BSF4ooRexx

Sockets ("java.net", "javax.net"), SSL/TLS ("javax.net.ssl")

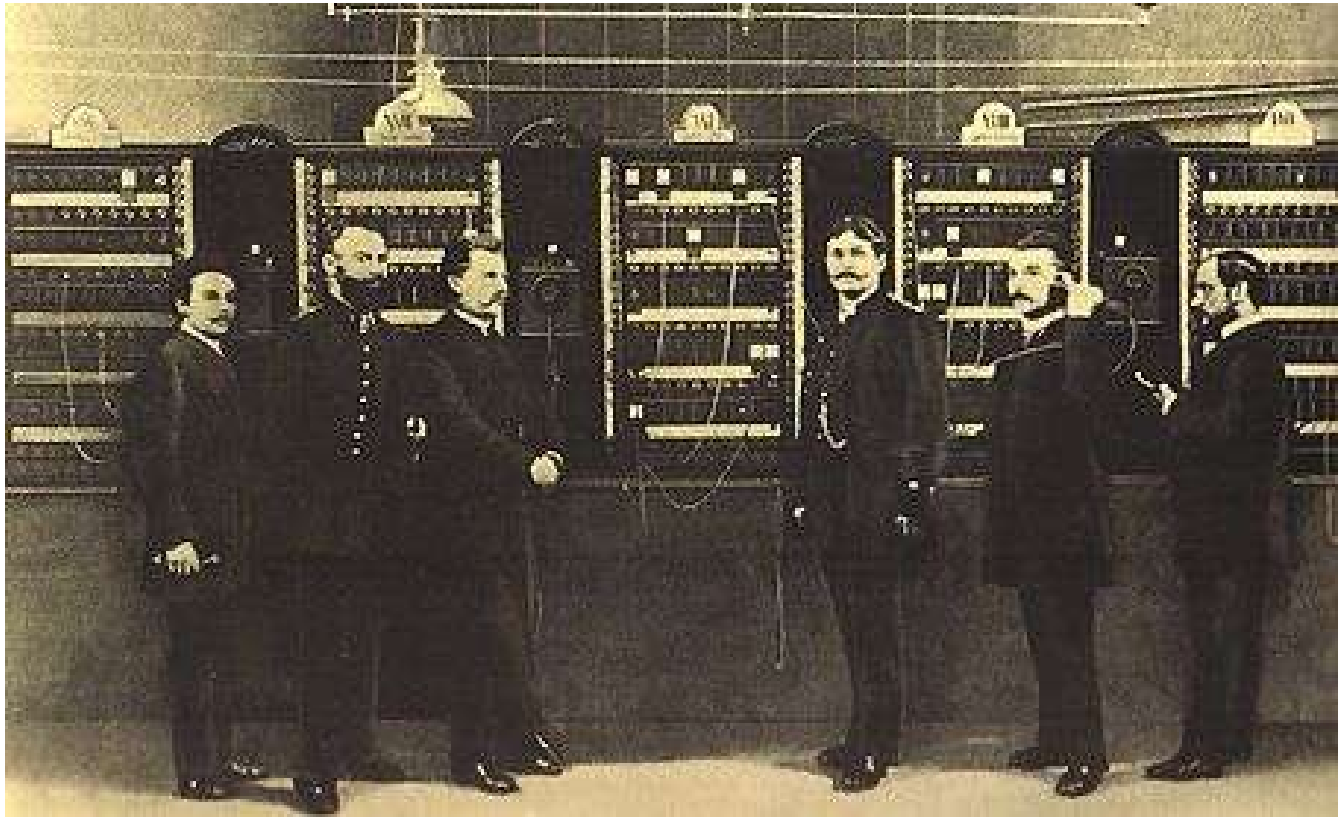
Business Programming 2

Windows GUIs (AWT)	Sockets SSL/TLS	XML SAX/DOM JSON	Scripting AOO/LO (UNO)	Rexx Script Engine	Portable GUIs (JavaFX)	Java Web Server (Tomcat)	Java Classes written in Rexx style

