COMP90015 Distributed Systems

Interprocess Communication

School of Computing and Informati

2022 Semester II

1. Abstract IPC
   - Data Exchange
   - Mechanisms of IPC
   - Communication Protocols and Interactions
   - Da
2. Socke
   - Network Communication
   - Network Address
   - Stream
   - Datagram

Application/User-level Data Exchange

IPC is the exchange of data between processes.

- Processes arrange data into data structures, often leading to a quite complex and significantly large aggregate structure representing an application's state.
- Data must be transferred from persistent storage, or files, into memory in order for the process to work on it, and results must be transferred back to the persist s lifetime.
- Ostens ng to the same fi
  - file loc
  - if a distributed file system is available (discussed in later lectures) then the same file can be accessible from processes on different machines,
  - vastly different applications can exchange data in this way, e.g or can exchange data with an Email Client,
  - OS user interfaces often provide user-level mechanisms for ex ween processes, e.g. cut-and-paste between applications.

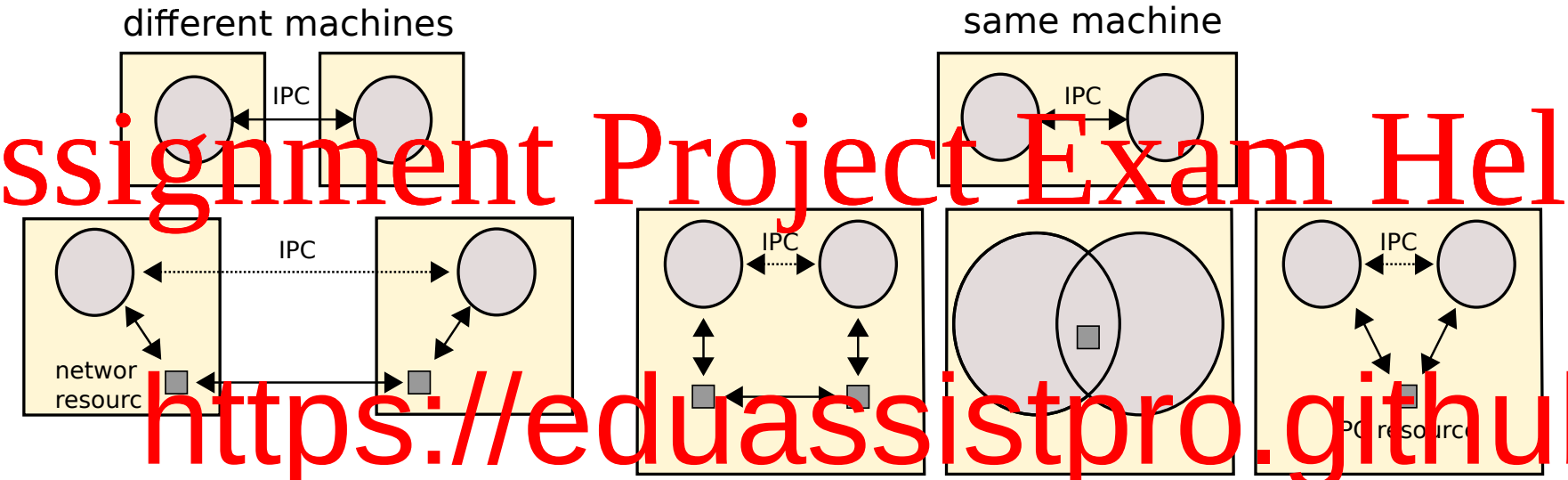
However these high-level, somewhat ad-hoc IPC approaches can be grossly inefficient, sometimes ill-defined and downright dangerous to make use of, compared to functionality specifically provided by the OS to undertake IPC.

Data Format

Whether high-level data is exchanged in ad-hoc ways or using specific IPC mechanisms, the data format and more specifically the data structures and representations used by the application process, as well as the application or user requirements that drive the need for data exchange in the first place, can s ign of the distribut

- file trans
- data entry, databases – high iops and throughput
- audio and video streaming – high throughput and high qu
- instant chat, voice and video conferencing – interactive
- collaborative document editing – complex interactio
- remote user interface and control – responsive, light weight
- online games – low latency, responsive

The availabilty of IPC mechanisms is determined by the process locations



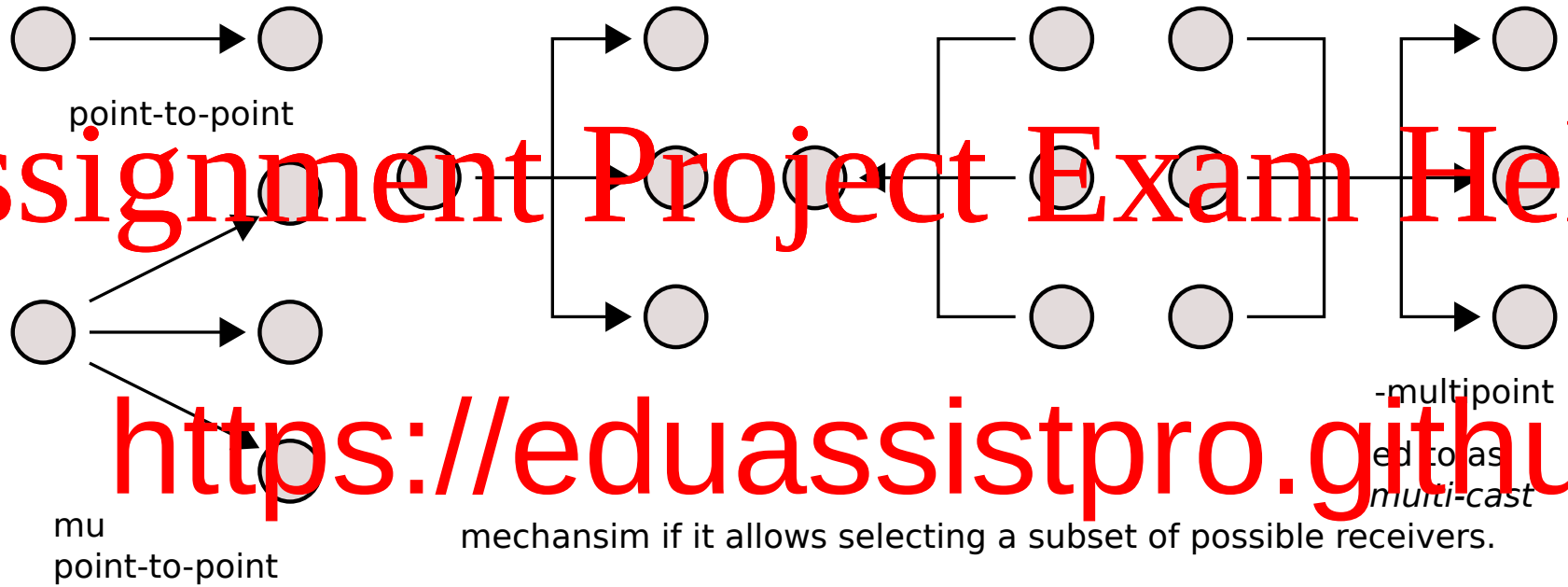
- Unlike threads within a process that share the same addre an refer to the same data, the address space of processes are ini ive and for processes to refer to the same data they must communi ta to each other somehow.
  - Network-based IPC can take place between processes on diff between processes on the same machine – processes need not know if they are local or remote to each other.
  - Shared Memory IPC can only take place between processes on the same machine – it is the fastest form of IPC, much like thread interaction within a process.
  - Other forms of IPC resources like Pipes and Memory Mapped IO are also only available between processes on the same machine – they are faster than network-based IPC.
  - Shared Memory, Pipes and Memory Mapped IO are usually quite OS specific: we can study them later as an advanced topic.

