



**Dr. D. Y. Patil Institute of Technology, Pimpri, Pune – 411018**  
**Department of Information Technology**

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## **LABORATORY MANUAL**

Academic Year-(2023-2024)

### **LAB-PRACTICE-V (Distributed System)**

**SEMESTER-VIII**

**Subject Code: 414454**

**TEACHING SCHEME**  
Lectures: 4Hrs/Week  
Practical: 4 Hrs/Week

**EXAMINATION SCHEME**  
Practical: 25 Marks  
Term Work: 50 Marks

Name of Faculty  
**Prof. Maheshwari S. Divate**

**Final Year Information Technology (2019  
Course)  
414454: Lab Practice – V**

**Teaching Scheme:**  
**Practical (PR): 4 hrs/week**

**Credit Scheme:**  
**02 Credits**

**Examination Scheme:**  
**PR: 25 Marks**  
**TW: 50 Marks**

**Prerequisites:**

- 1. Operating Systems**
- 2. Computer Network Technology**
- 3. Web Application Development**

**Course Objectives:**

1. The course aims to provide an understanding of the principles on which the distributed systems are based, their architecture, algorithms and how they meet the demands of Distributed applications.
2. The course covers the building blocks for a study related to the design and the implementation of distributed systems and applications.

**Course Outcomes:**

Upon successful completion of this course student will be able to:

1. Demonstrate knowledge of the core concepts and techniques in distributed systems.
2. Learn how to apply principles of state-of-the-Art Distributed systems in practical application.
- 3. Design, build and test application programs on distributed systems**

**Guidelines for Student's Lab Journal**

1. The laboratory assignments are to be submitted by students in the form of journals. The Journal consists of prologue, Certificate, table of contents, and handwritten/printed write-up of each assignment (Title, Objectives, Problem Statement, Outcomes, Software & Hardware requirements, Date of Completion, Assessment grade/marks and assessor's sign, Theory-Concept, algorithms, printouts of the code written using coding standards, sample test cases etc.)
- 2. Candidate is expected to know the theory involved in the experiment.**
3. The practical examination should be conducted if the journal of the Student is completed in all respects and certified by concerned faculty and head of the department.

**Guidelines for Lab /TW Assessment**

The term work based on performance of students considering the parameters such as

- 1)timely conduction of practical assignment,
- 2)methodology adopted for implementation of practical assignment,
- 3)timely submission of assignment in the form of handwritten/printed write-up along with results of implemented assignment,
- 5)attendance etc.
- 6)The understanding of the practical performed in the examination by asking some questions related to theory & implementation of experiments he/she has carried out.

**Guidelines for Laboratory Conduction**

All the assignments should be conducted on the latest version of Open-Source Operating Systems, tools and Multi-core CPU supporting Virtualization and Multi-Threading.



### **List of Laboratory Assignments**

- 1. Implement multi-threaded client/server Process communication using RMI.**
- 2. Develop any distributed application using CORBA to demonstrate object brokering.(Calculator or String operations).**
- 3. Develop a distributed system, to find sum of N elements in an array by distributing N/n elements to n number of processors MPI or OpenMP. Demonstrate by displaying the intermediate sums calculated at different processors.**
- 4. Implement Berkeley algorithm for clock synchronization.**
- 5. Implement token ring based mutual exclusion algorithm.**
- 6. Implement Bully and Ring algorithm for leader election.**
- 7. Create a simple web service and write any distributed application to consume the web service.**
- 8. Mini Project (In group): A Distributed Application for Interactive Multiplayer Games**

### **Reference Books:**

1. Distributed Systems –Concept and Design, George Coulouris, Jean Dollimore, Tim Kindberg& GordonBlair,Pearson,5th Edition,ISBN:978-13-214301-1.
2. Distributed Algorithms,Nancy Ann Lynch, Morgan Kaufmann Publishers, illustrated, reprint, ISBN:9781558603486.
3. Java Network Programming & Distributed Computing by David Reilly, Michael Reilly
4. Distributed Systems - An Algorithmic approach by Sukumar Ghosh (good book for distributed algorithms)
5. Distributed Algorithms: Principles, Algorithms, and Systems by A. D. Kshemkalyani and M. Singhal(Good for algorithms, but very detailed, has lots of algorithms; good reference)
6. Design and Analysis of Distributed Algorithms by Nicola Santoro (good, distributed algorithms book)

## ASSIGNMENT NO. 1

### Problem Statement:

Implement multi-threaded client/server Process communication using RMI.

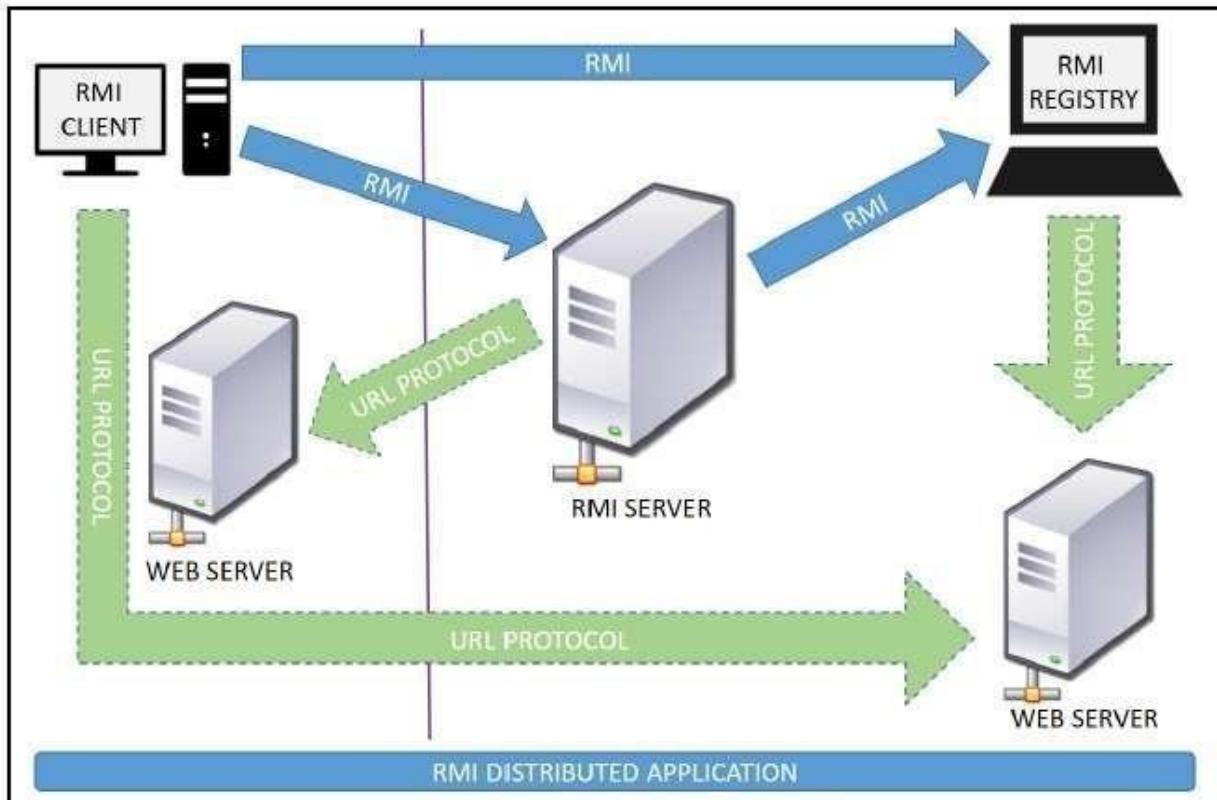
### Tools / Environment:

Java Programming Environment, jdk 1.8, rmiregistry

### Related Theory:

RMI provides communication between java applications that are deployed on different servers and connected remotely using objects called **stub** and **skeleton**. This communication architecture makes a distributed application seem like a group of objects communicating across a remote connection. These objects are encapsulated by exposing an interface, which helps access the private state and behavior of an object through its methods.

The following diagram shows how RMI happens between the RMI client and RMI server with the help of the RMI registry:



**RMI REGISTRY** is a remote object registry, a Bootstrap naming service, that is used by **RMI SERVER** on the same host to bind remote objects to names. Clients on local and remote hosts then look up the remote objects and make remote method invocations.

### Key terminologies of RMI:

The following are some of the important terminologies used in a Remote Method Invocation. **Remote object**: This is an object in a specific JVM whose methods are exposed so they could be invoked by another program deployed on a different JVM.

**Remote interface**: This is a Java interface that defines the methods that exist in a remote object. A remote object can implement more than one remote interface to adopt multiple remote interface behaviors.

**RMI**: This is a way of invoking a remote object's methods with the help of a remote interface. It can be carried with a syntax that is similar to the local method invocation.

**Stub**: This is a Java object that acts as an entry point for the client object to route any outgoing requests. It exists on the client JVM and represents the handle to the remote object.

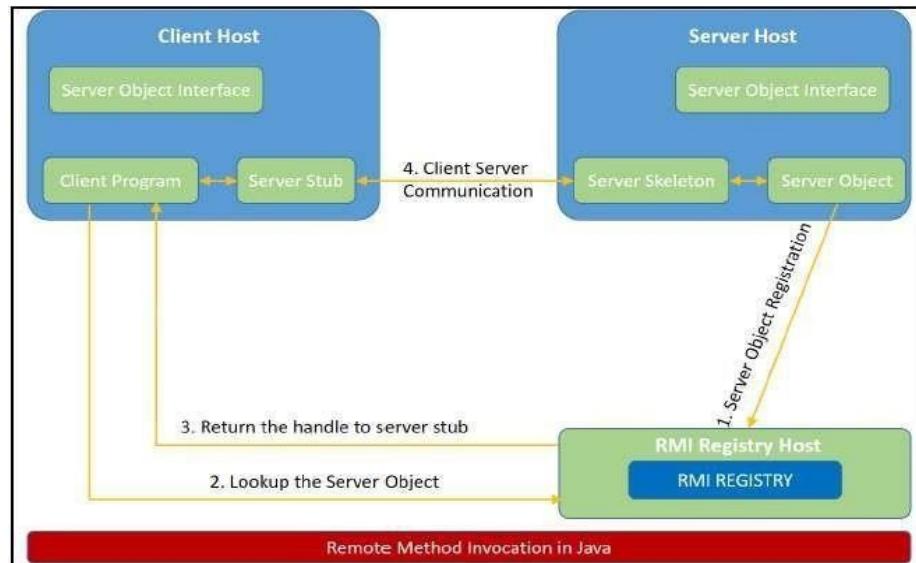
If any object invokes a method on the stub object, the stub establishes RMI by following these steps:

1. It initiates a connection to the remote machine JVM.
2. It marshals (write and transmit) the parameters passed to it via the remote JVM.
3. It waits for a response from the remote object and unmarshals (read) the returned value or exception, then it responds to the caller with that value or exception.

**Skeleton**: This is an object that behaves like a gateway on the server side. It acts as a remote object with which the client objects interact through the stub. This means that any requests coming from the remote client are routed through it. If the skeleton receives a request, it establishes RMI through these steps:

1. It reads the parameter sent to the remote method.
2. It invokes the actual remote object method.
3. It marshals (writes and transmits) the result back to the caller (stub).

The following diagram demonstrates RMI communication with stub and skeleton involved:



## **Designing the solution:**

The essential steps that need to be followed to develop a distributed application with RMI are as follows:

1. Design and implement a component that should not only be involved in the distributed application, but also the local components.
2. Ensure that the components that participate in the RMI calls are accessible across networks.
3. Establish a network connection between applications that need to interact using the RMI.

**Remote interface definition:** The purpose of defining a remote interface is to declare the methods that should be available for invocation by a remote client.

Programming the interface instead of programming the component implementation is an essential design principle adopted by all modern Java frameworks, including Spring. In the same pattern, the definition of a remote interface takes importance in RMI design as well.

**2. Remote object implementation:** Java allows a class to implement more than one interface at a time. This helps remote objects implement one or more remote interfaces. The remote object class may have to implement other local interfaces and methods that it is responsible for. Avoid adding complexity to this scenario, in terms of how the arguments or return parameter values of such component methods should be written.

**3. Remote client implementation:** Client objects that interact with remote server objects can be written once the remote interfaces are carefully defined even after the remote objects are deployed.

Let's design a project that can sit on a server. After that different client projects interact with this project to pass the parameters and get the computation on the remote object execute and return the result to the client components.

## **Implementation:**

### **Consider building an application to perform diverse mathematical operations.**

The server receives a request from a client, processes it, and returns a result. In this example, the request specifies two numbers. The server adds these together and returns the sum.

