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# Chapter 2a
# SOCKET PROGRAMMING

Computer Networks

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Summer 2007

# *Overview*

- Basic socket concepts
- Java socket programming
  - Client & server
  - TCP & UDP
  - Threads
- C socket programming
  - API details
  - TCP client and server
  - Asynchronous I/O and events
- Bonus: EiffelNet API slides

# *Socket programming*

Goal

- Learn building client/server applications that communicate using sockets, the standard application programming interface

Socket API

- introduced in BSD4.1 UNIX, 1981
- explicitly created, used, released by applications
- client/server paradigm
- two types of transport service via socket API
  - unreliable datagram
  - reliable, byte stream-oriented

**socket**

a *host-local*, *application-created/owned*, *OS-controlled* interface (a “door”) into which application process can both send and receive messages to/from another (remote or local) application process

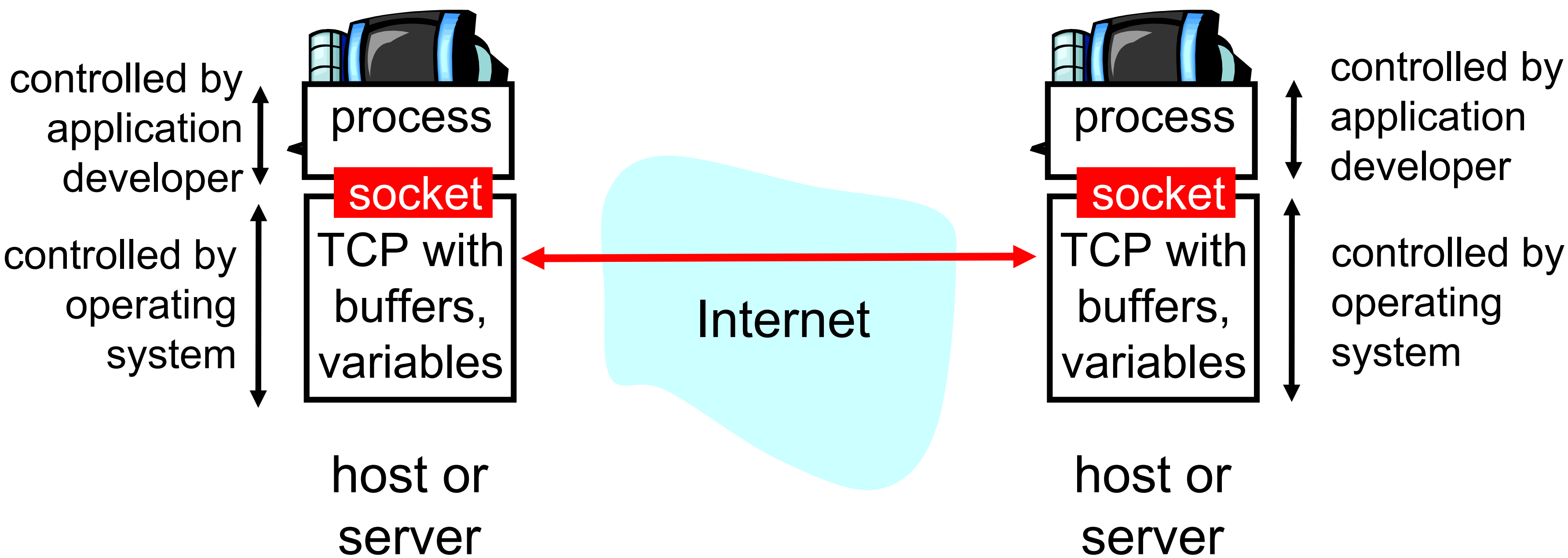
# *Socket programming with TCP*

Socket

- a door between application process and end-end-transport protocol (UDP or TCP)

TCP service

- reliable transfer of *bytes* from one process to another



# *Socket programming with TCP*

Client must contact server

- server process must first be running already
- server must have created socket (“door”) that welcomes client’s contact

Client contacts server by

- creating client-local TCP socket
- specifying IP address and port number of server process

- When client creates socket: client TCP establishes connection to server TCP
- When contacted by client, server TCP creates new socket for server process to communicate with client
  - allows server to talk with multiple clients

application viewpoint

*TCP provides reliable, in-order transfer of bytes (“pipe”) between client and server*

# *Socket programming with UDP*

Remember: UDP: no “connection” between client and server

- no handshaking
- sender explicitly attaches IP address and port of destination
- server must extract IP address, port of sender from received datagram

**application viewpoint**

*UDP provides unreliable transfer of groups of bytes (“datagrams”) between client and server*