Open Systems Interconnection (OSI) model

With respect to Network IPC, we consider distributed systems that are based upon functionality associated with the Transport Layer of the OSI model. The Transport Layer provides mechanisms for host-to-host or point-to-point interprocess communication over a network. At the Session Layer we make use of these mechanisms to implement long-running communication protocols that support the requirements of the Application Layer. In be ta
represen rm
suitable fo

- **Applic** nd
  Email, supporting services like the Domain Name Service (DNS) and the Network Time Protocol (NTP), and middleware like publish/subscribe systems.
- **Presentation Layer**: Data representations of com
- **Session Layer**: Long-running communication pr ion
  requirements.
- **Transport Layer**: Host-to-Host communication services for applications; primarily TCP and UDP.
- Network Layer: Packet forwarding and routing through the network.
- Data Link Layer: Packet transmission from one device to another.
- Physical Layer: Data transmission over a communication channel.

Multi-party Communication



- Usually we consider IPC to be between 2 processes/part *int*.
- Communication between 3 or more parties is usually co ple, independent point-to-point communications.
- However multi-party communication mechanism ble that can be more efficient than using multiple point-to-point IPCs:
  - UDP provides *point-to-multipoint* communication, where a process can send a single packet, replicated by the network as required, and delivered to multiple processes. Multiple point-to-point would require the sending process to send the same packet multiple times.
  - Multipoint-to-point and multipoint-to-multipoint are less common. In this case the IPC mechanism must provide some kind of aggregation of communication that is more efficient that using multiple point-to-point or point-to-multipoint IPCs.

Discussion questions

Question (1): What kind of application functionality do you think would be suitable for multipoint-to-point and/or multipoint-to-multipoint IPC mechanisms? For the functionality that you discussed, without such multipoint IPC mechanisms, how many individual messages would need to be sent usin ve the same function solution?

Questio somethi nsmit a signal that is received (practically) simultaneously b h a wireless broadcast mechanism cannot provide mul tion. Why not? In what situations could it be provided if any?

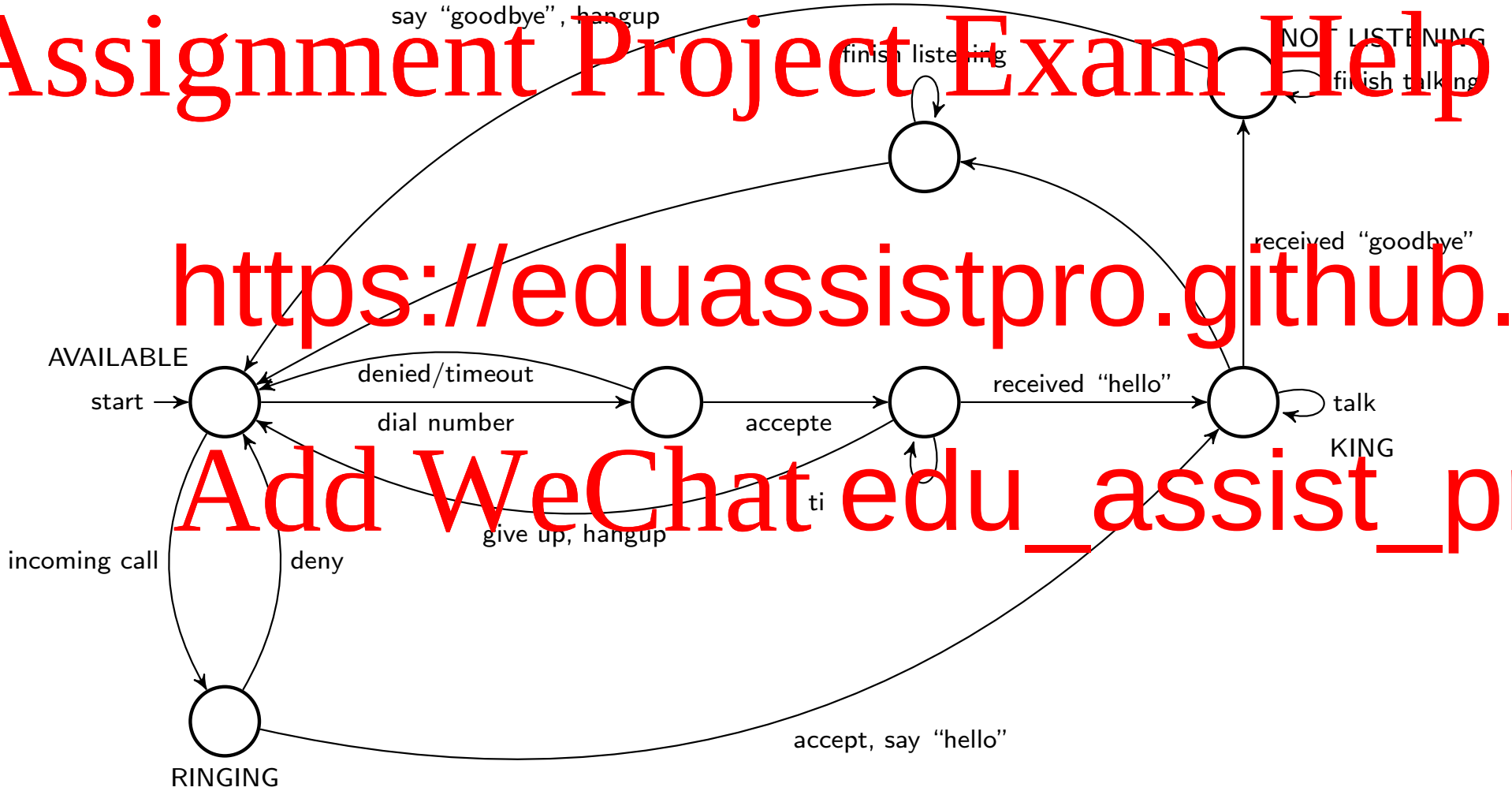
Question (3): Shared memory can be established between more than 2 processes, if those processes are on the same machine, i.e. 3 processes can address the same physical memory location. Is this point-to-multipoint or multipoint-to-point or multipoint-to-multipoint or something else? Justify your answer.

Communication Protocols

A *communication protocol* defines a deterministic, potentially unbounded sequence of interactions between a number of communicating parties. The purpose of the protocol is to define how the parties can systematically interact in order to effectively communicate given some existing commun

- A comm t a
  protoc minates
- Comm ower as a
  Finite State Machine (FSM):
  - A party engaged in communication is in one of several states defi ocol, or is transitioning from one state to another.
  - State transitions are triggered by events in the environment or b ch as communicating parties, e.g. data is received, data is sent, or oth timeouts.
  - Communication protocols apply to *all* layers of a distributed system, from the lowest layer (Physical Layer) to the highest layer (Application or User Layer).