Portability

- Operating system independency
  - Graphical and graphical user interface (GUI) programs should ideally run unchanged on at least
    - Linux
    - MacOS
    - Windows
  - Ideally wherever ooRexx is available
- "Omni-available"
  - Java and the Java runtime environment (JRE)
  - JRE already installed on most computers!
- Bridging ooRexx with Java
  - BSF4ooRexx

Switchboard, 1



Switchboard, Berlin around 1881

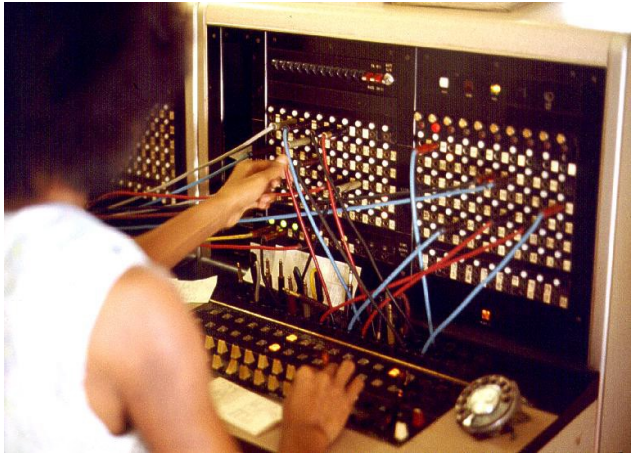
Source: http://www.sultan-zonk.de/history/telefon/vermittlung.htm (2003-06-06)

Sockets, 1

- "Socket"
  - Concept originates from the early days of telephony
    - "Switchboard", which possesses a number of sockets (end-points), each with a single port
      - Each phone line leads to exactly one port
  - "Patch cords" (connection cables) are used to connect two sockets via their ports
    - Sockets are end-points of a bi-directional connection

Sockets, 2

- "Socket" (Telephony)
  (1) Switchboard operator answers call and asks for the callee
  (2) Switchboard operator inserts a "phone-plug" into the ports of the caller and callee
  (3) Caller and callee communicate bi-directionally



Joseph A. Carr, (C) 1975:
JT Switchboard

Source: http://commons.wikimedia.org/wiki/File:JT_Switchboard_770x540.jpg (2010-11-20)

Sockets, 3: TCP/IP "Sockets"

- Caller and callee are two programs
- 65.536 ports
  - Numbered from 0 to 65.535
    - "Portnumber"
    - Port numbers 0 through 1024 are protected
      - E.g. on Unix systems not available to normal users
  - "Well-Known-Ports"
    - E.g. port number "80": reserved for WWW requests
      - A (server, daemon) program which must be addressed using the "http" protocol
      - E.g. Apache Server, Microsoft's IIS (Internet Information Server)

Sockets, 4: TCP/IP "Sockets"

- Assignment of "port" numbers
  - Pre-defined "well-known ports": http, ftp, telnet, gopher, ...
    - Usually from the reserved number range 1 through 1024
  - File "services"
    - E.g. well-known port numbers for databases like DB2, Oracle, ...
  - Port numbers starting from 1025 freely available
    - Collisions, if a port number is already in use by another program
    - E.g. unprivileged users using port "8080" for their http daemon
      - Used quite often by programmers who are temporarily in a need for a web server (e.g. for developing or testing purposes)

Switchboard, 2

- On your computer: 65.535 ports!
  - Ports to 1023 are known system ports, e.g.:
    - Port 22: Secure Shell Host (SSH)
    - Port 25: Simple Mail Transfer Protocol (SMTP)
    - Port 53: Domain Name System (DNS)
    - Port 67/68: Dynamic Host Configuration Protocol (DHCP)
    - Port 80: Hypertext Transfer Protocol (HTTP)
    - Port 443: HTTP Secure (HTTPS)
  - Port 1024 to 49151 are registered ports
  - Port 49152 to 65535 are dynamic or private ports