- UDP: transmitted data may be received out of order, or lost

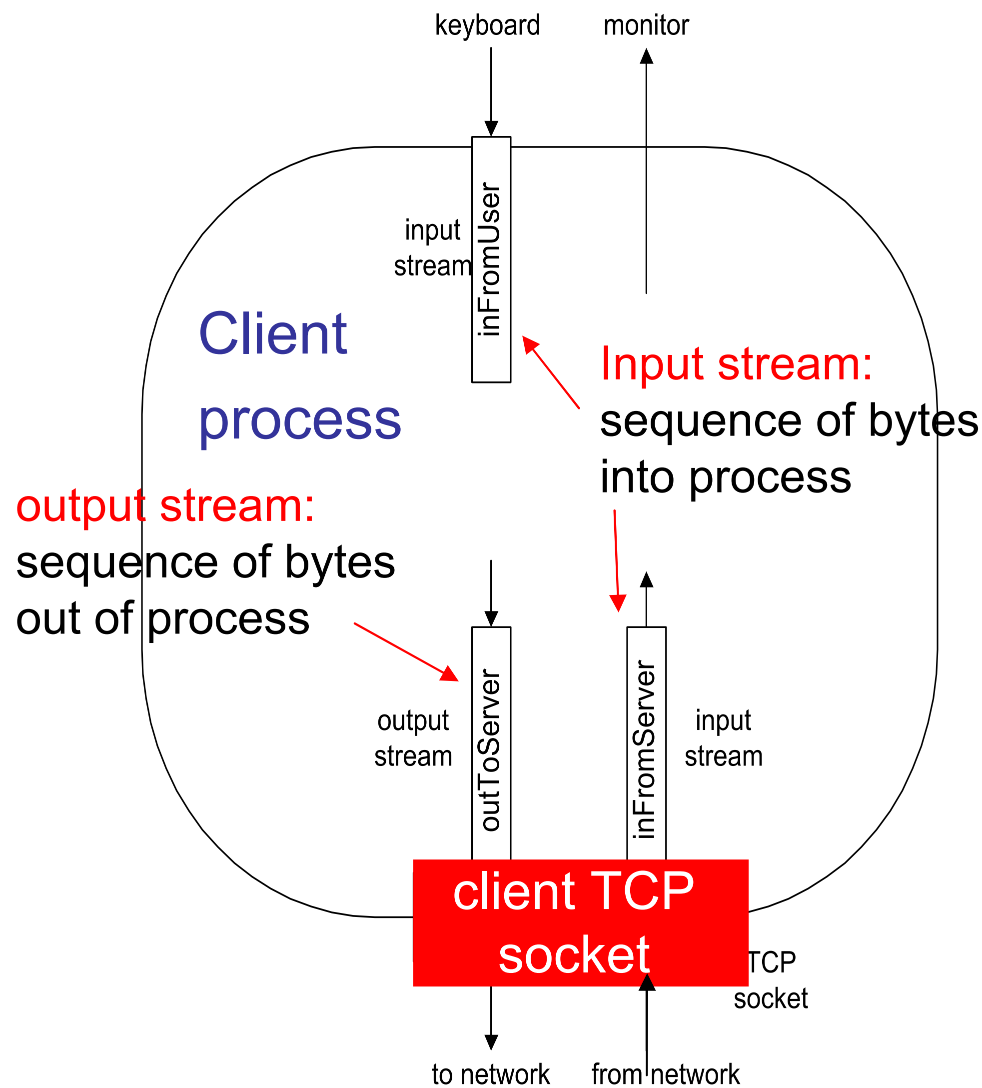
# *Java API vs. C API*

- Java:
  - High-level, easy to use for common situations
  - Buffered I/O
  - Failure abstracted as exceptions
  - Less code to write
- C:
  - Low-level $\Rightarrow$ more code, more flexibility
  - Original interface
  - Maximum control
  - Basis for all other APIs in Unix (and Windows)

# *Socket programming with TCP (Java)*

Example client-server application

- client reads line from standard input (**`inFromUser`** stream), sends to server via socket (**`outToServer`** stream)
- server reads line from socket
- server converts line to uppercase, sends back to client
- client reads and prints modified line from socket (**`inFromServer`** stream)



# *Client/server socket interaction with TCP (Java)*

**Server** (running on **hostid**)

create socket,
port=**x**, for
incoming request:
welcomeSocket =
ServerSocket()

wait for incoming
connection request
connectionSocket =
welcomeSocket.accept()

read request from
connectionSocket

write reply to
connectionSocket

close
connectionSocket

TCP
connection setup

**Client**

create socket,
connect to **hostid**, port=**x**
clientSocket =
Socket()

send request using
clientSocket

read reply from
clientSocket

close
clientSocket

# Example: Java client (TCP)

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

class TCPClient {
    public static void main(String argv[]) throws Exception
    {
        String sentence;
        String modifiedSentence;
```

Create input stream

```
        BufferedReader inFromUser =
          new BufferedReader(new InputStreamReader(System.in));
```

Create client socket, connect to server

```
        Socket clientSocket = new Socket("hostname", 6789);
```

Create output stream attached to socket

```
        DataOutputStream outToServer =
          new DataOutputStream(clientSocket.getOutputStream());
```

# Example: Java client (TCP), continued

Create input stream attached to socket

```
BufferedReader inFromServer =
  new BufferedReader(new
  InputStreamReader(clientSocket.getInputStream()));

sentence = inFromUser.readLine();
```

Send line to server

```
outToServer.writeBytes(sentence + '\n');
```

Read line from server

```
modifiedSentence = inFromServer.readLine();

System.out.println("FROM SERVER: " +
                   modifiedSentence);

clientSocket.close();

  }
}
```

# Example: Java server (TCP)

Create welcoming socket at port 6789

Wait on welcoming socket for contact by client

Create input stream, attached to socket

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

class TCPServer {

  public static void main(String argv[]) throws Exception
   {
     String clientSentence;
     String capitalizedSentence;

     ServerSocket welcomeSocket = new ServerSocket(6789);

     while(true) {

         Socket connectionSocket = welcomeSocket.accept();

        BufferedReader inFromClient =
          new BufferedReader(new
          InputStreamReader(connectionSocket.getInputStream()));
```

# *Example: Java server (TCP), continued*

Create output stream, attached to socket

```
DataOutputStream outToClient =
  new DataOutputStream(connectionSocket.getOutputStream());
```