#### **1. Creating remote interface, implement remote interface, server-side and client-side program and Compile the code.**

This application uses four source files. The first file, **AddServerIntf.java**, defines the remote interface that is provided by the server. It contains one method that accepts two **double** arguments and returns their sum. All remote interfaces must extend the **Remoteinterface**, which is part of **java.rmi**. **Remote** defines no members. Its purpose is simply to indicate that an interface uses remote methods. All remote methods can throw a **RemoteException**.

The second source file, **AddServerImpl.java**, implements the remote interface. The implementation of the **add()** method is straightforward. All remote objects must extend

**UnicastRemoteObject**, which provides functionality that is needed to make objects available from remote machines.

The third source file, **AddServer.java**, contains the main program for the server machine. Its primary function is **to update the RMI registry on that machine**. This is done by using the **rebind()** method of the **Naming** class (found in **java.rmi**). That method associates a name with an object reference. The first argument to the **rebind()** method is a string that names the server as “AddServer”. Its second argument is a reference to an instance of **AddServerImpl**.

The fourth source file, **AddClient.java**, implements the client side of this distributed application. **AddClient.java** requires three command-line arguments. The first is the IP address or name of the server machine. The second and third arguments are the two numbers that are to be summed.

The application begins by forming a string that follows the URL syntax. This URL uses the **rmi** protocol. The string includes the IP address or name of the server and the string “AddServer”. The program then invokes the **lookup( )** method of the **Naming** class. This method accepts one argument, the **rmi** URL, and returns a reference to an object of type **AddServerIntf**. All remote method invocations can then be directed to this object.

The program continues by displaying its arguments and then invokes the remote **add()** method. The sum is returned from this method and is then printed.

Use **javac** to compile the four source files that are created.

## 2. Generate a stub

Before using client and server, the necessary stub must be generated. In the context of RMI, a *stub* is a Java object that resides on the client machine. Its function is to present the same interfaces as the remote server. Remote method calls initiated by the client are actually directed to the stub. The stub works with the other parts of the RMI system to formulate a request that is sent to the remote machine.

All of this information must be sent to the remote machine. That is, an object passed as an argument to a remote method call must be serialized and sent to the remote machine. If a response must be returned to the client, the process works in reverse. **The serialization and deserialization facilities are also used if objects are returned to a client.**

To generate a stub the command is **RMICompiler** is invoked as follows:

**rmic AddServerImpl.**

This command generates the file **AddServerImpl\_Stub.class**.

## 3. Install Files on the Client and Server Machines

Copy **AddClient.class**, **AddServerImpl\_Stub.class**, **AddServerIntf.class**

to a directory on the client machine.

Copy **AddServerIntf.class**, **AddServerImpl.class**, **AddServerImpl\_Stub.class**, and **AddServer.class** to a directory on the server machine.

#### **4. Start the RMI Registry on the Server Machine**

Java provides a program called **rmiregistry**, which executes on the server machine. It maps names to object references. Start the RMI Registry from the command line, as shown here:

```
start rmiregistry
```

#### **5. Start the Server**

The server code is started from the command line, as shown here:

```
java AddServer
```

The **AddServer** code instantiates **AddServerImpl** and registers that object with the name “AddServer”.

#### **6. Start the Client**

The **AddClient** software requires three arguments: the name or IP address of the server machine and the two numbers that are to be summed together. You may invoke it from the command line by using one of the two formats shown here:

```
java AddClient 192.168.13.14 7 8
```

## Writing the source code:

The screenshot shows a Java development environment with four tabs open in separate windows:

- AddServerIntf.java**: Contains the interface definition:

```
import java.rmi.*;  
public interface AddServerIntf extends Remote {  
    double add(double d1, double d2) throws RemoteException;  
}
```
- AddServerImpl.java**: Contains the implementation class:

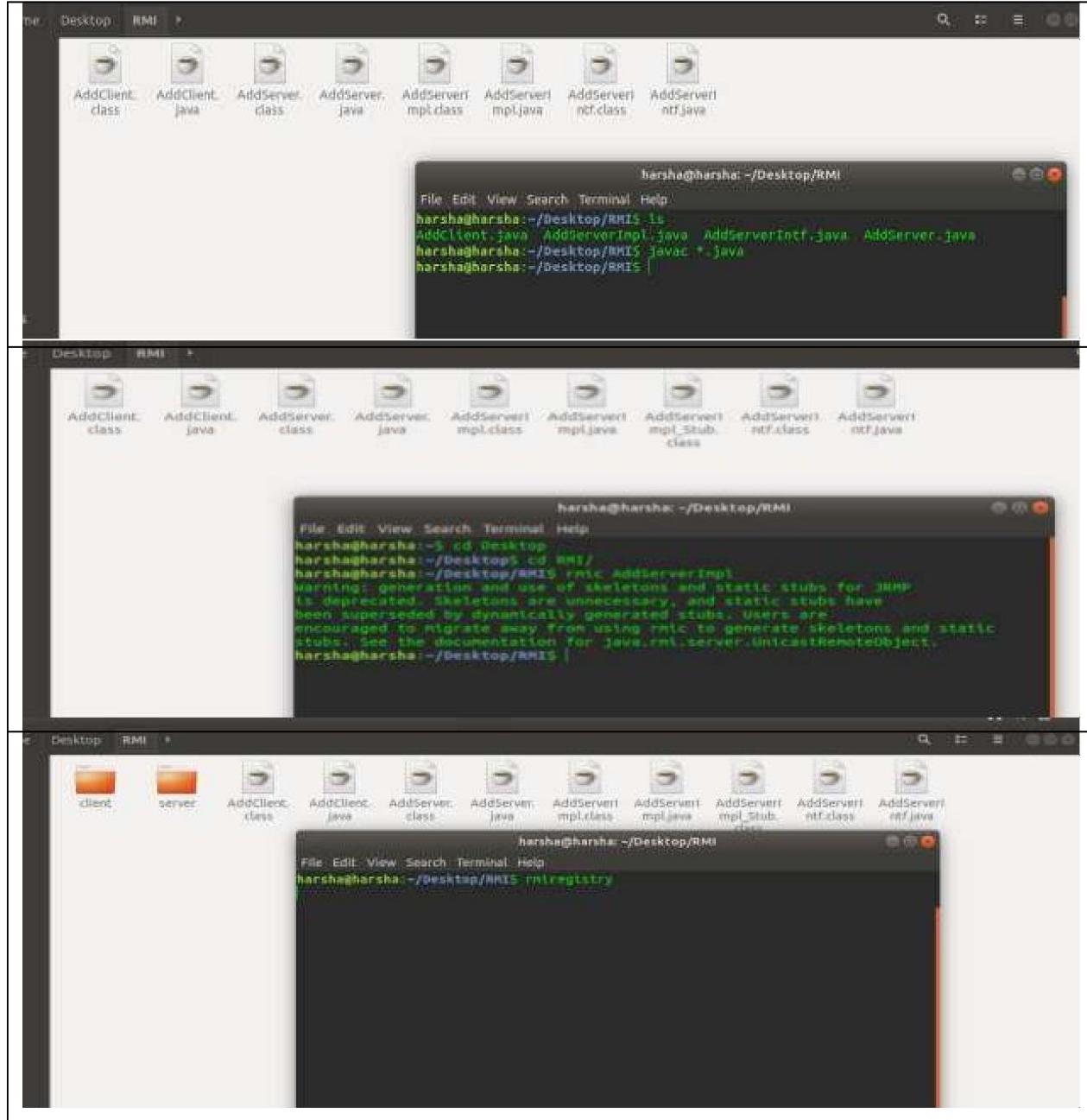
```
import java.rmi.*;  
import java.rmi.server.*;  
public class AddServerImpl extends UnicastRemoteObject  
implements AddServerIntf {  
    public AddServerImpl() throws RemoteException {  
    }  
    public double add(double d1, double d2) throws RemoteException {  
        return d1 + d2;  
    }  
}
```
- AddServer.java**: Contains the main method for starting the server:

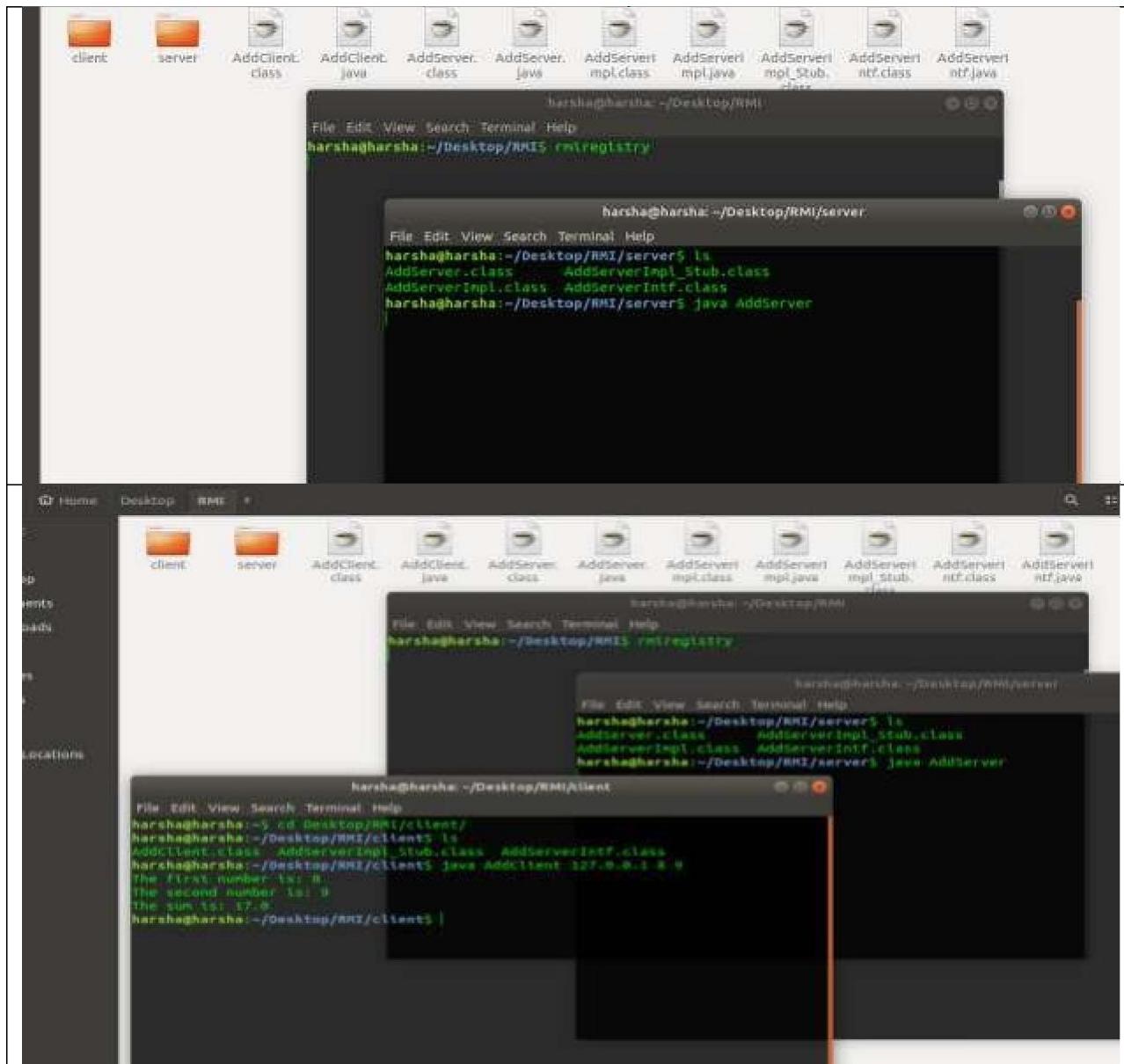
```
import java.net.*;  
import java.rmi.*;  
public class AddServer {  
    public static void main(String args[]) {  
        try {  
            AddServerImpl addServerImpl = new AddServerImpl();  
            Naming.rebind("AddServer", addServerImpl);  
        } catch(Exception e) {  
            System.out.println("Exception: " + e);  
        }  
    }  
}
```
- AddClient.java**: Contains the client code:

```
import java.rmi.*;  
public class AddClient {  
    public static void main(String args[]) {  
        try {  
            String addServerURL = "rmi://" + args[0] + "/AddServer";  
            AddServerIntf addServerIntf =  
                (AddServerIntf)Naming.lookup(addServerURL);  
            System.out.println("The first number is: " + args[1]);  
            double d1 = Double.valueOf(args[1]).doubleValue();  
            System.out.println("The second number is: " + args[2]);  
            double d2 = Double.valueOf(args[2]).doubleValue();  
            System.out.println("The sum is: " + addServerIntf.add(d1, d2));  
        } catch(Exception e) {  
            System.out.println("Exception: " + e);  
        }  
    }  
}
```

## Compilation and Executing the solution:

The steps for compilation and execution are captured in a snapshots given:





