

2.7.2 Socket Programming with TCP

Unlike UDP, TCP is a connection-oriented protocol. This means that before the client and server can start to send data to each other, they first need to handshake and establish a TCP connection. One end of the TCP connection is attached to the client socket and the other end is attached to a server socket. When creating the TCP connection, we associate with it the client socket address (IP address and port number) and the server socket address (IP address and port number). With the TCP connection established, when one side wants to send data to the other side, it just drops the data into the TCP connection via its socket. This is different from UDP, for which the server must attach a destination address to the packet before dropping it into the socket.

Now let's take a closer look at the interaction of client and server programs in TCP. The client has the job of initiating contact with the server. In order for the server to be able to react to the client's initial contact, the server has to be ready. This implies two things. First, as in the case of UDP, the TCP server must be running as a process before the client attempts to initiate contact. Second, the server program must have a special door—more precisely, a special socket—that welcomes some initial contact from a client process running on an arbitrary host. Using our house/door analogy for a process/socket, we will sometimes refer to the client's initial contact as "knocking on the welcoming door."

With the server process running, the client process can initiate a TCP connection to the server. This is done in the client program by creating a TCP socket. When the client creates its TCP socket, it specifies the address of the welcoming socket in the server, namely, the IP address of the server host and the port number of the socket. After creating its socket, the client initiates a three-way handshake and establishes a TCP connection with the server. The three-way handshake, which takes place within the transport layer, is completely invisible to the client and server programs.

During the three-way handshake, the client process knocks on the welcoming door of the server process. When the server "hears" the knocking, it creates a new door—more precisely, a *new* socket that is dedicated to that particular client. In our example below, the welcoming door is a TCP socket object that we call `serverSocket`; the newly created socket dedicated to the client making the connection is called `connectionSocket`. Students who are encountering TCP sockets for the first time sometimes confuse the welcoming socket (which is the initial point of contact for all clients wanting to communicate with the server), and each newly created server-side connection socket that is subsequently created for communicating with each client.

From the application's perspective, the client's socket and the server's connection socket are directly connected by a pipe. As shown in Figure 2.29, the client process can send arbitrary bytes into its socket, and TCP guarantees that the server process will receive (through the connection socket) each byte in the order sent. TCP thus provides a reliable service between the client and server processes. Furthermore, just as people can go in and out the same door, the client process not only sends bytes

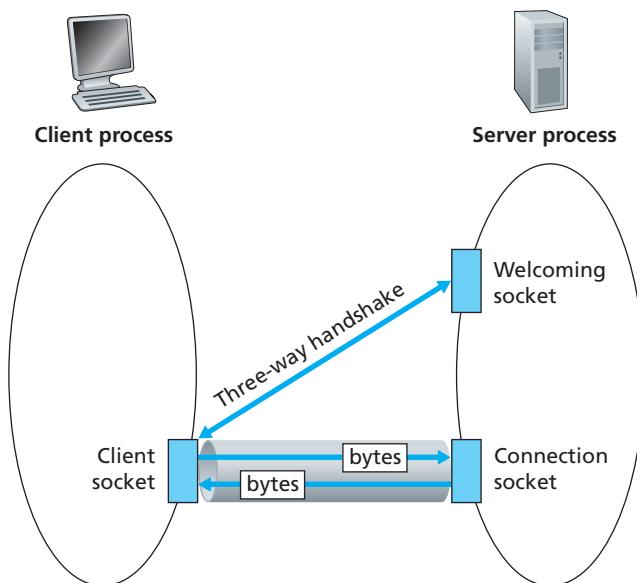


Figure 2.29 ♦ The TCPserver process has two sockets

into but also receives bytes from its socket; similarly, the server process not only receives bytes from but also sends bytes into its connection socket.

We use the same simple client-server application to demonstrate socket programming with TCP: The client sends one line of data to the server, the server capitalizes the line and sends it back to the client. Figure 2.30 highlights the main socket-related activity of the client and server that communicate over the TCP transport service.

TCPClient.py

Here is the code for the client side of the application:

```
from socket import *
serverName = 'servername'
serverPort = 12000
clientSocket = socket(AF_INET, SOCK_STREAM)
clientSocket.connect((serverName,serverPort))
sentence = raw_input('Input lowercase sentence: ')
clientSocket.send(sentence)
modifiedSentence = clientSocket.recv(1024)
print 'From Server:', modifiedSentence
clientSocket.close()
```