Read in line from socket

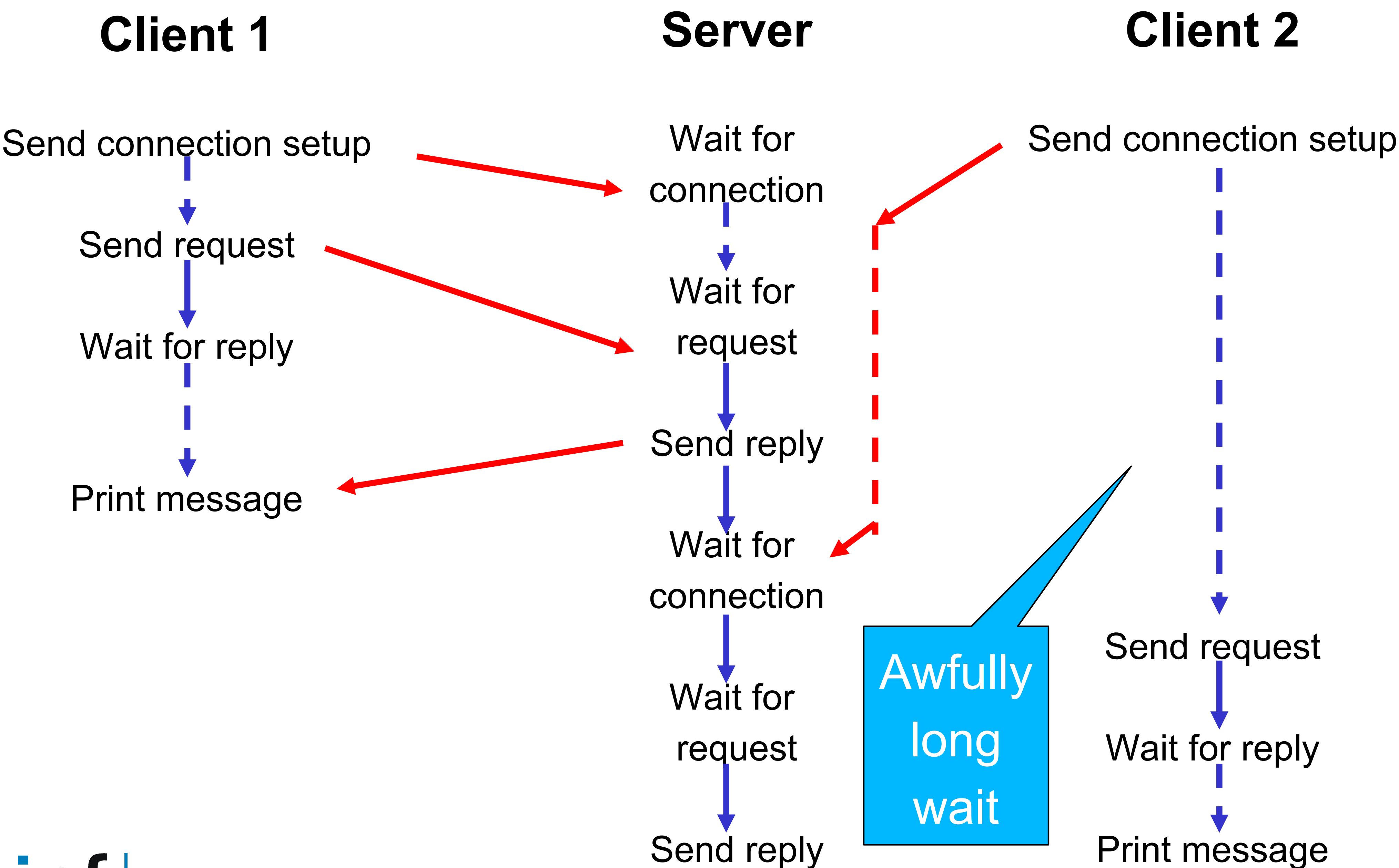
```
clientSentence = inFromClient.readLine();

capitalizedSentence = clientSentence.toUpperCase() + '\n';
```

Write out line to socket

```
outToClient.writeBytes(capitalizedSentence);
      }
    }
  }
```

End of while loop, loop back and wait for another client connection

# Problem: One client can delay other clients



# *In fact, one client can block other clients*

**Client 1**

Send connection setup

Doesn't send request!

**Server**

Wait for connection

Wait for request

**Client 2**

Send connection setup

Never makes progress

*More generally, only one machine (client or server) can run at a once!*

# *The Problem: Concurrency*

- Networking applications are
  - Inherently *concurrent*
  - Prone to *partial failure*
- Hence, “blocking” (waiting for something else) can
  - Slow things down (only one machine running at a time)
  - REALLY slow things down (mostly, no machines running at a time)
  - Stop things (something stops and everything else waits)
- Central problem of *distributed systems*
  - Not really networking, but probably should be