Telephone Communication Protocol



Discussion questions

Consider the Telephone Communication Protocol.

Question (4): Explain what happens if an incoming call arises when the person is TALKING.

Questio

the same ti ng it with a number of k at a time.

Question (6): What *communication errors* protocol? What common telephone communicati ndled by the protocol? Expand the protocol by including new dle one of the communication errors that you discussed.

Question (7): Explain why there are states where the person is either NOT TALKING or NOT LISTENING.

Interaction Diagrams

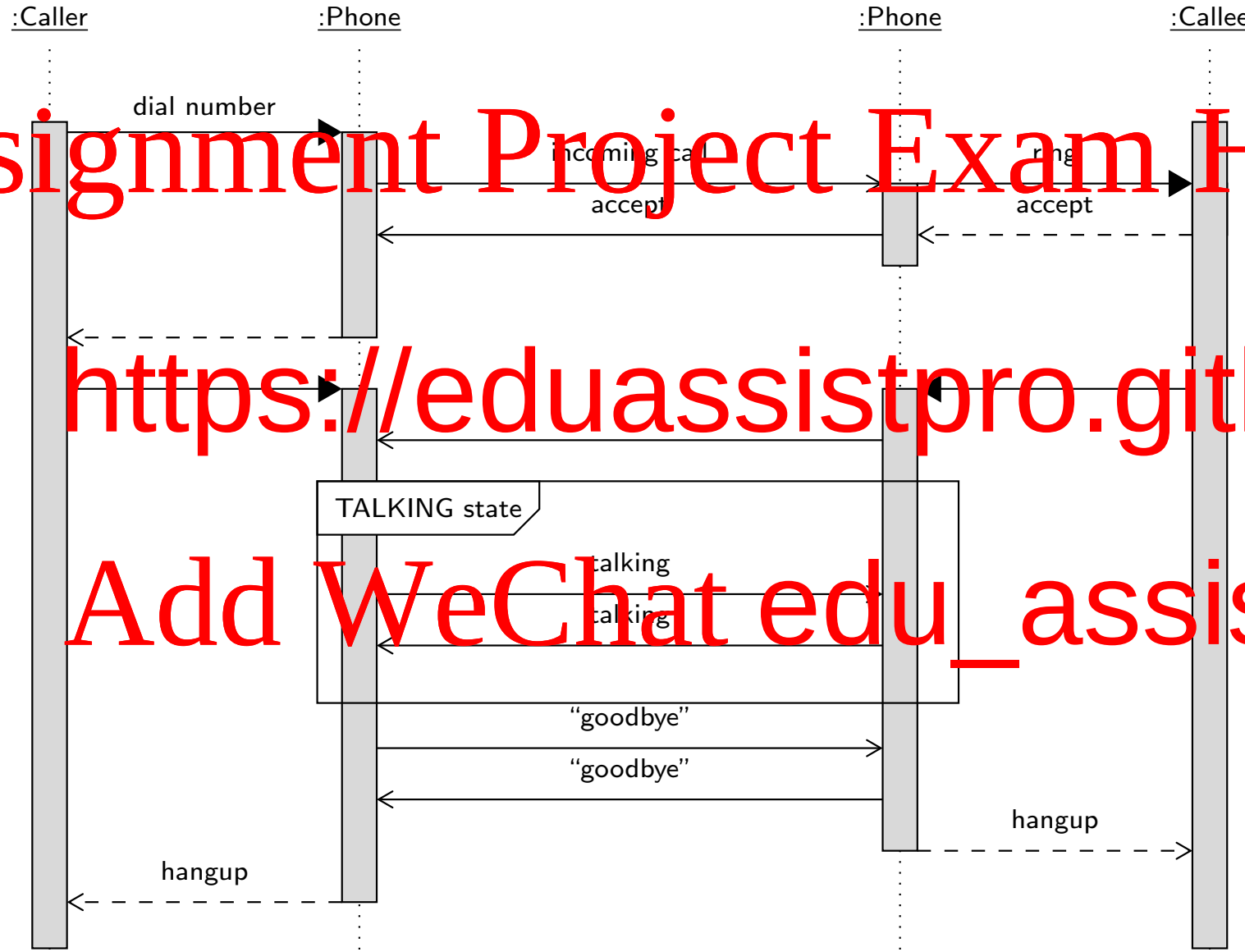
https://www.omg.org/spec/UML

It is sometimes helpful to represent sequences of interactions between communicating parties, arising from a communication protocol, using a sequence or *interaction diagram*, sometimes called an event diagram.

- The inte ime sequen
- Paralle f threads and oth thod calls and mes
  - A solid arrow head represents a *synchronous* ope l the operation completes (returns) before it can continue.
  - A Hollow arrow head represents an *asynchronou* continue without having to wait for the operation's outcome.
  - Activation boxes on the timelines show activity being undert

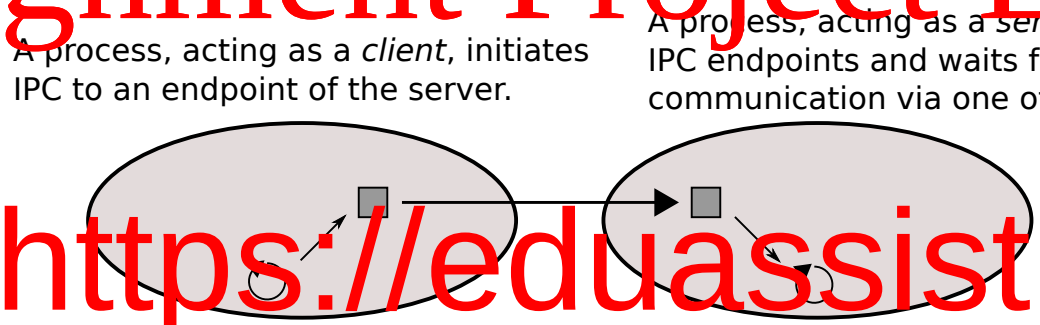
In this subject we make use of UML when its convenient and useful to do so, however we are not concerned with a rigorous treatment of UML techniques – that would be of interest in Software Engineering.

An interaction arising from the Telephone Communication Protocol



Caller/Callee ⇒ Client/Server roles

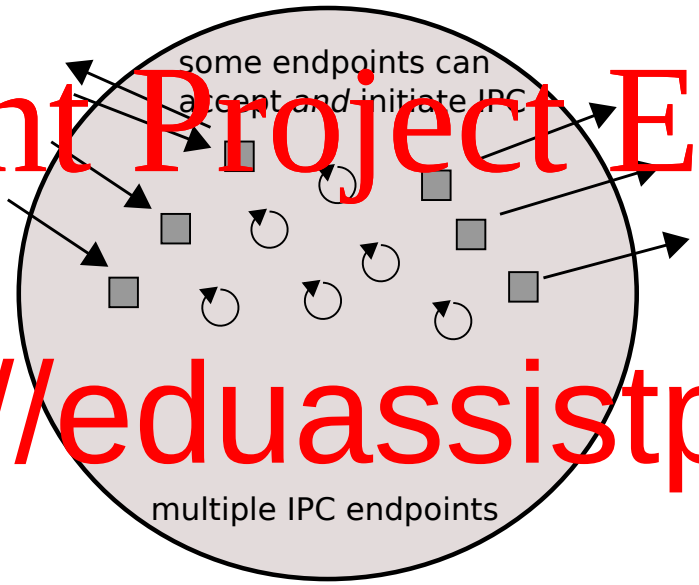
Two communicating parties take on roles depending on who initiates the communication



- IPC endpoints are resources provided by the OS.
- IPC requires a process to act as a *server*, whi acting as a *client*, to initiate IPC.