"Switchboard" with 100 ports

Source: http://www.sultan-zonk.de/history/telefon/vermittlung.htm (2003-06-06)

IP-Addresses and Computer Names, 1

- Each computer possesses a worldwide (!) unique IP-Address
  - Internet "phone number" of a computer
  - Two versions of addresses in use
    - **IPv4**-Addresses: **32-Bit** values(4 bytes), notation "A.B.C.D"
      - Each computer possesses usually a "loopback" address
        - 127.0.0.1
        - "localhost"
      - Used for developing and testing of socket programs
    - **IPv6**-Addresses: **128-Bit** values (16 bytes), different notations
      - Address space of IPv4 has become far too small
      - Newer version which will replace IPv4 addresses in the long run
      - Address range practically unlimited
  - Java class "InetAddress"

IP-Addresses and Computer Names, 2

- Computer name
  - Easier to memorize for humans than "naked" numbers
  - "Name services"
    - Maintaining mapping of "computer name → IP address"
    - Makes it possible that a computer may have any number of names
      - If a computer possesses more than one name, all names resolve to the same IP address
    - Program "**nslookup**" (name server lookup)
      - Resolves computer names and IP addresses at the command line

IP-Addresses and Computer Names, 3

- Computer name and domain
  - Each computer belongs to a domain
  - Domain names are maintained on a world-wide scope
    - Intended to assure name resolving works world-wide
  - Examples

    - www.wu.ac.at
    - www.keio.ac.jp
    - teletext.orf.at
    - www.RexxLA.org
    - zicklin.baruch.cuny.edu
    - www.ibm.com

IP-Addresses and Computer Names, 4

- IP address objects in Java
  - Class "**java.net.InetAddress**"
  - Attention! No public constructors available!
    - ➔ Instead use the following static methods which return an instance of this class:

InetAddress InetAddress.getByName(String hostname)

```
InetAddress   ia=InetAddress.getByName("www.wu.ac.at");
```

InetAddress InetAddress.getByAddress(byte[] addr)

```
byte    addr[]={ (byte)137, (byte)208, (byte)3, (byte)112 };
InetAddress ia=InetAddress.getByAddress(addr);
```

InetAddress InetAddress.getLocalHost()

- Address of your own computer

```
InetAddress   ia=InetAddress.getLocalHost();
```

IP-Addresses and Computer Names, 5

```java
import java.io.*;
import java.net.*;
import java.util.*;
class GetHostInfo
{
    public static void main (String args[])
    {
        InetAddress ia=null;
        if (args.length==0) // give localhost-infos
        {       // attempt to get InetAddress object of localhost
            try { ia=InetAddress.getLocalHost(); }
            catch (UnknownHostException uhe)
            {
                System.err.println("No localhost defined for your computer!");
                System.exit(-1);
            }
        }
        else
        {       // attempt to get InetAddress object by hostname
            try { ia=InetAddress.getByName(args[0]); }
            catch (UnknownHostException uhe)
            {
                try     // attempt to get InetAddress object by IP address
                {
                    StringTokenizer st = new StringTokenizer(args[0], ".");
                    byte ab[] = new byte [st.countTokens()];    // create appropriate byte array
                    for (int i=0; st.hasMoreTokens();i++)       // loop over tokens
                        ab[i]=Byte.parseByte(st.nextToken());   // get value and create byte of it

                    ia=InetAddress.getByAddress(ab);
                }
                catch (UnknownHostException uhe2)
                {
                    System.err.println("["+args[0]+"]: not a valid hostname nor IP-address!");
                    System.exit(-1);
                }
            }
        }
        System.out.println("         HostName: ["+ia.getHostName()+"]\n"+
                           "       IP address: ["+ia.getHostAddress()+"]\n\n"+
                           "canonicalHostName: ["+ia.getCanonicalHostName()+"]\n"+
                           "       toString(): ["+ia+"]");
    }
}
```