Note :Make all proxy and firewall settings disable

server commands:

```
base) comp@SL15:~$ javac AddServerIntf.java
(base) comp@SL15:~$ javac AddServerImpl.java
(base) comp@SL15:~$ javac AddServer.java
(base) comp@SL15:~$ rmic AddServerImpl          //for generation of stub and skeleton
Warning: generation and use of skeletons and static stubs for JRMP
is deprecated. Skeletons are unnecessary, and static stubs have
been superseded by dynamically generated stubs. Users are
```

encouraged to migrate away from using rmic to generate skeletons and static stubs. See the documentation for java.rmi.server.UnicastRemoteObject.

```
(base) comp@SL15:~$  
(base) comp@SL15:~$ rmiregistry 1099 &  
[1] 13965  
(base) comp@SL15:~$ java AddServer
```

client commands:

```
(base) comp@SL15:~$ javac AddClient.java  
(base) comp@SL15:~$ java AddClient 6 7  
The first number is: 7  
Exception: java.lang.ArrayIndexOutOfBoundsException: 2  
(base) comp@SL15:~$ javac AddClient.java  
(base) comp@SL15:~$ java AddClient 6 4  
The first number is: 6  
The second number is:4  
The sum is:10.0  
(base) comp@SL15:~$
```

## AddServerIntf.java

```
import java.rmi.*;  
public interface AddServerIntf extends Remote {  
    double add(double d1, double d2) throws RemoteException;  
}
```

## AddServerImpl.java

```
import java.rmi.*;  
import java.rmi.server.*;  
public class AddServerImpl extends UnicastRemoteObject implements AddServerIntf  
{  
    public AddServerImpl() throws RemoteException  
    {  
    }  
    public double add(double d1, double d2) throws RemoteException  
    {  
        return d1 + d2;  
    }  
}
```

## AddServer.java

```
import java.net.*;  
import java.rmi.*;  
public class AddServer {  
    public static void main(String args[]) throws ConnectIOException  
    {  
        try {
```

```

AddServerImpl addServerImpl = new AddServerImpl();

Naming.rebind("AddServer", addServerImpl);
}
catch(Exception e) {
System.out.println("Exception: " + e);
}
}
}
}

```

## AddClient.java

```

import java.rmi.*;
public class AddClient {
public static void main(String args[])throws ConnectIOException
{
try {
String addServerURL = "rmi://" + "172.16.236.15" + "/AddServer";
AddServerIntf addServerIntf=(AddServerIntf)Naming.lookup(addServerURL);
System.out.println("The first number is: " + args[0]);
double d1 = Double.valueOf(args[0]).doubleValue();
System.out.println("The second number is:" + args[1]);
double d2 = Double.valueOf(args[1]).doubleValue();
System.out.println("The sum is:"+ addServerIntf.add(d1, d2));
}
catch(Exception e)
{
System.out.println("Exception: " + e);
}
}
}
}

```

## Conclusion:

Remote Method Invocation (RMI) allows you to build Java applications that are distributed among several machines. Remote Method Invocation (RMI) allows a Java object that executes on one machine to invoke a method of a Java object that executes on another machine. This is an important feature, because it allows you to build distributed applications.

## ASSIGNMENT NO. 2

### Problem Statement:

To develop any distributed application with CORBA program using JAVA IDL.

### Tools / Environment:

Java Programming Environment, JDK 1.8

### Related Theory:

Common Object

#### **Request Broker Architecture (CORBA):**

CORBA is an acronym for Common Object Request Broker Architecture. It is an open source, vendor-independent architecture and infrastructure developed by the **Object Management Group (OMG)** to integrate enterprise applications across a distributed network. CORBA specifications provide guidelines for such integration applications, based on the way they want to interact, irrespective of the technology; hence, all kinds of technologies can implement these standards using their own technical implementations.

When two applications/systems in a distributed environment interact with each other, there are quite a few unknowns between those applications/systems, including the technology they are developed in (such as Java/ PHP/ .NET), the base operating system they are running on (such as Windows/Linux), or system configuration (such as memory allocation). **They communicate mostly with the help of each other's network address or through a naming service.** Due to this, these applications end up with quite a few issues in integration, including content (message) mapping mismatches.

An application developed based on CORBA standards with standard **Internet Inter-ORB Protocol (IIOP)**, irrespective of the vendor that develops it, should be able to smoothly integrate and operate with another application developed based on CORBA standards through the same or different vendor.

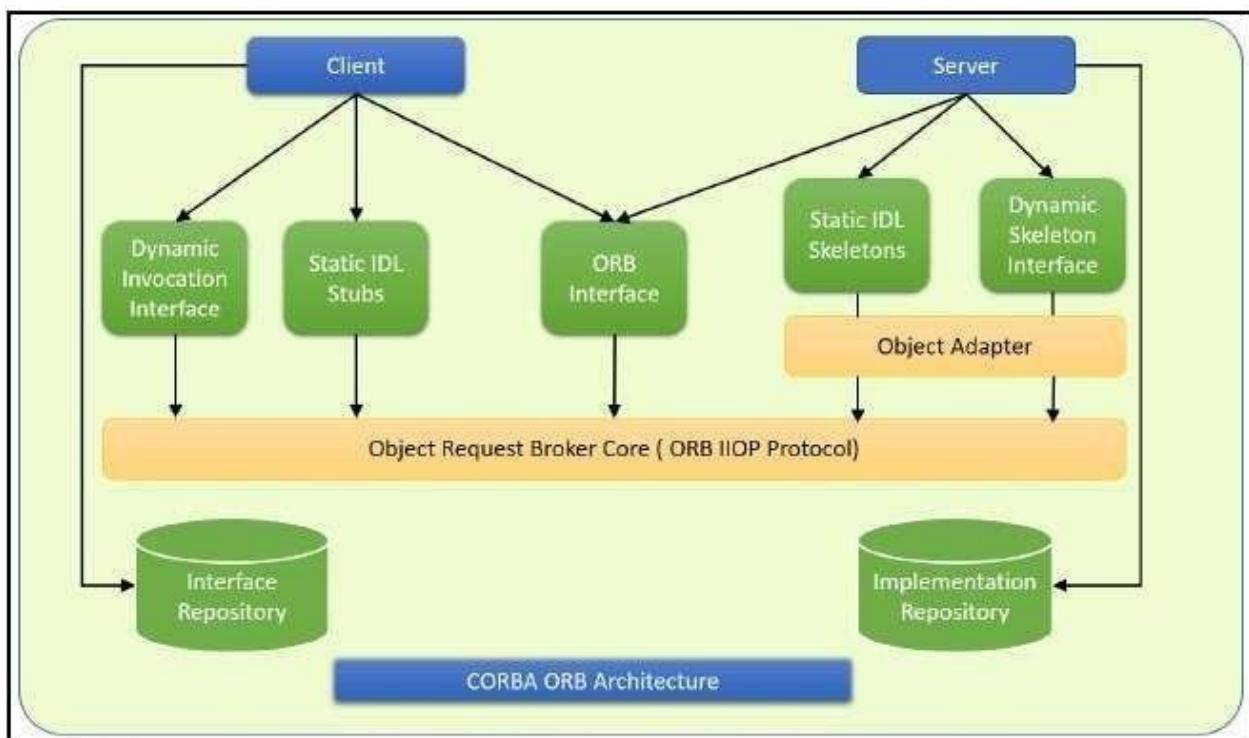
Except legacy applications, most of the applications follow common standards when it comes to object modeling, for example. All applications related to, say, "HR&Benefits" maintain an object model with details of the organization, employees with demographic information, benefits, payroll, and deductions. They are only different in the way they handle the details, based on the country and region they are operating for. For each object type, similar to the HR&Benefits systems, we can define an interface using the **Interface Definition Language (OMG IDL)**.