- The server's endpoint must be known *a prior*
- A process that acts only as a client does not allow other processes to initiate IPC to it and we typically call it a *client process* or *client*.
- A process that acts only as a server never initiates IPC to other processes and we typically call it a *server process* or *server*.

A process can be both a client and server



A process may act as both a client and a server, allowing processes to initiate IPC to it, and also initiating IPC to other processes

- A server in a multi-server achitecture may receive connections from clients but also make/receive connections to/from other servers.
- A *peer*, in a file sharing system may act as a client and make connections to the file index servers, but may also act as a server and allow other peers to connect to it.

Session Layer

The protocols that allow the communicating parties to initiate communication, provide the rules that they must follow to communicate data, and the rules for terminating the communication, are expressed in the **Sess**

- A *sessi* nge of large ar
- Sessio rules of the session, e.g. to support different protocols, data formats and algorithms used throughout the session.
- Sessions typically allow an unbounded amount of com ace, or as allowed by the negotiated protocols. The session pro cify how and when the different kinds of data will be transmitte
- Sessions have a well defined termination, rather than the communicating parties simply ceasing to communicate.

Presentation Layer

Whatever the high level format of data to be communicated, IPC will ultimately lead to that data being represented as an *array of bytes*, either as a fixed (known) size array, e.g. when the source of the data is a file or data struc the source of the data is ta. Perhaps the only exc a may be commun case we know that all data is represented in the machine as information

The **Presentation Layer** is concerned with AP of high level data formats to byte arrays, in an *external data representation* that is agreed upon by the communicating parties, and *vice versa*, which is sometimes called *marshalling* and *unmarshalling* respectively.

Data Encodings

While the data is in its most basic form an array of bytes, how information is encoded into those bytes is called the data *encoding*, and there are a number of popular choices:

- *Text encodings* are used to represent textual information:
  - **ASCII**: The American Standard Code for Information Interchange is one of the first global stan pper and lowe rn, back bit to encode a rang ended alph
  - **Unicode**: The modern standard for representing text written in all of the world's languages. The Unicode standards inlude Unicode Transfo : UTF-8, UTF-16, and UTF-32, and several other encodings. U e standard encoding on the World Wide Web and on many OSes. T de points of UTF-8 represent ASCII encodings for backwards compati l code point is also a UTF-8 code point. Some UTF-8 code ponts use more t e.
- *Binary encodings* are used to represent non-textual information:
  - Primitive data types: integer, float, boolean
  - Executable data: machine code
  - Image, audio and video: JPEG, MP3, MP4
  - Compressed data: GZIP
  - Encrypted data: RSA, AES

ASCII CONTROL CODE CHART

b7 b6 b5 / BITS b4 b3 b2 b1	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
	CONTROL		SYMBOLS NUMBERS		UPPER CASE		LOWER CASE	
0 0 0 0	0 0 NUL 0	16 10 DLE 20	32 20 SP 40	48 30 0 60	64 40 @ 100	80 50 P 120	96 60 ‘ 140	112 70 p 160
0 0 0 1	1 1 SOH 1	17 11 DC1 21	33 21 ! 41	49 31 1 61	65 41 A 101	81 51 Q 121	97 61 a 141	113 71 q 161
0 0 1 0	2 2 STX 2	18 12 DC2 22	34 22 " 42	50 32 2 62	66 42 B 102	82 52 R 122	98 62 b 142	114 72 r 162
0 0 1 1	3 3 ETX 3	19 13 DC3 23	35 23 # 43	51 33 3 63	67 43 C 103	83 53 S 123	99 63 c 143	115 73 s 163
0 1 0 0	4 4 EO 4	20 14 2 24	36 24 52	52 34 68	68 44 84	84 54 100	100 64 116	116 74
0 1 0 1	5 5 EN 5	21 15 2 25						
0 1 1 0	6 6 AC 6	22 16 2 26						
0 1 1 1	7 7 BE 7	23 17 27	39 27 47	55 37 67	71 47 107	87 57 127	103 67 147	119 77 167
1 0 0 0	8 8 BS 10	24 18 CAN 30	40 28 (50	56 38 8 70	72 48 H 110	88 58 X 130	104 68 h 150	120 78 x 170
1 0 0 1	9 9 HT 11	25 19 EM 31	41 29) 51	57 39 9 71	73 49 I 111	89 59 Y 131	105 69 i 151	121 79 y 171
1 0 1 0	10 A LF 12	26 1A SUB 32	42 2A * 52	58 3A : 72	74 4A J 112	90 5A Z 132	106 6A j 152	122 7A z 172
1 0 1 1	11 B VT 13	27 1B ESC 33	43 2B + 53	59 3B ; 73	75 4B K 113	91 5B [133	107 6B k 153	123 7B { 173
1 1 0 0	12 C FF 14	28 1C FS 34	44 2C , 54	60 3C < 74	76 4C L 114	92 5C \ 134	108 6C l 154	124 7C | 174
1 1 0 1	13 D CR 15	29 1D GS 35	45 2D − 55	61 3D = 75	77 4D M 115	93 5D] 135	109 6D m 155	125 7D } 175
1 1 1 0	14 E SO 16	30 1E RS 36	46 2E . 56	62 3E > 76	78 4E N 116	94 5E ^ 136	110 6E n 156	126 7E ~ 176
1 1 1 1	15 F SI 17	31 1F US 37	47 2F / 57	63 3F ? 77	79 4F O 117	95 5F _ 137	111 6F o 157	127 7F DEL 177

LEGEND: dec / hex / oct / CHAR

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Data Formats

A data format is a syntax that describes how potentially arbitrary complex data and high-level semantics is assembled from encoded text and binary data:

- Complex data structures using text encodings: XML, JSON
- Text documents using text encodings: ASCII and UTF-8 files
- Forma
- Forma files
- Propri

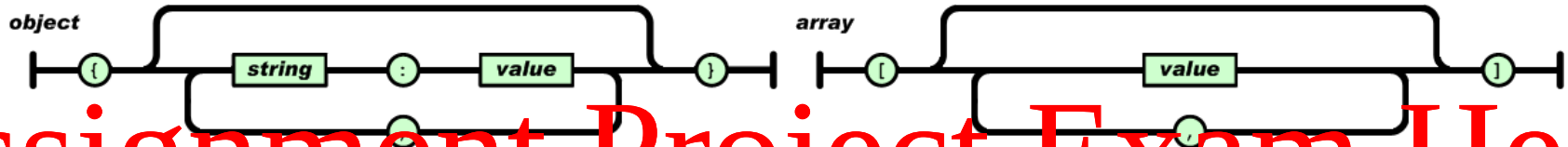
rmat, DOC

ion

Usually, data formats based on text encodings canno e binary encoded data, e.g. including a binary encoded i II file is not valid. However there are formats that allow mixi rent encodings:

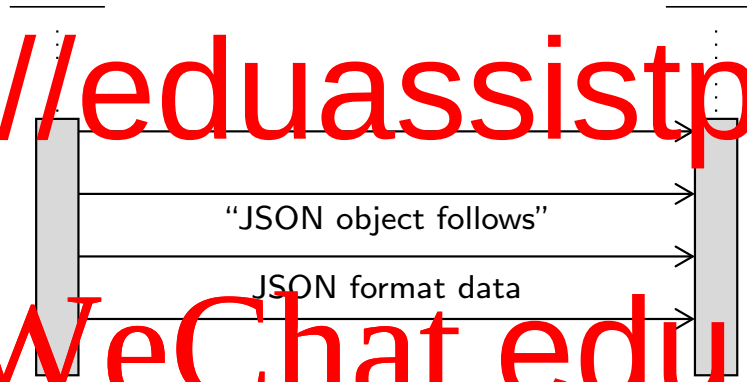
- Base64 encoding: encode binary data as text data.
- MIME: Multipurpose Internet Mail Extensions, uses Base64 encoding to allow email (which uses text encoded data) to effectively include images and other binary data.

Example: JSON Syntax Diagrams



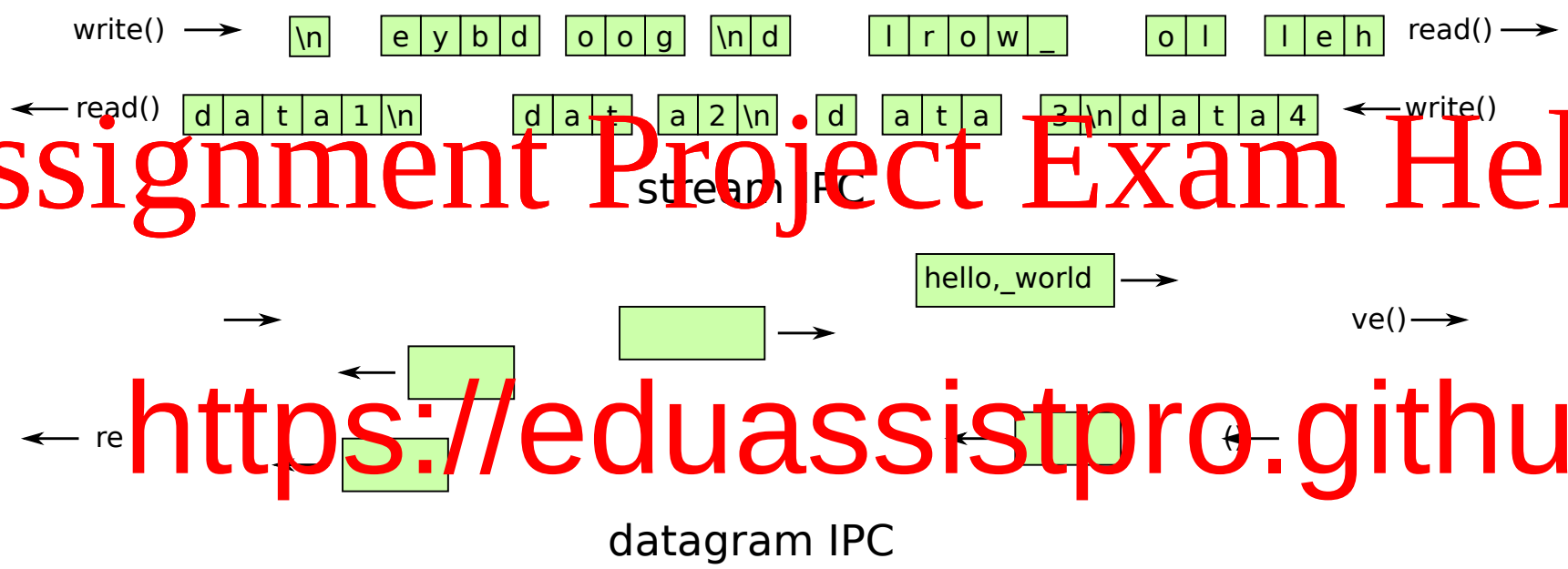
Data Protocol

The **Session Layer** protocols need to support communication of the desired data formats, so that e.g. the server knows what to expect and how to unmarshall or interpret the data that it receives.



Sometimes the encodings and data format are either implicit or possibly the protocol itself follows a data format such that there is little or no distinction between the protocol and the format.

Streams and Datagram IPC



- A stream is an *unbounded sequence* of data el ds primitive elements:
  - The sending process *writes* elements to the stream an elements from the stream.
  - Data elements are read in the same order that they are written.
  - No data corruption is allowed.
- A datagram is a *bounded or fixed size* data array:
  - The sending process *sends* the datagram to the receiver which *receives* it.
  - The order that datagrams are sent is not necessarily the order that they are received.
  - Datagram loss is assumed; not all datagrams sent are received.

POSIX Socket API

- The *Socket* paradigm is the dominant API for IPC over the Internet, originating with the 4.2BSD Unix OS, released in 1983.
- The Soc naged by the OS, b s well.
  - TCP
  - UDP
- The PO any OSes.
- On Microsoft Windows OSes, the WinAPI provides Wi similar to the POSIX standard.
- In this subject we use the Java VM and the Java Socket API for programming, which allows our programs to run on all co are/OS platforms with relatively few platform-specific code variations required.

Port Numbers

- Protocols such as TCP/UDP use a set of 2^{16} *ports*, numbered 0 to 65535, called *port numbers*, to identify individual processes or services on a machine.
- The OS manages access to port numbers: processes can request to be associated with them.
- All TCP/UDP based IPC always specifies an IP address and a port number as the destination.

20	File Transfer Protocol (FTP) Data Transfer
21	File TRansfer Protocol (FTP) Command Control
22	Secure Shell (SSH) Secure Login
23	Telnet remote login service, unencrypted text messag
25	Simple Mail Transfer Protocol (SMTP) email deliver
53	Domain Name System (DNS) service
67, 68	Dynamic Host Configuration Protocol (DHCP)
80	Hypertext Transfer Protocol (HTTP)
110	Post Office Protocol (POP3)
119	Network News Transfer Protocol (NNTP)
123	Network Time Protocol (NTP)
143	Internet Message Access Protocol (IMAP)
161	Simple Network Management Protocol (SNMP)
194	Internet Relay Chat (IRC)
443	HTTP Secure (HTTPS) HTTP over TLS/SSL

IP Address

- Each machine on the Internet or on a private network using the Internet Protocols has one or more network interfaces (typically Ethernet) and one or more assigned IP addresses that each associate to a given network interface on the machine. An interface may associate with multiple IP addresses.
- IPv4 is 4 b SPs is growin discuss
- An inter ne connec
- An interface with a private IP address can be reached by any n the same private network.
- Some addresses have special meaning:
  - `127.0.0.1` is a *loopback* address, any packet sent this a but rather is looped back to the machine itself, i.e. so that processe chine can use network communication to other processes on the same machine, without requiring an actual network interface.
  - `localhost` usually resolves to `127.0.0.1`
  - Some address ranges are reserved for private networks, including `10.0.0.0/8` and `192.0.0.0/24` and `192.168.0.0/16`

InetAddress class

The InetAddress class encapsulates an IP address and provides a range of helper methods.

