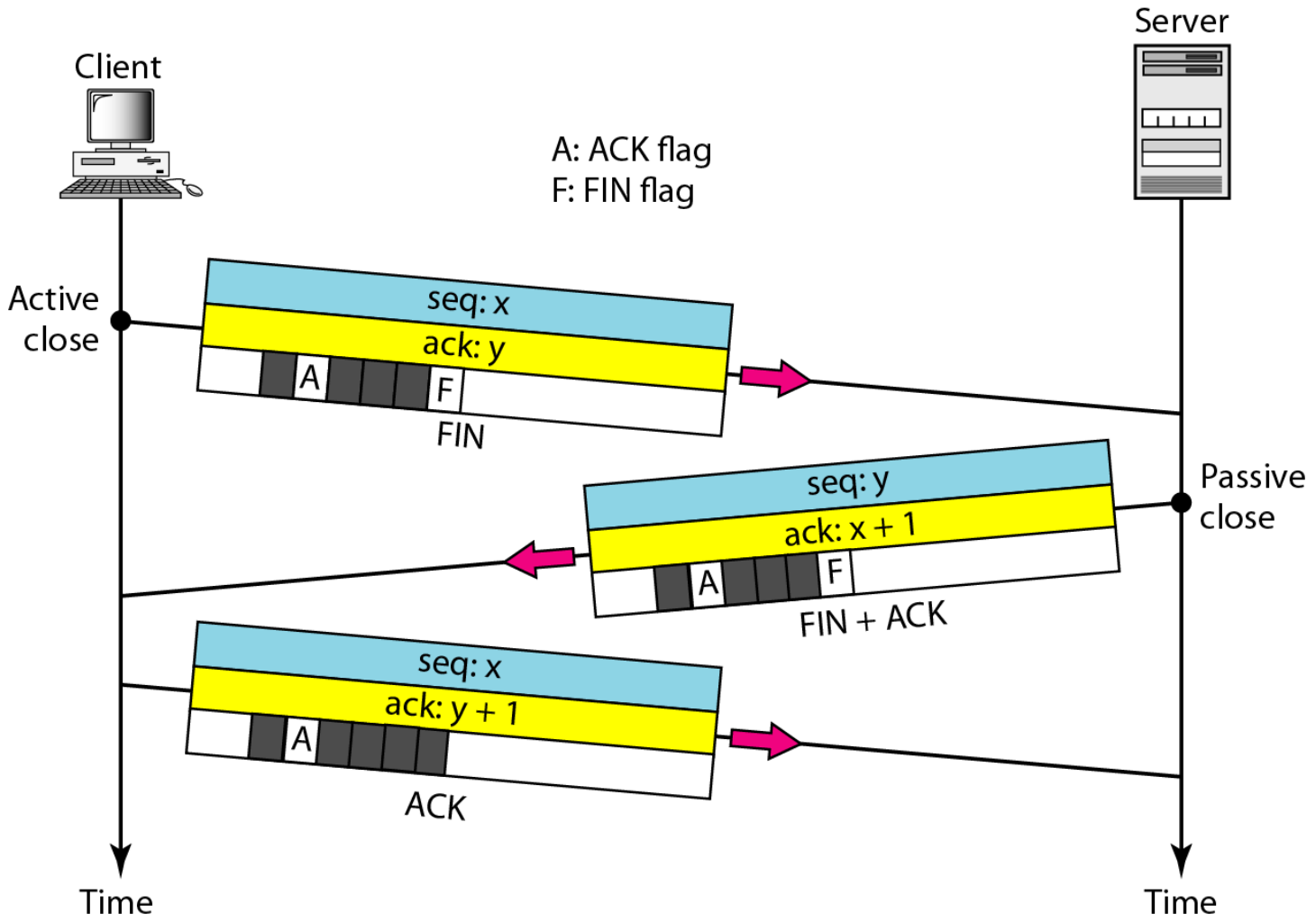


Figure 23.20 *Connection termination using three-way handshaking*



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*

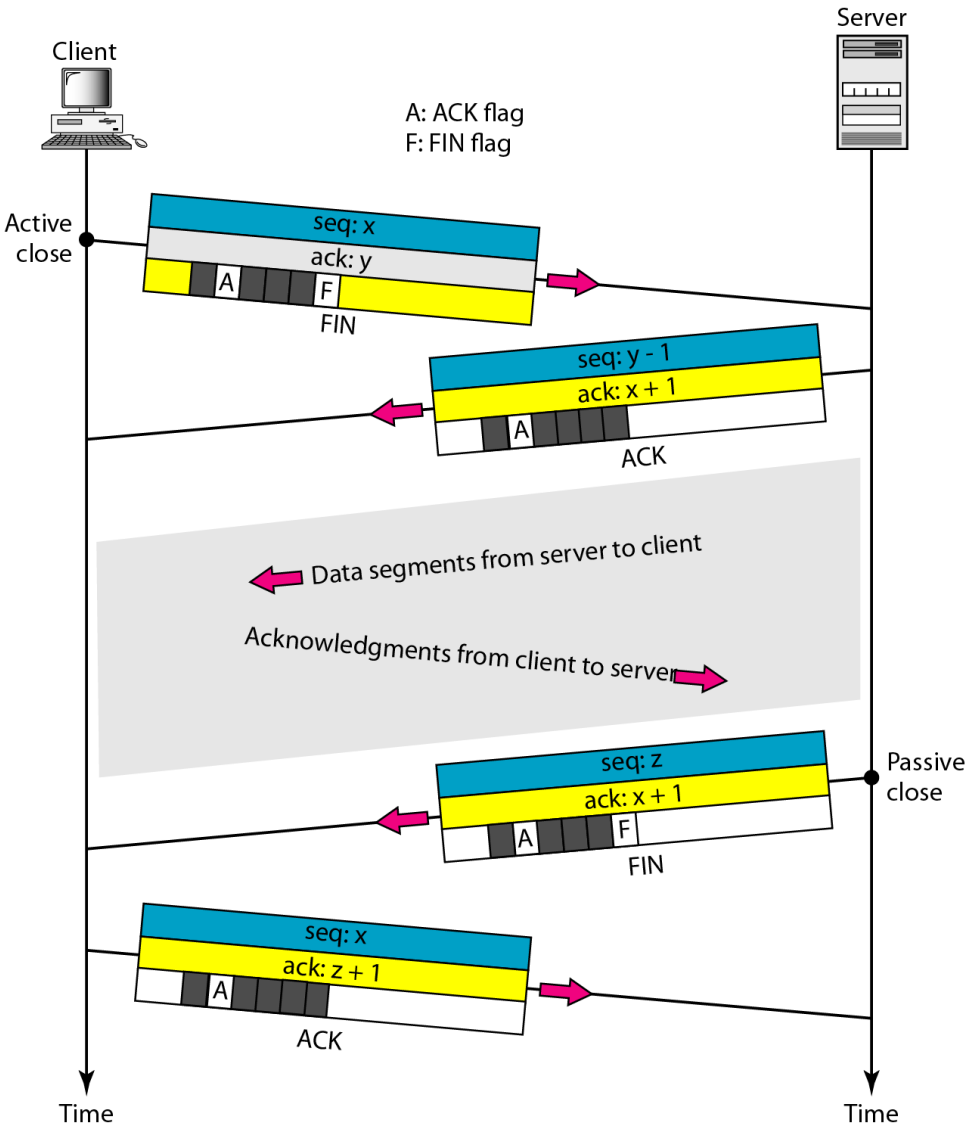
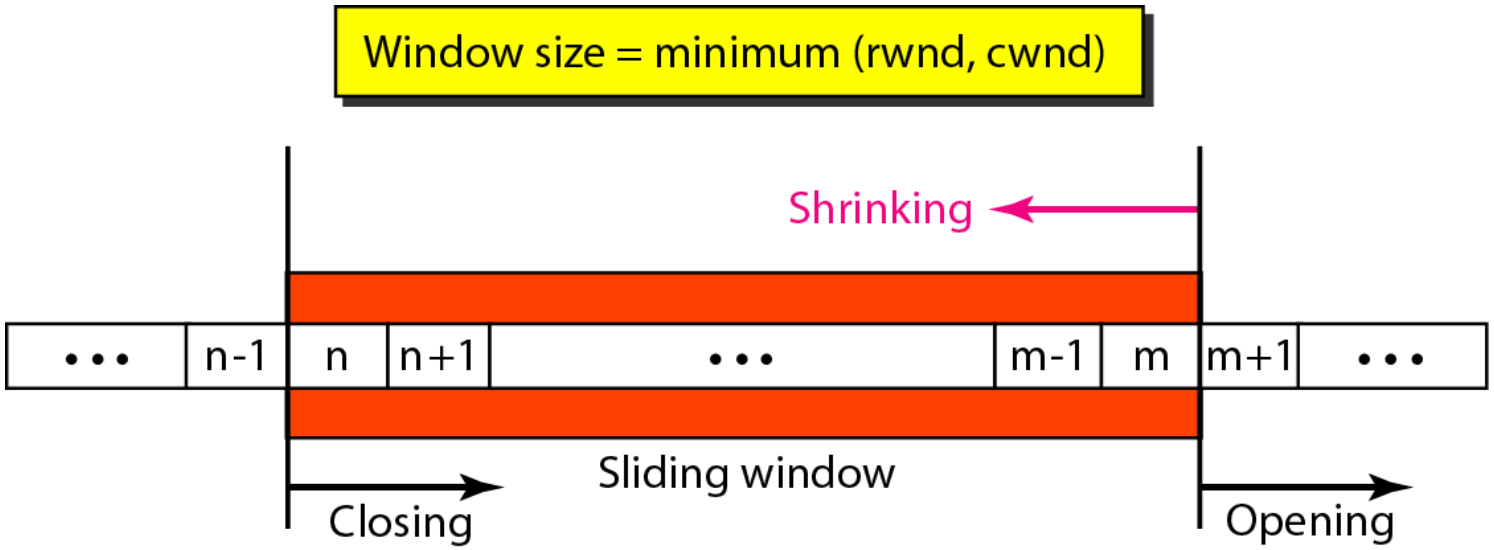


