Chapter 7
Support for Communication-Based Services

Abstract In most cases, network communication is all about providing and accessing services. This chapter introduces the support offered by the Java programming language for various communication-based services. Control and diagnostic services including Packet InterNet Groper and Internet Control Message Protocol are presented. Electronic mail services making use of the SMTP and POP3 protocols, file transfer services using FTP, and web content transfer via HTTP are described. Java database connectivity services and programming support for database management systems communication are also discussed. The chapter ends with a presentation of the increasingly popular multimedia content delivery services.

7.1 Introduction

All network applications and services require some form of communication support and often they employ the client–server paradigm. Such applications and services include control and diagnostic services, e-mail, file transfer, web content exchange, and database access services.

Control and diagnostic services require communication mechanisms to support status information exchange in request–response manner and transmission of messages (often regular) to communication partners for information purposes via networks.

The e-mail service involves e-mail clients running on user terminals exchanging electronic messages with e-mail servers. These servers provide support for message storage and forwarding to destination e-mail servers via the network. Remote clients communicate with the e-mail servers for access to the received electronic messages and/or for sending other information. The e-mail service is based on both client–server and server–server network communications.

File transfer applications also use a client–server model. File transfer client applications running on user devices allow for local file access and, most importantly, remote file access in terms of upload and download to and from file servers. Additionally, these file applications have limited file management functions such as folder creation, deletion, etc., both locally and remotely.

Web applications use network communications support to enable the delivery of web documents to web clients (i.e., web browsers such as Firefox, Internet Explorer,

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Chrome, or Safari). The web clients send requests for the documents (web-pages) to web servers which either retrieve or generate them dynamically and deliver them to the client via networks.

Remote database access services can be seen as a particular case of web applications which involve clients establishing network connectivity with servers which have access to databases. Once security aspects have been cleared, the clients are able to run remote queries on the database, retrieve, and process the data.

This chapter presents the protocols these communication-based applications and services rely on and describes step-by-step, with the help of examples, how applications built on top of these protocols can be developed using Java.

7.2 Control and Diagnostic Services

7.2.1 Packet InterNet Groper

Packet InterNet Groper (PING) is a network utility available in most of the operating systems used today. PING is used in diagnosing network problems as well as requesting and receiving performance-related information in terms of delay and packet loss.

The name (PING) comes from an active sonar terminology which sends a sound pulse and then listens for the echo in order to detect objects underwater. Similar to the sonar, PING sends one or several data packets to a host and waits for an identical reply from the destination machine.

PING assumes that if the host machine replies to the received packet, it exists and is connected to the network. Moreover, PING measures the time elapsed between sending the data packet and receiving the echo packet from the target host (round-trip-time). Lost packets are also recorded so packer loss can also be estimated. These two aspects provide a significant metric for learning about the status of a host and for estimating the performance of the network connecting the host to the client machine.

PING uses the Internet Control Message Protocol (ICMP) protocol to send the data packet and receive the expected echo packet as response [12].

7.2.2 Internet Control Message Protocol

ICMP [12] is an unreliable transport layer protocol that uses network layer services offered by the IP protocol [13]. ICMP was standardized as RFC 792 in 1981, making it not only one the oldest protocols in operation today, but also one still widely used by network administrators.

ICMP verifies the correct operation of an IP host and checks that routers are correctly routing packets to the specified destination address.

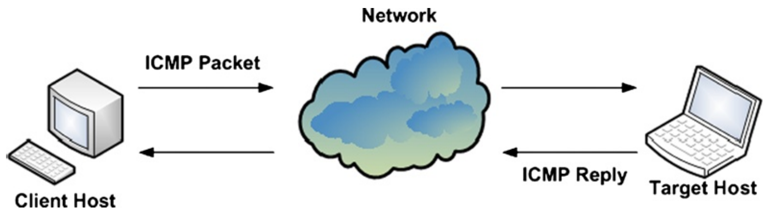
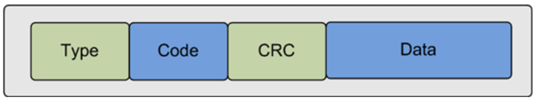


Fig. 7.1 Internet Control Message Protocol (ICMP)

Fig. 7.2 ICMP packet format



The basic principle of ICMP is presented in Fig. 7.1. It can be seen how a simple ICMP request packet is sent from the client host machine to the remote host via the network and the target machine replies with an identical copy of the message received addressed this time to the sender.

The ICMP packet fields include Type, Code, ICMP Header Checksum (CRC), and Data.

Type is an 8 bit field and indicates the type of the ICMP message. Mostly used types are Echo reply (0), Destination unreachable (3), Echo request (8), Time exceeded (11). Based on the Type field, the format of the ICMP packet may change.

Code is an 8 bit field which further qualifies the ICMP message type by offering extra information. For instance, for a Type=3 message (destination unreachable), most often used codes are Net Unreachable (0), Host Unreachable (1), Protocol Unreachable (2), and Port Unreachable (3).

ICMP Header Checksum is a 16 bit field and represents the checksum for the whole ICMP message. This field is used to determine if the packet has been received correctly and no information has been altered in transit. The data in this field is the 16-bit one's complement of the one's complement sum of the ICMP message starting with the Type field.

Data is a variable-length field which contains the data specific to the message type indicated by Type and Code fields.

The detailed format of data packets used by ICMP is illustrated in Fig. 7.2.

7.2.3 PING Java Example

Java does not offer direct support to implement applications that use PING to diagnose hosts within the network and check network basic functionality. There is a complete Oracle PING implementation example [14], but it is very complex and often difficult to understand in terms of network connectivity support. Instead, a simpler PING solution which uses the java.nio.DatagramChannel class and extends an existing solution [15] is presented. This solution involves several implementation steps, which are described next.

- Step 1—Import a network datagram I/O class

```
import java.nio.DatagramChannel;
```

- Step 2—Create and open a DatagramChannel.

```
/*Create and open a DatagramChannel object*/
DatagramChannel ch = DatagramChannel.open();
```

- Step 3—Connect the channel to a remote host.

```
/*Set remote host IP Address and port no*/
InetSocketAddress addr =
  new InetSocketAddress("136.206.35.201", 7);
/*Connect the channel*/
ch.connect(addr);
```

- Step 4—Prepare send and receive buffers.

```
/*Create the buffer for the outgoing packet*/
ByteBuffer sbuff =
  ByteBuffer.wrap("PING".getBytes());

/*Create the buffer for the incoming packet*/
ByteBuffer rbuff =
  ByteBuffer.allocate("PING".getBytes().length);
```

- Step 5—Send and receive packets.

```
/*Send an outgoing packet*/
ch.send(sbuff, addr);
/*Wait for the response*/
Thread.sleep(200);
/*Receive the echo packet if any*/
ch.receive(rbuff);
String rtxt = new String(rbuff.array());
```

- Step 6—Check the content of receiving packet.

```
if (rtxt.equals("PING"))
  System.out.println("PING: Remote host is OK.");
else
  System.out.println("PING: Communication issue.");
```

In order for this basic PING example to work, remote host's echo services need to be enabled and also permissive rules have to be set in the network's firewalls. Unfortunately, many operating systems have the echo service disabled by default.

The basic PING Java example is presented next.

```
import java.net.*;
import java.nio.*;
import java.nio.channels.*;

/*method to send ping messages and receive responses*/
public void basicPing()
{
  try {
    /*Count number of tries*/
    int count = 0;

    /*Create the buffer for the outgoing packet*/
    ByteBuffer sbuff =
      ByteBuffer.wrap("PING".getBytes());

    /*Create the buffer for the incoming packet.
     *As the incoming packet is expected to be
     *an identical copy of the outgoing packet
     *the same buffer size has been used.
     */
    ByteBuffer rbuff =
      ByteBuffer.allocate("PING".getBytes().length);

    /*Connect the channel to the remote host
     *using an InetSocketAddress
     *using the default echo port 7
     */
    InetSocketAddress addr =
      new InetSocketAddress("136.206.35.201", 7);

    /*Create and open a DatagramChannel*/
    DatagramChannel ch = DatagramChannel.open();

    /*Set the channel as non-blocking*/
    ch.configureBlocking(false);

    /*Connect the channel*/
    ch.connect(addr);
    String rtxt = "";
    do
    {
    /*Send the outgoing packet*/
    ch.send(sbuff, addr);
```

Code Listing 7.1 PingClient.java—basicPing()

```
    /*Wait for the response*/
    Thread.sleep(200);

    /*Receive the echo packet if any*/
    ch.receive(rbuff);
    rtxt = new String(rbuff.array());


    /*increment count*/
    count++;
    }
    while (!rtxt.equals("PING") && count < 3);
    if (rtxt.equals("PING"))
      System.out.println("PING: Remote host is OK");
    else
      System.out.println("PING: Communication issue");
  }
  catch(Exception e)
  {
    /*Print the exception message.*/
    System.out.println(e.getMessage());
  }
}
```

Code Listing 7.1 (Continued)

7.3 Electronic Mail Services

Lately, electronic mail services (e-mail) are one of the most widely used means of communications. Exchanging e-mails involves clients sending electronic messages to other clients. In practice, sending client applications enable messages to be written and sent to local e-mail hosts (e-mail servers) which in turn forward them to the receiving clients' remote e-mail servers via the network. The remote clients contact their e-mail servers and if there are received messages, they are retrieved and offered for reading to the users.

In this context, the e-mail service system is composed of User Agents (UA) and Message Transfer Agents (MTA). The UAs allow the users to send and retrieve messages and may also provide graphical user interfaces. The MTAs enable transfers of messages from the source host to the destination. In general, UAs are deployed at the clients and MTAs operate at the e-mail servers.

This e-mail message exchange system involves several services provided by UA and MTA modules.

Composition is provided by UAs and refers to the creation of both original and reply messages at the level of clients.

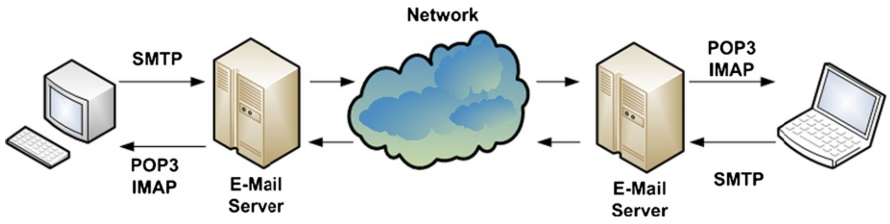
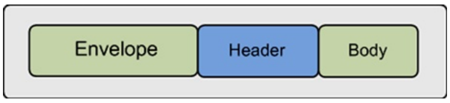


Figure 7.3 E-mail message exchange system—components, protocols, and principle

Figure 7.4 E-mail message format



Message *transfer* is supported by MTAs and refers to the delivery of messages from source to destination, including local client–server data exchange in which UAs are also involved.

Reporting is also provided by MTAs and involves informing the sender about the status of the messages sent.

Displaying is provided by UAs through the user interface and involves presenting the messages so that they can be accessed by the users. Depending on the type of content, sometimes the messages need to be converted before displaying. Often other programs are invoked, such as plug-ins (embedded in the e-mail client applications) or stand-alone applications (independent from the e-mail client applications).

Disposition, managed by the UAs, refers to what the remote user does with the messages (e.g., save, delete, etc.).

Figure 7.3 shows the basic principle of the e-mail service, including the message exchange system major components and communication protocols. These protocols are the Simple Mail Transfer Protocol (SMTP), Post-Office Protocol version 3 (POP3), and Internet Message Access Protocol (IMAP).

The **e-mail message structure** involves an envelope, a header, and a body, as outlined in Fig. 7.4. This has been formalized in RFC 822 [16] and RFC 2822 [17]. The envelope encapsulates the message and contains all the information required to transport the message such as destination address, priority, and security level. The header contains the control information required to display the message (e.g., date, subject). The body represents the message content, which is most useful to the human user. The message body was originally text only, but lately there was a clear need to allow for addition of other media formats.

The **Multipurpose Internet Mail Extensions (MIME)** is a standard (RFC 1341, RFC 2045-2049) [18], [19] that extends the original format of the e-mail messages to support extra features and encoding rules for non-ASCII messages. These features include characters with accents (e.g., in French, German, etc.), text in non-Latin alphabets (e.g., Cyrilic, Hebrew, etc.), text in non-alphabetic languages (e.g., Chinese, Japanese), non-text data (e.g., multimedia, images, audio), etc.

MIME defines five new message headers. The new headers include:

- MIME-Version—Indicates MIME version;
- Content-Description—String describing the content;
- Content-Id—Unique identifier;
- Content-Transfer-Encoding—How body is wrapped for transmission (e.g., 7-bit ASCII, 8-bit codes, base64 binary, etc.);
- Content-Type—Type and format of content. The standard defines 7 types of content as follows: Text (Plain, Enriched), Image (Gif, Jpeg), Audio (Basic), Video (Mpeg), Application, Message (RFC 822, Partial, External-body), and Multipart.

Messages not including the MIME-Version header are assumed to be in English plain text.

Simple Mail Transfer Protocol (SMTP), standardized as RFC 821 [20], allows messages to be sent from UA located at the client to MTA situated at server side. SMTP works on top of TCP and in general uses port 25.

The client initiates the TCP connection with the server and waits for the server to state it is ready for data reception. After the server confirms it is ready, the communication sequence commences in a command–response manner. The client sends commands, and the server responds with command status messages. Status messages include ASCII encoded numeric codes and details in text. The order of the commands is very important for the success of the message sending operation.

SMTP commands include:

- HELO—identifies the client;
- MAIL FROM:—starts a mail transfer session and identifies the mail sender;
- RCPT TO:—identifies the mail recipient; There may be multiple RCPT TO: commands;
- DATA:—sender ready to transmit a series of lines of text, each ending with CR&LF. A line containing a period only indicates the end of the data;
- QUIT:—request to finish the session and close the connection.

The extended SMTP (ESMTP) was defined in RFC 2821 [21]. EHLO is the new command for identifying the client as RFC 2821 compatible. If the SMTP server recognizes this command, often it sends a list of the available ESMTP commands back to the client. They include AUTH used for authentication purposes, STARTTLS employed for secure data transfer, and SIZE used to allow the client to indicate the message size or the server to specify the available buffer space. Other set of commands and parameters are also defined.

The **Post-Office Protocol version 3 (POP3)**, standardized in RFC 1939 [22], allows messages stored on the e-mail server to be accessed by the client. POP3 involves collaboration between the client-located UA and server's MTA. POP3 works on top of TCP and in general uses port 110.

POP3 requires a client–server connection to be established before client–server message exchange is permitted. The protocol message sequence includes the following stages. After the client connects to the server, it waits for the server to state it is ready. Once the server confirms its availability, the client starts sending commands which determine the server to perform actions and respond with status messages.

Table 7.1 IMAP vs. POP3

Protocol	RFC	TCP port	Email store	Email read	Mailboxes	Partial message
POP3	1939	110	Client	Offline	Simple	No
IMAP	2060	143	Server	Online	Multiple	Yes

POP3 requires sequential passing through three states: Authorization, Transaction, Update.

During the *Authorization* phase the client sends username and password details to the server. The following commands are involved:

- USER username—specifies the username;
- PASS password—indicates the password.

Only the authorized clients are allowed to proceed to the next stage.

During the *Transactions* phase, the client is allowed to retrieve the list of messages or a particular one, in a similar command–response fashion. The client may mark for deletion some (or all) of the messages. The following commands are involved:

- LIST—lists the e-mails received in order;
- RETR no—retrieves message number no;
- DELE no—marks for deletion message number no.

During the *Update* phase, the QUIT command is sent by the client and when receiving it, the server actually deletes all messages marked for deletion then sends a disconnect message, and disconnects the client.

POP3 allows the client to download the messages to the client's machine and manipulate them offline.

The **Internet Message Access Protocol (IMAP)**, standardized in RFC 2060 [23], is also used to enable client access to the e-mail messages on the server. IMAP works on top of TCP and in general listens at port 143.

The fundamental difference between POP3 and IMAP is that the latter assumes that the server keeps all the messages and the client accesses them online only. There is no message copy retrieved and stored by the client locally.

Additionally, IMAP enables the user to have and manipulate multiple mailboxes and permits e-mail access from multiple locations.

IMAP requires client–server connectivity as well. The command–response IMAP message sequence includes the following stages. The client connects to the server and waits for the server to state it is ready. After the server send its ready status confirmation, the client sends commands and the server performs the command-related actions and sends responses with action status messages to the client.

Specific commands are defined by IMAP for searching for messages, reading messages or part of them, addressing an e-mail by attributes (e.g., from source), creating and managing multiple mailboxes, etc.

A summary of IMAP and POP3 features are described in a comparative Table 7.1.

7.3.1 SMTP Java Example

This section illustrates via Java examples how e-mail messages can be sent to the e-mail server via SMTP. There are two distinct methods. The first approach uses basic socket communication, but it is more complex and requires extensive knowledge of the SMTP protocol. The second method uses the JavaMail API, and it is less complex, as the API hides the protocol-related implementation complexity.

7.3.1.1 Socket-based SMTP Example

In order to build the socket-based SMTP Java example, several major steps need to be followed. The steps are listed below.

- Step 1—Import the required packages:

```
import java.io.*;
import java.net.*;
import java.util.*;
import java.text.*;
```

- Step 2—Prepare server details and SMTP fields:

```
/*set the server details*/
private String host = new String("136.206.35.46");
private int port = 25;

/*set email message parameters*/
String from = new String("jack@eeng.dcu.ie");
String to = new String("jane@eeng.dcu.ie");
String cc = new String("john@eeng.dcu.ie");
String bcc = new String("jill@eeng.dcu.ie");
String subj = new String("SMTP email");
String body = new String("Message body!");
```

- Step 3—Establish socket connection with the server:

```
/*create and open the socket*/
sock = new Socket(host, port);

/*create the I/O data streams*/
os = new DataOutputStream(sock.getOutputStream());
is = new DataInputStream(sock.getInputStream());
if(sock != null && os != null && is != null)
{
  /*Connection successful.*/
  System.out.println("Connected OK!");
  /*Send email.*/
```

```
    [...]
  }
  else
  {
    /*Unsuccessful connection.*/
    System.out.println("Connection error!");
  }
```

- Step 4—Communicate with the server using SMTP commands:

```
/*communicate with the server using SMTP commands*/
os.writeBytes("HELO\r\n");
/*set email message details*/
/*sender address*/
os.writeBytes("MAIL From: <" + from + ">\r\n");

/*destination email address*/
os.writeBytes("RCPT To: <" + to + ">\r\n");

/*CC email address*/
os.writeBytes("RCPT Cc: <" + cc + ">\r\n");

/*BCC email address*/
os.writeBytes("RCPT Bcc: <" + bcc + ">\r\n");

/*email message and header*/
os.writeBytes("DATA\r\n");

os.writeBytes("X-Mailer: Via Java\r\n");
os.writeBytes("DATE:"+dFormat.format(dDate)+"\r\n");
os.writeBytes("From: source <" + from + ">\r\n");
os.writeBytes("To: destination <" + to + ">\r\n");
os.writeBytes("Cc: CC dest. <" + cc + ">\r\n");

/*message content*/
os.writeBytes("Subject: "+ subj +"\r\n");
os.writeBytes(body + " \r\n");

/*indicates the end of message data*/
os.writeBytes("\r\n.\r\n");
```

- Step 5—Send the message:

```
/*start the SMTP update phase*/
os.writeBytes("QUIT\r\n");
```

- Step 6—Check for server's answer:

```
String rcv;
while((rcv = is.readLine()) != null) {
  if(rcv.indexOf("Ok") != -1)
  {
    /*Server success confirmation*/
    [...]
  }
}
```

- Step 7—Deal with all exceptions:

```
try
{
  [...]
}
catch()
{
  [...]
}
```

Next the complete SMTP example using sockets is presented.

```
import java.io.*;
import java.net.*;
import java.util.*;
import java.text.*;  // Used for date formatting.

/*class implementing the email service*/
public class SockSMTPeMail
{
  /*socket used for communication with the server*/
  private Socket sock = null;

  /*data streams for reading/writing to/from the
   socket*/
  private DataOutputStream os = null;
  private DataInputStream is = null;

  /*server details*/
  private String host = null;
  private int port = 25;

  /*email message parameters*/
  String from = null;
```

Code Listing 7.2 SockSMTPeMail.java

```
  String to = null;
  String cc = null;
  String bcc = null;
  String subj = null;
  String body = null;

  /*args are the command line arguments*/
  public static void main(String[] args)
  {
    SockSMTPeMail mail = new SockSMTPeMail();
    mail.SendMail();
  }

  public void SendMail()
  {
    /*set the server details*/
    String host = new String("136.206.35.46");
    int port = 25;

    /*set email message parameters*/
    from = new String("jack@eeng.dcu.ie");
    to = new String("jane@eeng.dcu.ie");
    cc = new String("john@eeng.dcu.ie");
    bcc = new String("jill@eeng.dcu.ie");
    subj = new String("SMTP email");
    body = new String("Message body!");

    /*get and format the current date and time*/
    Date dDate = new Date();
    DateFormat dFormat;
    dFormat = DateFormat.getDateInstance(
      DateFormat.FULL, Locale.US);

    try
    {
      /*create and open the socket*/
      sock = new Socket(host, port);

      /*create the I/O data streams*/
      os = new DataOutputStream(sock.getOutputStream());
      is = new DataInputStream(sock.getInputStream());

      if(sock != null && os != null && is != null)
```

Code Listing 7.2 (Continued)

```
      {
        /*Connection successful.*/
        System.out.println("Connected OK!");
        try
        {
          os.writeBytes("HELO\r\n");
          /*set email message details*/
          /*sender address*/
          os.writeBytes("MAIL From: <"
                        + from + ">\r\n");

          /*destination email address*/
          os.writeBytes("RCPT To: <" + to + ">\r\n");

          /*CC email address*/
          os.writeBytes("RCPT Cc: <" + cc + ">\r\n");

          /*BCC email address*/
          os.writeBytes("RCPT Bcc: <" + bcc + ">\r\n");

          /*email message and header*/
          os.writeBytes("DATA\r\n");

          os.writeBytes("X-Mailer: Via Java\r\n");
          os.writeBytes("DATE: " +
            dFormat.format(dDate) + "\r\n");
          os.writeBytes("From: source <"
                        + from + ">\r\n");
          os.writeBytes("To: destination <"
                        + to + ">\r\n");
          os.writeBytes("Cc: CC dest. <"
                        + cc + ">\r\n");

          /*message content*/
          os.writeBytes("Subject: "+ subj +"\r\n");
          os.writeBytes(body + " \r\n");

          /*specify the end of message data*/
          os.writeBytes("\r\n.\r\n");

          /*sends the message by issuing the QUIT
          command*/
          os.writeBytes("QUIT\r\n");
```

Code Listing 7.2 (Continued)

```
          /*check the server reply against OK*/
          String rcv;
          while((rcv = is.readLine()) != null)
          {
            System.out.println(rcv);
            if(rcv.indexOf("Ok") != -1)
            /*Server success confirmation*/
              break;
          }
        }
        catch(Exception e)
        {
          System.out.println("Communication error.");
        }
      }
      else
      {
        /*Unsuccessful connection.*/
        System.out.println("Connection error!");
      }
    }
    catch(Exception e)
    {
      System.out.println("Host " + host + "unknown");
    }
  }
}
```

Code Listing 7.2 (Continued)

7.3.1.2 JavaMail API-Based SMTP example

The second approach to building SMTP Java applications is to use the JavaMail API. The following major steps need to be considered.