Possible Output:

```
         HostName: [waldi]
       IP address: [127.0.1.1]

canonicalHostName: [waldi.localdomain]
       toString(): [waldi/127.0.1.1]
```


Package: java.io, java.net, java.util

Java Class "java.net.Socket"

- Allows to establish a connection to a server program on a(nother) computer
  - Computer will be identified by IP address or name and
  - Port number ("int")
- Input and output operations via "Stream" objects
  - "java.io.InputStream" object for reading (receiving) data
    - "getInputStream()"
  - "java.io.OutputStream" object for writing (sending) data
    - "getOutputStream()"
- Sockets get closed with the method "close()"

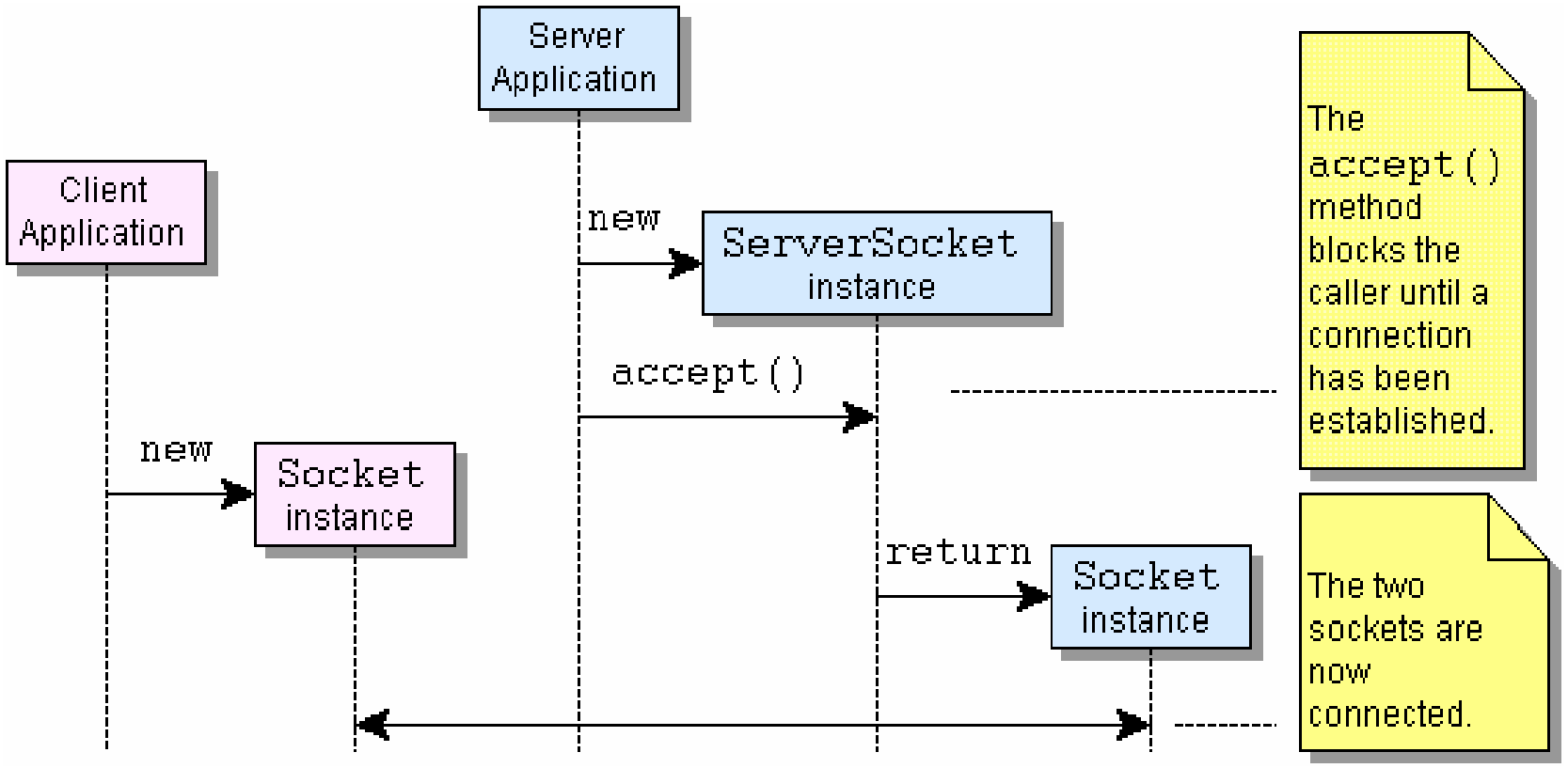
Server Program "java.net.ServerSocket"