Figure 23.22 Flow Control: *Sliding window*



- ✓ Sliding window of TCP is byte-oriented
- ✓ Sliding window is of variable size

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 congestion window (cwnd) is 3500 bytes?

Solution

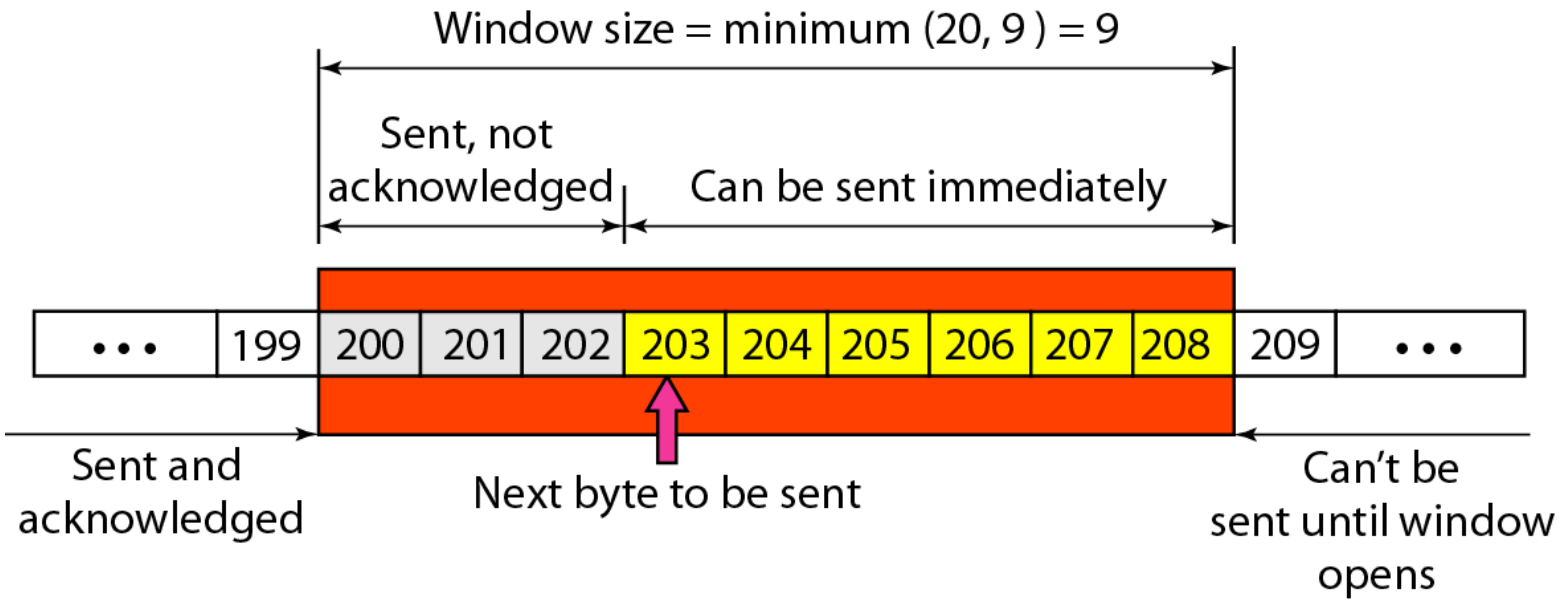
The size of the window is the smaller of rwnd and cwnd, which is 3000 bytes.