- Step 1—Download JavaMail package and unzip it.

```
http://www.oracle.com/technetwork/java/javamail/
  index.html
```

- Step 2—Update your CLASSPATH to include:

```
mail.jar; mailapi.jar;
pop3.jar; smtp.jar; activation.jar
```

- Step 3—Import the required packages:

```
import javax.mail.*;
import javax.mail.internet.*;
import java.util.*;
```

- Step 4—Prepare server details and SMTP fields:

```
/*set the server details*/
srv = new String("136.206.35.46");

/*set email message parameters*/
String from = new String("jack@eeng.dcu.ie");
String to = new String("jane@eeng.dcu.ie");
String cc = new String("john@eeng.dcu.ie");
String bcc = new String("jill@eeng.dcu.ie");
String subj = new String("SMTP email");
String body = new String("Message body!");
```

- Step 5—Get the communication with the server session:

```
/*get the default comms. session,
 *or start a new one*/
Properties props = System.getProperties();
props.put("JavaMailSMTPeMail", srv);
Session session =
    Session.getDefaultInstance(props, null);
```

- Step 6—Prepare the message:

```
/*create a new message*/
Message msg = new MimeMessage(session);
/*set the message fields*/
msg.setFrom(new InternetAddress(from));
msg.setRecipients(Message.RecipientType.TO,
        InternetAddress.parse(to, false));
msg.setRecipients(Message.RecipientType.CC
        InternetAddress.parse(cc, false));
msg.setRecipients(Message.RecipientType.BCC
        InternetAddress.parse(bcc, false));
/*Set the message subject and body*/
msg.setSubject(subj);
msg.setText(body);
```

- Step 7—Send message to the server:

```
/*send the message*/
Transport.send(msg);

System.out.println("Message sent OK.");
```

- Step 8—Deal with all exceptions:

```
try
{
  [...]
}
catch()
{
  [...]
}
```

A complete simple SMTP example using JavaMail API built based on the examples provided in the JavaMail documentation [24] is presented next. The JavaMail API documentation also includes examples which make use of the extended SMTP features such as authentication.

```
import javax.mail.*;
import javax.mail.internet.*;
import java.util.*;

public class JavaMailSMTPeMail
{
  /*server details*/
  private String srv = null;

  /*email message parameters*/
  String from = null;
  String to = null;
  String cc = null;
  String bcc = null;
  String subj = null;
  String body = null;

  /*Main method to send a message to the SMTP server*/
  public static void main(String[] args)
  {
    JavaMailSMTPeMail mail = new JavaMailSMTPeMail();
    mail.SendMail();
  }

  public void SendMail()
  {
    /*set the server details*/
    srv = new String("136.206.35.46");
```

Code Listing 7.3 JavaMailSMTPeMail.java

```
/*set email message parameters*/

from = new String("jack@eeng.dcu.ie");
to = new String("jane@eeng.dcu.ie");
cc = new String("john@eeng.dcu.ie");
bcc = new String("jill@eeng.dcu.ie");
subj = new String("SMTP email");
body = new String("Message body!");

try
{
  /*get the default comms.
   *session, or start a new one*/
  Properties props = System.getProperties();
  props.put("JavaMailSMTPeMail", srv);
  Session session =
      Session.getDefaultInstance(props, null);

  /*create a new message*/
  Message msg = new MimeMessage(session);
  /*set the message fields*/
  msg.setFrom(new InternetAddress(from));
  msg.setRecipients(Message.RecipientType.TO,
    InternetAddress.parse(to, false));
  msg.setRecipients(Message.RecipientType.CC,
    InternetAddress.parse(cc, false));
  msg.setRecipients(Message.RecipientType.BCC,
    InternetAddress.parse(bcc, false));
  /*Set the message subject and body*/
  msg.setSubject(subj);
  msg.setText(body);

  /*set other header information*/
  msg.setSentDate(new Date());

  /*send the message*/
  Transport.send(msg);

  System.out.println("Message sent OK.");
}
catch (Exception ex)
```

Code Listing 7.3 (Continued)

```
    {
      ex.printStackTrace();
    }
    System.exit(0);
  }
}
```

Code Listing 7.3 (Continued)

7.3.2 POP3 Java Example

This section provides a Java example to illustrate how e-mail messages can be retrieved from the e-mail server via POP3. This example makes use of the JavaMail API which hides the POP3-related implementation aspects.

- Step 1—Download JavaMail package and unzip it.

```
http://www.oracle.com/technetwork/java/javamail/
  index.html
```

- Step 2—Update your CLASSPATH to include:

```
mail.jar; mailapi.jar; pop3.jar;
smtp.jar; activation.jar
```

- Step 3—Import the required packages:

```
import javax.mail.*;
import javax.mail.internet.*;
import java.util.*;
import java.io.*;
```

- Step 4—Prepare parameters for server authentication:

```
/*set server details*/
String srv = new String("136.206.35.46");
String user = new String("john");
String pass = new String("Secret@19_02_13");
```

- Step 5—Get the session and connect to the server:

```
/*get the default session*/
Properties props = System.getProperties();
Session session = null;
session = Session.getDefaultInstance(props, null);

/*get a POP3 message store, and connect to it*/
store = session.getStore("pop3");
store.connect(srv, user, pass);
```

- Step 6—Open Inbox folder and access all e-mails:

```
/*get the INBOX*/
folder = folder.getFolder("INBOX");
if (folder == null)
  throw new Exception("No POP3 INBOX");

/*open the folder (read only)*/
folder.open(Folder.READ_ONLY);

/*get the messages and print them*/
Message[] msgs = folder.getMessages();
for (int i = 0; i < msgs.length; i++)
  printEmail(msgs[i]);
```

- Step 7—Print an e-mail message:

```
/*get header information*/
String from = null;
from = ((InternetAddress)msg.getFrom()[0])
      .getPersonal();
if (from == null)
  from=((InternetAddress)msg.getFrom()[0])
      .getAddress();
/*print sender details*/
 System.out.println("FROM: "+from);

/*get and print the subject*/
String subj = msg.getSubject();
System.out.println("SUBJECT: "+subject);

/*get the message itself*/
Part msgPart = msg;
Object content = msgPart.getContent();

/*or its first body part
 *if it is a multipart message*/
if (content instanceof Multipart)
{
  msgPart = ((Multipart)content).getBodyPart(0);
  System.out.println("[ Multipart Message ]");
}

/*get the content type*/
String ct = msgPart.getContentType();

/*if the content is plain text, print it*/
```

```
System.out.println("CONTENT:" + ct);
if (ct.startsWith("text/plain") ||
  ct.startsWith("text/html"))
{
  InputStream is = msgPart.getInputStream();
  BufferedReader br = null;
  br = new BufferedReader(new InputStreamReader(is));

  String line = br.readLine();

  while (line != null)
  {
    System.out.println(line);
    line = br.readLine();
  }
}
System.out.println("");
```

- Step 8—Deal with all exceptions:

```
try
{
  [...]
}
catch()
{
  [...]
}
```

A complete POP3 example using JavaMail API built based on the examples provided in the JavaMail documentation [24] is presented next.

```
import javax.mail.*;
import javax.mail.internet.*;
import java.util.*;
import java.io.*;

public class JavaMailPOP3eMail
{
  /*store server details*/
  String srv = null;
  String user = null;
  String pass = null;
```

Code Listing 7.4 JavaMailPOP3eMail.java

```
public static void main(String[] args)
{
  JavaMailPOP3eMail mail = new JavaMailPOP3eMail();
  mail.SendMail();
}

public void SendMail()
{
  /*set server details*/
  srv = new String("136.206.35.46");
  user = new String("john");
  pass = new String("Secret@19_02_13");

  /*save store and folder details*/
  Store store = null;
  Folder folder = null;

  try
  {
    /*get the default session*/
    Properties props = System.getProperties();
    Session session = null;
    session = Session.getDefaultInstance(props, null);

    /*get a POP3 message store, and connect to it*/
    store = session.getStore("pop3");
    store.connect(srv, user, pass);

    /*get the default folder*/
    folder = store.getDefaultFolder();
    if (folder == null)
      throw new Exception("No default folder");

    /*get the INBOX*/
    folder = folder.getFolder("INBOX");
    if (folder == null)
      throw new Exception("No POP3 INBOX");

    /*open the folder (read only)*/
    folder.open(Folder.READ_ONLY);

    /*get the messages and print them*/
    Message[] msgs = folder.getMessages();
```

Code Listing 7.4 (Continued)

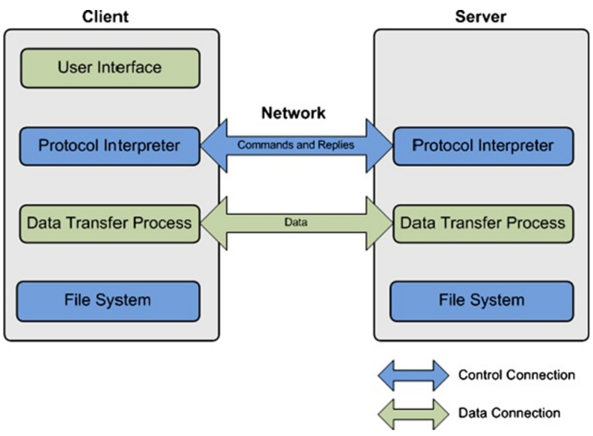
```
      for (int i = 0; i < msgs.length; i++)
      {
        printEmail(msgs[i]);
      }
    }
    catch (Exception ex)
    {
      ex.printStackTrace();
    }
    finally
    {
      /*close session*/
      try
      {
        if (folder != null)
          folder.close(false);
        if (store != null)
          store.close();
      }
      catch (Exception ex2)
      {
        ex2.printStackTrace();
      }
    }
  }

  /*print email*/
  public static void printEmail(Message msg)
  {
    try
    {
      /*get header information*/
      String from = null;
      from = ((InternetAddress)msg.getFrom()[0])
                  .getPersonal();
      if (from == null)
        from=((InternetAddress)msg.getFrom()[0])
                  .getAddress();
      /*print sender details*/
      System.out.println("FROM: "+from);

      /*get and print the subject*/
      String subj = msg.getSubject();
```

Code Listing 7.4 (Continued)

```
      System.out.println("SUBJECT: "+subj);

      /*get the message itself*/
      Part msgPart = msg;
      Object content = msgPart.getContent();

      /*or its first body part
       *if it is a multipart message*/
      if (content instanceof Multipart)
      {
        msgPart = ((Multipart)content).getBodyPart(0);
        System.out.println("[ Multipart Message ]");
      }

      /*get the content type*/
      String ct = msgPart.getContentType();

      /*if the content is plain text, print it*/
      System.out.println("CONTENT:" + ct);
      if (ct.startsWith("text/plain")
          || ct.startsWith("text/html"))
      {
        InputStream is = msgPart.getInputStream();
        BufferedReader br = null;
        br = new BufferedReader(new
             InputStreamReader(is));
        String line = br.readLine();
        while (line != null)
        {
          System.out.println(line);
          line = br.readLine();
        }
      }
      System.out.println("");
    }
    catch (Exception ex)
    {
      ex.printStackTrace();
    }
  }
}
```

Code Listing 7.4 (Continued)

Figure 7.5 FTP session



7.4 File Transfer Protocol Service

File transfers account for both a high number of flows and huge amount of data transferred over the current networks. They involve clients transferring file content in reliable and efficient manner to and from a remote server.

These file transfers make use of the File Transfer Protocol (FTP) which was developed in 1985 and is still used today. The protocol has been first standardized in RFC 959 [8], and then various extensions have been proposed to enhance flexibility and security (RFC 1579, RFC 2228) [9, 10].

FTP works on top of TCP and in general uses port 21; however, in some situations the server administrator may choose to use different ports. FTP involves a client connecting to the server and sending commands during a communication session. The server responds with actions and command status messages. In general, each such session involves at least one file transfer.

The basic principle of file transfers using FTP is outlined in Fig. 7.5.

Theoretically, FTP involves two connections: for control and data. FTP commands and replies are exchanged via the control connection, while data is exchanged over the data connection. There is a requirement for the control connection to be working when data is transferred over its dedicated connection. In practice, a single connection is used for both data and control information exchange.

The FTP commands belong to one of the following three categories.

- *Access control* commands include:
  - USER—indicates the user;
  - PASS—indicates the password;
  - CWD—changes directory;
  - CDUP—changes directory to parent;
  - QUIT—logouts.
- *Transfer parameter* commands include:
  - PORT—publishes local data port;

  - PASV—makes server passive (listen);
  - TYPE—indicates data representation (A-ASCII, E-EBCDIC, I-Image, L-Local);
  - MODE—indicates transfer mode (S-Stream, B-Block, C-Compressed);
  - STRU—sets file structure (F-FILE, R-RECORD, P-PAGE).

- *Service* commands include:
  - RETR—retrieves file;
  - STOR—sends and stores the file remotely;
  - APPE—sends file and appends;
  - DELE—deletes the file;
  - MKD—makes a new directory;
  - RMD—removes a directory;
  - PWD—prints working directory;
  - LIST—lists files.

Every command must generate some action and at least one reply from the server. This enables the synchronization of requests sent by clients and actions performed by the server and also allows the clients to know the server status. In general, the reply is a single line; however, multiple lines are also accepted. The reply must contain a three digit status code which enables machines to assess the server status and a text message which describes the server status in human language.

There are several issues involved when using FTP for file transfers. Security is an important issue for many companies that have installed firewalls. Firewalls prevent unauthorized users from getting access to the networks. However, firewalls may also inadvertently prevent valid users from accessing some resources, including files. When FTP is involved, the network administrators must design rules for classes of FTP connections which may be a costly and error prone process.

Another issue is standardization. There are many FTP client applications with different interpretations of the FTP protocol. Consequently, FTP server administrators must know how to support all of these different client application types.

An alternative to classic FTP is a Web-based file transfer. A Web-based file transfer client runs within the Web browser. There is no need for any software to install, license to purchase or software to maintain. Additionally, there is no need to set-up firewall rules for each user class.

7.4.1 Simple FTP Java Client Example

A Java FTP client can be implemented in three ways.

The first approach requires the implementation of an own FTPClient class. This solution can use standard sockets and FTP commands to interact and exchange data files with the file server. The second approach is to find an existing implementation of an FTPClient class and make use of it in order to perform the file transfer. The third possibility is to employ a Web-based FTP client.

The simple FTP Java client file transfer example presented next uses the second approach and makes use of the FTPClient implementation available as part of the Apache Commons Net API [25]. The Apache Commons Net API-based FTP client file transfer application implementation involves the following steps.

- Step 1—Download Apache Commons Net API version 3.2.

  ```
  http://commons.apache.org/net/download_net.cgi
  ```

- Step 2—Update your CLASSPATH to include:

  ```
  commons-net-3.2.jar
  ```

- Step 3—Import the required packages:

  ```
  import java.io.*;
  import org.apache.commons.net.ftp.FTP;
  import org.apache.commons.net.ftp.FTPClient;
  ```

- Step 4—Prepare parameters for server authentication:

  ```
  /*sets server parameters*/
  String srv = new String("136.206.35.46");
  int port = 21;
  String user = new String("john");
  String pass = new String("Secret@19_02_13");
  ```

- Step 5—Create the FTPClient object:

  ```
  FtpClient client = new FtpClient(host);
  ```

- Step 6—Connect, login to the FTP server, and set transfer mode:

  ```
  /*connects to FTP server*/
  ftpClient.connect(srv, port);
  /*authenticates on the server*/
  ftpClient.login(user, pass);

  /*sets connection to client-server mode*/
  ftpClient.enterLocalPassiveMode();
  /*sets transferred file type*/
  ftpClient.setFileType(FTP.BINARY_FILE_TYPE);
  ```

- Step 7—Set local and remote files and perform transfer:

  ```
  /*remote file*/
  String rf = "/remotefolder/remotefile.txt";
  /*local file*/
  File lf = new File("C:/localfolder/localfile.txt");

  /*enables data writing*/
  OutputStream os =
  ```

```
new BufferedOutputStream(new FileOutputStream(lf));

/*gets remote file content*/
if(ftpClient.retrieveFile(rf, os))
  System.out.println("File transfer success.");
```

- Step 8—Close output stream, perform server logout and disconnect:

```
/*closes output stream*/
os.close();
/*logouts and disconnects*/
if (ftpClient.isConnected())
{
  ftpClient.logout();
     ftpClient.disconnect();
}
```

- Step 9—Deal with all exceptions:

```
try
{
  [...]
}
catch()
{
  [...]
}
```

The complete Apache Commons Net API-based FTP download client Java example application is included next. An alternative FTP download solution which makes use of the Apache Commons Net API FTPClient's InputStream retrieveFileStream(String remote) method is presented in [26].

```
import java.io.*;

import org.apache.commons.net.ftp.FTP;
import org.apache.commons.net.ftp.FTPClient;

public class ApacheJavaFTP
{
  public static void main(String[] args)
  {
    /*sets server parameters*/
    String srv = new String("136.206.35.46");
    int port = 21;
```

Code Listing 7.5 ApacheJavaFTP.java

```
String user = new String("john");
String pass = new String("Secret@19_02_13");

/*creates FTPClient object*/
FTPClient ftpClient = new FTPClient();
try
{
  /*connects to FTP server*/
  ftpClient.connect(srv, port);
  /*authenticates on the server*/
  ftpClient.login(user, pass);

  /*sets connection to client-server mode*/
  ftpClient.enterLocalPassiveMode();
  /*sets transferred file type*/
  ftpClient.setFileType(FTP.BINARY_FILE_TYPE);

  /*remote file*/
  String rf = "/remotefolder/remotefile.txt";
  /*local file*/
  File lf =
  new File("C:/localfolder/localfile.txt");

  /*enables data writing*/
  OutputStream os =
  new BufferedOutputStream(new
        FileOutputStream(lf));

  /*gets remote file content*/
  if(ftpClient.retrieveFile(rf, os))
    System.out.println("File transfer success.");

  /*closes output stream*/
  os.close();
}
catch (IOException ex)
{
  System.out.println("Error: " + ex.getMessage());
  ex.printStackTrace();
}
finally
{
  try
```

Code Listing 7.5 (Continued)

```
      {
        /*logouts and disconnects*/
        if (ftpClient.isConnected())
        {
          ftpClient.logout();
          ftpClient.disconnect();
        }
      }
      catch (IOException ex)
      {
        ex.printStackTrace();
      }
    }
  }
}
```

Code Listing 7.5 (Continued)

7.5 Web Content Transfer Service

Web content transfers account for most data exchange over the Internet. They involve communications between Web clients (browsers) and Web servers as illustrated in Fig. 7.6.

These communications are performed based on the Hypertext Transfer Protocol (HTTP), whose version 1.0 was standardized as RFC 1945 [27] and version 1.1 was standardized as RFC 2616 [11]. HTTP works in general on top of TCP. The default port number is 80, but other ports can also be used. Communications are performed in sessions. During these sessions, clients make requests to severs for Web content and the servers respond performing Web content transfers to the requesting clients. The servers also respond with status messages for client information purpose. In general, each session involves at least one client–server request–response and at least one Web content transfer.

In terms of HTTP connections, there may be one (HTTP v.1.0) or multiple simultaneous connections (HTTP v.1.1) between each client–server pair, approaches which mostly differ in terms of efficiency. When HTTP v.1.0 is employed, the HTTP requests and responses are exchanged sequentially. For each Web item to be transferred, a single TCP connection is established, an HTTP request is sent, an HTTP response is received, and then TCP connection is released. In HTTP v.1.1, persistent connections are used, and one or more TCP connections are established between client and server. HTTP requests are sent and HTTP responses are received over all connections. Pipelining is sometimes used (sending multiple requests before responses are received). Figure 7.7 illustrates the HTTP-based Web document delivery process.

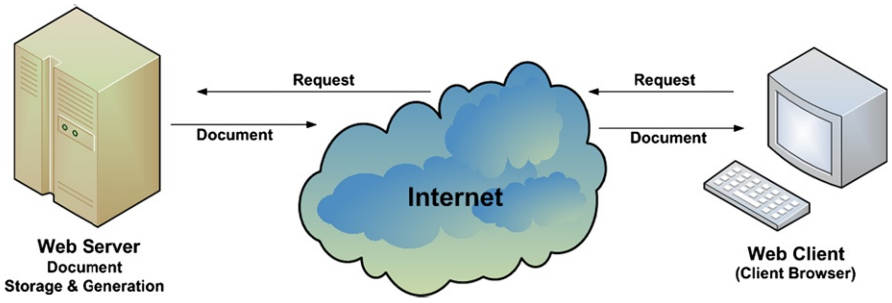


Figure 7.6 World Wide Web document delivery process

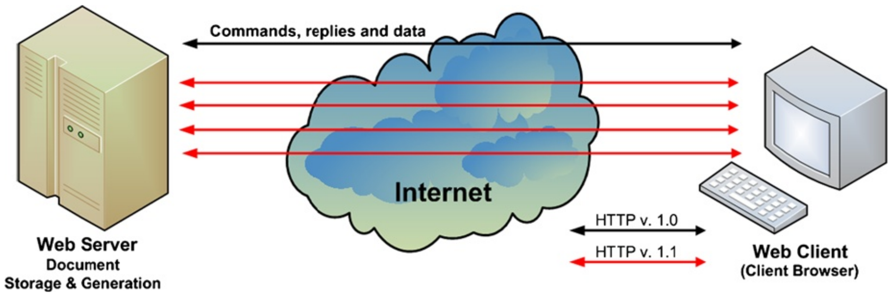


Figure 7.7 Web document delivery process using HTTP

As already mentioned, the HTTP-based client–server interaction is performed using a series of requests–responses. Each request consists of one or more lines of text (ASCII). The first line is the *Request-line* and includes:

- Name of the HTTP method;
- Universal Resource Identifier (URI) of the Web resource;
- HTTP version.

The HTTP method names are case sensitive. Method-related *Headers* follow the Request-line. Depending on the method, *Content* will follow after a blank line or not.

Next the HTTP methods are presented, indicating their names and a brief description.

- GET—request to retrieve a Web page;
- HEAD—request to read a Web page's header;
- PUT—request to store a Web page;
- POST—append to a Web page;
- DELETE—remove the Web page;
- TRACE—echo incoming request;
- CONNECT—reserved for future use;
- OPTIONS—query certain options.

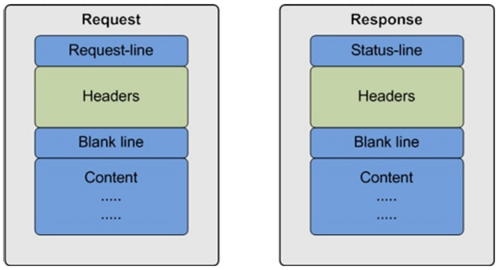


Figure 7.8 HTTP request and response structure

The location of Web resources are indicated using URIs. URIs were defined in RFC 2396 [28] and are either *relative*, listing the resource relative path, or *absolute*, indicating the protocol, host, port, and path.

Next are two examples of valid HTTP requests.

GET http://www.dcu.ie:80/index.html HTTP/1.1

GET /index.html HTTP/1.1

Figure 7.8 shows the structure of both HTTP request and response.

Each response consists of one or more lines of text (ASCII). The first line is the *Status-line* and includes:

- HTTP version;
- A three digit status code;
- A human readable status message.

Response-related *Headers* follow the Status-line and, depending on the response type, *Content* will be present after a blank line or not.

The status codes are determined by the server response following client request. The first status code digit divides responses in five categories:

- 1—Information;
- 2—Success;
- 3—Redirection;
- 4—Client error (e.g., invalid request);
- 5—Server error.

The second digit indicates the type of error that has occurred, if any (e.g., file system, command syntax error). The third digit further qualifies the error.

There may be zero or more HTTP headers after each request or response. Each header consists of a single line of the following format:

- Attribute name
- ":"
- Space
- Attribute value

Both attribute name and value are text-based.

Request headers give information to the server about the client in terms of client type, what content is accepted, who makes the request, etc. Each header line ends with a CRLF (\r \n).

Table 7.2 HTTP header structure

Message header	Type	Content
User-agent	Request	Info about browser and platform
Accept	Request	Type of pages the client can handle
Host	Request	Server's DNS name
Authorization	Request	List of client's credentials
Cookie	Request	Send a previously set cookie
Date	Request–response	Date and time message was sent
Server	Response	Information about server
Content-length	Response	Page length in bytes
Content-type	Response	Page's MIMO type
Set-Cookie	Response	Sets a new cookie

Response headers provide information to the client about the returned data in terms of document type, size, encoding, last modified time, etc. Response header lines also end with a CRLF (\r \n).

Table 7.2 presents the most important HTTP message headers, their meaning, and whether or not they are used as part of the request and/or response.

7.5.1 HTTP Java Client Example

Next the major steps to follow when designing a HTTP-based Web content transfer Java application are presented.

- Step 1—Import required packages:

```
import java.io.*;
import java.net.*;
```

- Step 2—Set path of file to transfer:

```
String path =
new String("http://www.eeng.dcu.ie/index.html");
```

- Step 3—From path create the URL object:

```
URL url = new URL(path);
```

- Step 4—Open an input stream from the url:

```
is = new DataInputStream(new
  BufferedInputStream(url.openStream()));
```

- Step 5—Read data from the stream line by line and print it:

```
String s;
while ((s = is.readLine()) != null)
  System.out.println(s);
```

- Step 6—Close the connection:

```
is.close();
```

- Step 7—Deal with exceptions:

```
try
{
  [...]
}
catch()
{
  [...]
}
```

The complete HTTP client Java example to retrieve Web content given its location at the server is presented.

```
import java.io.*;
import java.net.*;

/*HTTP client implementation*/
public class JavaHTTPClient
{
  /*main method invoked when the application starts*/
  public static void main (String[] args)
  {
    /*Process input parameters*/
    String path =
    new String("http://www.eeng.dcu.ie/index.html");
    DataInputStream is = null;

    try
    {
      /*Create URL object*/
      URL url = new URL(path);

      /*Open an input stream from the url*/
```

Code Listing 7.6 JavaHTTPClient.java

```
      is = new DataInputStream(new
        BufferedInputStream(url.openStream()));

      /*Reads line by line and prints them on the
      screen*/
      String s;
      while ((s = is.readLine()) != null)
      {
        System.out.println(s);
      }
    }
    catch (Exception e)
    {
      System.out.println("An exception occurred");
      e.printStackTrace();
      System.exit(1);
    }
    finally
    {
      /*Close the input stream*/
      try
      {
        is.close();
      }
      catch (IOException ioe)
      {
        System.out.println("IOException occured");
        ioe.printStackTrace();
        System.exit(1);
      }
    }
  }
}
```

Code Listing 7.6 (Continued)

7.6 Java Database Connectivity Services

Database management systems are a very important part of any information system. Databases are the most popular approach to storing data in an efficient and easy to access way. As a consequence, many network applications developed lately involve a database for data storage. In this context, Java software development enables support for database communication.