- "Server"
  - Program, which accepts requests for services
  - Must be assigned a port
    - Program listens at the port for requests from possible client programs
  - Server programs need to
    - Create a "**ServerSocket**" object
      - The port number to listen to can be supplied to the constructor or can be assigned later with the method "bind(...)"
    - Wait for a request to accept
      - Method "accept()"
    - Answering a request
      - Communication is carried out with the help of a **Socket** object, which the method "accept()" creates and returns

Client Program: Client and Server

- "Client"
  - Program, which sends requests to a server
    - Creates a "**java.net.Socket**" object
      - Different constructors available
        - Possibility to denote the server computer (String, InetAdress)
        - Possibility to denote the desired port number
      - Possibility to denote computer and port number with the "connect(...)" method
- "Client" and "Server"
  - Need to define communication rules
    - "Protocol", e.g.
      - http, ftp, telnet, sendmail, ...
        - As RFCs ("request for comments") available on the Internet

Client Program: Client and Server



Source: http://download.oracle.com/javase/1.4.2/docs/guide/net/overview/overview.html (2003-06-06)

Example: Server Program (Java)

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

class TestSocketServer
{
    public static void main (String args[])
    {
        try
        {
            ServerSocket srvSock=new ServerSocket( 8888 );  // port to listen to

            Socket socket2client = null;
            System.out.println("Server (Java): starting to accept clients...");
            socket2client = srvSock.accept();
            System.out.println("Server (Java): client accepted.");

            byte b[]=new byte [2048];                       // set read buffer to 2 KB
            int n=socket2client.getInputStream().read(b);
            System.out.println("Server (Java): received client data: ["+new String(b, 0, n)+"]");

            System.out.println("Server (Java): sending data to client ...");
            String msg="Hello from Server!";
            socket2client.getOutputStream().write(msg.getBytes());
        }
        catch (Exception exc)
        {
            System.err.println("Exception: ["+exc+"]");
            exc.printStackTrace();
            System.exit(-1);
        }
    }
}
```


Package: java.io, java.net

Example: Client Program (Java)

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

class TestSocketClient
{
    public static void main (String args[])
    {
        try
        {
            Socket socket2server= new Socket(InetAddress.getLocalHost(), 8888);
            System.out.println("CLIENT (Java): socket created!");

            System.out.println("CLIENT (Java): sending data to server ...");
            String msg="Hello, this is your client speaking!";
            socket2server.getOutputStream().write(msg.getBytes());

            byte b[]=new byte [100];    // set read buffer to 100 bytes auf
            int n=socket2server.getInputStream().read(b);
            System.out.println("CLIENT (Java): received server data: ["+new String(b,0,n)+"]");
        }
        catch (Exception exc)
        {
            System.err.println("Exception: ["+exc+"]");
            exc.printStackTrace();
            System.exit(-1);
        }
    }
}
```


Package: java.io, java.net

Example: Output

Server-side:

```
Server (Java): starting to accept clients...
Server (Java): client accepted.
Server (Java): received client data: [Hello, this is your client speaking!]
Server (Java): sending data to client ...
```

Client-side:

```
CLIENT (Java): socket created!
CLIENT (Java): sending data to server ...
CLIENT (Java): received server data: [Hello from Server!]
```