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*

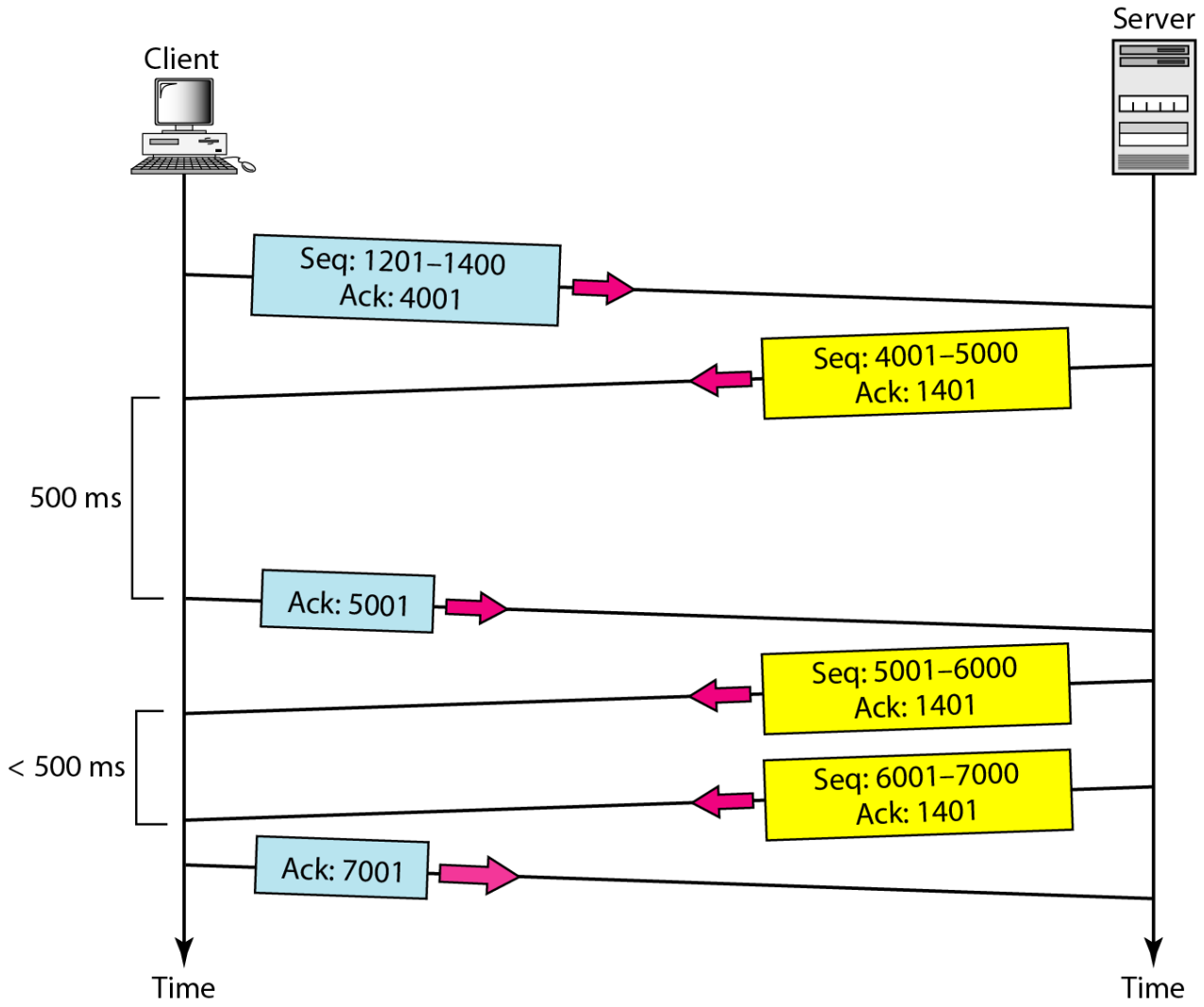
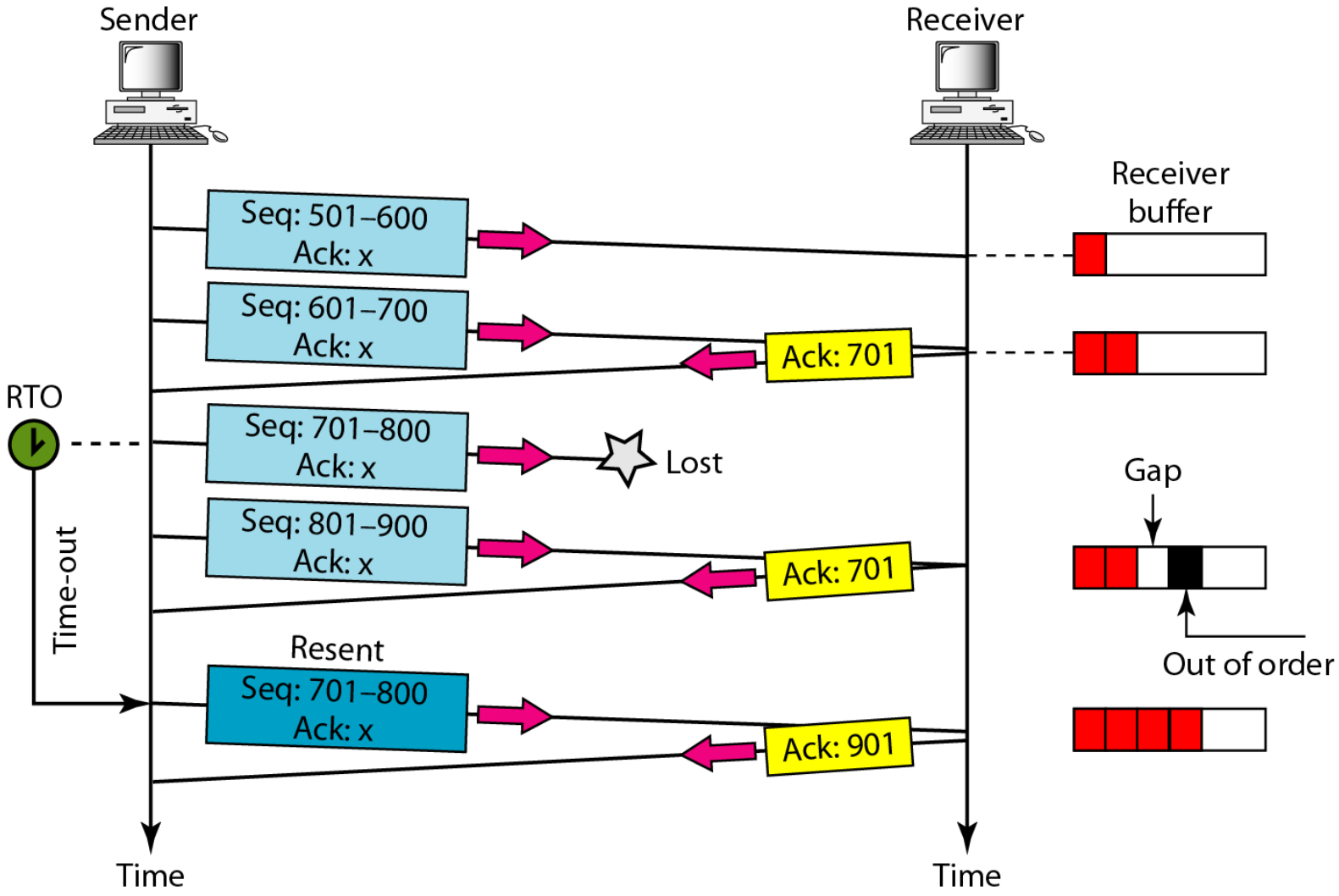


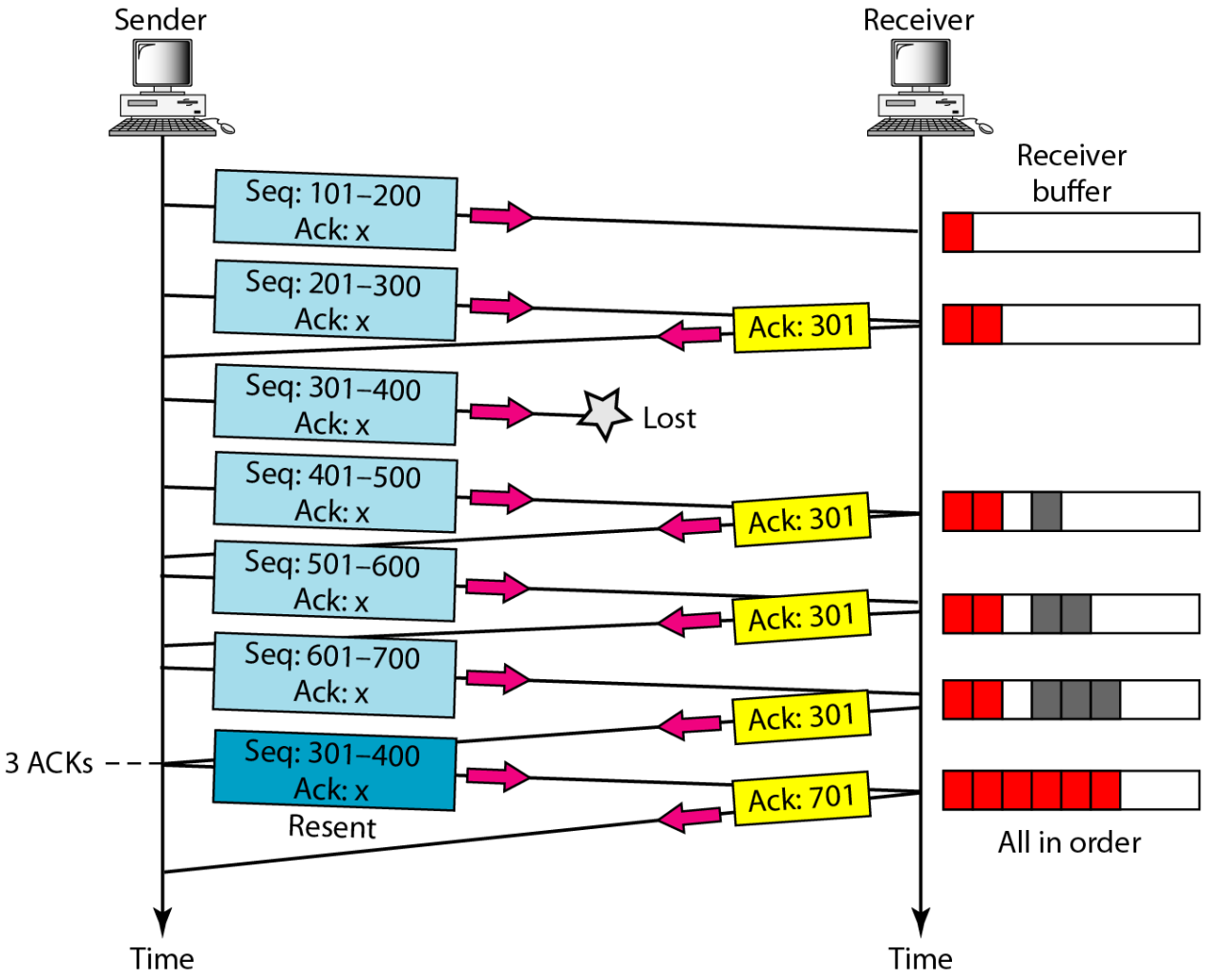
Figure 23.25 *Lost segment*



Note

The receiver TCP delivers only ordered data to the process.

Figure 23.26 *Fast retransmission*



23-4 SCTP

Stream Control Transmission Protocol (SCTP) is a new reliable, message-oriented transport layer protocol. SCTP, however, is mostly designed for Internet applications that have recently been introduced. These new applications need a more sophisticated service than TCP can provide.