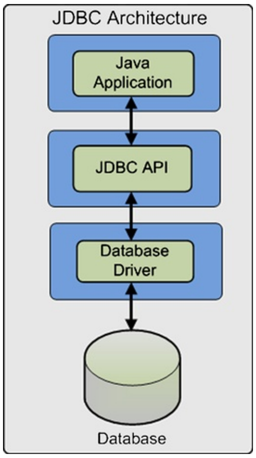


Figure 7.9 JDBC architecture

The communication between an application and a database management system occurs in a client–server manner. The user application implements the client-side modules and the database management system is in charge with the server-side modules.

Java Database Connectivity or JDBC, is a Java-based data access technology which enables database-independent connectivity between Java applications and a wide range of databases.

JDBC leverages existing database technologies and allows SQL-based database access. The process of accessing a database via this method involves establishing a connection to a database or tabular data source, sending SQL statements and retrieving and processing the results.

7.6.1 JDBC Architecture

JDBC architecture involves the following four blocks as presented in Fig. 7.9: Java Application, JDBC API, Database Driver, and Database System. These architectural blocks are be described in the context of JDBC database interaction process which involves the following steps.

Java Application calls JDBC library methods to connect and interact with the database. JDBC communicates with the Database System via the correct Database Driver (according to the database technology employed). The driver used has to match the database management system used. For example, if the data is stored in a MySQL database server, the MySQL specific driver has to be loaded. There are many drivers and database communication solutions including MySQL, Postgres, and Oracle.

The results are transferred from the Database System to the Java Application in the inverse way, via the driver and JDBC API.

Several types of database drivers can be used by applications developers.

Direct-to-Database Pure Java Driver allows JDBC calls to be converted directly into the protocol used by the database. The advantages of such a driver include good performance and no need to install special software on the client side or server. Disadvantages involve reduced optimization for server operating system and the need for a different driver for each different database.

Database Middleware Pure Java Driver allows JDBC calls to be converted into a middleware-specific protocol which is then converted into database specific protocol by a middleware server. Middleware server manages multiple database connectivity. This type of driver can be used when multiple databases need to be connected to via the same JDBC driver. It is server-based, so there is no need for a JDBC driver on the client machine. For performance reasons, the server-side component is optimized for the operating system of the server machine. The main disadvantage occurs when the middleware must run on different platforms as database-specific code must run on the middleware server.

Native API Partly Java Driver allows JDBC calls to be converted into calls on the client API for specific database systems (e.g., Oracle, Informix). Specific drivers must be loaded on each client machine. Advantages for using this type of driver include flexibility (allows access to almost any database as long as ODBC drivers are available), significantly better performance and limited Java feature set. As a disadvantage, this solution requires specific client library to be installed.

JDBC-ODBS Bridge allows JDBC to accesses the database via Microsoft's ODBC drivers. ODBC drivers must be loaded on each client machine in order for the database interaction to be performed. Advantages include flexibility, almost any database for which ODBC driver is installed can be accessed via this method. Disadvantages are represented by performance overhead and the need to install an ODBC driver on the client machine which makes it unsuitable for applets.

7.6.2 JDBC Database Access

JDBC database access can be performed by following several steps. Theses steps will be detailed with code examples in the following paragraphs.

- Step 1—Load database driver, by loading the appropriate driver class. The current class instantiates the driver class and register it with the JDBC driver manager.

  ```
  /*Use Class::forName(String classname)*/
  // Class.forName("sun.jdbc.odbc.JdbcOdbcDriver");
  // Class.forName("connect.microsoft.MicrosoftDriver");
  Class.forName("oracle.jdbc.driver.OracleDriver");
  ```

- Step 2—Establish connection with the database. Create connection URL which includes "jdbc", protocol, host, port number, database name. Host and port number are required for remote access. Connect to the database which uses DriverManager::getConnection(String URL, String username, String password) or DriverManager::getConnection(String URL). Return a reference to an object of type Connection and throw SQLException if a database access error occurs.

```
jdbcodbcURL = "jdbc:odbc:BankDatabase";
Connection link = getConnection(jdbcodbcURL);
```

- Step 3—Create a statement object. Use Connection class's method createStatement() and catch SQLException id thrown.

```
Statement st = link.createStatement();
```

- Step 4—Run the query statement.

```
/*create query*/
String query = "SELECT account, balance FROM
                Accounts";
/*execute query and retrieve the results*/
ResultSet resultSet = st.executeQuery(query);
/*throws SQLException*/
```

- Step 5—Run the update statement.

```
/*Create update statement*/
/*Uses SQL statements INSERT, UPDATE, DELETE*/
String ins =
  "INSERT INTO Accounts (1234, "John Doe",
   "02/03/2007")";
String upd =
  "UPDATE Accounts SET (account=1234,
   name="John Doe")";
String rem =
  "DELETE FROM Accounts WHERE account=1234";

/*Execute update*/
/*Returns an int representing the row count*/
/*Throws SQLException */
int result = st.executeUpdate(ins);
int result = st.executeUpdate(upd);
int result = st.executeUpdate(rem);
```

- Step 6—Process and display the database operation results.

```
/*Process returned data*/
/*Use ResultSet's methods
 *next() - moves cursor down to the next row
 *previous() - moves cursor up to the previous row
 *XXX getXXX(String colName)
 *returns the value of designated
 *column in current row;
 *XXX can be Byte, String, Int, Date, etc.
 *XXX getXXX(int colNo)
 *returns the value of designated
 *column in current row;
 *XXX can be Byte, String, Int, Date, etc.
 *Throw SQLException
 */
resultSet.next();
resultSet.getInt("account");
```

- Step 7—Close connection.

```
/*Close Statement object*/
/*Use Statement::close()
 *Throws SQLException*/
st.close();

/*Close Connection
 *Use Connection::close()
 *Throws SQLException*/
link.close();
```

The complete example of a Java application enabling access a database via JDBC is presented next.

```
import java.sql.*;

/*JDBC application implementation*/
public class JDBCApp {

  /*define connection, statement and result set*/
  static Connection link;
  static Statement statement;
  static ResultSet results;

  /*main method to be invoked
   *when the application starts*/
  public static void main(String[] args)
  {
    System.out.println("Welcome to JDBC program!");
    try {
      /*load the driver*/
      Class.forName("sun.jdbc.odbc.JdbcOdbcDriver");
      /*initiate the connection*/
      link = DriverManager.getConnection
        ("jdbc:odbc:BankDatabase","","");
    }
```

Code Listing 7.7 JDBCApp.java

```
      catch(ClassNotFoundException e) {
      System.out.println("Error: Unable to load
                          driver!");
      System.out.exit(1);
    }
    catch(SQLException e) {
      System.out.println("Error: Connect to
                          database!");
      System.exit(1);
    }

    try {
      /*create statement*/
      statement = link.createStatement();
      /*execute the statement and retrieve the result*/
      results =
      statement.executeQuery("SELECT * FROM Accounts");
    }
    catch(SQLException e) {
      System.out.println("Error: Cannot execute
                          query!");
      e.printStackTrace();
      System.exit(1);
    }

    try {
      /*process the results*/
      while (results.next()) {
        System.out.println();
        System.out.println("Account:"
        + results.getInt(1));
        System.out.println("Holder:  "
        + results.getString(2));
        System.out.println("Balance: "
        + results.getFloat(3));
        System.out.println("Modified: "
        + results.getDate(4));
      }
    }
    catch(SQLException e) {
      System.out.println("Error: Retrieving data!");
      e.printStackTrace();
      System.exit(1);
    }
```

Code Listing 7.7 (Continued)

```
    try {
      /*close the statement and connection*/
      statement.close();
      link.close();
    }
    catch(SQLException e) {
      System.out.println("Error: Unable to
                          disconnect!");
      e.printStackTrace();
    }
  }
}
```

Code Listing 7.7 (Continued)

7.6.3 JDBC Transactions

Most databases require protection against errors that may leave the entire data storage in an inconsistent state. For example, when multiple tables are to be updated as a result of an operation, it is important to make sure that either all operations succeed or none of them. Unfortunately, data processing, network and database errors may occur, and a mechanism should be in place to protect the database consistency.

A transaction consists of a number of statements that are related logically and make sense only if all of them are successfully executed. By default, after each database statement is executed, the changes are automatically committed to the database (auto-commit is on). As a consequence, the changes are saved on the disk and are irreversible.

Before a transaction that consists of two or more statements is performed, the auto-commit feature must be turned off (Connection::setAutoCommit(false)). This will prevent the changes to be saved to disk directly. When all the statements are executed successfully, the changes should be permanently recorded to the database by using a commit operation (Connection::commit());

All changes from the last call to commit() method are recorded without being actually saved on the disk. If an error occurs, the database must be returned to the state before transaction started and this is made by using the rollback method (Connection::rollback()). When rollback is performed, all changes from the last call to commit() are dropped.

```
Connection con =
  DriverManager.getConnection(url, username, passwd);

/*turn auto-commit off*/
con.setAutoCommit(false);

try {
  statement.executeUpdate(sqlStatement_1);
  ...
  statement.executeUpdate(sqlStatement_N);
  /*at this stages all the changes done
   *by running the above statements are recoded
   *but not saved on the disk*/

  /*commit changes as no error occurred*/
  con.commit();
}
catch (Exception e) {
  try{
    /*as an exception was thrown indicating an error*/
    /*and rollback is performed*/
    con.rollback();
  }
  catch (SQLException sqle)    {
    /*report problem rolling back*/
  }
}
finally {
  try{
    /*close connection*/
    con.close();
  }
  catch (SQLException sqle)    {
    /*report problem closing connection*/
  }
}
```

7.6.4 JDBC Metadata

All the examples presented so far assumed a known database structure. This means that the name of the tables as well as the name of the fields of each table and their order are known. Hence the statements can be formed and results can be processed using table names and columns ids.

However, often the database structure is unknown, and consequently it is necessary to have this information in order to interact with the database.

Information about database can be retrieved using *DatabaseMetaData's* methods. A reference to a *DatabaseMetaData* object is returned by Connection:: getMetaData().

Among the most important *DatabaseMetaData* methods are *ResultSet getCatalogs();* which gets all the names of catalogs available in this database, *ResultSet* *getTables(String catalog, String schemaPattern, String tableNamePattern, String[] types);* which retrieves a description of the tables available in the given catalog, and *boolean isReadOnly();* which checks if the database is read-only.

Data structure information can be retrieved using *ResultSetMetaData's* methods. A reference to a *ResultSetMetaData* object is returned by *ResultSet::getMetaData();* method.

Among the most important *ResultSetMetaData* methods are *int getColumn-Count();* which returns the number of columns in the data-set, *String getColumn-Name(int column-no);* which returns the column name given its order number (starting from 1, not 0), *int getColumnType(int column-no)* which returns the column type given its order number (starting from 1, not 0!), *String getColumnTypeName(int column-no)* which returns a string containing the indicated column's type name and *boolean isReadOnly(int column-no)* which checks if the column is read-only.

Most often used column type constants (defined in *java.sql.Types*) are *Types. NUMERIC, Types.DECIMAL, Types.INTEGER, Types.VARCHAR, Types.DATE, Types.REAL, Types.DOUBLE, Types.FLOAT*.

The following example shows how database information can be used in a Java application.

```
/*create a statement*/
Statement statement = link.createStatement();

/*create the query*/
String select = "SELECT * FROM Table WHERE Field =
                 Value";

/*execute the statement and retrieve the results set*/
ResultSet results = statement.executeQuery(select);

/*retrieve the ResultSetMetaData object*/
ResultSetMetaData metaData = results.getMetaData();

/*retrieve the number of fields*/
int noFields = metaData.getColumnCount();

/*check if results found*/
boolean found = results.next();

if (!found)
  System.out.println("Not found!");
else
  /*for each available column*/
  for (int i = 1; i <= noFields; i++) {
    /*display column name and column type*/
    System.out.println("Field name: "
            + metaData.getColumnName(i));
    System.out.println("Field type:  "
            + metaData.getColumnTypeName(i));

    /*depending on the column type*/
    /*retrieve entry value by type and display it*/
    switch (metaData.getColumnType(i))
    {
      case Types.INTEGER:
        System.out.println("Val:"+results.getInt(i));
        break;
      case Types.VARCHAR:
        System.out.println("Val:"+results.getString(i));
        break;
      case Types.NUMERIC:
        System.out.println("Val:"+results.getFloat(i));
        break;
      default:
        System.out.println("Val of unknown type");
    }
  }
/*close database connection*/
link.close();
```

7.7 Multimedia Content Delivery Services

Multimedia content delivery was usually associated with broadcasting in the traditional TV distribution services. Lately, due to the development and proliferation of other multimedia based services such as video-on-demand or video conferencing, unicast and multicast content delivery became closely associated with multimedia applications.

Broadcasting has the main advantage of being cost effective in terms of bandwidth. Delivering the same content to multiple users at the same time reduces resource utilization. As the users are more likely to prefer video-on-demand-like services [29], the popularity of broadcasting decreases.

Unicast has the main advantage of supporting video-on-demand services, as well as broadcast services. Another benefit of unicast is that network resources are used only when there is a user requiring a certain service [29]. In the context of multimedia delivery to mobile devices, unicast presents the benefit of supporting content adaptation for each user separately in order to meet his/her device capabilities as well as networking resources.

Multicast is beneficial especially for group content delivery in applications like video conferencing. However, the management of multicast groups is difficult and complex.

Various wireless solutions have been proposed to address multimedia content delivery to mobile users. Three typical categories can be identified: DVB-based solutions which enhance the Digital Video Broadcasting standard for mobile devices (hand-held), solution enhancing the third generation cellular networks including UMTS with Multimedia Broadcast Multicast Service (MBMS) support, and content delivery solutions exploiting the widespread popularity of WLAN (802.11—WiFi).

7.7.1 Protocols Specific to Real-Time Data Delivery

The *Real-time Transport Protocol (RTP)* [30] is used for delivering multimedia data over the IP networks. RTP uses transport layer protocols such as UDP, for example, and consequently some people consider RTP as an application layer protocol. However, as RTP is used to deliver multimedia content, often specialists state it is an upper transport layer protocol.

Real-time Transport Control Protocol (RTCP) [31] controls data delivery over RTP. RTP and RTCP use different port numbers (even and odd). As opposed to RTP which delivers the content, RTCP delivers control packets such as throughput, loss, jitter, etc. This information is not used by RTP, but it is usable by the application directly for bit-rate adaptation or delivery quality assessment. In this context, RTP cannot guarantee the Quality of Service (QoS) at all. The quality of delivery is maintained by adapting the content bit-rate to the network QoS based on delivery performance information provided by RTCP.

RTCP periodically transmits control packets to all participants in the streaming session, using the same distribution mechanism as the data packets. The underlying protocol used for transport must provide multiplexing of the data and control packets by using separate port numbers with UDP.

RTCP performs four functions: provides feedback on the quality of content delivery, carries a persistent transport-level identifier for an RTP source (i.e., canonical name), provides rate adaptation for the control packets based on the number of participants, and provides minimal session control information such as participant identification.

Real Time Streaming Protocol (RTSP) [32] enables a multimedia client to have access to the video remote control features, including play, stop, pause, etc. RTSP is often used in conjunction with RTP for delivering multimedia data and enabling its control.

RTSP controls one or many time-synchronized streams of continuous media such as audio and video. RTSP does not deliver the continuous streams itself, although it supports interleaving of the continuous media stream with the control stream. This protocols acts as a virtual "remote control" allowing the user player to provide VCR-like control options (i.e., play, pause, stop).

The set of streams is defined by a presentation description; however, a specific format is not defined. RTSP does not use connections; however, the media server keeps a session tagged by an identifier. This session is not linked in any way with

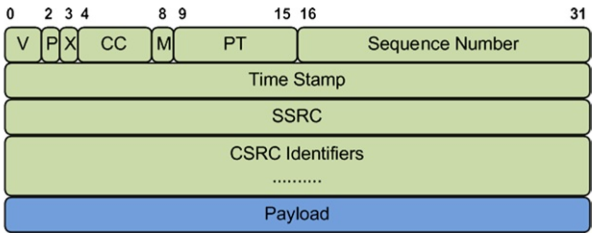


Figure 7.10 RTP packet format

a transport level connection such as TCP connections. RTSP sessions are independent of the transport solution used. RTSP requests will be transported over TCP connections when reliability is desired or over UDP when reliability is traded for speed.

Figure 7.10 shows the fields of the RTP packet header and the payload as follows. The header has a minimum size of 12 bites.

- V—2 bits, version number;
- P—1 bit, padding flag;
- X—1 bit, packet header extension flag;
- CC—4 bits, contributing source number flag;
- M—1 bit, special event flag;
- PT—7 bits, payload type flag;
- Sequence Number—16 bits, data packet sequence number;
- Time Stamp—32 bits, time stamp;
- SSRC—32 bits, synchronization source and synchronization source flag;
- CSRC LIST—32 bits, contributing source and contributing source flag list. Can be up to 15;
- Payload—Packet payload.

The following example shows how to use the Java Media Framework (JMF) [33] to build an RTP server delivering a local video file.

```
/*Import relevant packages*/
import java.awt.*;
import java.io.IOException;
import javax.media.*;
import javax.media.protocol.*;
import javax.media.format.*;
import javax.media.control.TrackControl;

/*Define media server class*/
public class MediaServer {

  /*Define relevant member variables*/
```

Code Listing 7.8 MediaServer.java

```
  private MediaLocator locator;
  private String ipAddress;
  private String port;
  private Processor processor = null;
  private DataSink  rtpTransmitter = null;
  private DataSource dataOutput = null;

  /*MediaServer constructor providing
  source location, streaming IP and Port*/
  public MediaServer(String mediaSource,
              String ipAddress, String port){
    this.locator = new MediaLocator(mediaSource);
    this.ipAddress = ipAddress;
    this.port = port;
  }

  /*Start the server*/
  public void start() {
    /*Create processor*/
    createProcessor();
    /*Create transmitter*/
    createTransmitter();
    /*Start streaming*/
    processor.start();
  }

  /*Stop the server*/
  public void stop() {
    /*Stop and destroy the processor*/
    processor.stop();
    processor.close();
    processor = null;

    /*Stop and destroy the transmitter*/
    rtpTransmitter.close();
    rtpTransmitter = null;
  }

  /*Create the processor*/
  private void createProcessor() {
    try {
      /*Create data source*/
      DataSource ds =
          Manager.createDataSource(locator);
```

Code Listing 7.8 (Continued)

```
      /*Create processor*/
      processor = Manager.createProcessor(ds);
    } catch (NoProcessorException e) {
      e.printStackTrace();
    } catch (NoDataSourceException e) {
      e.printStackTrace();
    } catch (IOException e) {
      e.printStackTrace();
    }

    /*Configure and realize the processor*/
    processor.configure();
    processor.realize();

    /*wait for the processor to initialize*/
    while (processor.getState() < Processor.Configured
      || processor.getState() < Processor.Realized) {
      try {
        this.wait(1000);
      } catch (InterruptedException e) {
        e.printStackTrace();
      }
    }

    /*Get the media file tracks*/
    TrackControl [] tracks =
          processor.getTrackControls();

    /*Search for a video track*/
    for (int i = 0; i < tracks.length; i++) {

      Format format = tracks[i].getFormat();

      if (tracks[i].isEnabled() &&
            format instanceof VideoFormat) {

        /*Video track found*/
        Dimension size =
            ((VideoFormat)format).getSize();

        float frameRate =
            ((VideoFormat)format).getFrameRate();
        /*Make the width and height multiples of 8*/
        int w = 0;
```

Code Listing 7.8 (Continued)

```
        if(size.width % 8 == 0){
          w = size.width;
        } else{
          w = (int)(size.width / 8) * 8;
        }

        int h = 0;
        if(size.height % 8 == 0){
          h = size.height;
        }else{
          h = (int)(size.height / 8) * 8;
        }

        VideoFormat videoFormat =
              new VideoFormat(VideoFormat.H263_RTP,
              new Dimension(w, h),
              Format.NOT_SPECIFIED,
              Format.byteArray,frameRate);
        tracks[i].setFormat(videoFormat);
      } else
        tracks[i].setEnabled(false);
    }
    /*Initialize the output content descriptor
    to RAW_RTP*/
    ContentDescriptor cd =
          new ContentDescriptor(ContentDescriptor.RAW_
                                      RTP);
    processor.setContentDescriptor(cd);
    /*Retrieve the output data source*/
    dataOutput = processor.getDataOutput();
  }

  /*Create the transmitter*/
  private void createTransmitter() {
  try {
    /*Define the streaming URL*/
    String rtpURL =
      "rtp://" + ipAddress + ":" + port + "/video";
    /*Create the transmitter and start streaming*/
    MediaLocator outputLocator =
        new MediaLocator(rtpURL);
    rtpTransmitter =
        Manager.createDataSink(dataOutput,
                                   outputLocator);
```

Code Listing 7.8 (Continued)

```
    rtpTransmitter.open();
    rtpTransmitter.start();
    dataOutput.start();
    } catch (NoDataSinkException e) {
      e.printStackTrace();
    } catch (SecurityException e) {
      e.printStackTrace();
    } catch (IOException e) {
      e.printStackTrace();
    }
  }

  public static void main(String [] args) {
    try {
      MediaServer vt =
      new MediaServer("file:\\video.avi", "localhost",
                       "1024");
      vt.start();
      Thread.currentThread().sleep(60000);
      vt.stop();
    } catch (InterruptedException e) {
      e.printStackTrace();
    }
  }
}
```

Code Listing 7.8 (Continued)

7.7.2 Multimedia Delivery over Cellular Networks

In cellular networks, multimedia delivery was introduced starting from the 2.5G technologies and continuing with the current 3G technologies. The packet-switched streaming (PSS) standard developed by the Third Generation Partnership Project (3GPP) provides the means of content transportation for streaming and downloading applications. PSS uses various protocols for content delivery and information exchange. Content is delivered using RTP over UDP. Other types of media including text and graphics are delivered over HTTP. RTSP is used for control information exchange. PSS supports user quality of experience monitoring which permits content adaptation for improving user satisfaction.

Apart from the transport mechanisms, PSS also specifies a set of media codecs including Adaptive Multirate (AMR), H.263 [34], H.264 [35], MPEG-4 Advanced Video Codec (AVC) [36], and MPEG-4 [37].

For further improvement of user perceived quality, PSS also includes an Adaptive Streaming feature [38] which is useful for adapting the content to network condition variations as well as variations in network characteristics due to handovers between systems [29] like GPRS to WCDMA and vice-versa.

The *IP Multimedia Subsystem (IMS)* [39] was developed within 3GPP as a service platform to provide multimedia services over 3G networks. IMS uses the Session Initiation Protocol (SIP) for signaling and session control, RTP for media transport and IPv6 at the network layer. The IMS platform is not directly involved in media transport (only in session control) [39], but QoS is maintained by collaboration between the IMS platform and the transport network. The Policy Decision Function (PDF) is the IMS sub-module which is responsible for QoS negotiation according to the application requirements.

3GPP also proposed the *Multimedia Broadcast/Multicast Service (MBMS)* for UMTS [40]. MBMS delivers multimedia content to a group of users in a point-to-multipoint manner using UMTS MBMS transmission bearer. MBMS is composed of two modules, the MBMS bearer service which deals with transmission procedures below the IP layer and the MBMS user service which manages streaming and downloading methods and procedures. The streaming methods used by MBMS are similar to PSS in terms of transfer protocols (e.g., RTP) and codecs.

Broadcast and Multicast Services (BCMCS) [41] protocol is similar to MBMS but was developed by 3GPP2 for the CDMA2000 protocol family for 3G networks. Similar to MBMS, BCMCS provides point-to-multipoint content delivery and guarantees QoS for two way multimedia applications. Content adaptation may be performed using SVC which was also introduced in MPEG-4 standard as *FGS (MPEG-4 FGS)* [42].