# *One solution: Threads*

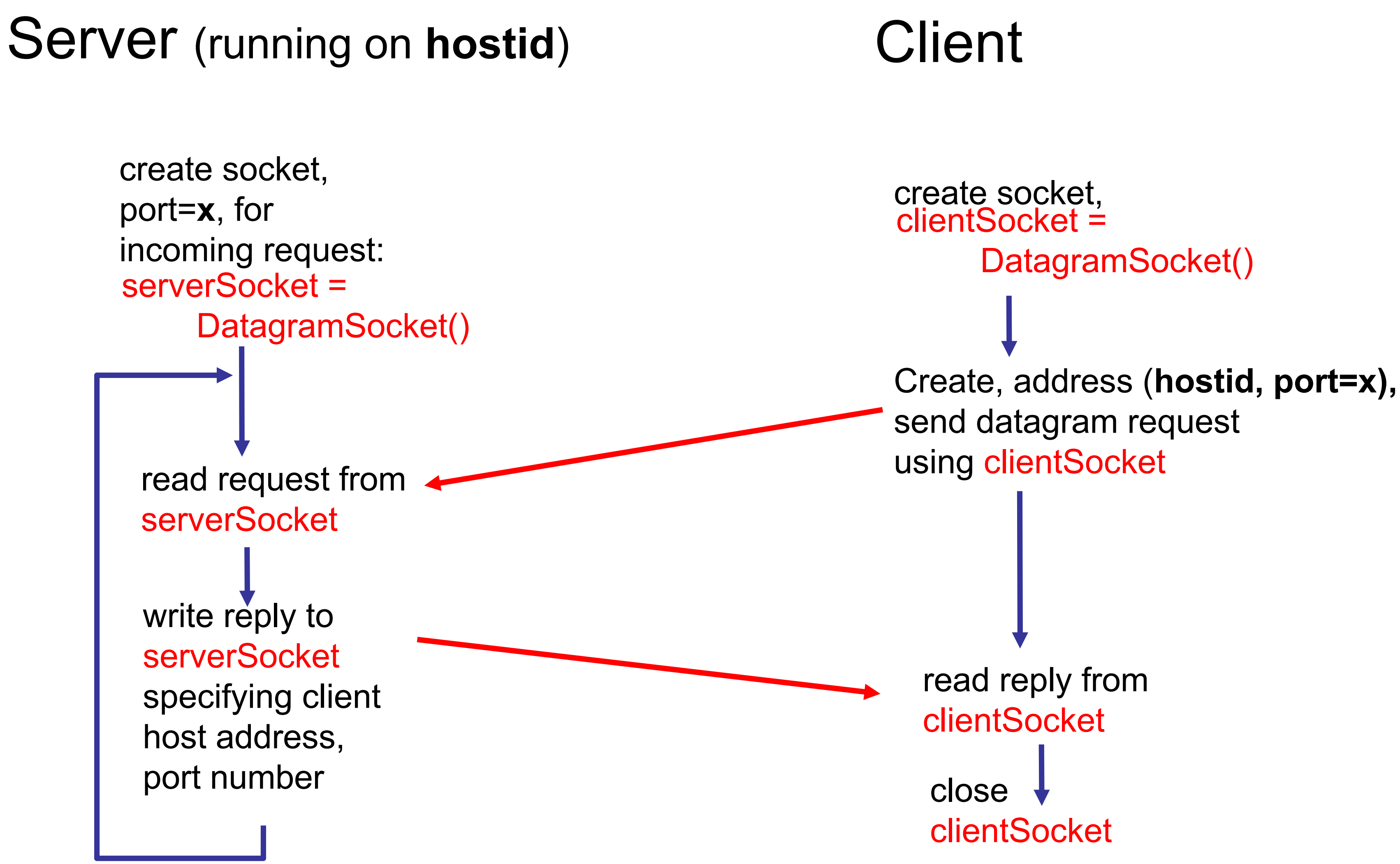
```
ServerSocket welcomeSocket = new ServerSocket(6789);
while(true) {
        Socket connectionSocket = welcomeSocket.accept();
        ServerThread thread = new ServerThread(connectionSocket);
        thread.start();
}
public class ServerThread extends Thread {
        /* … */
        BufferedReader inFromClient = new BufferedReader(new
            InputStreamReader(connectionSocket.getInputStream()));
        DataOutputStream outToClient = new DataOutputStream(
            connectionSocket.getOutputStream());
        clientSentence = inFromClient.readLine();
        capitalizedSentence = clientSentence.toUpperCase() + '\n';
        outToClient.writeBytes(capitalizedSentence);
        /* … */
    }
}
```

Does this solve the problem?