The contract between these applications is defined in terms of an interface for the server objects that the clients can call. This IDL interface is used by each client to indicate when they should call any particular method to marshal (read and send the arguments).

The target object is going to use the same interface definition when it receives the request from the client to unmarshal (read the arguments) in order to execute the method that was requested by the client operation. Again, during response handling, the interface definition is helpful to marshal (send from the server) and unmarshal (receive and read the response) arguments on the

client side once received. The IDL interface is a design concept that works with multiple programming languages including C, C++, Java, Ruby, Python, and IDLscript. This is close to writing a program to an interface, a concept we have been discussing that most recent programming languages and frameworks, such as Spring. The interface has to be defined clearly for each object. The systems encapsulate the actual implementation along with their respective data handling and processing, and only the methods are available to the rest of the world through the interface. Hence, the clients are forced to develop their invocation logic for the IDL interface exposed by the application they want to connect to with the method parameters (input and output) advised by the interface operation.

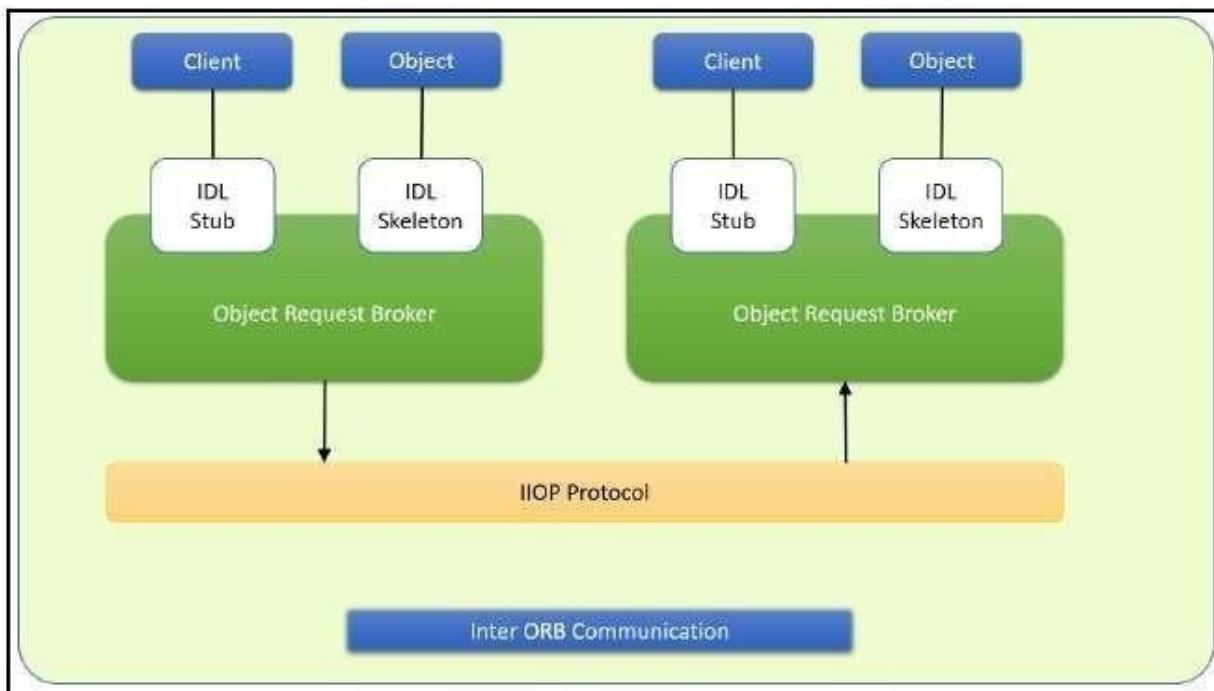
The following diagram shows a single-process ORB CORBA architecture with the IDL configured as client stubs with object skeletons. The objects are written (on the right) and a client for it (on the left), as represented in the diagram. The client and server use stubs and skeletons as proxies, respectively. The IDL interface follows a strict definition, and even though the client and server are implemented in different technologies, they should integrate smoothly with the interface definition strictly implemented.



In CORBA, each object instance acquires an object reference for itself with the electronic token identifier. Client invocations are going to use these object references that have the ability to figure out which ORB instance they are supposed to interact with. The stub and skeleton represent the client and server, respectively, to their counterparts. They help establish this communication through ORB and pass the arguments to the right method and its instance during the invocation.

## Inter-ORB communication

The following diagram shows how remote invocation works for inter-ORB communication. It shows that the clients that interacted have created **IDL Stub** and **IDL Skeleton** based on **Object Request Broker** and communicated through **IIOP Protocol**.



To invoke the remote object instance, the client can get its object reference using a naming service. Replacing the object reference with the remote object reference, the client can make the invocation of the remote method with the same syntax as the local object method invocation. ORB keeps the responsibility of recognizing the remote object reference based on the client object invocation through a naming service and routes it accordingly.

## Java Support for CORBA

CORBA complements the Java™ platform by providing a distributed object framework, services to support that framework, and interoperability with other languages. The Java platform complements CORBA by providing a portable, highly productive implementation environment, and a very robust platform. By combining the Java platform with CORBA and other key enterprise technologies, the Java Platform is the ultimate platform for distributed technology solutions.