7.7.3 DVB-based Multimedia Delivery

The Digital Video Broadcasting (DVB) [43] standards offer point-to-multipoint data services with high data rates for multimedia (especially TV) content delivery to end users. Apart from the satellite versions (DVB-S) [44], DVB also standardized a terrestrial wireless data service via DVB-T [5]. Although DVB-T broadcasts multimedia content to static and mobile users, including vehicular receivers, it is not optimized for highly mobile hand-held devices. However, the most recent DVB-T2 [45] is highly efficient and addresses many of the shortcomings of the previously-proposed DVB-T.

Consequently, the DVB community has developed DVB-H (hand-held) [6] for multimedia content delivery to mobile devices.

DVB-H specifies the protocol layers below the network layer only, and consequently there was a need for an Internet Protocol (IP) [46] interface for higher transport layers which was defined by the IP-based Data Broadcast (IP Datacast) [7] specification which was also introduced.

IP Datacast specified the protocols for higher layers in concordance with the Internet protocol stack. For the transport layer, UDP was chosen with RTP for real-time media broadcasting and File Delivery over Unidirectional Transport (FLUTE) [47] for non-real-time data transfer like download-based media delivery.

For media encoding, DVB-H aims for high compatibility between network components and terminals; therefore, MPEG-4/H.264 was chosen for video encoding as well as the Microsoft Windows Media 9 based VC-1 codec [48]. For audio MPEG 4, AAC+ [49] is recommended.

IP Datacast was developed towards a hybrid interoperability of several types of networks in order to benefit from their advantages and balance their disadvantages.

DVB-H has the advantage of being highly scalable with the number of users unlike cellular networks or WLANs which are basically point-to-point and suffer from severe QoS drops when congested. On the other hand, DVB-H interactivity is quite limited.

Considering these aspects, using a hybrid solution where the content management layer decides which network to use for delivery of a certain service depending on its popularity (the number of users requesting the same service at the same time) or its interactivity requirements may improve the overall quality of the service as perceived by the user.

7.7.4 Multimedia Delivery over WLAN

Wireless LAN is probably the most successful and cost-effective option for multimedia delivery. With encouraging link layer data rates, IEEE 802.11 based WLANs popularity is constantly increasing and many flavors have been proposed, addressing different wireless communications aspects including using different frequencies, supporting increased bitrates, focusing on mesh networks or on vehicular communications: IEEE 802.11b, IEEE 802.11a, IEEE 802.11g, IEEE 802.11s [4], IEEE 802.11p, etc.

Despite all the positive aspects WLANs suffer from the same unpredictability of the wireless links as well as from severe QoS drops when the wireless medium gets congested with the increase in the number of simultaneous hosts engaged in data sessions.

The IEEE 802.11 standards describe only the physical and MAC layer. There are several enhancements proposed for supporting multimedia applications including the IEEE 802.11e [1] and IEEE 802.11n [3] which provide QoS support features in the MAC layer. There are also various prioritization schemes [2] which allow traffic differentiation depending on the type of traffic (priority class).

WLANs use the Internet protocol stack for higher layers, consequently all the multimedia streaming solutions designed for the Internet may be used in scenarios including WLANs. Although WLANs are compatible with the IP based network paradigm, their particularities especially regarding the error prone and highly dynamic wireless links have to be considered by the higher layers in order to provide a high quality multimedia streaming service.

7.8 Adaptive Multimedia Delivery

User satisfaction is crucial for the success of any multimedia-based application. Various performance issues arise when multimedia content is delivered over best-effort networks to users with heterogeneous device capabilities and expectations. However, network conditions in terms of available bandwidth, packet loss, packet delay, and delay jitter have a major impact on the quality of delivered multimedia content and its timeliness, ultimately affecting the end-user perceived quality, or as it is most recently termed Quality of Experience (QoE).

In order to avoid the negative impact dynamic network conditions have on the multimedia content, measures have to be taken to adapt the streaming process to follow and match the current network capacity. If short term variations can be overcome by using buffering techniques [50], for long time-scale network dynamics rate adaptation techniques are among the most efficient solutions.

Several adaptive streaming solutions were proposed at the network and transport layer including TFRCP [51], LDA+ [52], and RAP [53]. These solutions present a reasonable performance in terms of QoS, but their major drawback is a poor correlation with the actual end-user perceived quality.

More advanced adaptive streaming techniques from the point of view of maintaining a high level of user perceived quality were developed at the application layer. Such a solution with good performance in terms of user perceived quality is LQA [54]. Cross-layer methods get closer to the user and try to achieve higher perceptual quality of streamed multimedia content. A good survey of these solutions can be found in [55].

The Quality Oriented Adaptation Scheme (QOAS) [56] involves a user perceived quality estimation in the feedback-based multimedia adaptation process. Consequently, QOAS shows significant improvements in end-user perceived quality when used for streaming multimedia content in both wired and wireless networking environments.

Diverse solutions were proposed for adaptive multimedia transmissions over wireless access networks [57] or wireless ad-hoc networks [58]. Among the proposed solutions are adaptation mechanisms at the level of layers [57] or objects [59], fine-granular scalability schemes [60], and perception-based approaches [61].

However, all these solutions involve content adjustments which affect equally the whole area of the video frames, regardless of different user interest in various frame regions as research on regions of interest (ROI) has demonstrated [62].

A cross-layer adaptive multimedia streaming solution was proposed in [63]. Unlike the other solutions discussed above, this one makes distinction between various elements of the video content by identifying, classifying, and assigning different priorities, and consequently different QoS levels for each element or group of elements. However, this solution does not consider the variation in user attention focus during the video sequence.

An ROI-based adaptive scheme is introduced in [64]. Unlike in the case of ROIAS, each macro-block is categorized as ROI or non-ROI based on a saliency map computed using luminance contrast, color-double-opponent, texture, skin color, and motion vector.

ROI-based adaptation of video content is also discussed in [65]. Although techniques for estimating the ROI within a video frame are presented, the adaptation consists in adjusting the frame resolution to match the maximum display resolution.

A similar approach is presented in [66]. Unlike ROIAS, the proposed solution focuses on resolution adaptation and targets specific types of content (i.e., news, interviews) where the ROI is predefined at the beginning of the material and then is tracked throughout the playback.

Although ROI is considered in the adaptation process, the above mentioned solutions do not reach the level of generality and performance in terms of smoothness and adaptability.

7.9 Conclusion

This chapter has presented the major communication-based services, has introduced the protocols these services rely on, and has described step-by-step, with the help of examples, how applications built on top of these protocols can be developed using Java.

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Chapter 8
Server-Side Network Programming

Abstract Server-side network programming involves designing and implementing programs to be run on a server. Server-side applications run as processes on a dedicated physical machine, virtual machine, or cloud infrastructure. Server-side applications receive requests from the clients and perform tasks as requested by the clients. This chapter introduces various server-side methods and techniques used to generate and deliver web documents to requesting clients, including Java specific solutions such as Java Servlets and Java Servlet Pages. Detailed examples are presented for both technologies.

8.1 Introduction

Server-side network programming involves designing and implementing programs to be run on the server.

Server-side applications run as processes on a dedicated physical machine, virtual machine or Cloud infrastructure, as schematically presented in Fig. 8.1. A server machine may run one or more applications at the same time.

Server-side applications perform tasks requested by the clients. The most popular server-side applications are Web server applications which deliver Web documents over the Internet to Web clients at their request.

A typical server-side application involves three distinct layers.

The *presentation layer* enables user access to data and translates data in user friendly content. It mainly involves graphical user interfaces and handles user inputs and data presentation to users.

The *business logic layer* deals with user-related commands, makes logic decisions, and processes data. This layer is the actual data processing layer which implements the core functionality of any application.

The *resource layer* organizes data storage and retrieval and uses a database management system or file system. This layer is mainly in charge of the persistent data storage and retrieval.

Based on the three layer model presented above, four types of server-side application architectures can be defined.

One-tier applications are usually suitable for small size applications. In this case, all layers are combined in a single entity. One single tier will deal with data storage

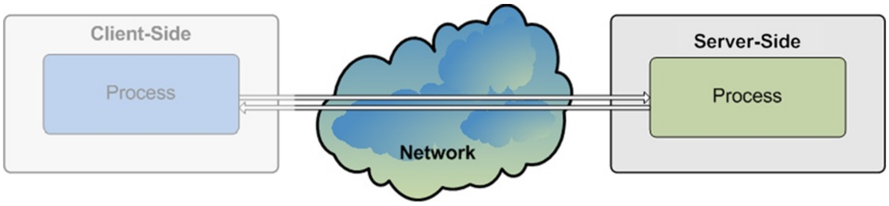

Fig. 8.1 Server-side network programming

and retrieval, data processing and decision making, as well as data presentation and user interface.

Two-tier applications are suitable for medium size applications. In this scenario, presentation has been separated from business logic. The user interface related modules are separated from the modules which deal with data processing and decision making

Three-tier applications are suitable for medium and large size applications. By separating the three layers into three tiers, the presentation layer is implemented by separate dedicated modules, the data processing tier has its own modules and the data storage tier gets its own components. Such an application is easier to develop, manage, scale, and maintain.

N-tier applications may also be implemented. This type of server-side application architectures are suitable for large size applications which add extra layers for security, efficiency, and scalability.

This chapter presents Java solutions for developing Web-based server-side applications and focuses on Servlets and Java Server Pages (JSP)-based solutions. For information purpose, brief descriptions of Common Gateway Interface (CGI) and Hypertext Pre-processor (PHP), as non-Java alternative solutions are also included.

8.2 Non-Java Server-Side Network Programming Solutions

8.2.1 Common Gateway Interface

Common Gateway Interface (CGI) is a protocol that enables remote users to access services provided at the servers. In general, a normal Web browser is located at the client-side, and at the server side there is a normal Web server. The Web server has to be able to run scripts or applications in order to provide services to the clients.

A Web server with CGI support needs to be configured such that it interprets a URL that it serves as a reference to a CGI script or application. A common convention for CGI script/application deployment is to have a cgi-bin/ directory at the base of the directory tree on the server and consider all executable files within this directory (and no other, for security reasons) to be CGI scripts/applications. Consequently, when the server receives a request, it will run the corresponding CGI script/application from the cgi-bin/ directory.

Another convention is to use .cgi file extensions for all CGI scripts. Consequently, the Web server can be configured to interpret all .cgi files as CGI scripts. Although convenient, this method opens the server to attacks if a remote user can upload its own scripts with the corresponding extension.

Any programming language such as C/C++, Visual Basic, PERL, and TCL can be used to write CGI processing code. Script-based languages are preferred due to their simple modification with no requirement in terms of code re-compile to generate the executable application and application redeployment.

Typical CGI script/application steps involve reading input data (i.e., from the standard input), processing the data provided, and generating an HTML output document to the standard output.

Among the main drawbacks of CGI are its security issues, as described above, and performance. Calling a command (CGI script) generally means the invocation of a newly created process running on the server. Starting a process consumes much more time and memory than the actual work of generating output of the task performed by the process.

This is valid especially when the program also needs to be interpreted or even compiled. Under these circumstances, if the script is called often, the resulting workload can quickly overload the server.

8.2.2 Hypertext Pre-processor

Hypertext Pre-processor (PHP) is a powerful server-side scripting language for dynamic Web-page generation. In general, a normal Web browser is located at the client-side, and a normal Web server runs at the server. For the Hypertext Pre-processor case, the Web server has to have the PHP package installed in order to be able to interpret PHP scripts.

PHP is a fully functional language which enables form processing, generation of various data types (not only text) as well as database access. PHP also provides object-oriented programming feature support.

The following code example shows how PHP scripts are specified and marked in an HTML document. In the example below, it can be seen how PHP can be used to print a message in an HTML document which is then delivered to the user. The *print* function is available within PHP.

```
<?
  print("Hello world!");
?>

<?php
  print("Hello world!");
php?>
```

```
<script language="php">
  print("Hello world!");
</script>
```

To further exemplify the capabilities of PHP, the following code sample defines a function which recursively deletes a folder and its content.

```
##remDir removes all files/folders from path ($path)
function remDir($path)
{
  ##add a '/' at the end of the path if it does not
    exist
  if (substr($dir, strlen($path)-1, 1) != '/')
    $path .= '/';

  ##display the complete path
  echo $path;

  ##if the folder is opened successfully
  if ($handle = opendir($path))
  {
    ##for each sub-folder
    while ($item = readdir($handle))
    {
      ##if not current or parent folder
      if ($item != '.' && $item != '..')
      {
        ##if it is a folder
        if (is_dir($path.$item))
        {
          ##delete recursively the folder
          if (!remDir($.$item))  return false;
        }
        ##if it is file
        elseif (is_file($path.$item))
        {
          ##delete the file
          if (!unlink($path.$item))  return false;
        }
      }
    }
    ##close the parent folder
```

Code Listing 8.1 remDir.php

```
    closedir($handle);
    ##remove the parent folder
    if (!@rmdir($dir))
      return false;
    return true;
  }
  return false;
}
```

Code Listing 8.1 (Continued)

PHP presents the following main advantages. It is open source, and consequently it is developed and maintained by a large community of developers. It is relatively fast and easy to use as it is using C-like syntax. It is fairly stable and provides a powerful library support for various types of features and functionality development. PHP is also easy to port on various platforms, and the built in database support makes it a very powerful server-side application development tool.

Among the disadvantages, security is probably the main one. Since it is open source, every bug in the system can be detected within the code and weaknesses can be exploited. PHP is not suitable for large applications as it is not very modular and consequently hard to maintain. Implicit conversions may be also considered by many developers as a weak point of PHP as it can easily generate confusion and unexpected bugs in the system.

8.3 Java Servlets

8.3.1 Servlet Overview

Java Servlets are programs that run on the server side and generate content dynamically following client requests.

The Java servlet architecture and its functionality principle is graphically presented in Fig. 8.2.

The architecture involves a client–server paradigm. At the client side, a Web browser, representing the user interface or user process, sends requests to the Web server addressed to a specific servlet. Responses from the Web server originating from the servlet are expected and hopefully will be received by the Web browser, and the corresponding Web document will be displayed on the user interface.

At the server side, there is a Servlet Container which is in charge of managing the servlets. The requests originating from the client process are first received by the servlet container which then dispatches them to the corresponding servlet. Upon receiving the request, the servlet will process it, perform the business logic operations (access the required resources such as database systems or file systems, for

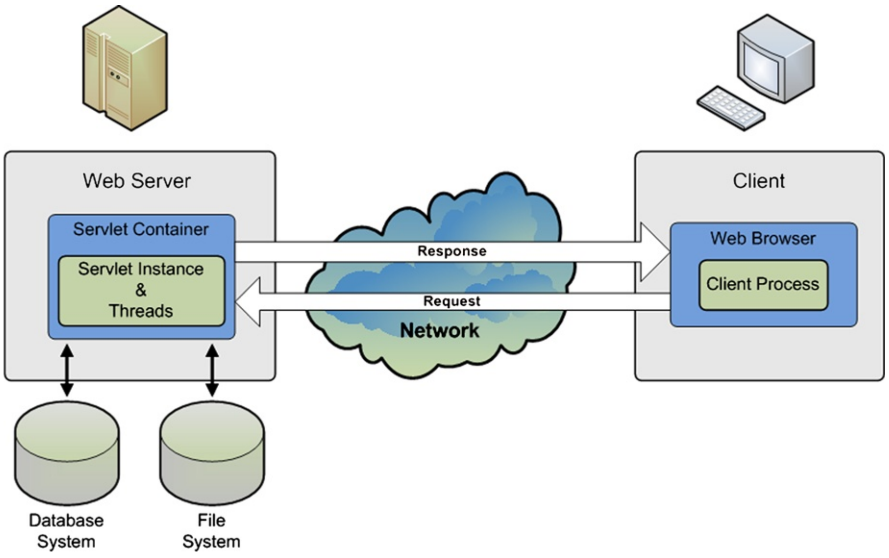

Figure 8.2 Java servlet architecture

example), and produce the results which are then sent to the client in the form of a response.

In this process, the Web browser is in charge of user inputs and data display, the servlet container is in charge of the management of servlet life cycle and with resource management, servlet deployment and security, while the servlet itself is in charge of the business logic (i.e., providing the requested service).

There are many advantages of using Java servlets for delivering dedicated services to clients over the Internet.

Efficiency. As Java Virtual Machine is always running, when starting a servlet, only a new Java thread is created, as opposed to a system process (as it happens in the case of CGI), which highly increases the efficiency and decreases the latency.

Persistency. A servlet which was already loaded by the servlet container remains in the memory and can maintain system resources such as database connectivity, offering a faster and more efficient access to resources.

Flexibility. Having access to the whole set of Java APIs, servlets represent a powerful tool for network application developers. They enable communication with Web servers, data sharing between servlets, maintaining information between requests, and managing sessions (for example, for database and file access support).

Security. Servlets are run by the Servlet Container in a restrictive sandbox, similar to that used by the Web browsers for applets (which will be discussed later in this book). This protects the whole system against malicious attacks, offering a high level of security.

Cost efficiency. There are many "free" or low-cost Web servers available for either personal use or low volume traffic. If you have a Web server, you can easily and cheaply add the servlet technology (if it is not already there!). Consequently, servlets offer a cost efficient approach to network service providing.

Convenience. Servlets take advantage of the Java platform and are supported by almost all Web servers. In general, servlet-based solutions can be deployed to any platform with no modifications, offering a highly portable solution.

8.3.2 Servlet Life-Cycle

The Servlet Container is in charge of managing servlets from various points of view. It listens and accepts requests from clients and other servlets and dispatches them to the correct servlet (indicated in the request). The container is also responsible for dispatching servlet responses to the invoking process (e.g., client).

However, the most important task performed by the servlet container is to manage servlet objects in terms of their life-cycle and access to resources.

The servlet life-cycle, as managed by the Servlet Container, consists of several stages, as illustrated in Fig. 8.3. When a request is mapped to a servlet, if an instance of the servlet does not exist, the servlet class is instantiated creating a servlet object that handles the request. Important to note is that there is a single servlet instance per servlet definition. This single servlet instance has to deal with multiple requests, often received simultaneously. Consequently, if a servlet object exists, the container creates a new thread to handle the request, which is highly time and processing efficient.

However, in this manner, different threads share the same memory space, which may cause data inconsistency. Consequently, while developing servlet applications, there is a need to include synchronization for all the methods that may be affected by the parallel processing of multiple simultaneous requests (e.g., queue management, database update, etc.).

When instantiating the servlet, the container initializes the instance by calling the *init()* method. It then invokes the *service()* method whenever a request is made, passing it request and response objects as parameters. The request parameter includes an indication of the service method invoked. For the HTTP servlets, these service methods include the HTTP methods: GET, DELETE, OPTIONS, POST, PUT, and TRACE. Most servlets follow the HTTP servlet model. However, other types of servlets with diverse different service methods can also be developed.

Depending on the service method requested to be run, the servlet thread performs different activities when executing the service() method and generates a response. This response is delivered to the calling method as part of the response object passed as a parameter.

A servlet instance runs until the container decides to destroy it. Often this happens some period of time after the last request. Typically, this period is either 15 or 30 minutes, but the system administrator can modify it.

When the container needs to remove the servlet, it finalizes the servlet by calling the *destroy()* method which destroys the servlet instance.

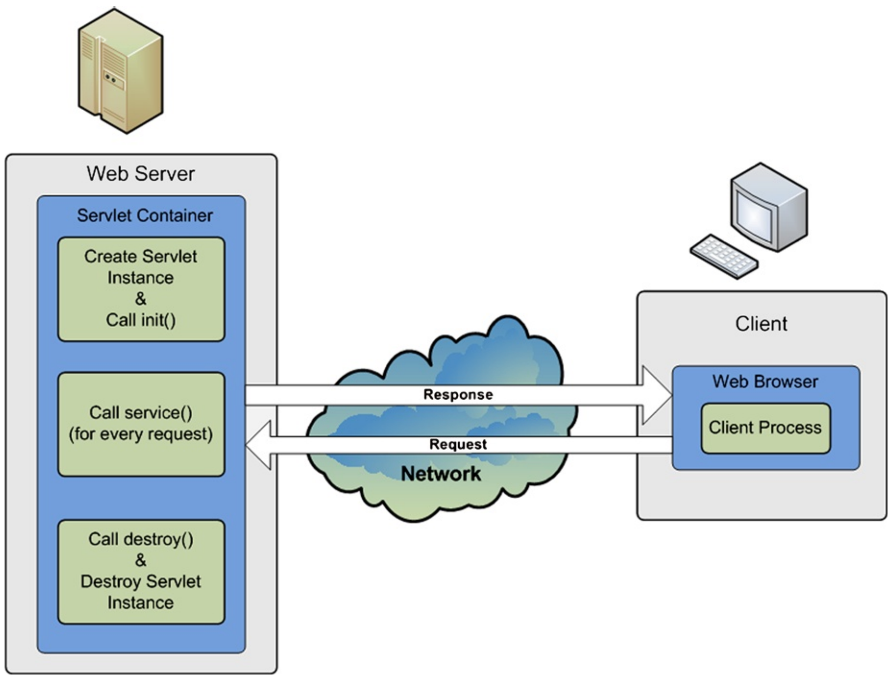
Web Server
Servlet Container
Create Servlet Instance & Call init()
Call service() (for every request)
Call destroy() & Destroy Servlet Instance
Response
Request
Network
Client
Web Browser
Client Process

Figure 8.3 Java servlets life-cycle

Servlet Life-cycle involves the following stages:

- Creating a servlet object;
- Calling init();
- Repeatedly calling service();
- Calling destroy();
- Destroying servlet object.

Many Web servers available commercially or open source-based support Java servlets. Some of the most popular are: Apache (Tomcat) (open source, non-commercial), JBoss (open source, commercial, standards compliant), and IBM WebSphere (commercial).

8.3.3 Servlet Programming

Java API provides the basic functionality for implementing Java servlets. The class hierarchy is presented in Fig. 8.4 and involves an interface (*Servlet*), an abstract class (*GenericServlet*), an implementation class (*HTTPServlet*), and an application specific programmer-defined class.

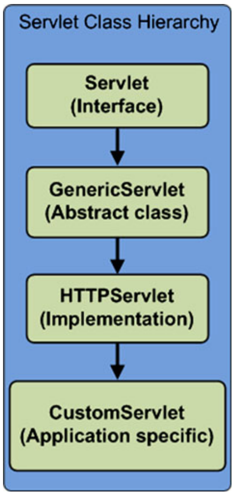
Servlet Class Hierarchy
Servlet (Interface)
GenericServlet (Abstract class)
HTTPServlet (Implementation)
CustomServlet (Application specific)

Figure 8.4 Java servlets class hierarchy

The *Servlet* interface publishes the *init()*, *destroy(),* and *service()* methods. *GenericServlet* is an abstract class implementing some of the methods involved in servlet programming. *HttpServlet* implements all the Servlet methods, including *service()*, which determines the request method type: GET, DELETE, OPTIONS, POST, PUT, or TRACE. The *service()* method then calls the corresponding default methods, for instance, *doGet()* or *doPost()*.

CustomServlet is a programmer-written class and is application specific. Depending on application requirements some methods (e.g., doGet(), doPost(), etc.) are overridden providing the application specific functionality.

8.3.3.1 Creating a Basic Servlet

Next the major steps in developing a servlet application will be presented in the context of a simple example of a HelloWorldServlet.

- Step 1—Import the required packages:

```
/*import java packages*/
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;
```

- Step 2—Define a customer class by extending HttpServlet:

```
public class HelloWorldServlet extends HttpServlet
{
[...]
}
```

- Step 3—Override the method corresponding to the expected request:

```
public void doGet(HttpServletRequest req,
      HttpServletResponse res)
    throws ServletException, IOException
{
[...]
}
```

- Step 4—Prepare the response:

```
/*set response's content type*/
res.setContentType("text/html");
/*get the write stream for the response*/
PrintWriter out = res.getWriter();
```

- Step 5—Generate the response:

```
/*generate the response document*/
out.println("<!DOCTYPE HTML PUBLIC
    \"-//W3C//DTD HTML 4.0 " +
    "Transitional//EN\">\n" + "<HTML>\n" +
    "<HEAD><TITLE>Hello WWW</TITLE></HEAD>\n" +
    "<BODY>\n" +
    "<H1>Hello World!</H1>\n" +
    "</BODY></HTML>");
```

- Step 6—Do cleanup:

```
out.close();
```

The complete code for the HelloWorld Servlet example is presented next.

```
/*import java packages*/
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/*define HelloWorldServlet
 *class extending HttpServlet*/
public class HelloWorldServlet extends HttpServlet
{
  /*override doGet() method which will be invoked
   *automatically by service()
   *when a GET request arrives*/
  public void doGet(HttpServletRequest req,
      HttpServletResponse res)
    thsrows ServletException, IOException
```

Code Listing 8.2 HelloWorldServlet.java

```
  {
    /*set response's content type*/
    res.setContentType("text/html");
    /*get the write stream for the response*/
    PrintWriter out = res.getWriter();

    /*generate the header for the response*/
    String docType =
      "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 " +
      "Transitional//EN\">\n";

    /*generate the response document*/
    out.println(docType + "<HTML>\n" +
      "<HEAD><TITLE>Hello WWW</TITLE></HEAD>\n" +
      "<BODY>\n" +
      "<H1>Hello World!</H1>\n" +
      "</BODY></HTML>");

    out.close();
  }
}
```

Code Listing 8.2 (Continued)

After the import of the two main Java API packages, *javax.servlet* which defines the major servlet classes and *javax.servlet.http* which provides the methods to handle service requests, the *HelloWorldServlet* class which extends *HttpServlet* is defined and the *doGet()* method is overridden.