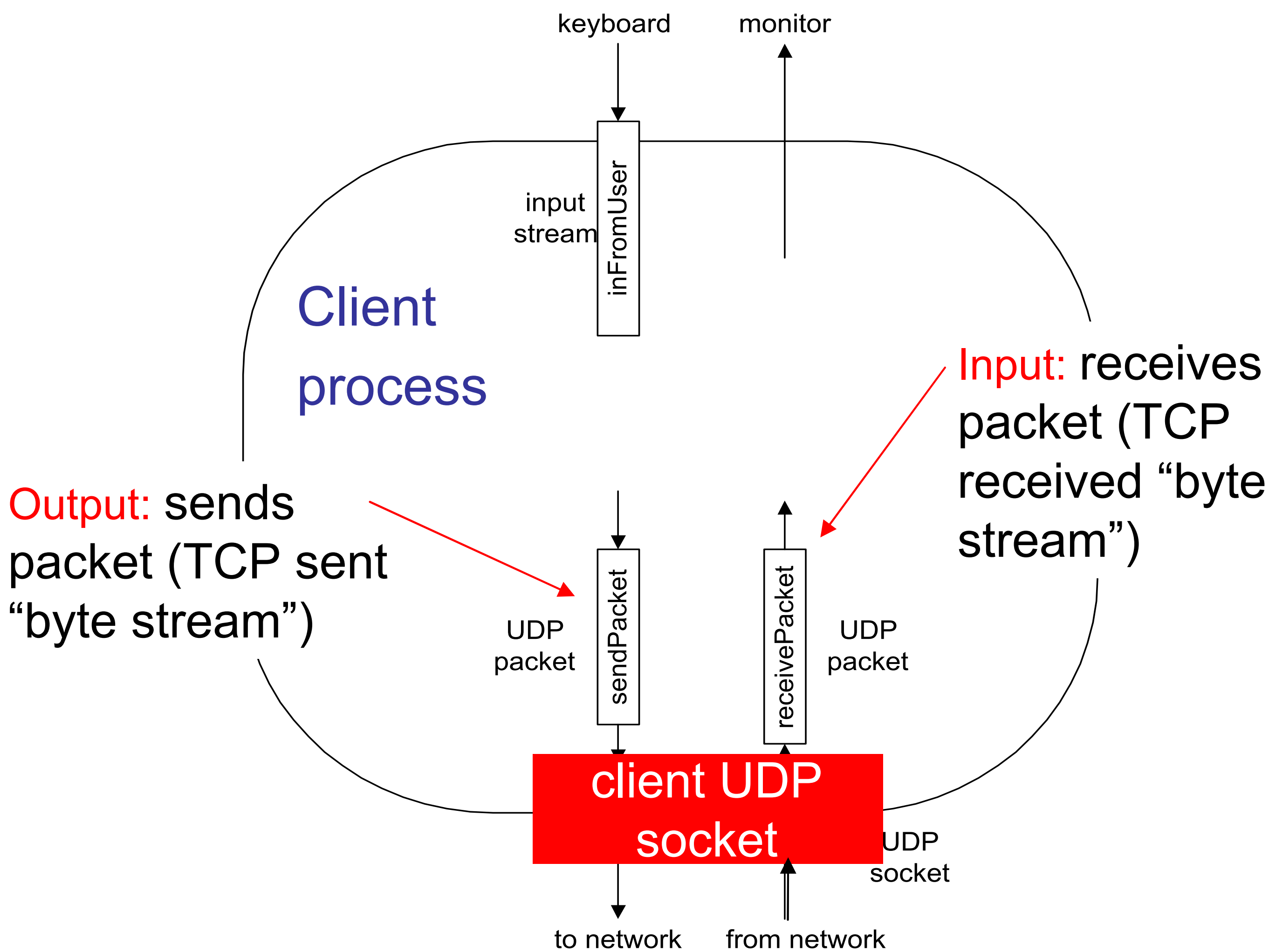
# *Threads*

- Threads are programming abstractions of separate activities
- Still need to worry about resources:
  - How many threads?
  - How long should each thread live for?
- Many programming patterns:
  - Thread-per-request
  - Worker pools
  - Etc.
- See distributed systems course for more on these

# Client/server socket interaction: UDP (Java)



# Example: Java client (UDP)



# Example: Java client (UDP)

Create input stream

Create client socket

Translate hostname to IP Address using DNS

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

class UDPClient {
    public static void main(String args[]) throws Exception
    {

      BufferedReader inFromUser =
        new BufferedReader(new InputStreamReader(System.in));

      DatagramSocket clientSocket = new DatagramSocket();

      InetAddress IPAddress = InetAddress.getByName("hostname");

      byte[] sendData = new byte[1024];
      byte[] receiveData = new byte[1024];

      String sentence = inFromUser.readLine();

      sendData = sentence.getBytes();
```

# Example: Java client (UDP), continued

Create datagram with data-to-send, length, IP addr, port

Send datagram to server

Read datagram from server

```
DatagramPacket sendPacket =
  new DatagramPacket(sendData, sendData.length, IPAddress, 9876);

clientSocket.send(sendPacket);

DatagramPacket receivePacket =
  new DatagramPacket(receiveData, receiveData.length);

clientSocket.receive(receivePacket);

String modifiedSentence =
   new String(receivePacket.getData());

System.out.println("FROM SERVER:" + modifiedSentence);
clientSocket.close();
}

}
```

# Example: Java server (UDP)

Create datagram socket at port 9876

Create space for received datagram

Receive datagram

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

class UDPServer {
  public static void main(String args[]) throws Exception
   {

      DatagramSocket serverSocket = new DatagramSocket(9876);

      byte[] receiveData = new byte[1024];
      byte[] sendData  = new byte[1024];

      while(true)
        {

          DatagramPacket receivePacket =
             new DatagramPacket(receiveData, receiveData.length);
          serverSocket.receive(receivePacket);
```

# Example: Java server (UDP), continued

```
String sentence = new String(receivePacket.getData());
```

Get IP addr port #, of sender

```
InetAddress IPAddress = receivePacket.getAddress();

int port = receivePacket.getPort();

        String capitalizedSentence = sentence.toUpperCase();

sendData = capitalizedSentence.getBytes();
```

Create datagram to send to client

```
DatagramPacket sendPacket =
  new DatagramPacket(sendData, sendData.length, IPAddress,
                     port);
```

Write out datagram to socket

```
serverSocket.send(sendPacket);
      }
    }
}
```

End of while loop, loop back and wait for another datagram

# *TCP Client in C step by step…*

- Create a socket
- Bind the socket
- Resolve the host name
- Connect the socket
- Write some data
- Read some data
- Close
- Exit

*General flavour: much lower level…*

# C API: `socket()`

```
#include <sys/types.h>
#include <sys/socket.h>
int socket(int domain, int type, int protocol);
                              ...
         int s = socket( AF_INET, SOCK_STREAM, 0);
```

*socket descriptor*: small integer (as with file descriptors)

*Address family* or *domain*: In this case IPv4.

*Service type* requested, e.g. **`SOCK_STREAM`** or **`SOCK_DGRAM`**.

*Protocol* within a service type; 0 ⇒ OS chooses: **`IPPROTO_TCP`** (often only one!)

# C API: Specifying local address

```
int bind(int s, const struct sockaddr *a, socklen_t len);
```

```
struct in_addr {
    u_int32_t s_addr;
};
```

IPv4 address: 4 bytes packed in an integer

```
struct sockaddr_in {
    short sin_family;
    u_short sin_port;
    struct in_addr sin_addr;
    char sin_zero[8];
};
```

- `sin_family`: Set to **`PF_INET`** (why?)
- `sin_port`, `sin_addr`: Port number and *local* address in *network endian* byte order
- `sin_zero`: Padding (why?)