Topics discussed in this section:

SCTP Services and Features
Packet Format
An SCTP Association
Flow Control and Error Control

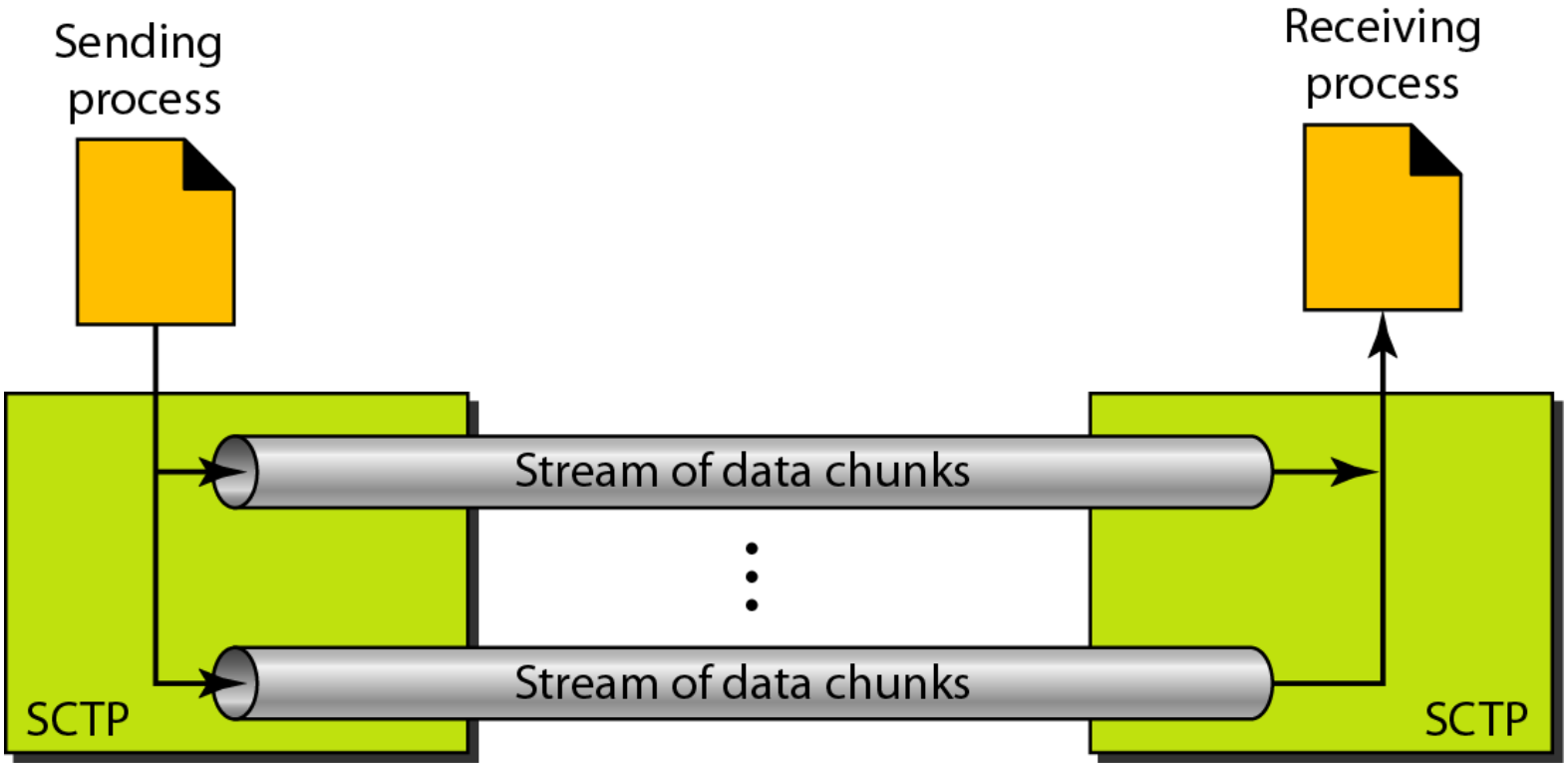
Note

SCTP is a message-oriented, reliable protocol that combines the best features of UDP and TCP.

Table 23.4 *Some SCTP applications*

Protocol	*Port Number*	*Description*
IUA	9990	ISDN over IP
M2UA	2904	SS7 telephony signaling
M3UA	2905	SS7 telephony signaling
H.248	2945	Media gateway control
H.323	1718, 1719, 1720, 11720	IP telephony
SIP	5060	IP telephony

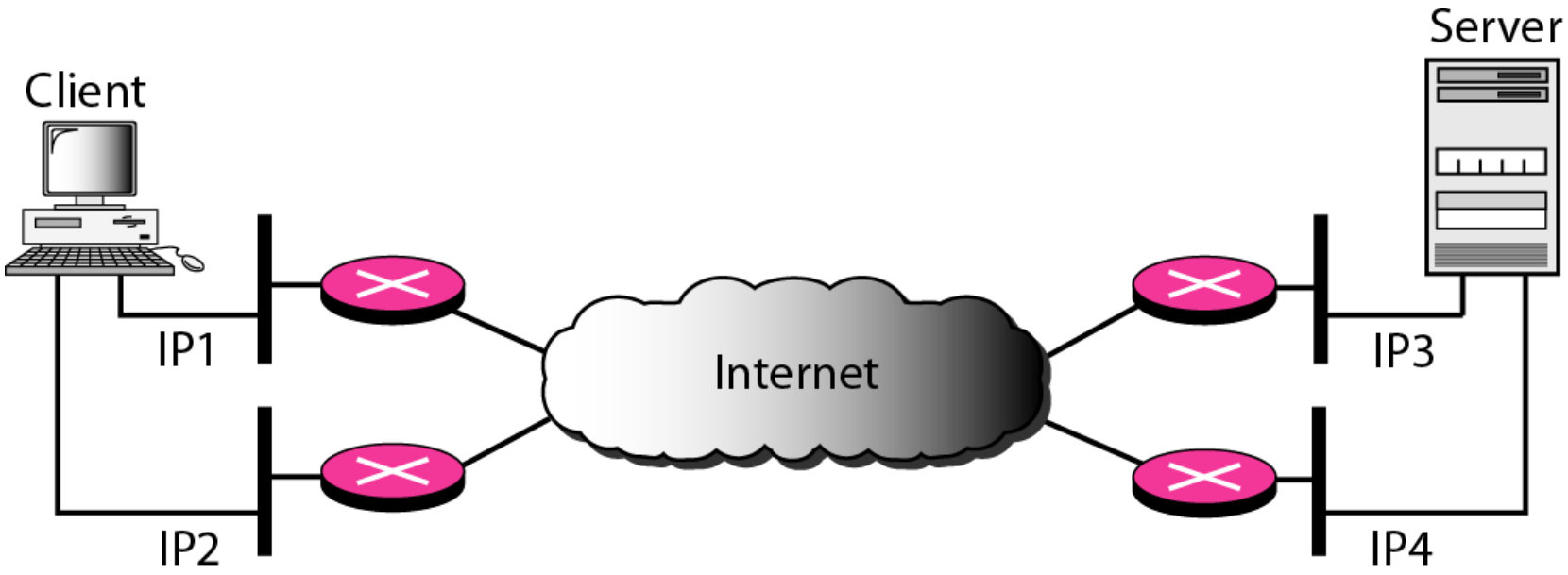
Figure 23.27 *Multiple-stream concept*



Note

An association in SCTP can involve multiple streams.

Figure 23.28 *Multihoming concept*



Note

SCTP association allows multiple IP addresses for each end.

Note

In SCTP, a data chunk is numbered using a TSN.

Note

To distinguish between different streams, SCTP uses an SI.

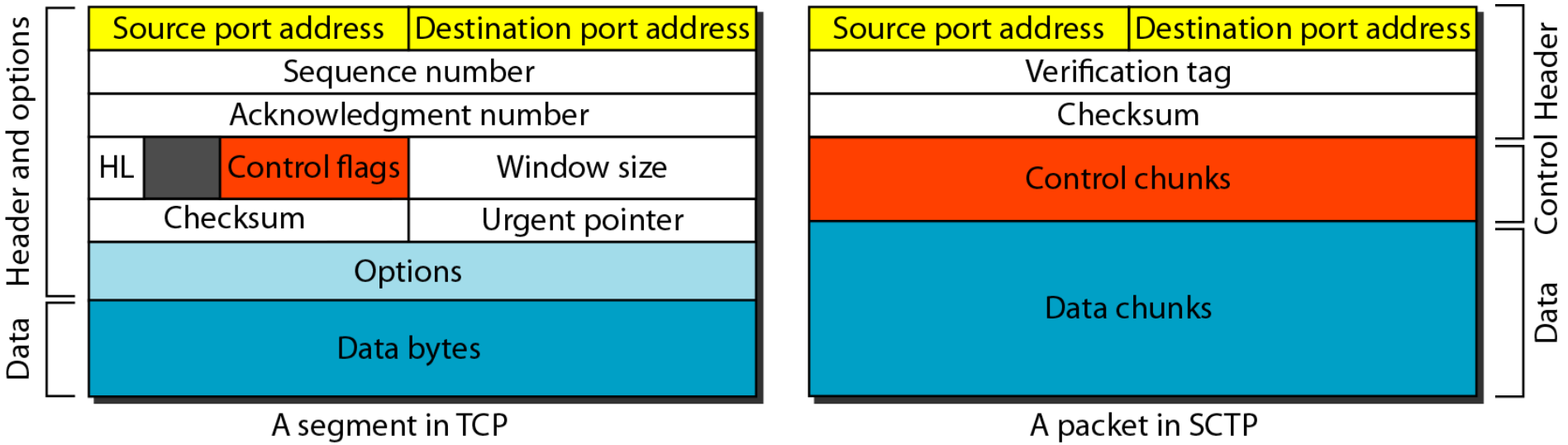
Note

To distinguish between different data chunks belonging to the same stream, SCTP uses SSNs.