CORBA standards provide the proven, interoperable infrastructure to the Java platform. IIOP (Internet Inter-ORB Protocol) manages the communication between the object components that power the system. The Java platform provides a portable object infrastructure that works on every major operating system. CORBA provides the network transparency, Java provides the implementation transparency. **An Object Request Broker (ORB) is part of the Java Platform. The ORB is a runtime component that can be used for distributed computing using IIOP communication. Java IDL is a Java API for interoperability and integration with CORBA.** Java IDL included both a Java-based ORB, which supported

IIOP, and the **IDL-to-Java compiler**, for generating client-side stubs and server-side code skeletons. J2SE v.1.4 includes an **Object Request Broker Daemon (ORBD)**, which is used to enable clients to transparently locate and invoke persistent objects on servers in the CORBA environment.

When using the **IDL programming model**, the interface is everything! It defines the points of entry that can be called from a remote process, such as the types of arguments the called procedure will accept, or the value/output parameter of information returned. Using IDL, the programmer can make the entry points and data types that pass between communicating processes act like a standard language.

CORBA is a language-neutral system in which the argument values or return values are limited to what can be represented in the involved implementation languages. In CORBA, object orientation is limited only to objects that can be passed by reference (the object code itself cannot be passed from machine-to-machine) or are predefined in the overall framework. Passed and returned types must be those declared in the interface.

With RMI, the interface and the implementation language are described in the same language, so you don't have to worry about mapping from one to the other. Language-level objects (the code itself) can be passed from one process to the next. Values can be returned by their actual type, not the declared type. Or, you can compile the interfaces to generate IIOP stubs and skeletons which allow your objects to be accessible from other CORBA-compliant languages.

### The IDL Programming Model:

The IDL programming model, known as Java™ IDL, consists of both the Java CORBA ORB and the idljcompiler that maps the IDL to Java bindings that use the Java CORBA ORB, as well as a set of APIs, which can be explored by selecting the org.omgprefix from the Package section of the API index.

Java IDL adds CORBA (Common Object Request Broker Architecture) capability to the Java platform, providing standards-based interoperability and connectivity. Runtime components include a Java ORB for distributed computing using IIOP communication.

To use the IDL programming model, define remote interfaces using OMG Interface Definition Language (IDL), then compile the interfaces using idljcompiler. When you run the idljcompiler over your interface definition file, it generates the Java version of the interface, as well as the class code files for the stubs and skeletons that enable applications to hook into the ORB.

**Portable Object Adapter (POA)** : An *object adapter* is the mechanism that connects a request using an object reference with the proper code to service that request. The Portable Object Adapter, or POA, is a particular type of object adapter that is defined by the CORBA specification. The POA is designed to meet the following goals:

- Allow programmers to construct object implementations that are portable between different ORB products.
- Provide support for objects with persistent identities.

## **Designing the solution:**

Here the design of how to create a complete CORBA (Common Object Request Broker Architecture) application using IDL (Interface Definition Language) to define interfaces and Java IDL compiler to generate stubs and skeletons. You can also create CORBA application by defining the interfaces in the Java programming language.

The server-side implementation generated by the idljcompiler is the *Portable Servant Inheritance Model*, also known as the POA(Portable Object Adapter) model. This document presents a sample application created using the default behavior of the idljcompiler, which uses a POA server-side model.

### **1. Creating CORBA Objects using Java IDL:**

In order to distribute a Java object over the network using CORBA, one has to define it's own CORBA-enabled interface and its implementation. This involves doing the following:

- Writing an interface in the CORBA Interface Definition Language
- Generating a Java base interface, plus a Java stub and skeleton class, using an IDL-to-Java compiler
- Writing a server-side implementation of the Java interface in Java

Interfaces in IDL are declared much like interfaces in Java.

### **Modules**

Modules are declared in IDL using the module keyword, followed by a name for the module and an opening brace that starts the module scope. Everything defined within the scope of this module (interfaces, constants, other modules) falls within the module and is referenced in other IDL modules using the syntax *modulename::x*. e.g.

```
//  
IDL  
module jen  
{  
    module corba {  
        interface NeatExample ...  
    };  
};
```

### **Interfaces**

The declaration of an interface includes an interface header and an interface body. The header specifies the name of the interface and the interfaces it inherits from (if any). Here is an IDL interface header:

```
interface PrintServer : Server {  
    ...
```

This header starts the declaration of an interface called PrintServer that inherits all the methods and data members from the Server interface.

### Data members and methods

The interface body declares all the data members (or attributes) and methods of an interface. Data members are declared using the attribute keyword. At a minimum, the declaration includes a name and a type.

```
readonly attribute string myString;
```

The method can be declared by specifying its name, return type, and parameters, at a minimum.

```
string parseString(in string buffer);
```

This declares a method called parseString() that accepts a single string argument and returns a string value.

### A complete IDL example

Now let's tie all these basic elements together. Here's a complete IDL example that declares a module within another module, which itself contains several interfaces:

```
module OS { module
services {interface Server {
readonly           attribute           string
serverName;
boolean init(in string sName);
};

interface Printable {
boolean print(in string header);
};

interface PrintServer : Server { boolean printThis(in
Printable p);
};

};
```

The first interface, Server, has a single read-only string attribute and an init() method

that accepts a string and returns a boolean. The Printableinterface has a single print() method that accepts a string header. Finally, the PrintServerinterface extends the Serverinterface and adds a printThis() method that accepts a Printableobject and returns a boolean. In all cases, we've declared the method arguments as input-only (i.e., pass-by-value), using the in keyword.

## 2. Turning IDL Into Java

**Once the remote interfaces in IDL are described, you need to generate Java classes that act as a starting point for implementing those remote interfaces in Java using an IDL-to-Java compiler.** Every standard IDL-to-Java compiler generates the following 3 Java classes from an IDL interface:

A Java interface with the same name as the IDL interface. This can act as the basis for a Java implementation of the interface (but you have to write it, since IDL doesn't provide any details about method implementations).

A *helper* class whose name is the name of the IDL interface with "Helper" appended to it (e.g., ServerHelper). The primary purpose of this class is to provide a static narrow() method that can safely cast CORBA Objectreferences to the Java interface type. The helper class also provides other useful static methods, such as read() and write() methods that allow you to read and write an object of the corresponding type using I/O streams.