*What is* **`bind()`** *actually for?*

# C API: Usage of `bind()`

```
struct sockaddr_in sa;

memset(&sa, 0, sizeof(sa);
sa.sin_family = PF_INET;
sa.sin_port = htons(0);
sa.sin_addr = htonl(INADDR_ANY);
If (bind (s, (struct sockaddr *)&sa, sizeof(sa)) < 0) {
    perror("binding to local address");
    close(s);
    return -1;
}
```

*Seems like a lot of work…*

# C sockets: resolving a host name

```
struct hostent *h;

h = gethostbyname(host)
if (!h || h->h_length != sizeof(struct in_addr)) {
    fprintf(stderr, "%s: no such host\n", host);
    return -1;
}
```

Result: `h->h_addr` points to the address of the machine we want to talk to.

# C API: Connecting (finally!)

```
struct sockaddr_in sa;

sa.sin_port = htons(port)
sa.sin_addr = *(struct sockaddr *)h->h_addr;

if (connect (s, (struct sockaddr *)&sa, sizeof(sa)) < 0 {
     perror(host);
     close(s);
     return -1;
}
```

Filled in from previous slide

Address structure gives all needed info about the remote end-point

# Sending and receiving data

```
ssize_t send(int s, const void *buf, size_t len, int flags);
```

- With no flags (0), equivalent to `write( s, buf, len )`

```
ssize_t recv(int s, void *buf, size_t len, int flags);
```

- With no flags, equivalent to `read( s, buf, len )`

```
ssize_t sendto(int s, const void *buf, size_t len, int flags,
               const struct sockaddr *to, socklen_t tolen);

ssize_t recvfrom(int s, void *buf, size_t len, int flags,
                 struct sockaddr *from, socklen_t *fromlen);
```

- And these two are for… ?

## *Putting it all together – the "W" client.*

# *TCP server programming in C*

```
int listen(int sockfd, int backlog);
```

- Takes a bound (but not connected!) socket
- Turns it into a listener for new connections
- Returns immediately
- **`backlog`**: number of outstanding connection attempts
  - See **`accept()`** on next slide
  - Traditionally, 5 (not any more…)
- What do you do with a listening socket?

# *TCP server programming in C*

```
int accept(int sockfd,
           struct sockaddr *addr, socklen_t *addrlen);
```

- Takes a listening socket sockfd
- Waits for a connection request, and accepts it (!)
  - You don't get to say "no"…
- Returns a *new* socket for the connection
  - Plus the address of the remote peer

# *TCP server: example pattern*

1. Create a server socket and bind to a local address
2. Call listen()
3. Loop:
    1. Call accept() and get a new (“connection”) socket back
    2. Read client‘s request from the connection socket
    3. Write response back to the connection socket
    4. Close the connection socket

- See real example server...

# *Asynchronous programming:* `O_NONBLOCK`

```
if ((n = fcntl (s, F_GETFL)) < 0
  || fcntl(s, F_SETFL, n | O_NONBLOCK) < 0) {
  perror("O_NONBLOCK");
}
```

Socket descriptor now behaves differently:

- **`read/recv`**: as normal if there is data to read. EOF returns `0`. Otherwise, returns `-1` and **`errno`** set to **`EAGAIN`**.
- **`write/send`**: if data cannot yet be sent, returns `-1` and **`errno = EAGAIN`**
- **`connect`**: if no immediate success, returns `-1` and **`errno = EINPROGRESS`**
- **`accept`**: if no pending connections, returns `-1` and **`errno = EWOULDBLOCK`**

# *Asynchronous programming:* `select()`

```
int select(int nfds,
           fd_set *readfds,
           fd_set *writefds,
           fd_set *exceptfds,
           struct timeval *timeout);
```

Sets of file descriptors to watch for activity

```
void FD_CLR(int fd, fd_set *set);
int FD_ISSET(int fd, fd_set *set);
void FD_SET(int fd, fd_set *set);
void FD_ZERO(fd_set *set);
```

- Returns when anything happens on any set file (i.e. socket) descriptor, or the timeout occurs.
- The fd_sets are modified to indicate fds that are active%%

# A basic event loop

- Operations to register callbacks for
  - File (socket) descriptors
  - Timeout events
- Map from socket descriptor $\rightarrow$ callback
- Priority queue of timer events
- Loop:
  - Process timeouts
  - Call select with next timeout
  - Process any active socket descriptors

# *Event programming:*

- Event programming is hard
  - Callbacks ⇒ need to maintain state machine for each activity (“stack ripping”)
  - Anything that blocks has to be handled with a callback
  - Hard to deal with long-running operations
- But…
  - No need for synchronization (at least, with one processor)
  - *Very* scalable (only one thread)
  - Model similar to interrupts ⇒ close to how one needs to implement a practical networking stack

# More information on TCP and C

- Upcoming labs…

- Some of this material is from the excellent:

  "Using TCP Through Sockets",

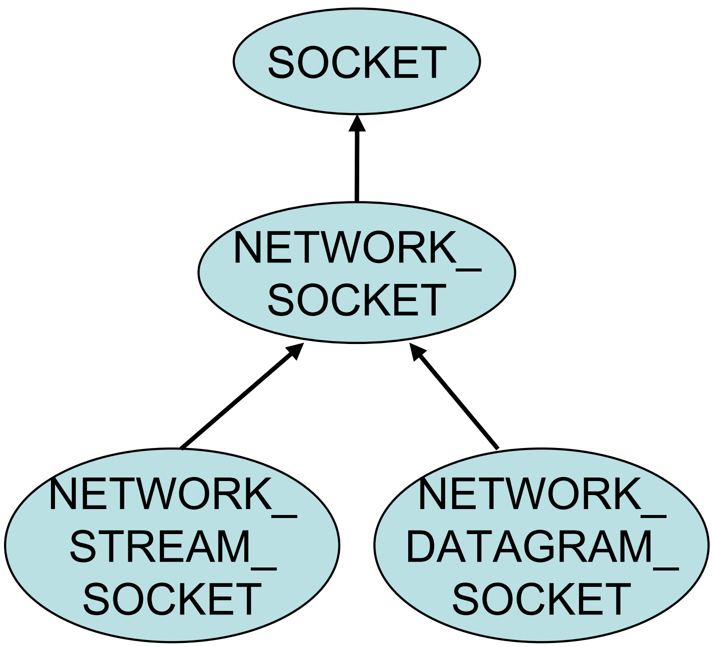
  by David Mazières, Frank Dabek, and Eric Peterson.

  http://people.inf.ethz.ch/troscoe/teaching/net2-1.pdf

# *Finally…*

- Backup slides also cover Eiffel networking classes
  - Exercises/labs will be Java and C
  - Eiffel abstracts events into “pollers” and related objects
- Next week:
  - Java development
  - Eclipse tutorial for Java and C
- Then:
  - Transport protocols.