The *doGet()* method receives references to request and response objects as parameters. The classes these two objects instantiate provide a set of methods for retrieving the information from their headers.

The following methods are used for accessing request object headers:

- getHeaders()—mostly used to retrieve headers;
- getCookies()—returns cookies;
- getAuthType()—gets authorization type;
- getRemoteUser()—gets user (e.g., obrien2);
- getRemoteAddr()—gets remote host IP Address (e.g., 136.206.35.123);
- getRemoteHost()—gets remote host name (e.g., pine.eeng.dcu.ie);
- getContentLength()—returns content length (bytes);
- getContentType()—returns content type;
- getDateHeader()—converts parameter to Date;
- getIntHeader()—converts parameter to Integer;
- getMethod()—returns the method used (e.g., GET, POST, HEAD);
- getRequestURI()—returns the URI/URL invoked;

- getProtocol()—returns the protocol used;
- getServerName()—returns the server name;
- getServerPort()—returns the server port number.

The following methods are used for assessing the response object header information:

- addCookie(Cookie c)—adds the specified cookie to the response;
- addHeader(String name, String value)—adds a response header with name and value;
- setStatus(int sc)—sets status code to the header (e.g., SC-OK, SC-BAD-REQUEST);
- setContentLength(int len)—sets content length (bytes);
- setContentType (String type)—sets content type (e.g., text/html);
- setDateHeader(String name, long date)—sets a response header with the given name and date value;
- setIntHeader(String name, int value)—sets a response header with the given name and integer value.

8.3.3.2 Initializing a Servlet

When the servlet is first instantiated, the *init()* method is called. This method allows dedicated servlet parameters to be initialized before any request is processed. The following steps need to be performed if servlet application-specific initialization is desired.

- Step 1—Set in the configuration file servlet initialization parameters in <name, value> pairs:

```
<servlet>
  <servlet-name>
    InitParamsServlet
  </servlet-name>
  <servlet-class>
    initparamsservlet.InitParamsServlet
  </servlet-class>
  <init-param>
    <param-name>msg</param-name>
    <param-value>This is the init text</param-value>
  </init-param>
  <init-param>
    <param-name>rep</param-name>
    <param-value>4</param-value>
  </init-param>
</servlet>
```

- Step 2—Map in the configuration file the servlet name on the servlet URL:

```
<servlet-mapping>
  <servlet-name>
    InitParams
  </servlet-name>
  <url-pattern>
    /servlet/InitParamsServlet
  </url-pattern>
</servlet-mapping>
```

- Step 3—Define a customer class by extending HttpServlet:

```
public class InitParamsServlet extends HttpServlet
{
[...]
}
```

- Step 4—Declare the parameters to be initialized:

```
/*private members which need to be initialized*/
private String text = null;
private int times = 1;
```

- Step 5—Override the init() method:

```
public void init(ServletConfig config)
    throws ServletException
{
[...]
}
```

- Step 6:—In init(), get the initialization parameters:

```
/*read the "msg" parameter
 *from the configuration file*/
text = config.getInitParameter("msg");

if (text == null)
  text= "No init message";

/*read the "rep" parameter
 *from the configuration file*/
String repeatString =
  config.getInitParameter("rep");

times = Integer.parseInt(repeatString);
```

- Step 7—Override the doGet() method to address GET requests:

```
public void doGet(HttpServletRequest req,
      HttpServletResponse res)
    throws ServletException, IOException
{
[...]
}
```

- Step 8—In doGet(), use the initialized parameters:

```
/*print the text message
 *a specified number of times*/
for(int i=0; i<times; i++)
{
  out.println(text + "<BR>");
}
```

- Step 9—Deal with all exceptions:

```
try
{
  [...]
}
catch()
{
  [...]
}
```

Next the complete code for the servlet initialization example is provided.

```
/*import java packages*/
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/*define InitParamsServlet class extending HttpServlet*/
public class InitParamsServlet extends HttpServlet
{
  /*private members which need to be initialized*/
  private String text;
  private int times = 1;

  /*overridden init() method called when
   *the servlet is created*/
```

Code Listing 8.3 InitParamsServlet.java

```
public void init(ServletConfig config)
    throws ServletException
{
  /*Always call super.init()*/
  super.init(config);

  /*read the "msg" parameter from
   *the configuration file*/
  text = config.getInitParameter("msg");
  if (text == null)
    text= "No init message";

  try {
    /*read the "rep" parameter
     *from the configuration file*/
    String repeatString =
        config.getInitParameter("rep");
    times = Integer.parseInt(repeatString);
  }
  catch(NumberFormatException nfe)
  {
    /*handle the case where
     *repeatString is null or illegal*/
    times  = 1;
  }
}

/*override doGet() method which will be invoked
 *automatically by service()
 *when a GET request arrives*/
public void doGet(HttpServletRequest req,
        HttpServletResponse res)
      throws ServletException, IOException
{
  /*set response's content type*/
  res.setContentType("text/html");
  /*get the write stream for the response*/
  PrintWriter out = res.getWriter();

  /*generate the header for the response*/
  String docType =
    "<!DOCTYPE HTML PUBLIC
```

Code Listing 8.3 (Continued)

```
      \"-//W3C//DTD HTML 4.0 " +
      "Transitional//EN\">\n";
    /*generate the response document*/
    out.println(docType + "<HTML>\n" +
      "<HEAD><TITLE>Hello WWW</TITLE></HEAD>\n" +
      "<BODY>\n" +
      "<H1>

    /*print the text message a
     *specified number of times*/
    for(int i=0; i<times; i++)
    {
      out.println(text + "<BR>");
    }

    out.println("</H1>\n</BODY></HTML>");

    out.close();
  }
}
```

Code Listing 8.3 (Continued)

The configuration file must be stored in xml format on the server. This file is provided as a parameter to the *init()* method. The following content is a suitable configuration file for the initialization servlet example provided, which specifies a message *msg* = "This is the init text" to be printed to the client *rep* = 4 times.

```
<?xml version="1.0" encoding="UTF-8"?>

<web-app version="2.4"
   xmlns="http://java.sun.com/xml/ns/j2ee"
  xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
  xsi:schemaLocation="http://java.sun.com/xml/ns/j2ee
  http://java.sun.com/xml/ns/j2ee/web-app_2_4.xsd">

  <servlet>
    <servlet-name>
      InitParamsServlet
    </servlet-name>
```

Code Listing 8.4 config.xml

```
    <servlet-class>
      initparamsservlet.InitParamsServlet
    </servlet-class>
    <init-param>
      <param-name>msg</param-name>
      <param-value>This is the init text</param-value>
    </init-param>
    <init-param>
      <param-name>rep</param-name>
      <param-value>4</param-value>
    </init-param>
  </servlet>

  <servlet-mapping>
    <servlet-name>InitParams</servlet-name>
    <url-pattern>
      /servlet/InitParamsServlet
    </url-pattern>
  </servlet-mapping>
  <session-config>
    <session-timeout>
      30
    </session-timeout>
  </session-config>

  <welcome-file-list>
    <welcome-file>
      index.jsp
    </welcome-file>
  </welcome-file-list>
</web-app>
```

Code Listing 8.4 (Continued)

8.3.3.3 Reading Individual Client Parameters

Most of the time, in order for a servlet to provide the service it was designed for, it has to read and client's input parameters need to be interpreted. In general, these parameters are collected via forms and sent across the network via client requests.

In order to highlight the major steps in building a servlet capable of reading client parameters, an example which allows the client user to input a name and a value via a form displayed by the client Web browser is presented. When the user has already input the data and presses the submit button, the browser communicates with the server-located servlet transmitting the client data as parameters for further processing. The servlet is required to read the client parameters before processing them in an application-dependent manner. The output of the parameter processing phase is a dynamical generated Web page to be delivered to the client and be displayed by the client's browser.

The major steps in developing the client parameter-reading servlet are listed next.

- Step 1—Enable user parameters to be read by a form:

```
 <form [...] >
  Propriety name:
    <input type="text" name="name"><br>
  Propriety value:
    <input type="text" name="value"><br>
  <input type="Submit">
 </form>
```

- Step 2—Invoke the servlet when submitting the form:

```
<form action="/ClientParams/servlet/
               CliParamsServlet"">
  [...]
</form>
```

- Step 3—Create a customer servlet class to extend HttpServlet:

```
public class CliParamsServlet extends HttpServlet
{
[...]
}
```

- Step 4—Override the doGet() method to address GET requests:

```
public void doGet(HttpServletRequest req,
      HttpServletResponse res)
    throws ServletException, IOException
{
[...]
}
```

- Step 5—In doGet(), get and use the parameters:

```
/*get the response write stream*/
PrintWriter out = res.getWriter();
 [...]
out.println ("<HTML>" +

  [...]

  "<B>Propriety name</B>: "
  /*retrieve the user input name*/
```

```
    + req.getParameter("name") + "\n" +

    [...]

    "<B>Propriety value</B>: "
    /*retrieve the user input value*/
    + req.getParameter("value") + "\n" +

    [...]

    "</HTML>");
```

The following html code allows the client to input a name and a value via a form which when submitted will send the corresponding request to the */Client-Params/servlet/CliParamsServlet* servlet.

```
<html>
 <head>
  <meta http-equiv="Content-Type"
      content="text/html; charset=UTF-8">
  <title>Client Parameters Input Page</title>
 </head>
 <body>

 <h1>Client Parameters Input Page</h1>

 <form action=
        "/ClientParams/servlet/CliParamsServlet">
  Propriety name:
      <input type="text" name="name"><br>
  Propriety value:
      <input type="text" name="value"><br>
  <input type="Submit">
 </form>

 </body>
</html>
```

Code Listing 8.5 client.html

The complete servlet implementation is presented in the following code example.

```
/*import java packages*/
import java.io.*;
import javax.servlet.*;
import javax.servlet.http.*;

/*define CliParamsServlet  class extending
 *HttpServlet*/
public class CliParamsServlet  extends HttpServlet
{
  /*override doGet() method which will be invoked
   *automatically by service()
   *when a GET request arrives*/
  public void doGet(HttpServletRequest req,
          HttpServletResponse res)
        throws ServletException, IOException
  {
    /*set content type*/
    res.setContentType("text/html;charset=UTF-8");
    /*get the response write stream*/
    PrintWriter out = res.getWriter();

    String title = "Client Parameters";

    /*generate the header type*/
    String docType =  "<HTML>" +
      "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 " +
      "Transitional//EN\">\n";
    out.println (docType +
      "<BODY BGCOLOR=\"#FDF5E6\">\n" +
      "<H1 ALIGN=CENTER>" + title + "</H1>\n" +
      "<UL>\n" +
      "  <LI><B>Propriety name</B>: "
        /*retrieve the user input name*/
        + req.getParameter("name") + "\n" +
      "  <LI><B>Propriety value</B>: "
        /*retrieve the user input value*/
        + req.getParameter("value") + "\n" +
      "</UL>\n" +
      "</BODY></HTML>");

    out.close();
  }
}
```

Code Listing 8.6 CliParamsServlet.java

8.3.3.4 Reading All Client Parameters

To exemplify servlet–client interaction when several parameters are involved, the following html form will be used which will be displayed by the client's web browser and will allow the user to input several parameters. Next the major steps in reading all input parameters are presented. The custom servlet class extension from HttpServlet and doGet() method overriding is assumed to be also performed (but not explicitly indicated).

- Step 1—Enable user parameters to be read by the client form:

```
<form [...]>
  Name:
    <input type="text" name="name"><br>
  Surname:
    <input type="text" name="surname"><br>
  <hr>Address:
  <textarea name="address" rows=3 cols=40>
  </textarea><br>
  Credit Card:<br>
  <input type="radio" name="cardType" value="Visa">
    Visa<br>
  <input type="radio" name="cardType" value="Master">
    Master<br>
  Credit Card Number:
  <input type="password" name="cardNum"><br>
  <input type="submit" value="Send Form">
</form>
```

- Step 2—Invoke the servlet when submitting the form:

```
<form action=
  "/ClientAllParams/servlet/CliAllParamsServlet">
[...]
</form>
```

- Step 3—In the doGet() method, get and print the parameters:

```
PrintWriter out = res.getWriter();
/*generate the HTML content*/
out.println ("<HTML>\n" + "<BODY>\n");
[...]

/*retrieve the parameter list*/
Enumeration paramNames = req.getParameterNames();
/*iterate through the parameter list*/
while(paramNames.hasMoreElements())
{
  /*retrieve and print parameter name*/
  String paramName =
      (String)paramNames.nextElement();
  out.print(paramName + "\n");

  /*retrieve and print the parameter values*/
  String[] paramValues =
      req.getParameterValues(paramName);

  /*iterate through the parameter values*/
  for(int i=0; i<paramValues.length; i++)
    out.println(paramValues[i] + "\n);
}
[...]
out.println("</BODY>\n</HTML>");
```

The full code for the HTML document which calls the all parameter printing servlet upon submission of the embedded form is presented next.

```
<!DOCTYPE HTML PUBLIC
    "-//W3C//DTD HTML 4.0 Transitional//EN">
<HTML>
<HEAD><TITLE>A Sample FORM using GET</TITLE></HEAD>
<BODY>
<H1 ALIGN="CENTER">A Sample FORM using GET</H1>
  <form action=
    "/ClientAllParams/servlet/CliAllParamsServlet">
    Name: <input type="text" name="name"><br>
    Surname: <input type="text" name="surname"><br>
    <hr>
    Address:
    <textarea name="address" rows=3 cols=40>
    </textarea><br>
    Credit Card:<br>
    <input type="radio" name="cardType" value="Visa">
      Visa<br>
    <input type="radio" name="cardType" value="Master">
      Master<br>
    Credit Card Number:
    <input type="password" name="cardNum"><br>
    <input type="submit" value="Send Form">
  </form>
</BODY>
</HTML>
```

Code Listing 8.7 all-params.html

The following full implementation of the doGet() method shows how all client parameters can be retrieved and printed in tabular fashion, by making use of the Java *Enumeration* class and its *nextElement()* and *hasmoreElements()* methods.

```
/*overrides doGet() method; to be invoked automatically
 *by service() when a GET request arrives*/
protected void doGet(HttpServletRequest req,
      HttpServletResponse res)
        throws ServletException, IOException
{
  /*set content type*/
  res.setContentType("text/html;charset=UTF-8");
  /*get the response write stream*/
  PrintWriter out = res.getWriter();

  /*generate the header type*/
  String docType =
    "<HTML>"
    + "<!DOCTYPE HTML PUBLIC \"-//W3C//DTD HTML 4.0 "
    + "Transitional//EN\">\n";

  out.println (docType +
    "<BODY>"
    + "\n<H1 ALIGN=CENTER>All Client Params</H1>\n"
    + "<TABLE BORDER=1 ALIGN=CENTER>\n"
    + "<TR>\n"
    +"<TH>Parameter Name<TH>Parameter Value(s)");

    /*retrieve the parameter list*/
    Enumeration paramNames = req.getParameterNames();

    /*iterate through the parameter list*/
    while(paramNames.hasMoreElements())
    {
      /*retrieve and print parameter name*/
      String paramName =
        (String)paramNames.nextElement();
      out.print("<TR><TD>" + paramName + "\n<TD>");
      /*retrieve and print the parameter values*/
      String[] paramValues =
        req.getParameterValues(paramName);
      if (paramValues.length == 1)
```

Code Listing 8.8 CliParamsServlet.java—doGet()

```
        {
          String paramValue = paramValues[0];
          if (paramValue.length() == 0)
            out.println("<I>No Value</I>");
          else
            out.println(paramValue);
        }
        else
        {
          out.println("<UL>");
          /*iterate through the parameter values*/
          for(int i=0; i<paramValues.length; i++)
            out.println("<LI>"
                + paramValues[i] + "</LI>");
          out.println("</UL>");
        }
      }
    out.println("</TABLE>\n</BODY></HTML>");
}
```

Code Listing 8.8 (Continued)

8.3.3.5 Sessions

As HTTP is a stateless protocol, its request–response transactions are self-contained and independent. However, often applications require data storage from one transaction to another, as different pages are visited or information of different types is collected and/or exchanged.

In order to bridge the gap between the support HTTP provides and application needs, Java *Sessions* have been introduced. A session is a specially defined container storing data relative to a series of client transactions. In fact, such a session container stores data about client activities in form of name–value pairs, which can be accessed at request by all servlets that have access to the session object.

Using sessions requires several steps to be performed by the servlet, as described next. As this step-by-step process description focuses on sessions-oriented Java programming support, some required servlet implementation-related aspects such as HTTPServlet inheritance and doGet() override are not listed.

- Step 1—Create a session

```
/*returns the current session or
 *creates one if it does not exist.*/
HttpSession session = req.getSession(true);
```

- Step 2—Get relevant data from the input parameters

```
/*get the parameters from the servlet request.*/
```

```
String dataName = req.getParameter("name");
String dataValue = req.getParameter("value");
```

- Step 3—Store data in name–value pairs

```
/*stores (dataName, dataValue)
 *pair with the session*/
session.setAttribute(dataName, dataValue);
```

- Step 4—Retrieve the object associated with a name

```
/*retrieves the value associated with the name*/
String value =
  session.getAttribute(dataName).toString();
```

- Step 5: Remove the (name, value) association

```
/*removes the data associated with dataName*/
removeAttribute(dataName);
```

The following code example illustrates the usage of the methods for accessing session objects from a servlet. The key object *session* is an instance of the HttpSession class which stores all (name, value)-pair associations. New client parameters are read and stored in a new (name, value)-pair with the session object, then all (name, value)-pair associations are printed, including the newly added one.

```
/*override doGet() method*/
protected void doGet(HttpServletRequest req,
      HttpServletResponse res)
    throws ServletException, IOException
{
  /*set content type*/
  res.setContentType("text/html");
  /*get the response write stream*/
  PrintWriter out = res.getWriter();

  /*get the session object*/
  HttpSession session = req.getSession(true);

  /*print session-related data*/
  String id = session.getId();
  Date ctime =
    new Date(session.getCreationTime());
  Date atime =
    new Date(session.getLastAccessedTime());
  out.println("<br>Session ID: " + id);
```

Code Listing 8.9 JavaServlet.java—doGet()

```
  out.println("<br>Created: " + ctime);
  out.println("<br>Last accessed: " + atime);
  /*get the new name
   *from servlet request*/
  String dataName = req.getParameter("name");
  if (dataName != null && dataName.length() > 0)
  {
    /*get the new parameter
     *value from servlet request*/
    String dataValue = req.getParameter("value");
    /*set the new (name,value)
     *pair with the session*/
    session.setAttribute(dataName, dataValue);
  }

  /*print all session contents*/
  Enumeration e = session.getAttributeNames();
  /*iterate through session elements*/
  while (e.hasMoreElements())
  {
    /*get the name of the next element*/
    String name = (String)e.nextElement();
    /*retrieve the value*/
    String value =
      session.getAttribute(name).toString();
    out.println("<br>" + name + " = " + value);
  }

  out.close();
}
```

Code Listing 8.9 (Continued)

The following html code can be used to allow the user to input parameter values, call the above servlet, and pass it the parameters.

```
<html>
  <head>
    <meta http-equiv="Content-Type"
      content="text/html; charset=UTF-8">
    <title>Session Servlet Main Page</title>
  </head>
```

Code Listing 8.10 session-servlet.html

```
  <body>

    <h1>Session Servlet</h1>
    <form action=
      "/SessionServlet/servlet/SessionServlet">
      Propriety name:
        <input type="text" name="name"><br>
      Propriety value:
        <input type="text" name="value"><br>
      <input type="Submit">
    </form>
  </body>
</html>
```

Code Listing 8.10 (Continued)

8.3.3.6 Cookies

The previous section has presented sessions as a method to store information between user requests. When users navigate from one Web page to another, they lose the information stored in the requests made to the server. Although a temporary data storage solution, sessions' saved data is not persistent and expires once the client has logged out or closed the Web browser application. As a direct consequence, the data stored in sessions is eventually lost. However, often there is a need for accessing information from previous sessions. This requires an additional solution to store the data in between the sessions.

In order to solve this data persistence issue, *cookies* have been used. Cookies are small pieces of information stored on the client machine. When the client connects to a server, the server-specific cookies are retrieved by the browser from the client machine. If cookies are found, information about the client previous sessions' activity can be extracted and used by the server to personalize its behavior. If no cookies are found, new cookies can be created and stored at the client's side. The cookies are usually stored by the Web browser, and for security reasons browsers can disable cookies. If the client browser does not accept cookies, it will discard them.

Although the most important information cookies store is often considered the (name, content)-pair, the cookies are stored in a container with several other fields. There fields include:

The *name* of the cookie is typically used to identify the cookie and therefore to retrieve and examine the cookie's content. This name cannot contain comma, space, or other special characters (reserved). Often the *content* is a simple value, but it can also be an array of values.

The *domain* represents the domain of the server that is to receive the cookie. The domain of server requesting the cookie must match the domain stored in the cookie.

This mechanism prevents other servers from accessing cookies that do not belong to them.

Expiration time is a time stamp that indicates the time when the cookie expires. This time is stored in a specific format and provides a cookie with a certain lifespan.

The *path* on the server where the cookie originates from is also saved. If not specified, this path indicates the full path from where the cookie was set.

Secure field states if the cookie requires secure communication (i.e., https) or not. The default value is no.

Cookies are set using HTTP headers in the following format:

```
Set-Cookie: user=NetworkProgrammer;
  domain=.netprogramming.eu;
path=/servlet/NewCookie;
expires=Fri, 1-Mar-2013, 16:15:00 GMT;
```

In order to create, store and retrieve cookies, several steps have to be followed. These steps are indicated next and make use of the following methods:

HTTPServletResponse method *void addCookie(Cookie cookie)*. HTTPServletResponse method *Cookies[] getCookies()*. Once a cookie is retrieved, it can be manipulated using Cookie class specific methods. *String getName()* retrieves the name associated with the cookie. *String getValue()* retrieves the value associated with the cookie. *void setValue(String value)* sets the value associated with the cookie.