Note

TCP has segments; SCTP has packets.

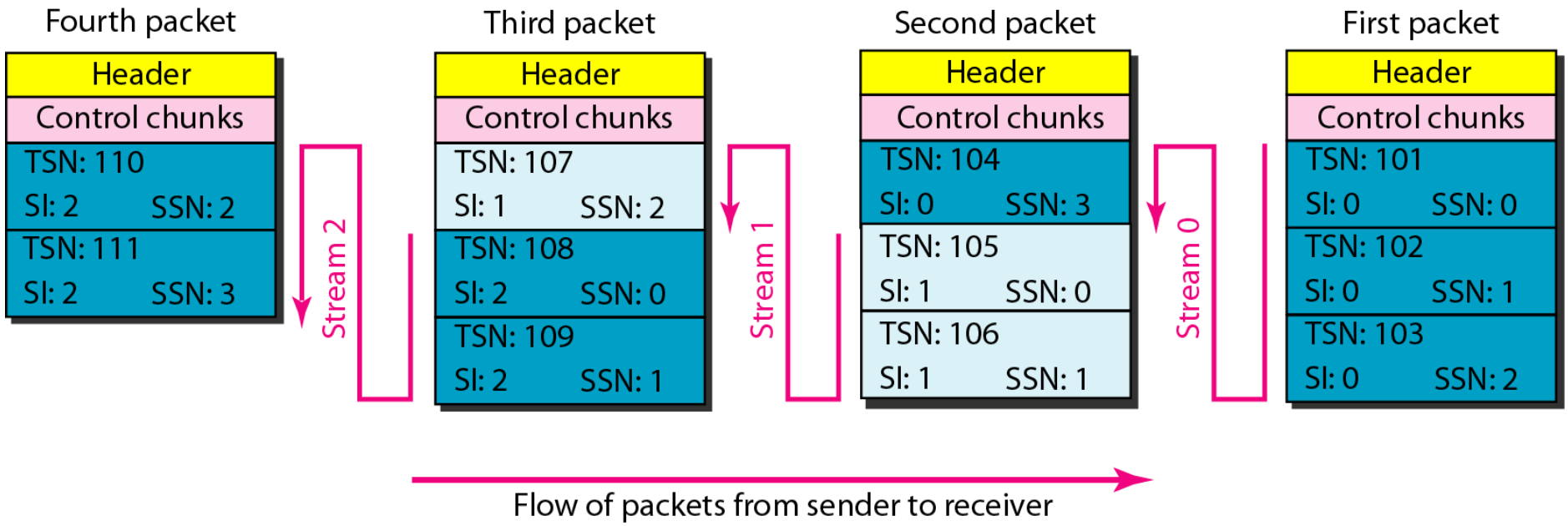
Figure 23.29 *Comparison between a TCP segment and an SCTP packet*



Note

In SCTP, control information and data information are carried in separate chunks.

Figure 23.30 *Packet, data chunks, and streams*



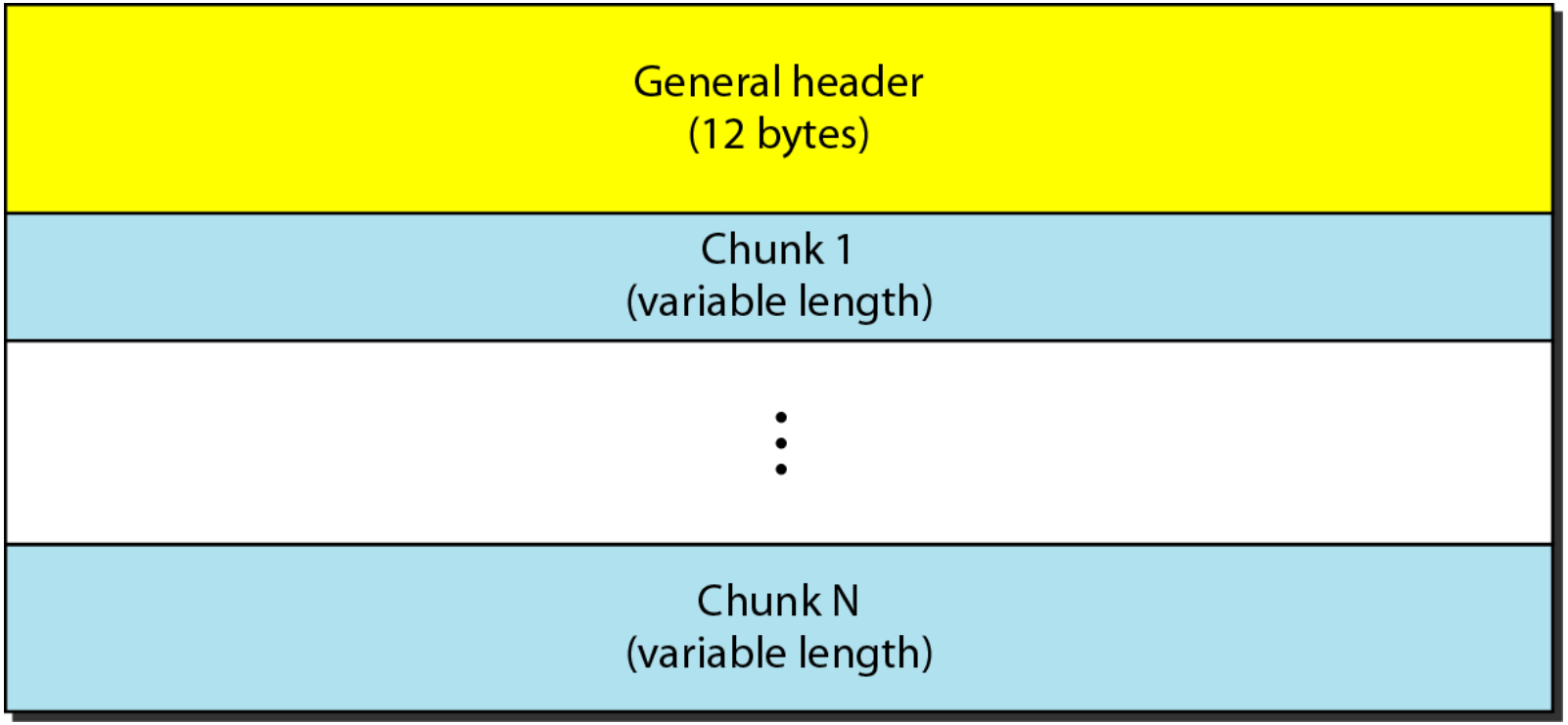
Note

Data chunks are identified by three items: TSN, SI, and SSN. TSN is a cumulative number identifying the association; SI defines the stream; SSN defines the chunk in a stream.

Note

In SCTP, acknowledgment numbers are used to acknowledge only data chunks; control chunks are acknowledged by other control chunks if necessary.

Figure 23.31 *SCTP packet format*



Note

In an SCTP packet, control chunks come before data chunks.