# EiffelNet: Sockets and communication modes




- Two modes of socket communication:
  - stream communication
  - datagram communication
- Stream socket:
  - provided by the STREAM_classes
  - provides sequenced communication without any loss or duplication of data
  - *synchronous*: the sending system waits until it has established a connection to the receiving system and transmitted the data
- Datagram socket:
  - provided by the DATAGRAM_classes
  - *asynchronous*: the sending system emits its data and does not wait for an acknowledgment
  - efficient, but it does not guarantee sequencing, reliability or non-duplication

# Example: Eiffel Server (TCP - stream socket)

```
class  OUR_SERVER
inherit
            SOCKET_RESOURCES
            STORABLE
create
            make
feature
            soc1, soc2: NETWORK_STREAM_SOCKET
            make (argv: ARRAY [STRING])  is
              local
                    count: INTEGER
              do
                    if argv.count /= 2 then
                         io.error.putstring ("Usage: ")
                         io.error.putstring (argv.item (0))
                         io.error.putstring ("portnumber")
                    else
                         create soc1.make_server_by_port (argv.item (1).to_integer)
                         from
                              soc1.listen (5)
                              count := 0
                           until
                              count := 5
                         loop
                              process
                              count := count + 1
                         end
                         soc1.cleanup
                    end
                rescue  soc1.cleanup
                end
```

CLIENT:

1) Sends to the server a list of strings
5) Receives the result from the server and print it

SERVER:

2) Receives the corresponding object structure
3) Appends to it another string
4) Returns the result to the client

Accepts communication with the client and exchange messages

Create server socket on 'portnumber'

Listen on socket for at most '5' connections

- Accepts communication with the client
- Receives a message from the client
- Extends the message
- Sends the message back to the client

Closes the open socket and frees the corresponding resources

# Example: Eiffel Server (TCP), contd.

Receives a message from the client, extend it, and send it back.

```
process is
    local
        our_new_list: OUR_MESSAGE
    do
        soc1.accept
        soc2 ?= soc1.accepted
        our_new_list ?= retrieved (soc2)

        from
            our_new_list.start
        until
            our_new_list.after
        loop
            io.putstring (our_new_list.item)
            our_new_list.forth
            io.new_line
        end

        our_new_list.extend ("Server message. %N")
        our_new_list.general_store (soc2)
        soc2.close
    end
end
```

- the server obtains access to the server
- *accept* - ensures synchronization to with the client
- *accept* - creates a new socket which is accesible through the attribute *accepted*
- the *accepted* value is assigned to *soc2* - this makes *soc1* available to accept connections with other clients

The message exchanged between server and client is a linked list of strings

```
class OUR_MESSAGE

inherit
        LINKED_LIST
[STRING]
        STORABLE
        undefine
            is_equal, copy
        end

create
        make
end
```

Extends the message received from the client

Sends the extended message back to the client

Closes the socket

# Example: Eiffel Client (TCP - stream socket)

```
class  OUR_CLIENT
inherit
            NETWORK_CLIENT
                redefine
                    received
                end
create
            make_client
feature
            our_list:  OUR_MESSAGE
            received: OUR_MESSAGE

            make_client (argv: ARRAY [STRING])  is
                -- Build list, send it, receive modified list, and
print it.
                do
                    if argv.count /= 3 then
                      io.error.putstring ("Usage: ")
                      io.error.putstring (argv.item (0))
                      io.error.putstring ("hostname portnumber")
                 else
                      make (argv.item (2).to_integer, argv.item (1))
                      build_list
                      send (our_list)
                      receive
                      process_received
                      cleanup
                 end
                rescue
                 cleanup
                end
            ...
```

The message exchanged between server and client

1. Creates a socket and setup the communication

2. Builds the list of strings

3. Sends the list of strings to the server

4. Receives the message from the server

5. Prints the content of the received message

6. Closes the open socket and free the corresponding resources

# Example: Eiffel Client (TCP ), continued

```
build_list is
 do
       create our_list.make
       our_list.extend ("This ")
       our_list.extend ("is ")
       our_list.extend (“a")
       our_list.extend ("test.")
 end

process_received is
 do
       if received = Void then
              io.putstring ("No list received.")
       else
              from received.start until received.after loop
                     io.putstring (received.item)
                     received.forth
              end
       end
 end
end
```

Builds the list of strings ‘our_list’ for transmission to the server

Prints the content of the received message in sequence

# Example: Eiffel Server (UDP - datagram socket)

```
class OUR_DATAGRAM_SERVER
create
        make
feature
        make (argv: ARRAY [STRING]) is
            local
                soc: NETWORK_DATAGRAM_SOCKET
                ps: MEDIUM_POLLER
                readcomm: DATAGRAM_READER
                writecomm: SERVER_DATAGRAM_WRITER
            do
                if argv.count /= 2 then
                    io.error.putstring ("Usage: ")
                    io.error.putstring (argv.item (0))
                    io.error.putstring (" portnumber")
                else
                    create soc.make_bound (argv.item (1).to_integer)
                    create ps.make

                    create readcomm.make (soc)
                    ps.put_read_command (readcomm)
                    create writecomm.make (soc)
                    ps.put_write_command (writecomm)
                    . . .
```