Example: Server Program (ooRexx)

```
say "SERVER (ooRexx): program started."

   /* create server socket listening on port 8888  */
srvSock=.bsf~new("java.net.ServerSocket", 8888)
say "SERVER (ooRexx): starting to accept clients..."
socket2client=srvSock~accept  -- accept client, returns socket to client
say "SERVER (ooRexx): client" pp(socket2client~toString) "accepted."

   /* get data from the client */
b=.bsf~bsf.createArray('byte.class', 2048)     -- create a "byte"-array
received=socket2client~getInputStream~read(b)  -- returns number of bytes read
       /* turn received byte array to Rexx string */
say "SERVER (ooRexx): data received from client:" pp(BsfRawBytes(b,received))

   /* send data to client */
os=socket2client~getOutputStream
msg="Hello from the ooRexx-server!"
say "SERVER (ooRexx): sending" pp(msg) "to client..."
socket2client~getOutputStream~write(BsfRawBytes(msg)) -- turn Rexx string to byte array

say "SERVER (ooRexx): program ended."

::requires BSF.CLS            -- get Java support
```

Example: Client Program (ooRexx)

```
say "CLIENT (ooRexx): program started."

   /* create socket and connect to server on port 8888   */
lh=.bsf~bsf.import('java.net.InetAddress') ~getLocalHost -- get InetAddress
socket2server=.bsf~new('java.net.Socket', lh, 8888)      -- connect to server
say "CLIENT (ooRexx): connected to server" pp(socket2server~toString)

   /* send the server data */
msg="Hello, this is from your ooRexx-client!"
say "CLIENT (ooRexx): sending" pp(msg) "to server..."
socket2server~getOutputStream~write(BsfRawBytes(msg))  -- turn Rexx string to byte array

   /* receive data from server */
b=.bsf~bsf.createArray('byte.class', 100)              -- create a "byte"-array
received=socket2server~getInputStream~read(b)          -- returns number of bytes read
say "CLIENT (ooRexx): data received from server: ["||BsfRawBytes(b,received)"]"

say "CLIENT (ooRexx): program ended."

::requires BSF.CLS            -- get Java support
```

Example: Possible Output

Server-side:

```
SERVER (ooRexx): program started.
SERVER (ooRexx): starting to accept clients...
SERVER (ooRexx): client [Socket[addr=/137.208.114.24,port=53813,localport=8888]] accepted.
SERVER (ooRexx): data received from client: [Hello, this is from your ooRexx-client!]
SERVER (ooRexx): sending [Hello from the ooRexx-server!] to client...
SERVER (ooRexx): program ended.
```

Client-side:

```
CLIENT (ooRexx): program started.
CLIENT (ooRexx): connected to server [Socket[addr=T450sRGF/137.208.114.24,port=8888,localport=53813]]
CLIENT (ooRexx): sending [Hello, this is from your ooRexx-client!] to server...
CLIENT (ooRexx): data received from server: [Hello from the ooRexx-server!]
CLIENT (ooRexx): program ended.
```

Sockets – Potential Risk

- Sockets transport data without any encryption!
- Popular solution
  - **SSL**: Secure Socket Layer (until 2015)
  - **TLS**: Transport Layer Security (successor of SSL)
- Java makes it easy to employ the TLS protocol (dubbed "SSL/TLS" on the following slides)
  - Keeps the socket semantics
  - Uses a factory class to allow for using the default Java cryptographic infrastructure or for using third party implementations

SSL/TLS, 1: Overview

- Needs public key infrastructure
  - Complex to implement
  - However Java's JDK has that infrastructure "on-board"!
    - "keytool" to generate a certificate file
    - Certificate file needs to be stored on server and client
- Specialized socket classes to employ security
  - "javax.net.ssl.SSLServerSocketFactory"
  - "javax.net.ssl.SSLSocketFactory"
- Example modelled after tutorial on the Internet
  - Cf. http://stilius.net/java/java_ssl.php (as of: 2011-10-13)

SSL/TLS, 2: Overview

- Java executable "keytool"
  - Create certificate file, e.g. with password "123456"

```
keytool -genkey -keystore mySrvKeystore -keyalg RSA
```