Figure 23.32 *General header*

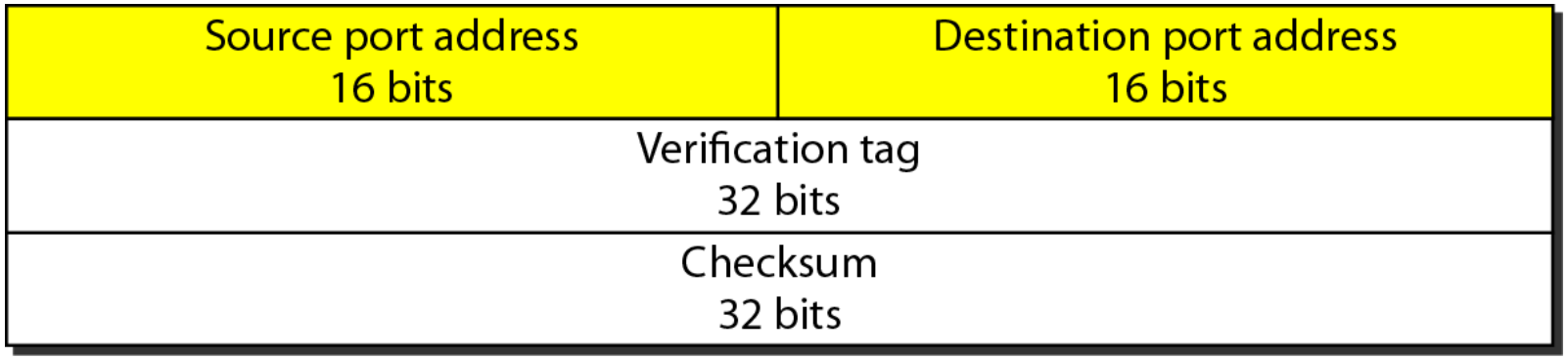


Table 23.5 *Chunks*

Type	*Chunk*	*Description*
0	**DATA**	User data
1	**INIT**	Sets up an association
2	**INIT ACK**	Acknowledges INIT chunk
3	**SACK**	Selective acknowledgment
4	**HEARTBEAT**	Probes the peer for liveliness
5	**HEARTBEAT ACK**	Acknowledges HEARTBEAT chunk
6	**ABORT**	Aborts an association
7	**SHUTDOWN**	Terminates an association
8	**SHUTDOWN ACK**	Acknowledges SHUTDOWN chunk
9	**ERROR**	Reports errors without shutting down
10	**COOKIE ECHO**	Third packet in association establishment
11	**COOKIE ACK**	Acknowledges COOKIE ECHO chunk
14	**SHUTDOWN COMPLETE**	Third packet in association termination
192	**FORWARD TSN**	For adjusting cumulative TSN

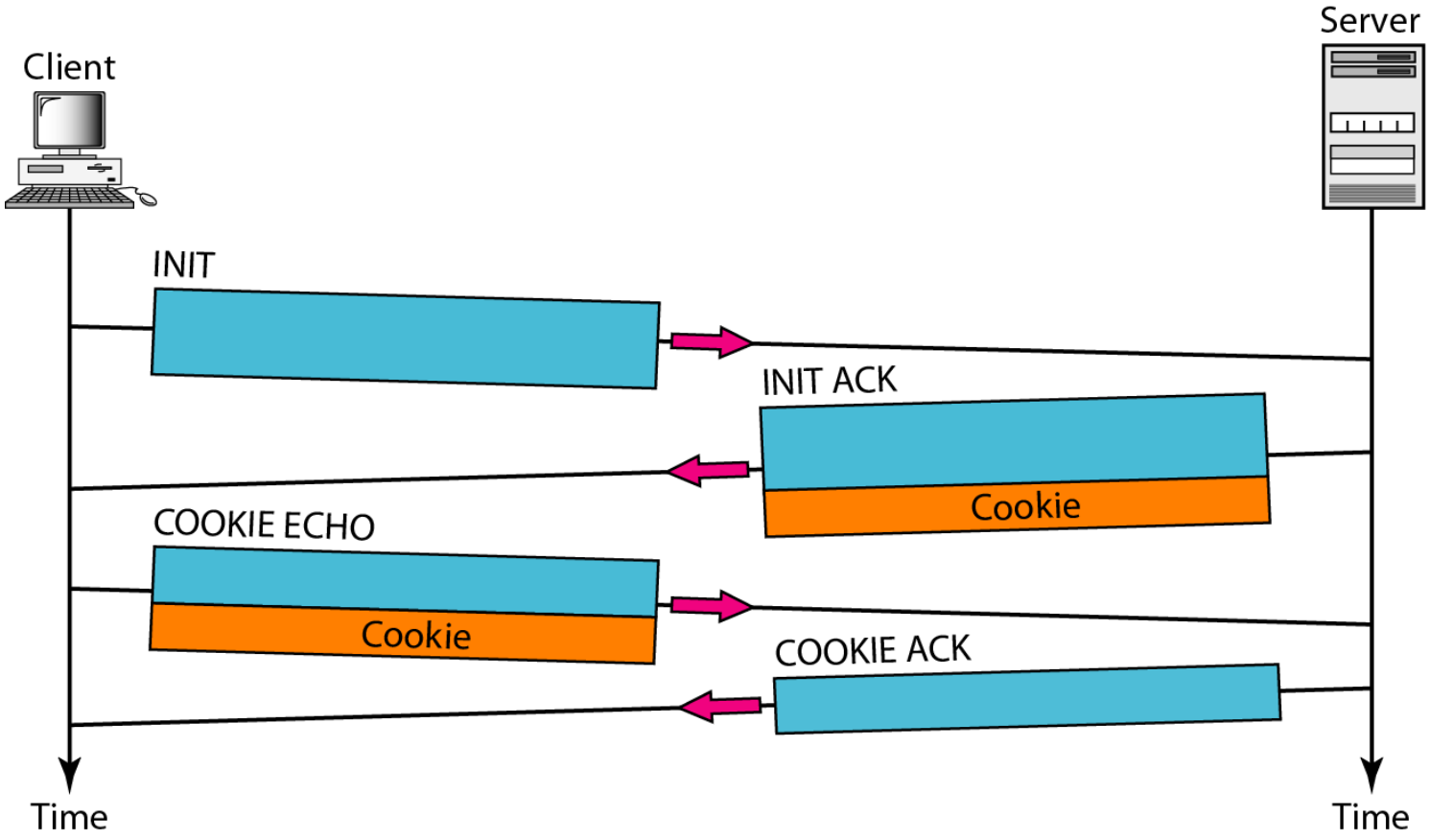
Note

A connection in SCTP is called an association.

Note

No other chunk is allowed in a packet carrying an INIT or INIT ACK chunk. A COOKIE ECHO or a COOKIE ACK chunk can carry data chunks.

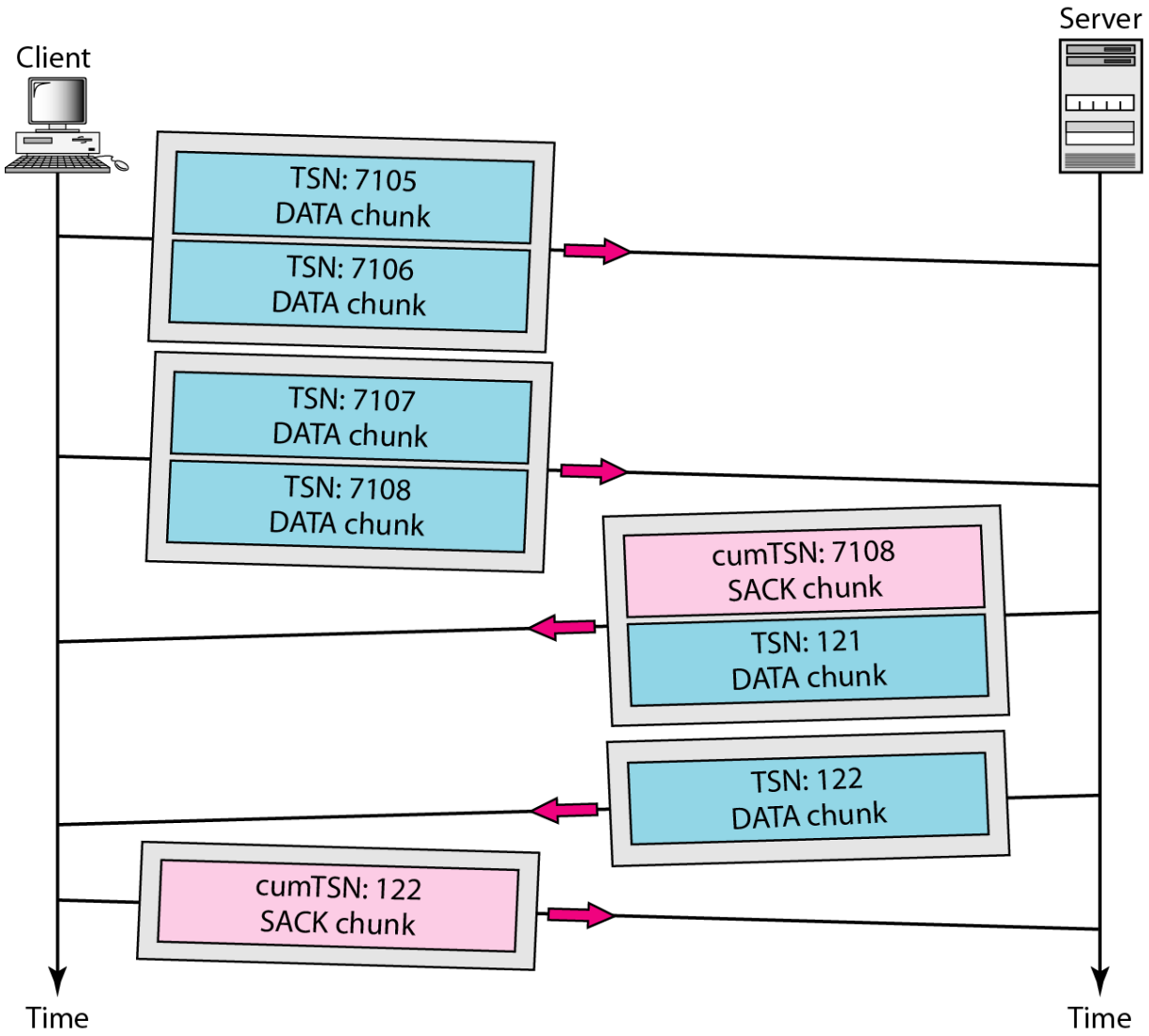
Figure 23.33 *Four-way handshaking*



Note

In SCTP, only DATA chunks consume TSNs; DATA chunks are the only chunks that are acknowledged.