InetAddress API: selected methods

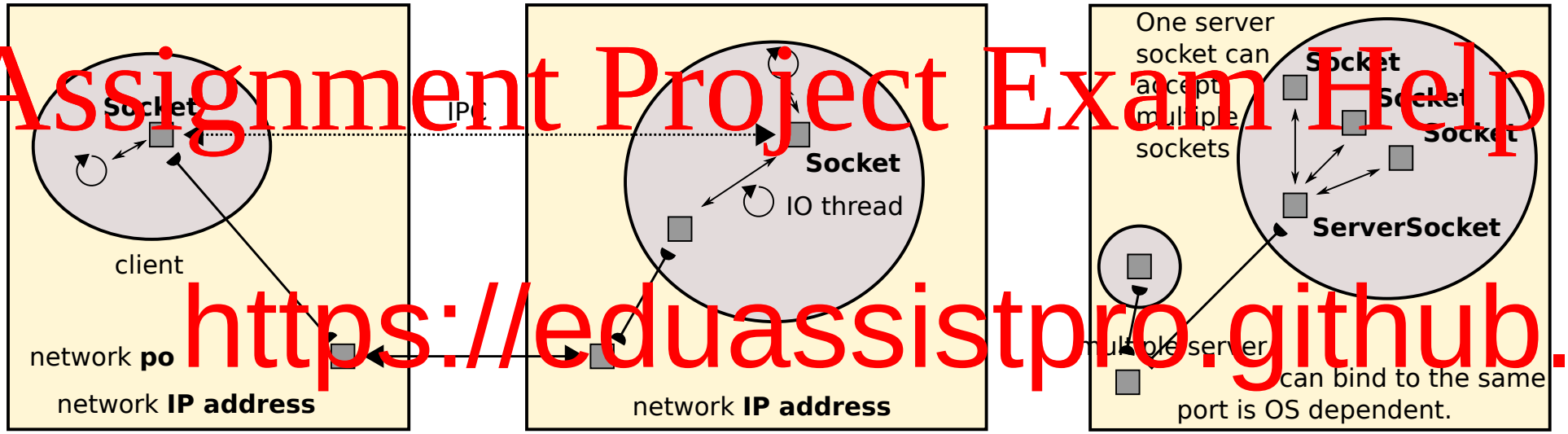
static InetAddress	getByName(String host) throws UnknownHostException Determine the IP address of a host, given the host's name. The host name can either be a dress. If a literal
static Ine	nos from
boolean	Test whether the address is reachable. Best effort is made by the implementation to try to reach the host, but firewalls and server configuration may block re achable status while some specific ports may be accessible. The ti , indicates the maximum amount of time the try should take. If the oper tting an answer, the host is deemed unreachable.
String	getHostName() Get the host name for this IP address. If this host name will be remembered and returned; otherwise, a reverse name lookup will be performed and the result will be returned based on the system configured name lookup service.
String	getCanonicalHostName() Get the *fully qualified domain name* for this IP address. Best effort method, meaning we may not be able to return the FQDN depending on the underlying system configuration.
String	getHostAddress() Return the IP address string in textual presentation.

Discussion questions

Review your understanding of computer networks to answer this question.

Question (8): A process running on a machine with a private IP address can initiat net if it knows the twork is connecte how can the machine on the public Internet initiate communicati e on the private network? Note that the private IP address is o e within the private network that the machine resides, and so mu ess in many different private networks may have the same pr ess.

Socket and ServerSocket

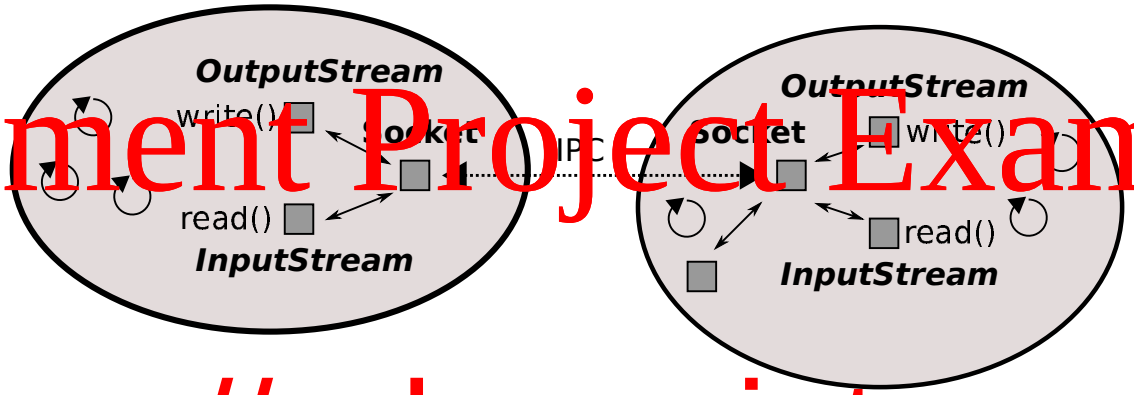


- The `Socket` and `ServerSocket` classes use T
- The server process creates a `ServerSocket` *port number* and network *IP address* on the machin
- The client process creates a `Socket` and *co* server's port number and IP address. The client's socket is also bound to a port number and IP address, which allows the server to respond.
- The `ServerSocket` creates a `Socket` for each incomming connection.
- The two processes communicate using a stream via their respective `Socket` objects.
- When communication is finished, the associated `Socket` objects are destroyed.

ServerSocket API: selected constructors and methods	
	`ServerSocket(int port) throws IOException` Create a server socket bound to the specified port. A port number of 0 means that the port number is automatically allocated. The maximum queue length for incoming connection indications (a request to connect) is set to 50. If a connection indication arrives when the queue is full, the connection is refused.
`Socket`	`accept() throws IOException` Listen for a connection to this socket and accept it. *Blocks* until a connection is made.
`void`	`close() throws IOException` Close this server socket. Any thread currently blocked in `accept()` will throw a `SocketException`.
`InetAddress`	`getInetAddress()` Get the *local* address of this server socket.
`int`	`getLocalPort()`

	os is null, it is the
`void`	Close the socket. Any thread currently blocked in an I/O operation upon this socket will throw a `SocketException`. Once a socket has been closed, it is not available for furt . can't be reconnected or rebound). A new socket needs to be created. C close the socke's InputStream and OutputStream.
`OutputStream`	getOutputStream() throws OException Return the socket's *output stream*. Closing the returned ket.
`InputStream`	`getInputStream() throws IOException` Return the socket's *input stream*. Closing the returned `InputStream` will close the associated socket.
`InetAddress`	`getInetAddress()` Return the *remote* address to which the socket is connected.
`InetAddress`	`getLocalAddress()` Return the *local* address to which the socket is bound.
`int`	`getPort()` Return the *remote* port number to which this socket is connected.
`int`	`getLocalPort()` Return the *local* port number to which this socket is bound.