- Step 1—Create a cookie

```
/*returns the newly created cookie
 *object storing (cookieName, cookieValue) pair*/
Cookie cookie = new Cookie(cookieName, cookieValue);
```

- Step 2—Store the cookie at the client

```
/*stores the cookie with the
 *HTTPServletResponse void addCookie() method*/
res.addCookie(cookie);
```

- Step 3—Get all the cookies stored at the client

```
/*retrieves cookies via the HTTPServletRequest
 *Cookie[] getCookies() method*/
Cookies[] cookies = res.getCookies();
```

- Step 4—Identify a cookie given by "name" and update its value

```
/*checks all cookies names against "name"*/
/*if found, fetch its value and set a new value*/
String name = new String("name");
String newvalue = new String("newvalue");
for(int i=0; i<cookies.length; i++)
  if (name.equals(cookies[i].getName()))
  {
    String oldvalue = cookies[i].getValue();
    cookies[i].setValue(newvalue);
  }
```

Cookies can be used by servlets to store user data as the following example shows. This example retrieves the parameters from the client request: cookieName, cookieValue, searchName, and searchValue, sets a new cookie named cookieName with the value cookieValue, searches for a cookie named searchName, gets and prints its old value, and updates this cookie's content storing searchValue.

```
protected void doGet(HttpServletRequest req,
    HttpServletResponse res)
  throws ServletException, IOException
{
  res.setContentType("text/html");
  PrintWriter out = res.getWriter();

  /*read data from the Web page*/
  String cookieName =
    req.getParameter("cookiename");
  String cookieValue =
    req.getParameter("cookievalue");
  String searchName =
    req.getParameter("searchname");
    String searchValue =
    req.getParameter("searchvalue");

  /*set new cookie to the client*/
  if (cookieName != null && cookieValue != null)
  {
    Cookie cookie = null;
    try
    {

      /*create the cookie*/
      cookie = new Cookie(cookieName, cookieValue);
    }
    catch (IllegalArgumentException e)
    {
      e.printStackTrace();
    }
    /*add the cookie using the response object*/
    res.addCookie(cookie);
  }
```

Code Listing 8.11 CookieServlet.java—doGet()

```
  /*get all cookies from the client*/
  Cookie[] cookies = req.getCookies();

  if ((cookies != null) && (cookies.length > 0))
  {
    /*print all cookies' info*/
    for(int i = 0; i < cookies.length; i++)
    {
      /*print cookie's name and value*/
      out.println("<br>Cookie name:"
          + cookies[i].getName());
      out.println("<br>Cookie value:"
          + cookies[i].getValue());
      /*set cookie with the new value*/
      if (searchName.equals(cookies[i].getName()))
        cookies[i].setValue(searchValue);
    }
  }
  else
  {
    out.println("<br> There are no cookies!");
  }

  out.close();
}
```

Code Listing 8.11 (Continued)

The following html code represents the cookie servlet main page. The document is visualized on the client web browser, and the form allows the user to enter several parameters: cookieName, cookieValue, searchName, and searchValue. These will be passed to the servlet *CookieSerlvet* on the client's machine for processing, as already indicated.

```
<html>
  <head>
    <meta http-equiv="Content-Type"
      content="text/html; charset=UTF-8">
    <title>Cookie Servlet Main Page</title>
  </head>
  <body>
```

Code Listing 8.12 cookie-servlet.html

```
  <h1>Cookie Servlet Main Page</h1>

  <a href="/CookieServlet/servlet/CookieServlet">
    Read Cookie Servlet
  </a>

  <br>Set Cookie Form
  <form action="/CookieServlet/servlet/CookieServlet">
    Cookie attribute name:
    <input type="text" name="cookiename"><br>
    Cookie attribute value:
    <input type="text" name="cookievalue"><br>
    Cookie name to search for:
    <input type="text" name="searchname"><br>
    Cookie updated value:
    <input type="text" name="searchvalue"><br>
    <input type="Submit">
  </form>
  </body>
</html>
```

Code Listing 8.12 (Continued)

8.4 Java Server Pages

Java Server Pages (JSP) are web pages that have embedded Java code which runs on the server side and generates content dynamically.

Generating HTML code using servlets is inconvenient as multiple *out.println()* calls are required, even for typical HTML content generation. Writing servlets requires Java programming expertise, whereas writing HTML content can be performed by a less skilled a person. However, Java code flexibility is still provided via HTML-like tags embedded in the HTML code. As it will be seen in the following examples, JSP represents a powerful development tool for web applications.

The following example represents a html web page which contains a form allowing the user to input two values, a number and a power. When the form is submitted (by clicking the submit button), the request is sent to the server targeting the *ProcessJSP.jsp* page.

```
<html>
  <head>
    <meta http-equiv="Content-Type" content=
     "text/html">
```

Code Listing 8.13 jsp-access.html

```
    <title>JSP Page</title>
  </head>
  <body>
    <h1>Index JSP Page</h1>

    <form  method="POST"  action="ProcessJSP.jsp">
      Number:
        <input type="Text" name="Number" value=""
         size=5>
      Power:
        <input type="Text"  name="Power" value=""
         size=5>
      <input  type="Submit"  value = "Submit">
      <input  type="Reset"  value="Clear">
    </form>
  </body>
</html>
```

Code Listing 8.13 (Continued)

The *ProcessJSP.jsp* page is presented in the following code example. The Java code is contained within specific tags:

```
<%
[...]
%>
```

The following JSP retrieves the parameters from the request, calculates the power of the number input by the user, and displays the result.

```
<html>
  <head>
    <meta http-equiv="Content-Type"
     content="text/html">
    <title>JSP Page</title>
  </head>

  <body>
  <h1>Process JSP Page</h1>
 <%
    /*retrieve the parameters*/
    String strNumber = request.getParameter("Number");
    String strPower = request.getParameter("Power");
```

Code Listing 8.14 ProcessJSP.jsp

```
    int number = Integer.parseInt(strNumber);
    int power = Integer.parseInt(strPower);
    int res = 1;
    /*calculate the power*/
    for (int i = 0; i < power; i++)
      res *= number;
 %>
  <!-- display the number and its power-->
  <b><%= number %> power <%= power %> is <%= res %></b>
  </body>
</html>
```

Code Listing 8.14 (Continued)

JSP provides various scripting element. The following paragraphs present the major elements in order to exemplify their usage and the capabilities provided by this technology.

Java expressions are evaluated, converted into as string, and inserted in the page output at runtime. All information about the Web page request is available. The following predefined variables are available: *HTTPServletRequest request*, *HTTPServletResponse response*, *HTTPSession session,* and *JspWriter out* (a buffered version of PrintWriter).

A Java expression can be used in the following forms:

```
<%= java expression %>
```

or

```
<jsp:expression> java expression </jsp:expression>
```

For instance, the following expression displays the current date and time:

```
<%= new java.util.Date() %>
```

Properties can be set in JSP as follows:

```
<jsp:setProperty name = "author"
  property = "username" value = "John" />
```

An example which sets the name, property and value attributes is presented in the following code:

```
<jsp:setProperty>
  name = "user" property = "userID" value =
    '<%= Math.random() %>' />
```

Scriptlets represent pieces of Java code run by the server when a JSP page is invoked. The Java code will be executed at runtime and has access to the same pre-defined variables as expressions. Scriptlets can be inserted in a JSP page in the following ways:

```
<% java code %>
```

or

```
<jsp:scriptlet> java code </jsp:scriptlet>
```

The following example shows how java code can be used in a JSP page:

```
<% response.setContentType("text/plain"); %>

<% out.println("Your IP is"
    + request.getRemoteAddr()); %>

<% if (Math.random() < 0.5) { %>
  You are welcome!
  <% } else { %>
  You are NOT welcome!
  <% } %>
```

Declarations are also supported in JSP pages. Java code will be added to the JSP generated servlet and evaluated at runtime.

Declarations can be added to JSP in the following ways:

```
<%! java code %>
```

or

```
<jsp:declaration> java code </jsp:declaration>
```

The following code example indicates how two variables can be declared:

```
<%! private int balance = 0; %>
<jsp:declaration>
  private String username = "";
</jsp:declaration>
```

Often JSP requires importing new packages to have access to additional classes. In order to achieve this, the *page* directive with the *import* attribute has to be used in one of the following ways:

```
<%@ page import="packagename.classname" %>
```

or

```
<%@ page import="packagename1.classname1,
        packagename2.classname2, [...]" %>
```

The following code example shows the import of all classes from the javax.servlet.http package:

```
<%@ page import="javax.servlet.http.*" %>
```

8.5 Conclusion

This chapter has presented server-side network programming technologies, which include Common Gateway Interface (CGI) and Hypertext Pre-processor (PHP), as non-Java alternative solutions, and Java Servlets and Java Server Pages (JSP) on which the focus has been. Their key aspects are that they generate dynamic content which can consider various factors such as the values of initialization parameters, user input, environment variables, etc., and they run on the server, providing the client with the output for display.

Chapter 9
Client-Side Network Programming

Abstract Client-side network programming involves designing and writing code to be run on the client machine during client–server communication process. This chapter introduces various types of web documents used and conveyed over the Internet as well as their descriptive languages and characteristics. Java specific solutions for active and dynamic documents are introduced along with comprehensive examples to illustrate their capabilities and functionality. This includes Java Script language as well as Java Applets.

9.1 Introduction

Client-side network programming involves designing and writing code to be run on the client machine during the client–server communication process.

Although various network-based stand-alone applications can be built for the client, each serving a different purpose or invoking a specific service from the server, the most popular client-side application is a Web browser.

A Web browser runs as a client process, and its basic functionality involves communication with a Web server by making use of HTTP. Following document request, the browser also performs Web document retrieval, received document interpretation and display for the user, and responds to user actions. Most Web documents interpreted by Web browsers are HTML documents. However, the current Web browsers are more advanced and can also interpret and run specific code such as JavaScript or embed more advanced entities such as Java Applets.

Figure 9.1 illustrates the scope of the client-side network programming in terms of preparing code to run as a client process. This code may belong to stand-alone applications and be independently run, may be Java Script code to be executed by the Web browser or Java Applets code to run embedded in the Web browser.

9.2 Web Documents Classification

Based on their characteristics, three types of Web documents manipulated by networked applications can be identified.

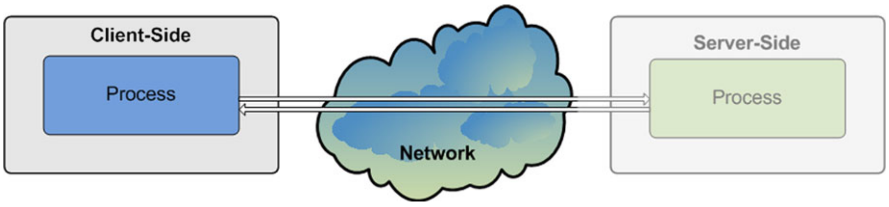

Fig. 9.1 Client-side network programming

Static documents include content which is identically delivered at every request, to any user, and to any device via any network. They do not require any additional processing at the server side following user request before content delivery. These types of documents are delivered as they are, and any modification is performed by replacing the original file with an updated file version on the server. Static documents are quick and easy to create, and are fast to retrieve as there is no request-dependent personalized processing involved which could have been time consuming. Moreover, as static documents seldom change, they are cache friendly, helping improve the delivery performance. Although using static documents has some clear advantages, there are difficulties in creating large sites, maintaining consistency and keeping up to date, and do not offer any provision for user personalization.

Active documents are basically static documents containing executable code to be run on the client side. Such a code may be a Java Script code, for example, which is interpreted and run by the client's Web browser.

Unlike the static documents, active documents offer user interactivity with limited user personalization. They support data display customization, while still being cache friendly. Cache friendliness is given by the fact that the active code (e.g., Java Script) is not changed (or it seldom changes) at the server side and can be successfully delivered from a cached location closer to the client. Although the code is static, by running it at the client side it can offer a certain level of dynamism. Moreover, the fact that active documents run code on the client-side brings further the advantage of distributed resource requirements (at client's side).

However, the fact that active documents involve code run at the client's side has two main disadvantages. The client runs unknown code which may be unsafe from a security point of view, and the active code may be slow to run if the client machine has low computational resources.

Dynamic documents are documents that are generated on the fly by the server at a client's request. The server will use, for example, Java servlets, PHP or JSP to generate the dynamic content which will be then forwarded to the client. Dynamic documents have been presented in the previous chapter on server-side network programming.

Dynamic documents enable user personalization, offer support for database access, as well as data display customization. As documents are dynamically generated for every client's request, dynamic documents can use time and date sensitive code in order to assemble the client's document.

Although dynamic documents are the solution to develop large sites and Web applications involving user interaction, they require skilled creators with strong knowledge of server-side network programming. Moreover, being dynamically generated at the server side, they have high resource requirements (computational and communication) and are not cache friendly.

9.3 Static Documents

Static documents include both content-related data and information about formatting the presentation of the content to the user. Originally data and presentation formatting-related information were combined into a single document.

The HyperText Markup Language (HTML) [1] and the Extensible HyperText Markup Language (XHTML) [2] are used to describe both data and presentation and are usually used to format the documents delivered to the client user.

Recently, content and formatting-related data are separated, and different languages are used to describe each of them.

The Extensible Markup Language (XML) [3] is used to describe data in a formalized, structured, and cross-platform way, allowing for easy data transport and manipulation. In general, no presentation-related information is included.

For formatting purposes, the Cascading Style Sheets (CSS) [4] and the Extensible Stylesheet Language (XSL) [5] can be used in conjunction with HTML and XML, respectively.

Static documents are delivered across the network using the HyperText Transfer Protocol (HTTP) [6] and the Hypertext Transfer Protocol Secure (HTTPS) [7] which enables content transfer from the server to clients over the networks in a regular or secure manner, respectively.

In order to access and retrieve any document from the server, the client request needs to provide the host details, the location of the document to be accessed, and the document name. The transfer protocol has also to be indicated. This information is specified using a Uniform Resource Locator (URL) with the structure presented in the following example.

```
<protocol>://<username>:<password>@
<host>:<port>/<path>/<name>
```

The *protocol* indicates the protocol used to deliver the document, and it is usually HTTP or HTTPS.

The *username* and *password* pair controls the access to the document. A public document is not protected by a username and a password so they will not be required.

The *host* represents the IP address of the server or the root domain name which is forwarded to the IP of the server.

The *port* specifies the port number on which the Web server is listening for connection requests from clients. The usual ports are 80 or 8080 and, if this is the case, they do not need to be specified in the URL.

The *path* and *name* uniquely indicate the location and name of the document in the server's file system.

9.3.1 HyperText Markup Language

The HyperText Markup Language (HTML) [1] is a language used to describe Web documents. A HTML file is a text file containing markup tags which are interpreted by the Web browser, informing it how to display the various components of the Web document.

HTML files are easy to create by using any plain text editor and typically have an *htm* or *html* file extension. They are composed of elements, and each element is contained inside a parent element, forming a tree-like structure in a hierarchical manner. HTML tags are used to markup HTML elements and are surrounded by angle brackets: < and >. HTML tags normally come in pairs as in the following example <*tagname*>*content* </*tagname*>. The first tag in any pair is the start tag and the second tag is the end tag, which differs from the start tag by the addition of a "/" in front of the tag name. The text between the start and end tags is the element content. The tag has effect on its content and on its children elements only. There are exceptions such as <*br*> which indicates a new line and which is a tab that does not have to be closed as it has no content. Generally, HTML tags are not case sensitive and most of them can have attributes. Attributes provide additional information to an HTML element such as properties.

The following example shows generally how an HTML tag is used in an HTML file, and it includes an attribute and its value:

```
<tag attribute="value"> element content </tag>
```

The following is an example of a Web document described in the HTML language:

```
<html>
  <head>
    <title>My New Page Title</title>
  </head>
  <body bgcolor="white">
    <p>A New Paragraph</p>
    <br>
    <table> [...] </table>
    [...]
  </body>
```

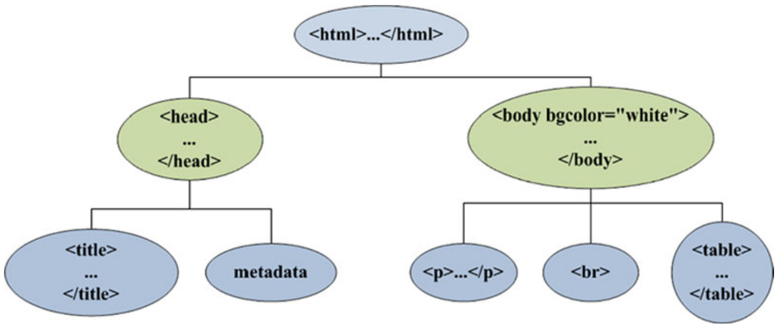

Fig. 9.2 HTML document tag hierarchy

```
</html>
```

The above HTML code example is presented in a hierarchical manner in Fig. 9.2. The <*html*> tag contains the whole document. Its direct children are <*head*> and <*body*>.

The <*head*> contains information about the document, such as the title of the document and metadata. Metadata identifies the version of the HTML used to describe the content of the document. For example, the following metadata identifies the content as HTML version 4.0 transitional.

```
<!DOCTYPE html public "-//w3c//dtd html 4.0
 transitional//en">
```

The <*body*> describes the content of the document and can include many tags of diverse types. One of the important tags probably is the <*table*> tag which allows for bi-dimensional structuring of the data presentation.

Next basic tags used to construct HTML documents and format them according to application requirements are presented.

The heading tags format the text within their boundaries at different sizes. There are several heading tabs available as it can be seen in the following example:

```
<h1>Text written with heading 1</h1>
<h2>Text written with heading 2</h2>
<h3>Text written with heading 3</h3>
<h4>Text written with heading 4</h4>
<h5>Text written with heading 5</h5>
<h6>Text written with heading 6</h6>
```

Paragraphs and new lines can be specified as follows:

```
<p> Paragraph </p>
<br> Newline
```

Text presentation formatting can be achieved using the following tags:

```
<i> Italics </i>
<b> Bold </b>
<font size="SIZE" color="COLOR"> Text </font>
```

Unordered and ordered lists, including nested lists, can be included in an HTML document as follows:

Unordered list:

```
<ul>
  <li> First item
  <li> Second item
</ul>
```

Ordered list:

```
<ol>
  <li> Item one
  <li> Item two
</ol>
```

Images can be added to an HTML document using the *img* tag, which has no closing tag. Attributes such as *width* and *height* can be used to control picture dimensions.

```
<img src="http://www.netprogramming.eu/examples/
          img.jpg">
```

Anchors or links can be specified, allowing the user to navigate to other pages. In the following example, a link is attached to a text and permits the user to navigate to a different URL. The URL can be absolute or relative to the existing site.

```
<a href="page2.html">Link Text</a>
```

Forms are used to allow the user to input data, which is then sent to the Web server via requests. A form can contain several form elements such as text fields, radio buttons, check-boxes, and a submit button used to submit the form and consequently send the request to the server.

A credit card details reading form example is presented next.

```
<form name="CardForm" action="form_action.html"
 method="get">
  <input type="text" name="name"> Name
  <input type="radio" name="card" value="VISA">
  <input type="radio" name="card" value="Master">
  <input type="checkbox" name="choice" value="Bag">
  <input type="checkbox" name="choice" value="Box">
  <input type="submit" value="Submit">
</form>
```

Comments in an HTML document can be specified in the following way.

```
<!-- This is a comment -->
```

Tables are used to structure the presentation of a HTML document in a table-like format. A table has a header row with a number of items and multiple rows with several items each. The tables can be nested to create more complex layouts.

```
<table>
  <!-- Header row -->
  <th>
    <td>Item</td>
  </th>

  <!-- One row -->
  <tr>
    <td>Item</td>
  </tr>
</table>
```

9.3.2 Extensible Markup Language

Extensible Markup Language (XML) [3] is a cross-platform, extensible, and text-based standard for representing data. Unlike HTML that was designed to enable data display, XML enables data representation. XML allows for structuring, storing, and sending of information over the networks in a flexible and efficient way.

Similar to HTML, XML was also designed to describe data by using tags. However, there are no predefined XML tags, they need to be defined for each application or service specifically. XML uses a Document Type Definition (DTD) [8] or a XML Schema Definition [3] to describe data.

An example of an XML document describing a message is presented in the following code snippet.

```
<msg>
  <to>John</to>
  <from>Jack</from>
  <topic>Gentle reminder</topic>
```

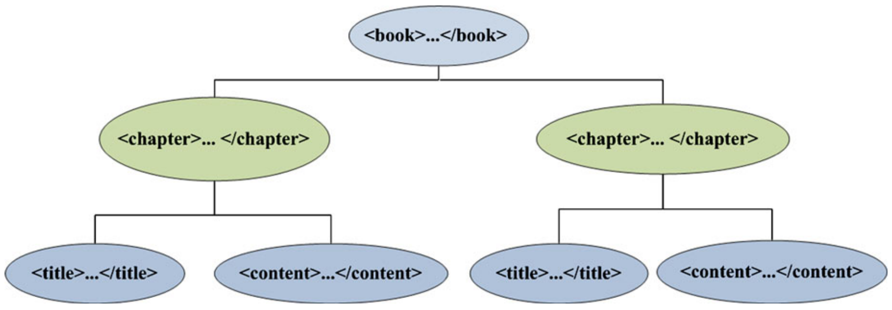

Fig. 9.3 XML document tag hierarchy example

```
  <body>The deadline is Friday at 14:00!</body>
</msg>
```

Any XML document is composed of elements identified by tags, <*tagname*> </*tagname*>, which must always be closed. Each element is contained inside a parent element (tree like hierarchical structure similar to HTML). There must be a single root and each element may have attributes, if defined.

The following example shows the representation of a book in XML form. The hierarchical structure is graphically presented in Fig. 9.3.

```
<book>
  <chapter>
    <title>Title 1</title>
    <content>
      <p>Paragraph A1</p>
      [...]
     </content>
  </chapter>
  <chapter>
    <title>Title 2</title>
    <content>
      <p>Paragraph B1</p>
      [...]
     </content>
  </chapter>
  [...]
</book>
```

9.3.2.1 Document Type Definition

A Document Type Definition or DTD [8] document defines the legal building blocks of an XML document. It defines the document structure with a list of legal elements.

DTD can be declared inline in an XML document or externally. Using a DTD allows independent groups of people to use common data structures. Based on the DTD, verification of both generated and received data structure can be done.

Inline document type definition has the following format:

```
<!DOCTYPE root-element [element-declarations]>
```

An example defining a message is presented in the following code snippet:

```
<?xml version="1.0"?>
<!DOCTYPE msg [ <!ELEMENT msg (to, from, topic, body)>
<!ELEMENT to (#PCDATA)>
<!ELEMENT from (#PCDATA)>
<!ELEMENT topic (#PCDATA)>
<!ELEMENT body (#PCDATA)> ]>
```

External document type definition has the following form:

```
<!DOCTYPE root-element SYSTEM "filename">
```

The following is an example of external DTD definition usage:

```
"msg.xml" file:
<?xml version="1.0"?>
<!DOCTYPE msg SYSTEM "msg.dtd">

"msg.dtd" file:
<!ELEMENT msg (to, from, topic, body)>
<!ELEMENT to (#PCDATA)>
<!ELEMENT from (#PCDATA)>
<!ELEMENT topic (#PCDATA)>
<!ELEMENT body (#PCDATA)>
```

9.3.2.2 XML Schema Definition

XML Schema Definition or XSD [3] document describes the structure of an XML document. XSD is an XML-based alternative to DTD and can also be declared inline in an XML document or externally.

XSD defines elements and attributes that can appear in a document and their data types. It defines which elements are child elements, their order and number, whether an element is empty or can include text and default and fixed values for elements and attributes.

XSD are richer and more powerful than DTD, supporting data types and namespaces. XSD documents are written in XML and are extensible to future additions.

An example of an XSD file for representing the message introduced before is presented in the following code snippet:

```
<?xml version="1.0"?>

<xs:schema
      xmlns:xs="http://www.w3.org/2001/XMLSchema"
      targetNamespace="http://www.netprogramming.eu"
      xmlns="http://www.netprogramming.eu"
      elementFormDefault="qualified">
  <xs:element name="msg">
    <xs:complexType>
    <xs:sequence>
      <xs:element name="to" type="xs:string"/>
      <xs:element name="from" type="xs:string"/>
      <xs:element name="topic" type="xs:string"/>
      <xs:element name="body" type="xs:string"/>
    </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

For a better understanding of the XSD file components, their use will be further explained. From definition, *xmlns:xs="http://www.w3.org/2001/XMLSchema"* indicates that the elements and data types used in the schema come from the *"http://www.w3.org/2001/XMLSchema"* namespace and these elements and data types should be prefixed with "xs:".

The *targetNamespace="http://www.netprogramming.eu"* indicates that the elements defined by this schema *(to, from, topic, body)* come from the following namespace: *"http://www.netprogramming.eu"* .

The attribute *xmlns="http://www.netprogramming.eu"* indicates the default namespace.

The attribute *elementFormDefault="qualified"* indicates that any elements used by the XML instance document which were declared in this schema must be namespace qualified.

```
<?xml version="1.0"?>
<msg xmlns="http://www.netprogramming.eu"
    xmlns:xsi=
      "http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation=
      "http://www.netprogramming.eu msg.xsd">
<msg>
  <to>John</to>
  <from>Jack</from>
  <topic>Gentle reminder</topic>
  <body>The deadline is Friday at 14:00!</body>
</msg>
```

Within the *xml* file *xmlns="http://www.netprogramming.eu"* specifies the default namespace declaration. All the elements used in this XML document are declared in this with the following namespace *xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"*. SchemaLocation attribute has two values, the namespace to use and the location of the XML schema, *xsi:schemaLocation="http://www.netprogramming.eu msg.xsd"*.

XSD offer great flexibility for defining application specific data structures to be described using the XML language.

For instance, the following simple element definition includes XXX which is the name and YYY which is the data type of the element:

```
<xs:element name="XXX" type="YYY"/>
```

The most common XML schema has a lot of built-in data types including *xs:string, xs:decimal, xs:integer, xs:boolean, xs:date, xs:time,* and *xs:positiveInteger*.

Default and fixed values can be defined for the elements of the schema. For example, the following examples have ZZZ as default value and WWW as fixed value:

```
<xs:element name="XXX" type="YYY" default="ZZZ"/>

<xs:element name="XXX" type="YYY" fixed="WWW"/>
```

Optional and required elements can also be defined. In the following example, the XXX element is defined as required. Consequently, this simple element when composing a complex one will have to be present in the XML file:

```
<xs:element name="XXX" type="YYY" use="required"/>
```

Restrictions on elements values ("facets") can be defined as well. In the following example, a *gender* simple element is defined. Its value is of type string; however, it is restricted to two values, "Male" and "Female".