Figure 23.34 *Simple data transfer*



Note

The acknowledgment in SCTP defines the cumulative TSN, the TSN of the last data chunk received in order.

Figure 23.35 *Association termination*

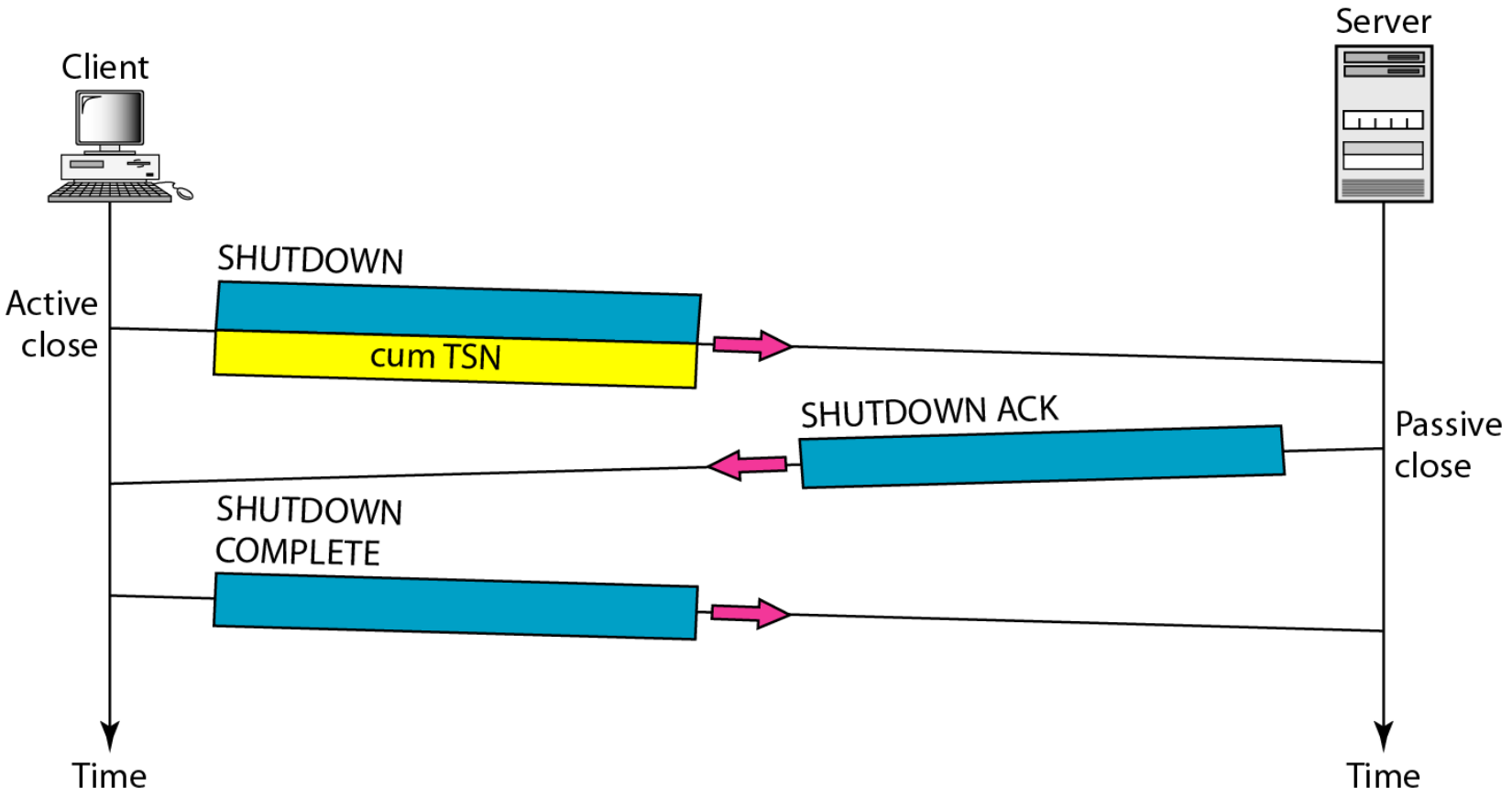


Figure 23.36 *Flow control, receiver site*

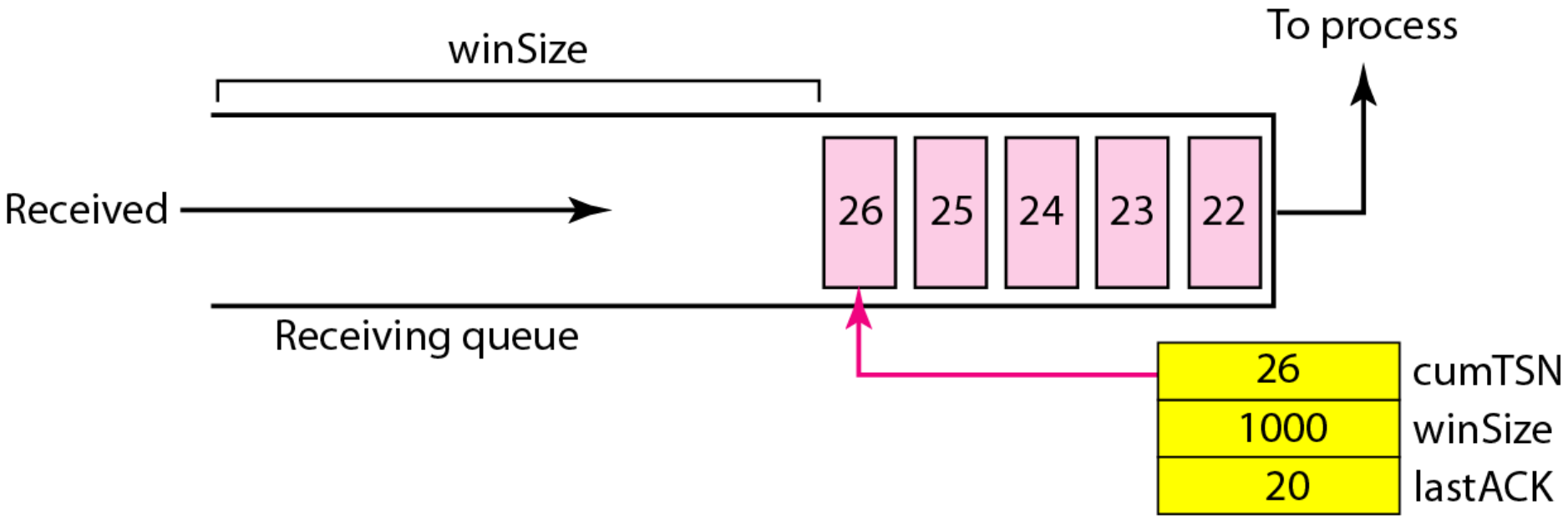