Abstract InputStream and OutputStream classes



The Soc d
OutputStream for writing data, with byte streams as the most primitive concrete class:

- BufferedInputStream and BufferedOut reams,
- DataInputStream and DataOutputStrea *streams*,
- ObjectInputStream and ObjectOutputStream for *Java object streams*.

For example we can create a DataInputStream from any InputStream object:

```
DataInputStream dataInputStream = new DataInputStream(socket.getInputStream());
```

TCP Client Code Snippet

```
1   import java.net.*;
2   import java.io.*;
3   public class TCPClient {
4       public static void main (String args[]) {
5           Socket socket = null;
6           try{
7               int serverPort = 7899; // the known server port
8               socket = new Socket(args[1], serverPort);  // connect to the server
9               System.out.println("Connected to: "+socket.getInetAddress()+":"+socket.getPort());
10                                                                  InputStream()));
11                                                                    flush true
12
13
14
15
16                   * block until an exception occurs, aka hanging. */
17              String data = in.readLine(); // read a line of data fr
18              System.out.println("Received: "+data);
19          } catch (UnknownHostException e) {
20              System.out.println("The provided host could not be r
21          } catch (IOException e){
22              e.printStackTrace(); // most of the IO operations abov
23          } finally {
24              if(socket!=null) try {
25                  socket.close(); // will also close IO streams
26              } catch (IOException e){
27                  System.out.println("close: "+e.getMessage());
28              }
29          }
30      }
31  }
```

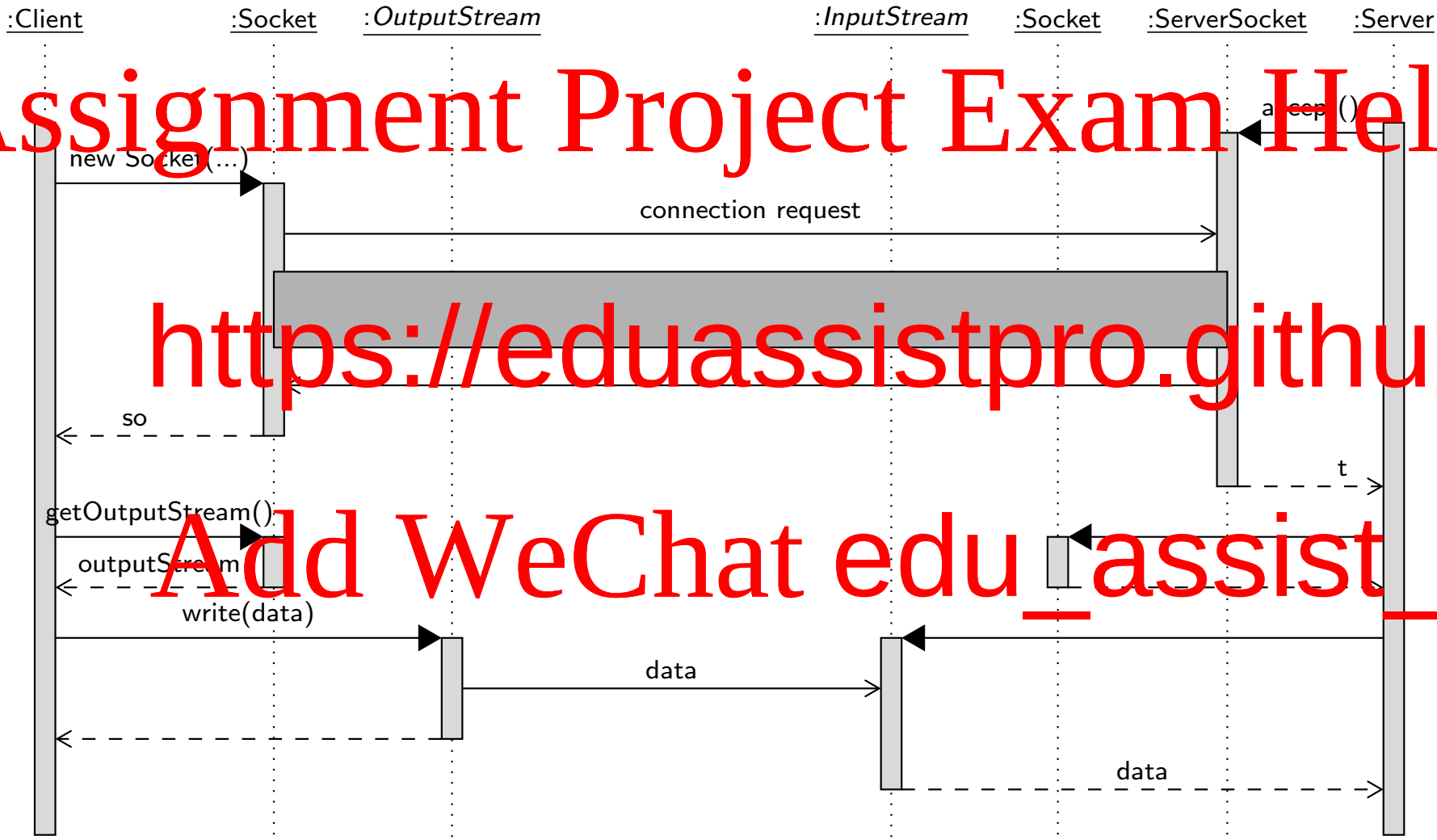
TCP Server Code Snippet

```
1   import java.net.*;
2   import java.io.*;
3
4   public class TCPServer {
5       public static void main (String args[]) {
6           try{
7               int serverPort = 7899; // the server port
8
9
10
11
12
13
14                  * an exception occurs. */
15              Socket clientSocket = serverSocket.acc
16              i++;
17              System.out.println("Received connection: "
18                  clientSocket.getInetAddress()+":"+
19              /* Hand the connection over to another (threaded) obje
20              Connection c = new Connection(clientSo
21          }
22      } catch(IOException e) {
23          e.printStackTrace()
24      }
25      }
26  }
```

Connection Code Snippet

```
1   class Connection extends Thread {
2       BufferedReader in;
3       PrintWriter out;
4       Socket clientSocket;
5       public Connection (Socket clientSocket) {
6           try {
7               this.clientSocket = clientSocket;
8               in = new BufferedReader( new InputStreamReader(clientSocket.getInputStream()));
9               out = new PrintWriter( clientSocket.getOutputStream(),true);
10
11
12
13
14      }
15      pu
16          try { // an echo server
17              System.out.println("server reading data");
18              /* The following blocks until the client writes a line of data
19               * If the client fails to write a line then this line blocks unti
20                 an exception is thrown. */
21              String data = in.readLine(); // read a line of data fr
22              System.out.println("server writing: "+data
23              out.println(data);
24          } catch(IOException e) {
25              e.printStackTrace();
26          } finally {
27              try {
28                  clientSocket.close();
29              } catch (IOException e){/*close failed*/}
30          }
31      }
32  }
```