```
<xs:element name="gender"/>
<xs:simpleType>
<xs:restriction base="xs:string">
  <xs:enumeration value="Male"/>
  <xs:enumeration value="Female"/>
</xs:restriction>
</xs:simpleType>
```

The following example shows the definition of a custom element named "carReg" of custom type "regType". The "regType" is defined as having string type with values restricted to a specific pattern as defined in the following code snippet:

```
<xs:element name="carReg" type="regType">
<xs:simpleType name="genType">
```

```
  <xs:restriction base="xs:string">
    <xs:pattern value=
      "[0-9][0-9][A-Z]([A-Z])+([0-9])*"/>
  </xs:restriction>
</xs:simpleType>
</xs:element>
```

A complex element is an XML element that contains other elements and/or attributes. A complex element may be empty, may contain other elements, contain text only, or contain both other elements and text.

A complex type can be used by instantiation. In the following example, a complex type named "pers" is defined containing two element named "name" and "age". Then two elements named "employee" and "student" of type "pers" are defined, basically instantiating the type "pers":

```
<xs:element name="employee" type="pers"/>
<xs:element name="student" type="pers"/>
<xs:complexType name="pers">
  <xs:sequence>
    <xs:element name="name" type="xs:string"/>
    <xs:element name="age" type="xs:integer"/>
  </xs:sequence>
</xs:complexType>
```

Inheritance is also permitted. The following example defines a complex type named "fullpers" which extends the already defined type "pers" by adding an element called "addr" (address). Both types can be then used by instantiation:

```
<xs:element name="employee" type="fullpers"/>
<xs:element name="employee" type="pers"/>
<xs:complexType name="pers">
  <xs:sequence>
    <xs:element name="name" type="xs:string"/>
    <xs:element name="age" type="xs:integer"/>
  </xs:sequence>
</xs:complexType>
<xs:complexType name="fullpers">
  <xs:complexContent>
    <xs:extension base="pers">
      <xs:sequence>
        <xs:element name="addr" type="xs:string"/>
        <xs:element name="city" type="xs:string"/>
       </xs:sequence>
    </xs:extension>
  </xs:complexContent>
```

```
</xs:complexType>
```

Complex elements support indicators. The indicators control how elements will be used in XML documents. There are altogether seven indicators.

Order indicators may include *all, choice, and sequence*.

All requires all elements to be used as in the following example:

```
<xs:element name="employee">
  <xs:complexType>
 <xs:all>
   <xs:element name="name" type="xs:string"/>
   <xs:element name="id_number" type="xs:string"/>
 </xs:all>
  </xs:complexType>
</xs:element>
```

Choice allows one element to be chosen out of many:

```
<xs:element name="employee">
  <xs:complexType>
 <xs:choice>
   <xs:element name="manager" type="manager"/>
   <xs:element name="director" type="director"/>
 </xs:choice>
  </xs:complexType>
</xs:element>
```

Sequence specifies that the elements must appear in a specific order:

```
<xs:element name="employee">
   <xs:complexType>
 <xs:sequence>
   <xs:element name="firstname" type="xs:string"/>
   <xs:element name="lastname" type="xs:string"/>
 </xs:sequence>
  </xs:complexType>
</xs:element>
```

Occurrence indicators include *maxOccurs* and *minOccurs* and specify the minimum and maximum number of times an element can occur:

```
<xs:element name="employee" type="pers"/>
<xs:complexType name="pers">
  <xs:choice>
    <xs:element name="name" type="xs:string"/>
    <xs:element name="nick" type="xs:string"
```

```
          minOccurs="0" maxOccurs="unbounded"/>
  </xs:choice>
</xs:complexType>
```

Group indicators include element groups and attribute groups and are used to define related sets of elements.

The following example defines a group called "person-details" which can be used and referenced when defining a complex element such as "person-information" which contains the elements defined by the group plus an extra element, "address":

```
<xs:group name="person-details">
  <xs:sequence>
 <xs:element name="first_name" type="xs:string"/>
 <xs:element name="last_name" type="xs:string"/>
 <xs:element name="birthday" type="xs:date"/>
  </xs:sequence>
</xs:group>

<xs:element name="person" type="person-information"/>

<xs:complexType name="person-information">
  <xs:sequence>
 <xs:group ref="person-details"/>
 <xs:element name="address" type="xs:string"/>
  </xs:sequence>
</xs:complexType>
```

When defining an XSD schema, simple elements cannot have attributes. Only complex types can have attributes. Attributes themselves are always declared as a simple type. The following is an attribute with XXX being the name and YYY the data type:

```
<xs:attribute name="XXX" type="YYY"/>
```

Similar to elements, attributes can have default and fixed values, required or not. The following example shows the usage of attributes:

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
<xs:schema xmlns:xs= "http://www.w3.org/2001/
 XMLSchema">
<xs:element name="order">
<xs:complexType>
  <xs:sequence>
  [...]
  </xs:sequence>
  <xs:attribute name="orderid"
    type="xs:string" use="required"/>
</xs:complexType>
</xs:schema>
```

9.4 Active Documents

Active documents are static documents which include code to be run at the client side. Active documents can generate content dynamically at the client side and provide user interactivity, limited personalization, and data display customization. The code is sent with the Web document from the server and then is run on the client machine. The advantages include less processor resources requirements at the server and the fact that the document is relatively static at the server side (it seldom changes, not being generated at the client request) which makes it cache friendly.

There are various solutions for creating active documents, including using JavaScript, Java Applets, and AJAX.

Making use of JavaScript is one of the most popular solutions. JavaScript is a script language used to improve the Web document design, validate forms, detect browsers, create cookies, create dynamic behavior, and interact with the user.

Java Applets are Java applications that are embedded in Web documents and are run by a Java-aware Web browser.

AJAX is a technique for creating better, faster, and more interactive Web applications. It uses existing technologies and languages.

9.4.1 JavaScript

JavaScript is an object-oriented scripting language that adds interactivity to Web documents. A scripting language is a lightweight programming language, but offering enough flexibility and capabilities that makes it a powerful tool for active Web documents. JavaScript code is usually embedded directly into Web (HTML) pages and is executed without preliminary compilation (JavaScript is an interpreted language). However, external files containing JavaScript code are also used in practice.

The embedded JavaScript code can be placed in the header or body of an HTML document.

The HTML head scripts usually represent code (e.g., functions) to be executed when it is called or when events are triggered. The JavaScript code, indicated in the following example as “JSCODE”, is loaded in the memory before the document’s body is generated:

```
<head>
<script> JSCODE </script>
```

```
[...]
</head>
```

The HTML body scripts consist of JavaScript code which is executed when the page is loaded. In the following example, “JSCODE” generates the Web page content:

```
<body>
<script> JSCODE </script>
[...]
</body>
```

In general, HTML external scripts contain code to be used by more than one Web page. Often the code is written to be reused elsewhere. The external file (e.g., “javascript-file.js”) is loaded as follows:

```
<script src="javascript-file.js"> </script>
```

JavaScript offers a multitude of programming features which makes it a relatively powerful tool.

Variables can be defined, although with no explicit type associated at declaration. Declaration can be explicit (using var) or implicit at first assignment.

```
var varname = VALUE

or

varname = VALUE
```

The scope of a variable declared within a function is the body of that function (local). The scope of a variable declared outside a function is all the code after the declaration (global).

Several flow control statements can be used in JavaScript. The “if” statement can be used in a similar manner with its usage in Java or C++. The “else” branch may be present or missing. A typical “if” statement is provided as an example next:

```
if (CONDITION)
{
  BODY IF TRUE
}
else
{
  BODY IF FALSE
}
```

The “switch” statement is also similar with its corresponding statements in Java and C++. Its “default” option may be missing. An example of how “switch” can be used is shown below:

```
switch (EXPRESSION)
{
  case VALUE1: BODY IF VALUE1; break
  case VALUE2: BODY IF VALUE2; break
  ...
  default: BODY IF DEFAULT
}
```

Three types of loops can be used in JavaScript: “for”, “while”, and “do-while”. Next is an example of a “for” loop:

```
for (INTIALIZATION;
 CONDITION; UPDATE)
{
  BODY
}
```

In “for”, BODY is executed zero or more times depending on the CONDITION. UPDATE is executed after the BODY and before the CONDITION is re-evaluated. The “break” statement interrupts the execution of any loop, while the “continue” statement interrupts the execution of any iteration from within a loop.

In BODY, at least one variable affecting the CONDITION must be updated (otherwise there is a danger of creating an infinite loop).

Next is an example of a “while” loop:

```
while (CONDITION)
{
  BODY
}
```

In BODY. at least one variable affecting the CONDITION must be updated. In “while”, BODY is executed one or more times depending on the CONDITION.

Next is an example of a “do-while” loop:

```
do
{
  BODY
}
while (CONDITION)
```

Arrays can also be defined within JavaScript code. Declaration and instantiation of an Array is performed using the “new” directive as follows:

```
var names = new Array()
```

Arrays can be initialized when created or after creation by initializing each element separately:

```
/*at declaration*/
var names = new Array("John", "Brian", "Sean")

/*after declaration*/
names[0] = "John";
names[1] = "Brian";
names[2] = "Sean"
```

Elements of an array can be accessed using an index or via a *for in* loop as in the following examples:

```
/*using an index*/
for (i = 0; i < names.length; i++)
{
  document.write(names[i])
}

/*using a for in loop*/
for (x in names)
{
   document.write(names[x])
}
```

For interaction with the user, a set of predefined message boxes or pop-up boxes can be used.

An *alert box* displays a text and the user has to press “OK”:

```
alert("text")
```

A *confirm box* allows the user to choose either “OK” or “Cancel”, and consequently the box returns “true” or “false”, respectively. This type of a pop-up box can be used to get the user’s confirmation to perform a certain operation:

```
confirm("text")
```

A *prompt box* allows the user to enter an input value and then click either “OK” or “Cancel”. If “OK” is clicked, the box returns the input value, otherwise it returns “null”. A default value can be indicated in case the user chooses not to input anything. However, she or he has to click either “OK” or “Cancel”:

```
prompt("text","defaultvalue")
```

JavaScript custom functions may be defined as follows using the “function” keyword. The function may return a value using “return”:

```
function NAME (VAR1, VAR2, \ldots, VARN)
{
  BODY

  return VAL
}
```

User generated events can also be handled by JavaScript code. Both mouse-related and key-related events may be captured and handled.

Mouse-related events include “onmousedown”, “onmouseover”, and “onclick”. A mouse-related event is triggered when a mouse button is pressed, the mouse pointer is over an element, or a mouse button clicked while the pointer is on an element. Key-related events include “onkeydown” and “onkeyup”. A key-related event is triggered when the key is pressed or released.

The following example shows how when the e-mail text field is modified the “verifyemail()” function is called:

```
<input type="text" size="20" id="email"
    onchange="verifyemail()">;
```

Exceptions can also be thrown, caught, and handled using the standard “try-catch” and “throw” directives.

In the following example, if an error occurs in CODE 1, CODE 2 will be executed:

```
try
{
  CODE 1
}
catch(err)
{
  CODE 2
}
```

The statement, “throw(EXCEPTION)” throws an exception that can be caught using catch.

As mentioned before, JavaScript is an object-oriented scripting language. Various objects are already defined and the application developer can further define custom objects.

Predefined objects include *Date* (with the standard methods: getTime(), getDay(), setFullYear()), *Math* (with the following methods: random(), round(), min(), pow(), cos(), sqrt()), and *String* (with the important methods: bold(), toUpperCase(), substr(), concat(), length).

The following is a user defined object named "Car" which can be instantiated and consequently used within the Web document:

```
function Car(brand, year, color)
{
  this.brand = brand
  this.year = year
  this.color = color

  this.changeBrand=changeBrand;

  function changeBrand(brand)
  {
    this.brand=brand;
  }
}
mycar = new Car("Ferrari", 2007, "red")
```

Timer is another predefined object. Its main methods are "setTimeout()" and "clearTimeout()". In the following example, the STATEMENT is executed after MILLISECONDS time. *t* is a handler to the timer and can be used to cancel it using clearTimeout() which clears the timer:

```
var t = setTimeout("STATEMENT", MILLISECONDS)

clearTimeout(t)
```

The following is a more complex example of timer usage. In this case, a form is used to start and stop the timer. The timer will then increment a variable which will be then written to a text field of the form.

```
<html>
<head>
  <script type="text/javascript">
  // counter
  var c=0
```

Code Listing 9.1 timer.html

```
  var t
  function timedCount()
  {
    document.getElementById('txt').value=c
    c=c+1
    t=setTimeout("timedCount()", 1000)
  }
  function stopCount()
  {
    clearTimeout(t)
    alert("Timer Cancelled")
  }
  </script>
</head>
<body>
  <form>
    <input type="button" value="Start count!"
      onClick="timedCount()">
    <input type="text" id="txt">
    <input type="button" value="Stop count!"
      onClick="stopCount()">
  </form>
</body>
</html>
```

Code Listing 9.1 (Continued)

9.4.2 Java Applets

9.4.2.1 Overview

Java applets are programs written in Java that can be included in a Web page and run on client devices. When a user requests a Web document containing a Java applet, the applet's code is transferred to the user's machine and is executed by the browser's Java Virtual Machine. As they run on the client's machine, in order to protect it, important security-related limitations are imposed on applets.

As it was the case for the servlets, which were presented in the server-side network programming chapter, the applets also have a specific class hierarchy. All applets inherit the main *java.applet.Applet* base class, which has ancestors in the class hierarchy *java.lang.Object*, *java.awt.Container,* and *java.awt.Panel*, as presented in Fig. 9.4. More recently, the applets extended the *javax.swing.JApplet* base class (in Java 2), which also has the *java.applet.Applet* class as an ancestor.

The *Applet* base class has the following methods: *init(), start(), stop(), destroy(), paint()*. These methods need to be overridden as they do not do anything as imple-

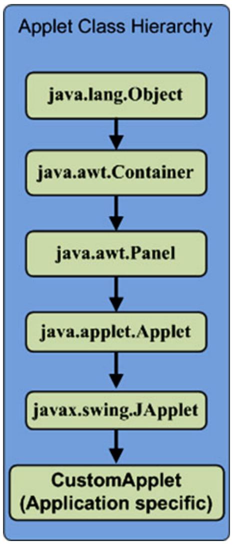

Figure 9.4 Applet class hierarchy

mented in the *Applet* class. The *JApplet* class extends *Applet,* and some methods are implemented in this case.

Finally, the *CustomerApplet* class is a programmer-written class implementing the application specific functionality. Some methods (e.g., init(), paint(), etc.) are overridden by this class.

9.4.2.2 Java Applet Life-Cycle

Java applet life-cycle begins with the creation of the applet. When the applet is created, it is first initialized. The *init()* method is called once, only when the applet is loaded. After the applet is created, the *start()* method is called. This method may be called many times whenever the user revisits the page.

Running on the client machine applets usually involve a user interface. In order to paint the user interface specific to the applet, the *paint()* method is called. This call can occur many times, every time when the browser needs to repaint the applet rectangular area. The *repaint()* method can be called when the applet area needs to be voluntarily redrawn (i.e., when changes occur).

When the user leaves the page, the *stop()* method is called. This call can happen many times, every time when the user leaves the page.

In order for the applet to be destroyed, the *destroy()* method is called. This call occurs once only, just before the applet is unloaded.

9.4.2.3 Java Applet Examples

The following code shows an example of an applet extending the Applet class. Each method call determines to simply add the method name to a text buffer. The content of the buffer is displayed every time the applet display area is repainted.

```
/*include the required packages*/
import java.applet.Applet;
import java.awt.Graphics;

/*define the applet class*/
public class FirstApplet extends Applet
{
  /*declare the buffer used to compose messages*/
  StringBuffer buffer;

  /*override the init() method*/
  public void init()
  {
    buffer = new StringBuffer();
    writeText("init()");
  }

  /*override the start() method*/
  public void start()
  {
    writeText("start()");
  }

  /*override the stop() method*/
  public void stop()
  {
    writeText("stop()");
  }

  /*override the destroy() method*/
  public void destroy()
  {
    writeText("destroy()");
  }
  /*implement the method which assembles text messages*/
  private void writeText(String text)
```

Code Listing 9.2 FirstApplet.java V1

```
  {
    System.out.println(text);
    buffer.append(text);
    repaint();
  }

  /*override the paint() method*/
  public void paint(Graphics g)
  {
    buffer.append("paint()");

    /*get dimensions*/
    int width = getWidth()/4;
    int height = getHeight()/4;
    /*draw a rectangle*/
    g.drawRect(width, height, getWidth()/2,
               getHeight()/2);
    /*draw the string in the middle of the rectangle*/
    g.drawString(buffer.toString(), getWidth()/2,
                 getHeight()/2);
  }
}
```

Code Listing 9.2 (Continued)

The following code shows an example of an applet extending the JApplet class:

```
/*include the required packages*/
import javax.swing.JApplet;
import java.awt.Graphics;

/*define the applet class*/
public class FirstApplet extends JApplet
{

  /*declare the buffer used to compose messages*/
  StringBuffer buffer;

  /*override the init() method*/
  public void init()
```

Code Listing 9.3 FirstApplet.java V2

```
  {
    buffer = new StringBuffer();
    writeText("init()");
  }

  /*override the start() method*/
  public void start()
  {
    writeText("start()");
  }

  /*override the stop() method*/
  public void stop()
  {
    writeText("stop()");
  }

  /*override the destroy() method*/
  public void destroy()
  {
    writeText("destroy()");
  }

  /*implement the method which assembles text messages*/
  private void writeText(String text)
  {
    System.out.println(text);
    buffer.append(text);
    repaint();
  }

  /*override the paint() method*/
  public void paint(Graphics g)
  {
    buffer.append("paint()");

    /*get dimensions*/
    int width = getWidth()/4;
    int height = getHeight()/4;

    /*draw a rectangle*/
    g.drawRect(width, height,
      getWidth()/2, getHeight()/2);
```

Code Listing 9.3 (Continued)

```
    /*draw the string in the middle*/
    g.drawString(buffer.toString(),
      getWidth()/2, getHeight()/2);
  }
}
```

Code Listing 9.3 (Continued)

9.4.2.4 Java Applet Security Aspects

Applets run on the client side code originating from a remote machine (server). This poses various security risks as, first, the origin of the code has to be identified and authenticated, and second, the code must be protected against unauthorized alterations.

In general, applets loaded over the network are prevented from reading and writing files from/to the client file system, making network connections except to the originating host, starting other programs on the client machine, loading libraries, and defining native method calls (giving the applet direct access to the remote computer). Furthermore, the applet is not allowed to perform reading of some system properties or accessing any system services.

Applets loaded from the file system, and not from the network, are not imposed such strict restrictions. Applets can usually make network connections to the host they came from. Applets running within a Web browser can load HTML documents and can invoke public methods of other applets on the same page.

Each browser has a *SecurityManager* object that implements its security policies. When the *SecurityManager* detects a violation, it throws a *SecurityException*. This also applies to applets. Any applet can catch this *SecurityException* and react to it according to its application specific implementation.

9.4.2.5 Java Applet Event Handling

Both classes extended by customer applet classes (i.e., *Applet* and *JApplet*) inherit the same *java.awt.Container* base class. Consequently, all applets inherit the event-handling methods from the *Container* class. To react to an event, an applet must override the appropriate event-specific method (e.g., mouse, keyboard, etc.).

The following example shows the implementation of an applet which catches mouse events and prints a distinct message for each event type:

```
/*import the mouse
events specific packages */
import java.awt.event.MouseListener;
```

Code Listing 9.4 FirstApplet.java V3

```
import java.awt.event.MouseEvent;

/*import the applet specific packages*/
import javax.swing.JApplet;
import java.awt.Graphics;

/*implement the applet extending JApplet
and implementing MouseListener interface*/
public class FirstApplet extends JApplet
      implements MouseListener
{
  /*define the text buffer*/
  StringBuffer buffer;

  /*override the init() method*/
  public void init()
  {
    addMouseListener(this);
    buffer = new StringBuffer();
  }

  /*overridden method, invoked when
  the mouse enters the applet rectangle*/
  public void mouseEntered(MouseEvent event)
  {
    writeText("MEnter!");
  }

  /*overridden method, invoked when
  the mouse exits the applet rectangle*/
  public void mouseExited(MouseEvent event)
  {
    writeText("MExit!");
  }

  /*overridden; invoked when mouse button is pressed*/
  public void mousePressed(MouseEvent event)
  {
    writeText("MPress!");
  }

  /*overridden; invoked when mouse button is released*/
  public void mouseReleased(MouseEvent event)
```

Code Listing 9.4 (Continued)

```
  {
    writeText("MRelease!");
  }

  /*overridden; invoked when mouse button is clicked*/
  public void mouseClicked(MouseEvent event)
  {
    writeText("MClick!");
  }

  /*method which assembles text messages*/
  private void writeText(String text)
  {
    System.out.println(text);
    buffer.append(text);
    repaint();
  }

  /*override the paint() method*/
  public void paint(Graphics g)
  {
    /*draw the string in the middle*/
    g.drawString(buffer.toString(),
        getWidth()/2, getHeight()/2);
  }
}
```

Code Listing 9.4 (Continued)

9.5 Conclusion

This chapter has presented the client-side network programming aspects with the focus on designing and writing the code to be run on the client machine following user request for content and its delivery from the server to the client.

The client-located Web browser communicates with the Web server requesting a document. Following the document request, the browser also performs Web document retrieval, received document interpretation and display for the user, and responds to user actions. During document interpretation, the Web browsers run JavaScript code or Java applet code.

This chapter presented details on how both JavaScript and Java applet code can be written and provided full examples to clearly illustrate the client-side network programming principles.

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Chapter 10
Advanced Client–Server Network Programming

Abstract Client–server communication is at the basis of service provisioning over the Internet. Clients connect to servers and request specific services or tasks to be performed. Sockets have been introduced as basic communication support for client–server data exchange. This chapter introduces advanced client–server network programming techniques. These include the Remote Method Invocation paradigm which allows the clients to invoke methods on servers and retrieve the results and Java applet–servlet communication techniques alongside comprehensive examples.

10.1 Introduction

The server-side network programming is concerned with the case when following client request, the server response involves running code on the server machine. Usually a response document is generated dynamically and is delivered to the client for processing, display, and further interaction with the user. The client-side network programming involves designing and writing code to be run at the client side. Following client requests, the code gets transferred to the client side, then run on client machines. The results are displayed to the users.

The client–server network programming refers to the situation when the code runs at both the server and client side, and the corresponding server and client processes exchange data. Figure 10.1 illustrates the scope of the client–server network programming in terms of communicating client and server processes. Sockets have already been introduced as a great solution for enabling the client–server interprocess communication, while hiding lower layer implementation details from the higher layer abstract tasks.

This chapter presents two alternative solutions for the client–server communication, focusing on Remote Method Invocation (RMI) and Applet–Servlet communication. RMI offers a mechanism for the clients to remotely access services made available at the servers providing all required input data and collecting the outputs following the remote processing at server side. The Applet–Servlet communication involves applets accessing servlet services and exchanging information. Due to the security limitations, the applets have to originate from the same servers that host the

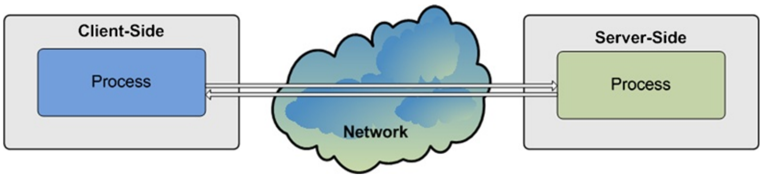

Fig. 10.1 Client–server network programming

communicating front-end servlet. However, there is no limitation in terms of any servlet invoking other servlets in their task execution process.

10.2 Remote Method Invocation

Most client–server communication approaches, including socket-bases solutions, rely on local method calls (both client and server calls are on the local machines). However, in distributed environments, often methods belonging to objects located on remote machines are called.

This is the principle behind Remote Method Invocation (RMI) paradigm which enables platform-independent remote method calls. Consequently, RMI is seen as a conceptual alternative to socket-based client–server communication. The latter exchanges data with the remote applications process in order to obtain results to be used locally. The former makes use of remote method calls to obtain results which are transferred to be used locally.