1. Creates read and write commands
2. Attach them to a poller
3. Set up the poller for execution

Creates a network datagram socket bound to a local address with a specific port

Creates poller with multi-event polling

1. Creates a read command which it attaches to the socket
2. Enters the read command into the poller
3. Creates a write command which it attaches to the socket
4. Enters the write command into the poller

# Example: Eiffel Server (UDP), continued

```
          . . .
                ps.make_read_only
                  ps.execute (15, 20000)
                ps.make_write_only
                ps.execute (15, 20000)
                soc.close
            end
        rescue
            if not soc.is_closed then
                soc.close
            end
        end
end
```

1. Sets up the poller to accept read commands only and then executes the poller -- enable the server to get the read event triggered by the client's write command

2. Reverses the poller's set up to write-only, and then executes the poller

Monitors the sockets for the corresponding events and executes the command associated with each event that will be received

# Example: Eiffel Client (UDP - datagram socket)

```
class  OUR_DATAGRAM_CLIENT

create
        make
feature
        make (argv: ARRAY [STRING])  is
            local
                soc: NETWORK_DATAGRAM_SOCKET
              ps: MEDIUM_POLLER
              readcomm: DATAGRAM_READER
              writecomm: CLIENT_DATAGRAM_WRITER
            do
              if argv.count /= 3 then
                   io.error.putstring ("Usage: ")
                   io.error.putstring (argv.item (0))
                   io.error.putstring ("hostname portnumber")
              else
                   create soc.make_targeted_to_hostname
                                (argv.item (1), argv.item
(2).to_integer)
                   create ps.make

                   create readcomm.make (soc)
                   ps.put_read_command (readcomm)
                   create writecomm.make (soc)
                   ps.put_write_command (writecomm)
                   . . .
```

1. Create read and write commands
2. Attach them to a poller
3. Set up the poller for execution

Command executed in case of a read event

Command executed by the client when the socket “is ready for writing”

Create a datagram socket connected to ‘hostname’ and ‘port’

Creates poller with multi-event polling

1. Creates a read command which it attaches to the socket
2. Enters the read command into the poller
3. Creates a write command which it attaches to the socket
4. Enters the write command into the poller

# Example: Eiffel Client (UDP), continued

```
                . . .
                ps.make_write_only
                ps.execute (15, 20000)
                ps.make_read_only
                ps.execute (15, 20000)
                soc.close
            end
        rescue
            if not soc.is_closed then
                soc.close
            end
end
```

1. Sets up the poller to write commands only and then executes the poller

2. Reverses the poller's set up to accept read commands only, and then executes the poller -- enables the client to get the read event triggered by the server's write command

Monitors the sockets for the corresponding events and executes the command associated with each event that will be received

# Example: Eiffel Command class (UDP)

```
class  OUR_DATAGRAM_READER

inherit
        POLL_COMMAND
        redefine
                active_medium
        end

create
        make
feature
        active_medium:
NETWORK_DATAGRAM_SOCKET

        execute (arg: ANY)  is
              local
                 rec_pack: DATAGRAM_PACKET
               i: INTEGER
              do
               rec_pack := active_medium.received (10, 0)
               io.putint (rec_pack.packet_number)
               from i := 0 until i > 9 loop
                    io.putchar (rec_pack.element (i))
                    i := i + 1
               end
              end
end
```

## Commands and events:

• Each system specify certain communication events that it wants to monitor, and certain commands to be executed on occurrence of the specified events

• The commands are objects, instances of the class POLL_COMMAND

• The class POLL_COMMAND has the procedure *execute* which executes the current command

## Command classes:

• OUR_DATAGRAM_READER – represents operations that must be triggered in the case of a read event

• CLIENT_DATAGRAM_WRITER – command executed by the client when the socket “is ready for writing”

• SERVER_DATAGRAM_WRITER – command executed by the server when the socket “is ready for writing”

Receive a packet of size 10 characters

Prints the packet number of the packet

Prints all the caracters from the packet

# Example: Eiffel Command class (UDP), contd.

```
class  CLIENT_DATAGRAM_WRITER
inherit
        POLL_COMMAND
        redefine
                active_medium
        end

create
        make
feature
        active_medium:
NETWORK_DATAGRAM_SOCKET

        execute (arg: ANY)  is
            local
                sen_pack: DATAGRAM_PACKET
                char: CHARACTER
            do
                -- Make packet with 10 characters ‘a’ to
‘j’
                -- in succesive positions
                create sen_pack.make (10)
                from char := ‘a’ until char > ‘j’ loop
                    sen_pack.put_element (char |-| ‘a’)
                    char := char.next
                end
                sen_pack.set_packet_number (1)
                active_medium.send (sen_pack, 0)
            end
end
```

Command executed by the client when the socket “is ready for writing”

```
class  SERVER_DATAGRAM_WRITER
inherit
        POLL_COMMAND
        redefine
                active_medium
        end

create
        make
feature
        active_medium:
NETWORK_DATAGRAM_SOCKET

        execute (arg: ANY)  is
            local
                sen_pack: DATAGRAM_PACKET
                i: INTEGER
            do
                -- Make packet with 10 characters ‘a’ in
                -- succesive positions
                create sen_pack.make (10)
                from i := 0 until i > 9 loop
                    sen_pack.put_element (‘a’, i)
                    i := i + 1
                end
                sen_pack.set_packet_number (2)
                active_medium.send (sen_pack, 0)
            end
end
```

Command executed by the server when the socket “is ready for writing”