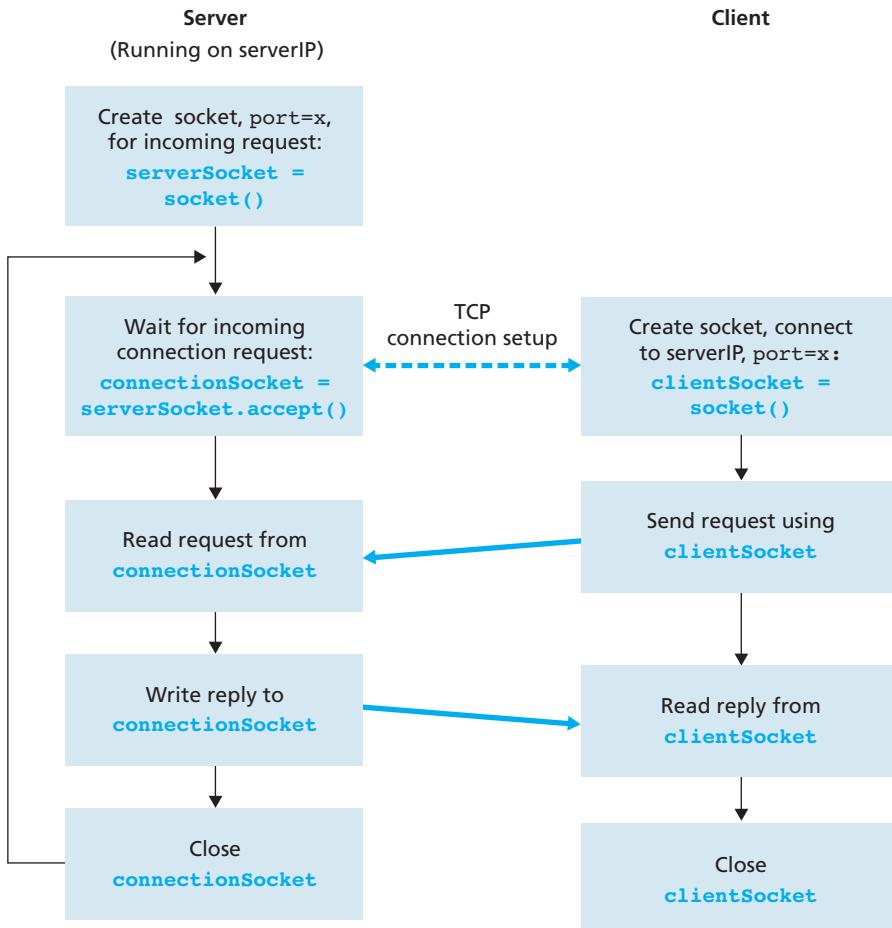


Figure 2.30 ♦ The client-server application using TCP

Let's now take a look at the various lines in the code that differ significantly from the UDP implementation. The first such line is the creation of the client socket.

```
clientSocket = socket(AF_INET, SOCK_STREAM)
```

This line creates the client's socket, called `clientSocket`. The first parameter again indicates that the underlying network is using IPv4. The second parameter indicates that the socket is of type `SOCK_STREAM`, which means it is a TCP socket (rather than a UDP socket). Note that we are again not specifying the port number

of the client socket when we create it; we are instead letting the operating system do this for us. Now the next line of code is very different from what we saw in UDPClient:

```
clientSocket.connect((serverName, serverPort))
```

Recall that before the client can send data to the server (or vice versa) using a TCP socket, a TCP connection must first be established between the client and server. The above line initiates the TCP connection between the client and server. The parameter of the `connect()` method is the address of the server side of the connection. After this line of code is executed, the three-way handshake is performed and a TCP connection is established between the client and server.

```
sentence = raw_input('Input lowercase sentence:')
```

As with UDPClient, the above obtains a sentence from the user. The string `sentence` continues to gather characters until the user ends the line by typing a carriage return. The next line of code is also very different from UDPClient:

```
clientSocket.send(sentence)
```

The above line sends the string `sentence` through the client's socket and into the TCP connection. Note that the program does *not* explicitly create a packet and attach the destination address to the packet, as was the case with UDP sockets. Instead the client program simply drops the bytes in the string `sentence` into the TCP connection. The client then waits to receive bytes from the server.

```
modifiedSentence = clientSocket.recv(2048)
```

When characters arrive from the server, they get placed into the string `modifiedSentence`. Characters continue to accumulate in `modifiedSentence` until the line ends with a carriage return character. After printing the capitalized sentence, we close the client's socket:

```
clientSocket.close()
```

This last line closes the socket and, hence, closes the TCP connection between the client and the server. It causes TCP in the client to send a TCP message to TCP in the server (see Section 3.5).

TCPServer.py

Now let's take a look at the server program.

```
from socket import *
serverPort = 12000
serverSocket = socket(AF_INET,SOCK_STREAM)
serverSocket.bind(('',serverPort))
serverSocket.listen(1)
print 'The server is ready to receive'
while 1:
    connectionSocket, addr = serverSocket.accept()
    sentence = connectionSocket.recv(1024)
    capitalizedSentence = sentence.upper()
    connectionSocket.send(capitalizedSentence)
    connectionSocket.close()
```

Let's now take a look at the lines that differ significantly from UDPServer and TCP-Client. As with TCPClient, the server creates a TCP socket with:

```
serverSocket=socket(AF_INET,SOCK_STREAM)
```

Similar to UDPServer, we associate the server port number, `serverPort`, with this socket:

```
serverSocket.bind(('',serverPort))
```

But with TCP, `serverSocket` will be our welcoming socket. After establishing this welcoming door, we will wait and listen for some client to knock on the door:

```
serverSocket.listen(1)
```

This line has the server listen for TCP connection requests from the client. The parameter specifies the maximum number of queued connections (at least 1).

```
connectionSocket, addr = serverSocket.accept()
```

When a client knocks on this door, the program invokes the `accept()` method for `serverSocket`, which creates a new socket in the server, called `connectionSocket`, dedicated to this particular client. The client and server then complete the handshaking, creating a TCP connection between the client's `clientSocket` and the server's `connectionSocket`. With the TCP connection established, the client and server can now send bytes to each other over the connection. With TCP, all bytes sent from one side are not only guaranteed to arrive at the other side but also guaranteed arrive in order.

```
connectionSocket.close()
```