  - Save certificate file on server and client
- Supply information about the certificate file either by setting "java.lang.System" properties or while invoking
  - SSL **Server** on the command line e.g. defining the system properties

```
-Djavax.net.ssl.keyStore=mySrvKeystore -Djavax.net.ssl.keyStorePassword=123456
```

  - SSL **Client** on the command line e.g. defining the system properties

```
-Djavax.net.ssl.trustStore=mySrvKeystore -Djavax.net.ssl.trustStorePassword=123456
```

Example 1a: SSL/TLS Server Program (ooRexx)

```
say "SERVER (ooRexx SSL/TLS): program started."
   -- define System properties for Java's security handling
system=.java.lang.System    -- gets preloaded by BSF4ooRexx
system~setProperty("javax.net.ssl.keyStore",         "mySrvKeystore")
system~setProperty("javax.net.ssl.keyStorePassword", "123456")

   -- create a SSL server socket, wait for a SSL client
socketFactory=bsf.loadClass("javax.net.ssl.SSLServerSocketFactory")~getDefault
srvSocket =socketFactory~createServerSocket(9999)
say "SERVER (ooRexx SSL/TLS): starting to accept clients..."
socket2client=srvSocket~accept   -- wait for a client
say "SERVER (ooRexx SSL/TLS): client" pp(socket2client~toString) "accepted."

   /* get data from the client */
b=.bsf~bsf.createArray('byte.class', 2048)   -- create a "byte"-array
n=socket2client~getInputStream~read(b)       -- returns number of bytes read
   /* turn received byte array into a Rexx string */
say "SERVER (ooRexx SSL/TLS): data received from client:" pp(BsfRawBytes(b,n))

   /* send data to client */
os=socket2client~getOutputStream
msg="Hello from the ooRexx-server via SSL/TLS!"
say "SERVER (ooRexx SSL/TLS): sending" pp(msg) "to client..."
socket2client~getOutputStream~write(BsfRawBytes(msg)) -- turn Rexx string to byte array

say "SERVER (ooRexx SSL/TLS): program ended."

::requires BSF.CLS           -- get Java support
```

Example 1b: SSL/TLS Client Program (ooRexx)

```
say "CLIENT (ooRexx SSL/TLS): program started."
   -- define System properties for Java's security handling
system=.java.lang.System    -- gets preloaded by BSF4ooRexx
system~setProperty("javax.net.ssl.trustStore",         "mySrvKeystore")
system~setProperty("javax.net.ssl.trustStorePassword", "123456")

   -- create a SSL server socket, wait for a SSL client
socketFactory=bsf.loadClass("javax.net.ssl.SSLSocketFactory")~getDefault
socket2server=socketFactory~createSocket("localhost", 9999) -- create socket
say "CLIENT (ooRexx SSL/TLS): connected to server" pp(socket2server~toString)

   /* send the server data */
msg="Hello, this is from your ooRexx-client via SSL/TLS!"
say "CLIENT (ooRexx SSL/TLS): sending" pp(msg) "to server..."
socket2server~getOutputStream~write(BsfRawBytes(msg))  -- turn Rexx string to byte array

   /* receive data from server */
b=.bsf~bsf.createArray('byte.class', 100) -- create a "byte"-array
n=socket2server~getInputStream~read(b)    -- returns number of bytes read
say "CLIENT (ooRexx SSL/TLS): data received from server: ["||BsfRawBytes(b,n)"]"

say "CLIENT (ooRexx SSL/TLS): program ended."

::requires BSF.CLS           -- get Java support
```

SSL/TLS Example 1: Possible Output

Server-side:

```
SERVER (ooRexx SSL/TLS): program started.
SERVER (ooRexx SSL/TLS): starting to accept clients...
SERVER (ooRexx SSL/TLS): client [SSLSocket[hostname=127.0.0.1, port=59276, Session(1655305614304|SSL_NULL_WITH_NULL_NULL)]] accepted.
SERVER (ooRexx SSL/TLS): data received from client: [Hello, this is from your ooRexx-client via SSL/TLS!]
SERVER (ooRexx SSL/TLS): sending [Hello from the ooRexx-server via SSL/TLS!] to client...
SERVER (ooRexx SSL/TLS): program ended.
```