Figure 23.37 *Flow control, sender site*

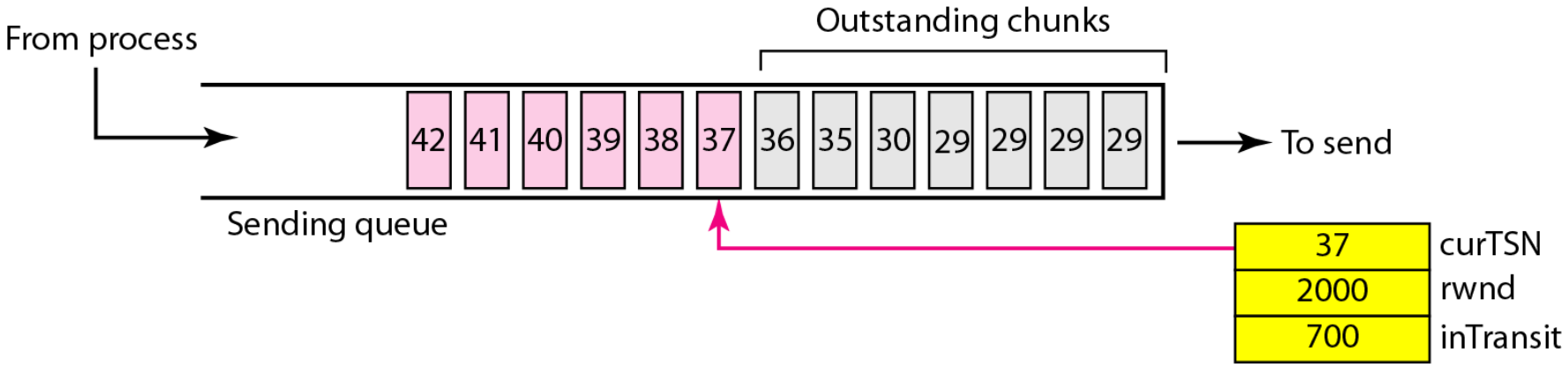


Figure 23.38 *Flow control scenario*

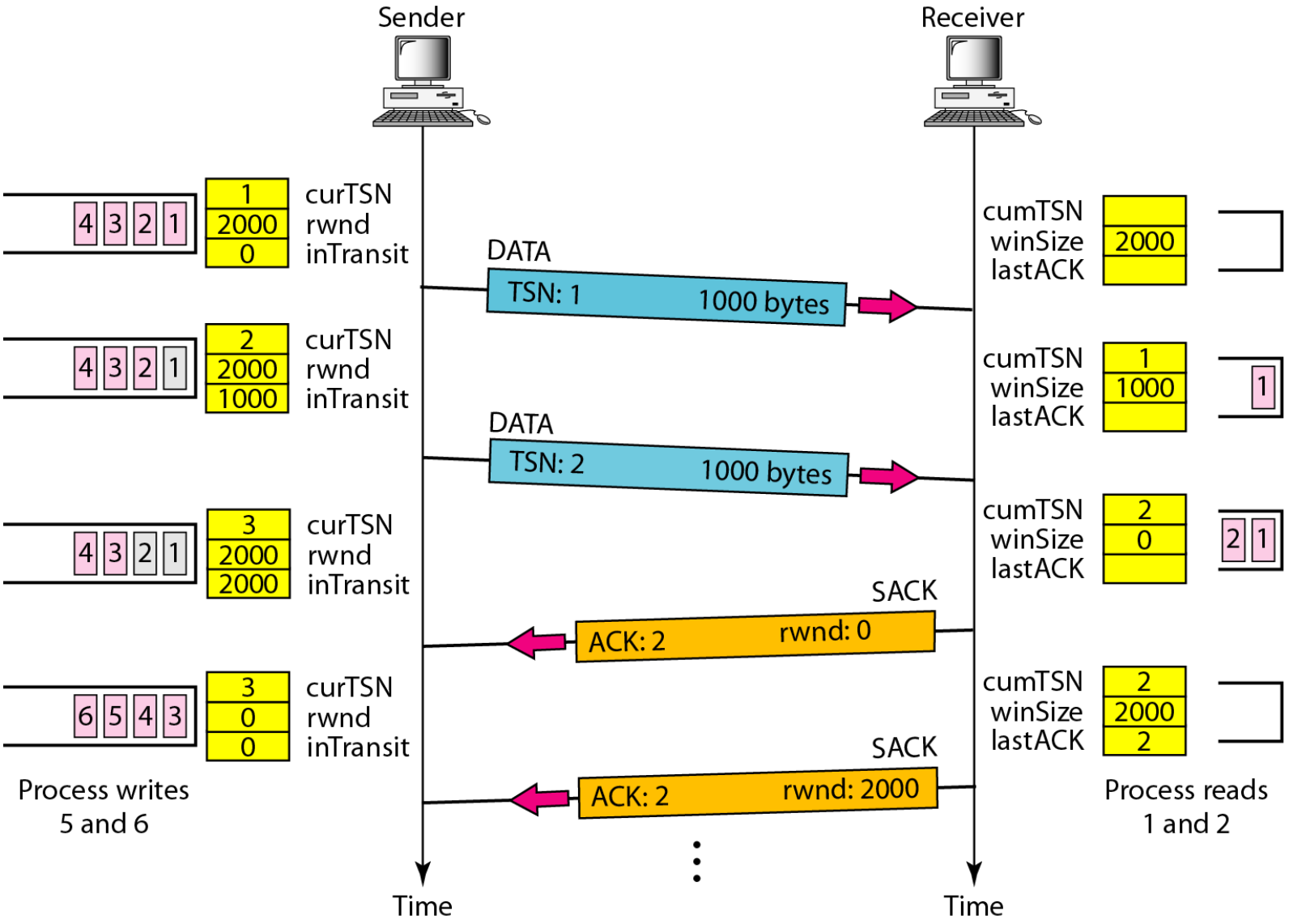


Figure 23.39 *Error control, receiver site*

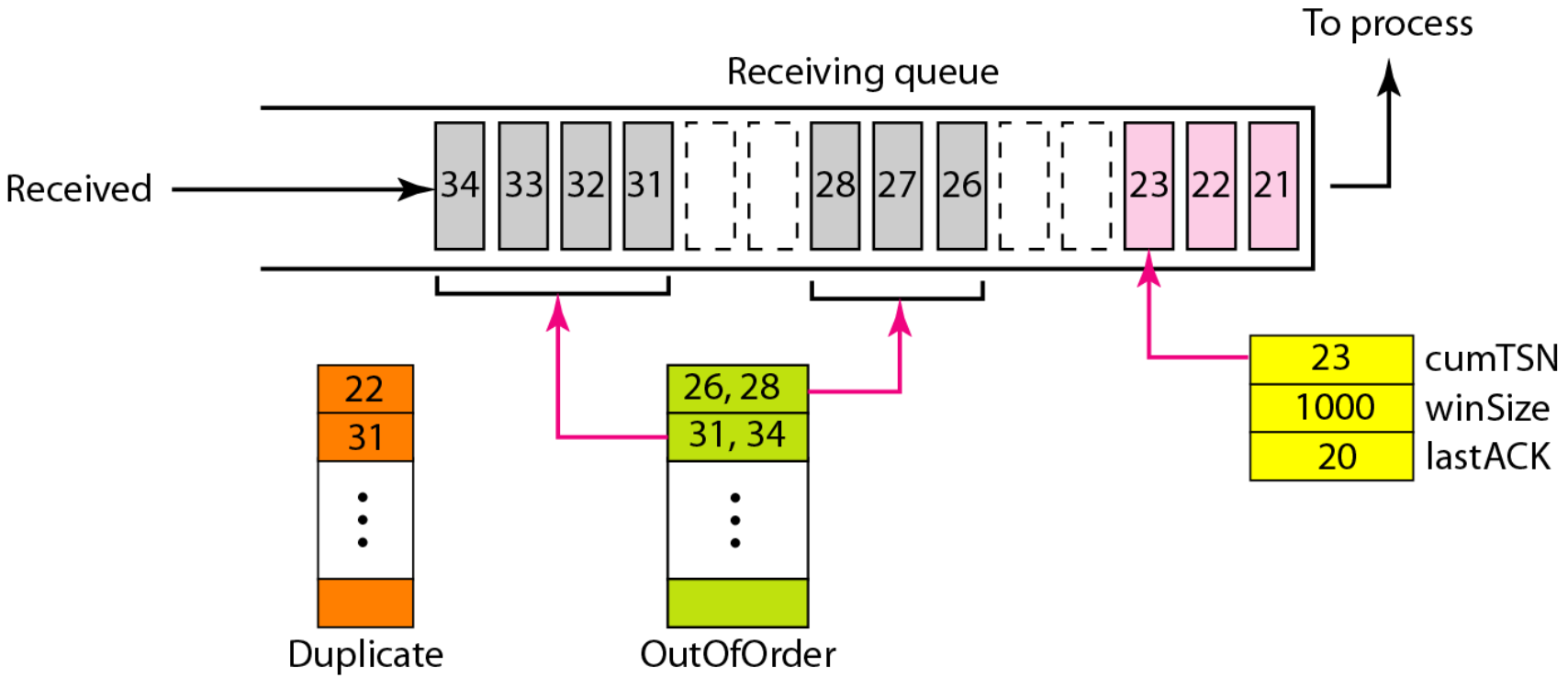


Figure 23.40 *Error control, sender site*