Simplified client/server socket interaction

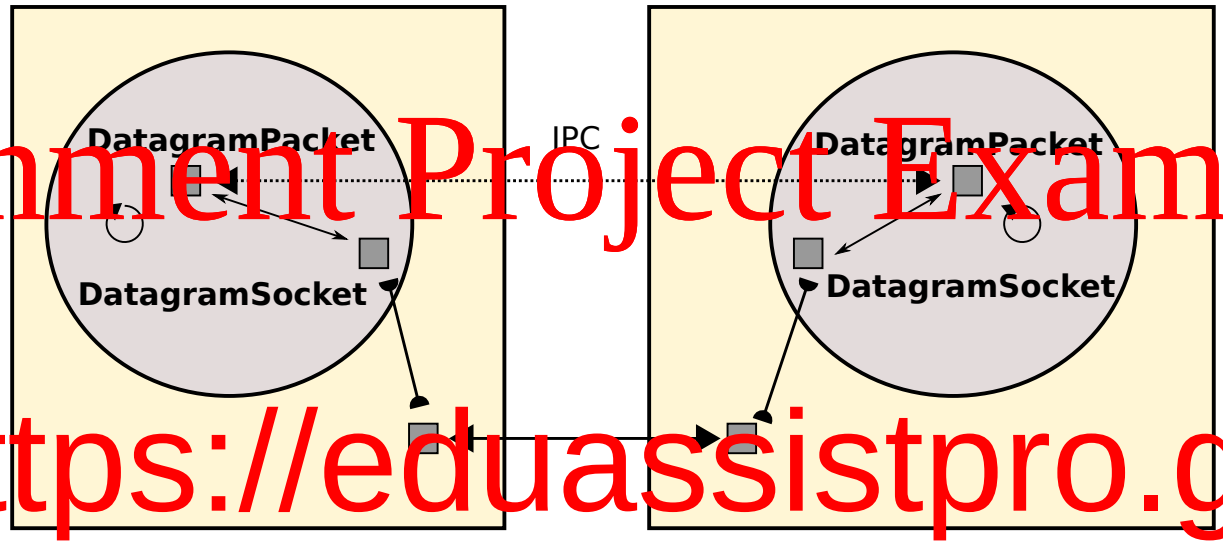


Discussion question

Question (9): The previous diagram is quite simplified. Draw a client/server socket interaction diagram that shows all of the objects involved, example code as a ref ails on the client and s ime of operations to succeed, and which method calls can be a order.

Question (10): Draw a FSM that describes the (a communication protocol employed by the TCP clie

DatagramSocket and DatagramPacket



- The `DatagramSocket` and `DatagramPacke` default.
- Both processes create a `DatagramSocket` t address.
- The client process initiates IPC by creating a `DatagramPacket` object and sending its content via its `DatagramSocket` to the server process.
- The server process receives data in a `DatagramPacket` object from its `DatagramSocket`.
- The server process can respond by sending the content of a `DatagramPacket`, using its `DatagramSocket`, back to the client process.

DatagramSocket API: selected constructors and methods	
	`DatagramSocket() throws SocketException` Constructs a datagram socket and binds it to any available port on the local host machine. The socket will be bound to the wildcard address, an IP address chosen by the kernel.
	`DatagramSocket(int port) throws SocketException` Constructs a datagram socket and binds it to the specified port on the local host machine. The socket will be bound to the wildcard address, an IP address chosen by the kernel.
`void`	gramPacket) upon
`void`	mPacket's buffer is dress, and the port number on the sender's machine. This method *blocks* until a datagram is received. The length field of the datagram packet object contains the length of the received mess n the packet's length, the message is truncated.
`void`	send(DatagramPacket p) throws IOException Sends a datagram packet from this socket. The Dat e dat to be sent, its length, the IP address of the remote host, and the port numbe .
`InetAddress`	`getLocalAddress()` Gets the local address to which the socket is bound.
`int`	`getLocalPort()` Returns the port number on the local host to which this socket is bound.

DatagramPacket API: selected constructors and methods	
	`DatagramPacket(byte[] buf, int length)` Constructs a DatagramPacket for receiving packets of length length. The length argument must be less than or equal to buf.length.
	`DatagramPacket(byte[] buf, int offset, int length)` Constructs a datagram packet for sending packets of length length, specifying an offset into the buffer. The length argument must be less than or equal to buf.length.
	`DatagramPacket(byte[] buf, int length, InetAddress address, int port)` Constructs a datagram packet for sending packets of length length to the specified port number on the specified host. The length argument must be less than or equal to buf.length.
	`DatagramPacket(byte[] buf, int offset, int length, InetAddress address, int port)` Constructs a datagram packet for sending packets of length length, specifying an offset into the buffer, ss than or equal to
InetAddres	get n the datagram
int	Returns the port number on the remote host to which this datagram is being sent or from which the datagram was received.
byte[]	getData() Returns the data buffer. The data received or the data to be sent starts fr ffer, and un for length long.
int	getOffset() Returns the offset of the data to be sent or the offset of the data received.
int	getLength() Returns the length of the data to be sent or the length of the data received.
void	setData(byte[] buf, int offset, int length) Set the data buffer for this packet. This sets the data, length and offset of the packet.
void	setAddress(InetAddress addr) Sets the IP address of the machine to which this datagram is being sent.
void	setPort(int port) Sets the port number on the remote host to which this datagram is being sent.

UDP Client Code Snippet

```
1   import java.net.*;
2   import java.io.*;
3   public class UDPClient {
4       public static void main(String args[]){
5       // args[0] is message args[1] is server's hostname
6           DatagramSocket aSocket = null;
7           try {
8               aSocket = new DatagramSocket(); // we don't care which port it binds to
9
10                                                                  rver's name
11
12
13
14
15              aSocket.send(request);
16              byte[] buffer = new byte[1000]; // magic number :-S
17              DatagramPacket reply = new DatagramPacket(
18              System.out.println("Client waiting to receive a resp
19              /* The following line blocks until the server sends a respons
20                 If the server fails to send a response then this line blocks
21                  * until an exception occurs. */
22              aSocket.receive(reply);
23              System.out.println("Reply: " + new String(reply.getData()));
24          } catch (SocketException e){
25              System.out.println("Socket: " + e.getMessage());
26          } catch (IOException e){
27              System.out.println("IO: " + e.getMessage());
28          } finally {if(aSocket != null) aSocket.close();}
29      }
30  }
```

UDP Server Code Snippet

```
1   import java.net.*;
2   import java.io.*;
3   public class UDPServer {
4       public static void main(String args[]){
5           DatagramSocket aSocket = null;
6           try {
7
8
9
10
11
12
13                  System.out.println("Received Data: " + new  String(request.getData()));
14                  DatagramPacket reply = new DatagramPac
15                      request.getLength(), request.getAd
16                  aSocket.send(reply);
17              }
18          } catch (SocketException e){
19              System.out.println("Socket: " + e.getMessa
20          } catch (IOException e) {
21              System.out.println("IO: " + e.getMessage());
22          } finally {if(aSocket != null) aSocket.close();}
23      }
24  }
```

Simplified client/server datagram interaction