Client-side:

```
CLIENT (ooRexx SSL/TLS): program started.
CLIENT (ooRexx SSL/TLS): connected to server [SSLSocket[hostname=localhost, port=9999, Session(1655305617537|SSL_NULL_WITH_NULL_NULL)]]
CLIENT (ooRexx SSL/TLS): sending [Hello, this is from your ooRexx-client via SSL/TLS!] to server...
CLIENT (ooRexx SSL/TLS): data received from server: [Hello from the ooRexx-server via SSL/TLS!]
CLIENT (ooRexx SSL/TLS): program ended.
```

SSL/TLS: Echo Server

- Example modelled after tutorial on the Internet
  - Cf. http://stilius.net/java/java_ssl.php (as of: 2011-10-13)
- Differences to previous SSL/TLS example
  - Server echoes characters received from client, closes when empty line gets sent
  - Streams (byte oriented) get wrapped up in Readers/Writers (character oriented) which get wrapped up in Buffers (e.g. allowing reading/writing characters in line oriented)

Example 2a: SSL/TLS Echo Server Program

```
   -- define System properties for Java's security handling
system=.bsf4rexx~system.class    -- get preloaded java.lang.System
system~setProperty("javax.net.ssl.keyStore",         "mySrvKeystore")
system~setProperty("javax.net.ssl.keyStorePassword", "123456")

   -- create a SSL server socket, wait for a SSL client
socketFactory=bsf.loadClass("javax.net.ssl.SSLServerSocketFactory")~getDefault
serverSocket =socketFactory~createServerSocket(9999)
sslSocket    =serverSocket~accept   -- wait for a client

   -- client connected, start to read its data
inputStream      =sslSocket~getInputStream
inputStreamReader=.bsf~new("java.io.InputStreamReader", inputStream)
bufferedReader   =.bsf~new("java.io.BufferedReader",    inputStreamReader)

   -- output text sent from SSL client
signal on syntax     -- activate signal handling, e.g. resetting socket
do until string=.nil
   string=bufferedReader~readLine
   if string<>.nil then
      say "<Rexx-SSL-server received>:" pp(string)
end
syntax:                 -- label (target) for syntax exception

::requires BSF.CLS      -- get Java support
```

Example 2b: SSL/TLS Echo Client Program

```
   -- define System properties for Java's security handling
system=.bsf4rexx~system.class    -- get preloaded java.lang.System
system~setProperty("javax.net.ssl.trustStore",         "mySrvKeystore")
system~setProperty("javax.net.ssl.trustStorePassword", "123456")

   -- create a SSL server socket, wait for a SSL client
socketFactory=bsf.loadClass("javax.net.ssl.SSLSocketFactory")~getDefault
sslSocket    =socketFactory~createSocket("localhost", 9999) -- create socket

   -- client connected, start to read its data
outputStream      =sslSocket~getOutputStream
outputStreamWriter=.bsf~new("java.io.OutputStreamWriter", outputStream)
bufferedWriter    =.bsf~new("java.io.BufferedWriter",     outputStreamWriter)

   -- get text from user, send it to SSL server
LF="0a"x       -- LF (linefeed) character
do until string=""
   parse pull string
   bufferedWriter ~~write( "["string"]" "<from the Rexx SSL client>"LF) ~flush
end

::requires BSF.CLS      -- get Java support
```

Roundup

- Using Java as an external function package using BSF4ooRexx
  - Camouflages Java as ooRexx
- Socket programming via Java is easy, allowing to take advantage of
  - IPv4 and IPv6 addresses
  - SSL/TLS
  - And much more ...
- Further information
  - Java tutorials that can easily be transcribed
  - Oracle Java documentation, books and tutorials