In order to better explain the basic principle of RMI, let us consider both a server and a client application. The server creates some objects, makes references to these objects accessible remotely, and waits for clients to call methods belonging to these objects. The client obtains a remote reference to a remote object on the server, calls its method(s), and uses the results.

The RMI architecture is presented in Fig. 10.2. Apparently, the remote object's method is called directly from the client object. However, from a development perspective, the client call uses a local place-holder for the remote object (Stub) to communicate with the server's interface (Skeleton), which has access to the remote object method implementation. In reality, the communication happens via a Remote Reference Layer (and transport layer) that serializes the parameters during the call and de-serializes resulting data (when the method returns a value or an object).

RMI involves several steps. First, the server creates the remote object. Then the server registers an interface with a naming service (e.g., registry) in order to make the object accessible to remote client programs. The interface (Skeleton) contains the signatures of those remote object methods the server wants to make accessible.

The client uses the same naming service to obtain reference to this interface. From this interface reference, the client Stub gets created as a local place-holder for the remote object.

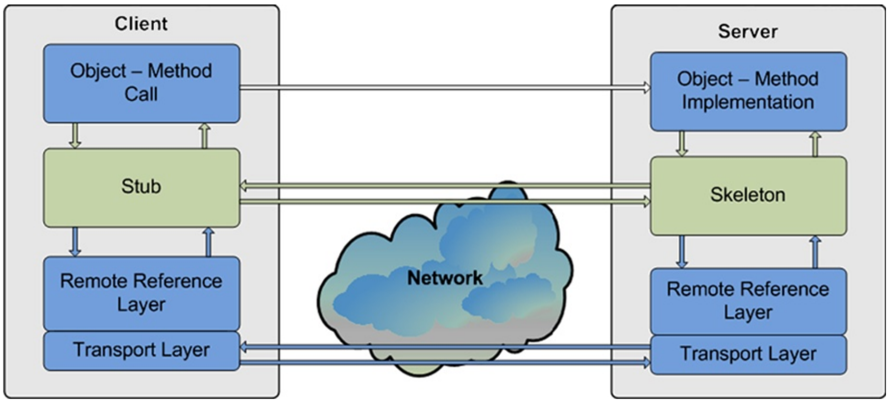

Fig. 10.2 Remote Method Invocation architecture

When the client invokes a method of the remote object, the local stub contacts the remote skeleton and forwards it the call and any required parameters. The Skeleton has access to the real object's method which is invoked. Any resulted value is passed to the Skeleton and then via the Stub is transmitted to the client local calling method.

Serialization and de-serialization of parameters and return value are also called marshalling and un-marshalling, respectively. The Remote Reference Layer hides all the details of the communication protocol between the Stub and the Skeleton. This layer uses transport services (e.g., TCP) provided by the Transport network layer for actual data transfer.

Next the RMI implementation steps are detailed:

- Step 1—Import three Java packages:

```
import java.rmi.*;
import java.rmi.server;
import java.rmi.registry;
```

- Step 2—Create the remote interface:

```
import java.rmi.*;
/*define the remote interface*/
public interface HelloWorld extends Remote {
/*define the method to be called remotely*/
  public String getHelloWorld()
      throws RemoteException;
}
/*Note: The interface must extend the
Remote interface which has no methods of her own*/
```

- Step 3—Define a class that implements the HelloWorld interface:

```
import java.rmi.*
import java.rmi.server.*
```

```
/*define the implementation interface*/
/*it implements the remote interface HelloWorld*/
public interface HelloWorldImpl
  extends UnicastRemoteObject implements HelloWorld
{
  public String HelloWorldImpl()
      throws RemoteException
  {
    /*constructor*/
  }

  /*implementation of the getHelloWorld method
   *exported by the remote interface*/
  public String getHelloWorld() throws RemoteException
  {
      return ("Hello World!");
  }
}
/*Note: The class must extend RemoteObject class
or one of its subclasses.*/
```

- Step 4—Create the server object and establish a connection between the object's name and its reference by registration:

```
import java.rmi.*;

/*implementation of the RMI server*/
/*the server creates the object to be exported*/
/*and publishes it*/
public class HelloWorldServer
{
/*server IP address or localhost if both
 *server and client run on the same physical machine
 *for experimental purposes*/
    private static final String HOST = "localhost";

/*main method is called when
 *starting the server application*/
  public static void main(String[] args)
          throws Exception
  {
    /*instantiates the HelloWorldImpl class*/
    HelloWorldImpl obj = new HelloWorldImpl();

    /*create the URL used to
     *publish the remote object*/
```

```
      String rmiRegName = "rmi://" + HOST +
                "/HelloWorld";

      /*publish the object*/
      Naming.rebind(rmiRegName, obj);

      System.out.println("Binding complete...\n");
    }
  }
  /*Note: the registration is performed using
  the static method rebind of class Naming
  that requires two parameters: a String that holds
  the name of the remote object as URL with RMI
  protocol and a reference to
  the remote object (of type Remote).*/
```

- Step 5—Create the client process, obtain a reference to the remote object from the registry, and use it:

```
  import java.rmi.*;

  /*client implementation class*/
  /*the client invokes the published method remotely*/
  public class HelloWorldClient
  {
  /*server IP address or localhost if both
   *server and client run on the same physical machine
   *for experimental purposes*/
    private static final String HOST = "localhost";

  /*main method is called when
   *starting the server application*/
    public static void main(String[] args) {
      try
      {
        /*retrieve a reference to the remote object*/
        HelloWorld obj=(HelloWorld)Naming.
          lookup("rmi://" +HOST+ "/HelloWorld");

        /*use remote server service
         *by invoking the method*/
        System.out.println
          ("Server output: " + obj.getHelloWorld());
      }
      catch (ConnectException conEx)   {
        System.out.println("Connection to server
          failed!");
        System.exit(1);
      }
      catch (Exception e)
      {
        e.printStackTrace();
        System.exit(1);
      }
    }
  }
  /*Note: The client obtains remote object's reference
  using lookup method of class Naming.
  The lookup method returns a Remote reference
  which needs to be typecasted into HelloWorld*/
```

As in general many methods and objects are needed to be accessed remotely, there are two possible strategies that can be used for building complex applications.

The first strategy uses a separate class to hold all the instances of objects which have methods to be invoked remotely. The second strategy involves multiple references to separate instances of objects allowing the client to make use of them separately, if and when needed.

10.2.1 RMI Strategy A—Using a Common Class

Use a single instance of the implementation class to hold an instance (or more) of a class whose methods will be called remotely. Pass an instance of the latter class as arguments to the constructor of the implementation class. Such an implementation is presented as an example in the following paragraphs.

The interface and the implementation of the first RMI strategy are presented next:

```
/*define the remote interface*/
import java.rmi.*;
import java.rmi.server.*;
import java.util.*;
public interface Numbers extends Remote
{
  public Vector getSetOfNumbers()
    throws RemoteException;
}
/*define the implementation interface*/
public class NumbersImpl
```

Code Listing 10.1 Number.java & NumberImpl.java

```
    extends UnicastRemoteObject implements Numbers
{
  /*define a set of numbers as a vector*/
  private Vector setOfNumbers;

  /*constructor initializing the set of numbers*/
  public NumbersImpl(Vector setNum)
    throws RemoteException
  {
    setOfNumbers = setNum;
  }

  /*access method for the set of numbers*/
  public Vector getSetOfNumbers() throws
  RemoteException
  {
    return setOfNumbers;
  }
}
```

Code Listing 10.1 (Continued)

Implementation of the passed object:

```
/*define Operations class with serializable objects*/
public class Operations implements java.io.Serializable
{
  /*balance stores the account balance*/
  private int balance;

  /*constructor initializing the balance*/
  public Operations (int b)
  {
    balance = b;
  }

  /*implement Operations method*/
  public void addMoney (int sum)
  {
    balance = balance + sum;
  }
```

Code Listing 10.2 Operations.java

```
  /*access method for the balance*/
  public int getBalance()
  {
    return balance;
  }
}
```

Code Listing 10.2 (Continued)

Implementation of the server:

```
/*define the server class*/
public class NumbersServer
{
/*server IP address or localhost if
 *both server and client run on the same
 *physical machine for experimental purposes*/
  private static final String HOST = "localhost";

/*main method is called when starting
 *the server application*/
  public static void main(String[] args)
                    throws Exception
  {
    /*create an array of Operations objects*/
    Operations[] oper =
    {
        new Operations(0),
        new Operations(1000)};

    /*create a vector*/
    Vector vectNum = new Vector();
    /*load the array of Operation
     *objects into the vector*/
    for (int i=0; i<oper.length; i++)
      vectNum.addElement(oper[i]);

    /*create a NumbersImpl object
     *holding the vector of Operations*/
    NumbersImpl obj = new NumbersImpl(vectNum);
```

Code Listing 10.3 NumbersServer.java

```
    /*create the URI to publish the object*/
    String rmiRegName = "rmi://" + HOST + "/Numbers";

    /*publish the object*/
    Naming.rebind(rmiRegName, obj);
    System.out.println("Binding success.\n");
  }
}
```

Code Listing 10.3 (Continued)

Implementation of the client:

```
import java.rmi.*;
import java.util.*;

/*define the client class*/
public class NumbersClient
{
/*server IP address or localhost if both server and
 *client run on the same physical machine for testing*/
  private static final String HOST = "localhost";

/*main() is called when starting the server
 *application*/
  public static void main(String[] args)
  {
    try
    {
      /*get a reference to the remote object*/
      Numbers obj = (Numbers)Naming.lookup
                ("rmi://"+HOST+ "/Numbers");

      /*get the vector of Operations*/
      Vector vectNum = obj.getSetOfNumbers();

      /*for each distinct object
       *perform the operations*/
      for (int i=0; i < vectNum.size(); i++)
```

Code Listing 10.4 NumbersClient.java

```
      {
        Operations oper =
            (Operations)vectNum.elementAt(i);
        oper.addMoney(1000);
        System.out.println
            ("Balance is: " + oper.getBalance());
      }
    }
    catch (ConnectException conEx)
    {
      System.exit(1);
    }
  catch (Exception e)
  {
      System.exit(1);
    }
  }
}
```

Code Listing 10.4 (Continued)

10.2.2 RMI Strategy B—Using Separate Instances

The second approach uses the implementation class to store directly required data and methods and creates instances of this class rather than using a separate class.

```
import java.rmi.*;
import java.rmi.server.*;
/*define the remote interface*/
public interface Numbers extends Remote
{
  /*define the methods to be published*/
  public void addMoney (int sum) throws
    RemoteException;
  public int getBalance() throws RemoteException;
}
```

Code Listing 10.5 Numbers.java

```
/*define the implementation interface*/
```

Code Listing 10.6 NumbersImpl.java

```
public interface NumbersImpl extends
    UnicastRemoteObject implements Numbers
{
  /*balance stores the account balance*/
  private int balance;

  /*constructor initializing the balance*/
  public NumbersImpl(int b) throws RemoteException
  {
    balance = b;
  }

  /*implement operation method*/
  public void addMoney (int sum) throws RemoteException
  {
    balance = balance + sum;
  }

  /*access method for the balance*/
  public int getBalance() throws RemoteException
  {
    return balance;
  }
}
```

Code Listing 10.6 (Continued)

Implementation of the server:

```
import java.rmi.*;
/*define the server class*/
public class NumbersServer
{
/*server IP address or localhost if both server and
 *client run on the same machine for testing purposes*/
  private static final String HOST = "localhost";

/*main() is called when starting the server
 *application*/
```

Code Listing 10.7 NumbersServer.java

```
  public static void main(String[] args)
        throws Exception
  {
    /*create and array of implementation objects*/
    NumbersImpl[] oper = {
        new NumbersImpl(0),
        new NumbersImpl(1000)};
    for (int i=0; i<oper.length; i++)
    {
      /*generate registration name
       by concatenating the position to URL*/
      String pos = new Integer(i).toString();
       /*generate the URL*/
      String rmiRegName = "rmi://" + HOST
              + "/Numbers" + pos;

      /*register every item of the
       *vector separately to publish it*/
      Naming.rebind(rmiRegName, oper[i]);

      System.out.println("Binding success.\n");
    }
  }
}
```

Code Listing 10.7 (Continued)

Implementation of the client:

```
import java.rmi.*;
/*define the client implementation*/
public class NumbersClient
{
/*server IP address or localhost for testing*/
  private static final String HOST = "localhost";

/*define the number of remote objects*/
  private static final int no = 2;
```

Code Listing 10.8 NumbersClient.java

```
/*main method is called when starting
 *the client application*/
  public static void main(String[] args)
  {
    try
    {
      for (int i=0; i < no; i++)
      {
        /*obtain a reference to the
         *object from registry*/
        String pos = new Integer(i).toString();

        String rmiRegName = "rmi://" + HOST
              + "/Numbers" + pos;

        Numbers obj=(Numbers)Naming.lookup(rmiRegName);

        /*use remote server service*/
        obj.addMoney(1000);

        System.out.println("Balance:"
              + obj.getBalance());
      }
    }
    catch (ConnectException conEx)
    {
      System.exit(1);
    }
    catch (Exception e)
    {
      System.exit(1);
    }
  }
}
```

Code Listing 10.8 (Continued)

10.3 Applet–Servlet Communication

This section presents another mechanism to enable the client–server communication by making use of inter-communicating applets and servlets. However, unlike RMI and socket-based communications which exclude each other, the applet–servlet communication is complementary to the other methods. In fact, the applets and servlets can communicate using three distinct methods, including sockets, HTTP connections, and RMI. In the following sections, we will discuss and exemplify the applet–servlet communication using sockets and HTTP. The same steps as in any client–server RMI communications are involved when applets use RMI to access resources offered by the servlet.

Note that, as already mentioned when discussing applet security restrictions, the applets can create network connections to the host they originate from only. This restriction limits the servlet hosting machine to be the same with that which hosts the applet.

The applet–servlet HTTP and socket communication require several steps to be performed at the server and client side.

The applet first needs to get information about the server (IP address, port number) in order to initiate the connection. When the required information is available, it creates and opens a connection to the server. Once the connection is established, the applet sends to the server requests for data, and then it reads server responses. After the communication session finishes, the connection is closed. Various exceptions may be thrown during the communication session, and therefore the applet needs to catch and handle all potential exceptions.

A servlet listens for connection requests, reads, and processes incoming requests and sends responses to the requesting applet.

A simple applet which establishes communication with the servlet is presented next. The applet initiates the communication with the server and fetches the date returned by the servlet every time the *start()* method is called. The date is appended to a buffer which has its whole content displayed at each repainting of the applet display area.

The applet which communicates with the servlet is presented next. Please note that different implementations for the *getDateFrom Servlet()* method will be presented next, employing different communication mechanisms.

```
/*include the required packages*/
import java.applet.Applet;
import java.awt.Graphics;
public class ServCommApplet extends Applet
{
  /*default port to connect to the server*/
  static final int port = 8084;

  /*store messages from server*/
  StringBuffer buffer;

  /*override the start() method*/
  public void start()
  {
    buffer.append(getDateFromServlet());
  }
```

Code Listing 10.9 ServCommApplet.java

```
  /*override the paint() method*/
  public void paint(Graphics g)
  {
    /*draw the string in the middle of the rectangle*/
    g.drawString(buffer.toString(),
        getWidth()/2, getHeight()/2);
  }
}
```

Code Listing 10.9 (Continued)

The HTML document created to load the *ServCommApplet* applet which communicates with the *AppCommServlet* servlet is presented in the following code example.

```
<html>
  <head>
    <meta http-equiv=
      "Content-Type" content="text/html;charset=UTF-8">
    <title>Applet-Servlet Communication Page</title>
  </head>

  <body>
    <h1>Applet-Servlet Communication Main Page</h1>
    <h2>Testing Servlet " AppCommServlet</h2>
    <a href="/servlet/AppCommServlet">AppCommServlet</a>

    <h2>Testing Applet - ServCommApplet</h2>
    <center>
      <applet code="ServCommApplet.class"
          width="300" height="180">
      </applet>
    </center>
  </body>
</html>
```

Code Listing 10.10 serv-comm.html

Servlets and applets may exchange data in the form of text messages or objects. When objects are exchanged, object serialization occurs. The applets and servlets exchange objects of type *Object*, and additional conversion of these objects to and from their original type is required. When applets and servlets exchange text, this is done in form of objects of type *String*. Conversion of data to and from type *String* is required.

Next these two situations are presented separately when the applet and the servlet communicate via text, and when they exchange objects, respectively. Sockets and HTTP connections are used in turn.

10.3.1 Applet–Servlet Communication—Exchanging Text

The following example shows the implementation of the *AppCommServlet* servlet which communicates with the *ServCommApplet* applet presented previously.

The next code snippet shows the implementation of the *doGet()* method of the servlet only. The *doGet()* method awaits applet connection request and responds by returning to the applet the current date.

```
protected void doGet(HttpServletRequest req,
        HttpServletResponse res)
          throws ServletException, IOException
{
  /*format response*/
  res.setContentType("text/html;charset=UTF-8");

  /*send current date in text format*/
  PrintWriter out = res.getWriter();
  out.println(getDate().toString());
  }
  /*close connection*/
  out.close();
}
```

Code Listing 10.11 ServCommApplet.java—doGet()

The following code shows the implementation of *ServCommApplet*'s *getDate-FromServlet()* method which implements the communication between the applet and servlet using sockets and exchanging text.

```
/*method which reads data from socket as text*/
private String getDateFromServlet()
{
  /*declare input reader*/
  InputStream in = null;
  try
```

Code Listing 10.12 ServCommApplet.java—getDateFromServer() V1

```
  {
    /*create the socket*/
    /*get server IP address via getHost()*/
    Socket sock = new Socket(getCodeBase().getHost(),
            port);

    /*send an empty line (request text format)*/
    PrintStream out =
        new PrintStream(socket.getOutputStream());
    out.println();
    out.flush();

    /*read the response*/
    in = sock.getInputStream();
    DataInputStream res=
        new DataInputStream(new
                BufferedInputStream(in));
    String date = res.readLine();

    /*return the retrieved string*/
    return date;
  }
  catch (Exception e)
  {
    e.printStackTrace();  return null;
  }
  finally
  {
    /*close the connection*/
    if (in != null)
    {
      try
      {
        in.close();
      }
      catch (IOException ignored)
      {
      }
    }
  }
}
```

Code Listing 10.12 (Continued)

The following code shows the implementation of *ServCommApplet*'s *getDate-FromServlet()* method which implements the communication between the applet and servlet using HTTP connections and exchanging text.

```
/*implement method which read data using HTTP as text*/
private String getDateFromServlet()
{
  /*declare input reader*/
  InputStream in = null;

  try
  {
    /*create and open URL connection to server*/
    URL url =
      new URL(getCodeBase(),
            "/servlet/AppCommServlet");
    URLConnection con = url.openConnection();
    con.setUseCaches(false);

    /*read response*/
    InputStream in = con.getInputStream();
    DataInputStream res =
      new DataInputStream(new BufferedInputStream(in));
    String date = res.readLine();

    /*return the retrieved string*/
    return date;
  }
  catch (Exception e)
  {
    e.printStackTrace();
    return null;
  }
}
```

Code Listing 10.13 ServCommApplet.java—getDateFromServer() V2

10.3.2 Applet–Servlet Communication—Exchanging Objects

Next the implementation of the *AppCommServlet* servlet's *doGet()* method which communicates with the *ServCommApplet* applet is presented.

The *doGet()* method awaits applet connection request and, if the applet's request is to exchange objects, the servlet responds by returning to the applet the current date as an object.

```
protected void doGet(HttpServletRequest req,
        HttpServletResponse res)
          throws ServletException, IOException
{
  /*format response*/
  res.setContentType("text/html;charset=UTF-8");

  /*if "format=object" send current date in object
   *format*/
    if ("object".equals(req.getParameter("format")))
  {
    ObjectOutputStream out =
      new ObjectOutputStream(res.getOutputStream());
    out.writeObject(getDate());

    /*close connection*/
    out.close();
    }
}
```

Code Listing 10.14 ServCommApplet.java—doGet()

The following example shows the *ServCommApplet*'s *getDateFromServlet()* method which implements the communication between the applet and servlet using sockets and exchanging objects.

```
/*implement method which read data from socket as
 *objects*/
private String getDateFromServlet()
{
  /*declare input reader*/
  InputStream in = null;
  try
  {
    /*create the socket*/
    /*get server IP address via getHost()*/
```

Code Listing 10.15 ServCommApplet.java—getDateFromServer() V1

```
    Socket sock = new Socket(getCodeBase().getHost(),
            port);
    /*send "object" (request an object)*/
    PrintStream out =
        new PrintStream(socket.getOutputStream());
    out.println("object");
    out.flush();
    /*read response*/
    ObjectInputStream res = new ObjectInputStream(
          new BufferedInputStream(in));
    /*read the object*/
     Object obj = res.readObject();
    /*perform conversion*/
    Date date = (Date)obj;
    return date.toString();
  }
  catch (Exception e)
  {
    e.printStackTrace();
    return null;
  }
  finally
  {
    /*close the connection*/
    if (in != null)
    {
      try
      {
        in.close();
      }
      catch (IOException ignored)
      {
      }
    }
  }
}
```

Code Listing 10.15 (Continued)

The following example shows the *ServCommApplet*'s *getDateFromServlet()* method which implements the communication between the applet and servlet using HTTP connections and exchanging objects.

```
/*implement method which read data using HTTP as
 *objects*/
private String getDateFromServlet()
{
  /*declare input reader*/
  InputStream in = null;

  try
  {
    /*create and open URL connection to server*/
    URL url =
      new URL(getCodeBase(), "/servlet/AppCommServlet");
    URLConnection con = url.openConnection();
    con.setUseCaches(false);

    /*read the Date object from the stream*/
    InputStream in = con.getInputStream();
    DataInputStream res =
      new DataInputStream(new BufferedInputStream(in));
    Object obj = res.readObject();
    /*object type conversion*/
    Date date = (Date)obj;

    /*convert Date to String and return*/
    return date.toString();
  }
  catch (Exception e)
  {
    e.printStackTrace();
    return null;
  }
}
```

Code Listing 10.16 ServCommApplet.java—getDateFromServer() V2

More details about the applet–servlet communications can be found in [1].

10.4 Conclusion

This chapter has presented two client–server communication approaches which are different from the basic socket-based solution already presented. Remote Method Invocation (RMI) is an alternative solution to socket communications and involves servers making available some of their methods for remote calls and clients passing parameters, calling the remote shared methods, and collecting and making use of the results. RMI is introduced along with two examples and a step-by-step implementation guide. The applet–servlet communication is a solution complementary not only to socket-based communication, but also to RMI and HTTP-based solutions. This chapter presented examples of how applets and servlets can be employed for remote data exchange when sockets and HTTP connections are used in conjunction.

References

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Chapter 11
Conclusion

Abstract This chapters concludes the book, summarizing its content chapter by chapter.

The network application programming is a large and active area of interest. This book approached this field in a balanced manner, targeting the practical side of network programming, yet offering enough theoretical insight into network architectures, technologies, protocols, and techniques to best inform the readers.

The book starts by introducing theoretical aspects related to network topologies and network types. Existing network topologies such as ring, star, bus, and tree are discussed along with newer approaches such as mesh and ad-hoc.

Still on the theoretical side, network communication protocols and services are introduced. The layered protocol models are discussed next, while relevant layers for application programming such as transport and application layer are further detailed. The main communication-based services such as electronic mail, the World Wide Web, and multimedia delivery applications are then discussed.

The basic network programming paradigms and techniques are introduced first, before processes and threads are presented along with examples to show their use. Inter-thread and inter-process communications are also introduced as the basic principle of network programming.

Next, the basic elements of network programming communication, namely sockets, are detailed. Examples are presented for both socket communication solutions based on connection-less (UDP) and connection-oriented (TCP) transport protocols, respectively.

From an interaction point of view, the client–server communication paradigm is at the basis of any service provided over the Internet. The basic client–server programming techniques are introduced along with the corresponding examples. Unicast, multicast, and broadcast communication paradigms are presented along with implementation examples.

Having the basic network programming techniques introduced, communication-based services are discussed next. Network control and diagnostic services are presented along with more user-oriented services such as electronic mail and file transfer services. The support for Web content transfer services and database connectivity

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services is also introduced as well as that for multimedia delivery applications, as these are the most important application development avenues in the current context.

Furthermore, techniques and technologies used to develop applications and provided services residing at both ther server-side and client-side are presented. Among the server-side technologies, Java servlets and Java Server Pages are introduced as extremely powerful programming resources for building networking applications. Discussing client-side solutions, active documents based on JavaScript and more advanced application development based on applets are presented and exemplified. The book concludes with more advanced client–server network programming techniques to support Remote Method Invocation (RMI) and applet–servlet communication.

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