A *holder* class whose name is the name of the IDL interface with "Holder" appended to it (e.g., ServerHolder). This class is used when objects with this interface are used as out or inout arguments in remote CORBA methods. Instead of being passed directly into the remote method, the object is wrapped with its holder before being passed. When a remote method has parameters that are declared as out or inout, the method has to be able to update the argument it is passed and return the updated value. The only way to guarantee this, even for primitive Java data types, is to force out and inout arguments to be wrapped in Java holder classes, which are filled with the output value of the argument when the method returns.

The idltoj tool generates 2 other classes:

**A client stub class**, called *\_interface-nameStub*, that acts as a client-side implementation of the interface and knows how to convert method requests into ORB requests that are forwarded to the actual remote object. The stub class for an interface named Server is called \_ServerStub.

**A server skeleton class**, called *\_interface-nameImplBase*, that is a base class for a server-side implementation of the interface. The base class can accept requests for the object from the ORB and channel return values back through the ORB to the remote client. The skeleton class for an interface named Server is called \_ServerImplBase.

So, in addition to generating a Java mapping of the IDL interface and some helper classes for the

Java interface, the *idltoj* compiler also creates subclasses that act as an interface between a CORBA client and the ORB and between the server-side implementation and the ORB. This creates the five Java classes: a Java version of the interface, a helper class, a holder class, a client stub, and a server skeleton.

### 3. Writing the Implementation

The IDL interface is written and generated the Java interface and support classes for it, including the client stub and the server skeleton. Now, concrete server-side implementations of all of the methods on the interface needs to be created.

#### Implementing the solution:

Here, we are demonstrating the "Hello World" Example. **To create this example, create a directory named hello/ where you develop sample applications and create the files in this directory.**

##### 1. Defining the Interface (Hello.idl)

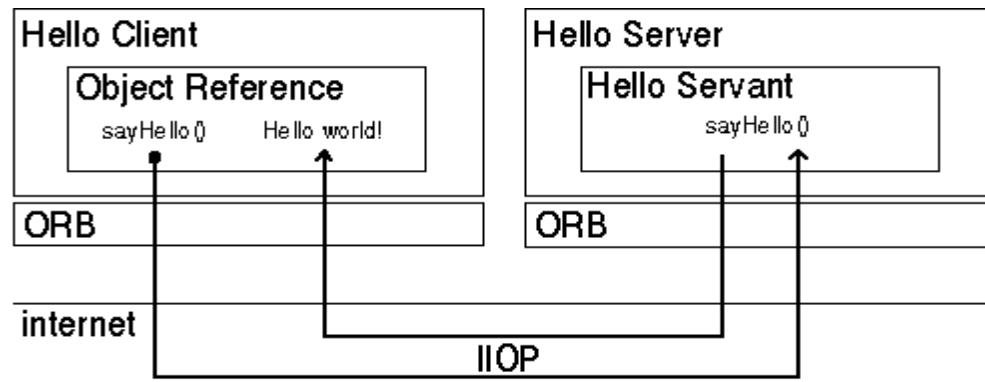
The first step to creating a CORBA application is to specify all of your objects and their interfaces using the OMG's Interface Definition Language (IDL). To complete the application, you simply provide the server (**HelloServer.java**) and client (**HelloClient.java**) implementations.

##### 2. Implementing the Server (HelloServer.java)

The example server consists of two classes, the servant and the server. The servant, HelloImpl, is the implementation of the HelloIDL interface; each Helloinstance is implemented by a HelloImplinstance. The servant is a subclass of HelloPOA, which is generated by the idljcompiler from the example IDL. The servant contains one method for each IDL operation, in this example, the sayHello() and shutdown() methods. Servant methods are just like ordinary Java methods; the extra code to deal with the ORB, with marshaling arguments and results, and so on, is provided by the skeleton.

The HelloServerclass has the server's main()method, which:

- Creates and initializes an ORB instance
- Gets a reference to the root POA and activates the POAManager
- Creates a servant instance (the implementation of one CORBA Helloobject) and tells the ORB about it
- Gets a CORBA object reference for a naming context in which to register the new CORBA object
- Gets the root naming context
- Registers the new object in the naming context under the name "Hello"
- Waits for invocations of the new object from the client.



### 3. Implementing the Client Application (HelloClient.java)

The example application client that follows:

- Creates and initializes an ORB
- Obtains a reference to the root naming context
- Looks up "Hello" in the naming context and receives a reference to that CORBA object
- Invokes the object's sayHello() and shutdown() operations and prints the result.

#### Writing the source code:

```

ReverseModule.idl
-/Desktop/IDL CORBA

module ReverseModule
{
    interface Reverse
    {
        string reverse_string(in string str);
    };
}

ReverseClient.java
-/Desktop/IDL CORBA

// Client

import ReverseModule.*;
import org.omg.CosNaming.*;
import org.omg.CosNaming.NamingContextPackage.*;
import org.omg.CORBA.*;
import java.io.*;

class ReverseClient
{

    public static void main(String args[])
    {
        Reverse ReverseImpl=null;

        try
        {
            // initialize the ORB
            org.omg.CORBA.ORB orb = org.omg.CORBA.ORB.init(args,null);

            org.omg.CORBA.Object objRef = orb.resolve_initial_references("NameService");
            NamingContextExt ncRef = NamingContextExtHelper.narrow(objRef);

            String name = "Reverse";
            ReverseImpl = ReverseHelper.narrow(ncRef.resolve_str(name));

            System.out.println("Enter String=");
            BufferedReader br = new BufferedReader(new InputStreamReader(System.in));
            String str= br.readLine();

            String tempStr= ReverseImpl.reverse_string(str);

```

```

  S TEXT EDITOR * TUE 13:19
  Open ▾ + ReverseImpl.java
  /Desktop/IDL CORBA
import ReverseModule.ReversePOA;
import java.lang.String;
class ReverseImpl extends ReversePOA
{
    ReverseImpl()
    {
        super();
        System.out.println("Reverse Object Created");
    }

    public String reverse_string(String name)
    {
        StringBuffer str=new StringBuffer(name);
        str.reverse();
        return ((("Server Send "+str));
    }
}

  Ies TEXT EDITOR * TUE 13:19
  Open ▾ + ReverseServer.java
  /Desktop/IDL CORBA
import org.omg.CosNaming.NamingContextPackage.*;
import org.omg.CORBA.*;
import org.omg.PortableServer.*;

class ReverseServer
{
    public static void main(String[] args)
    {
        try
        {
            // initialize the ORB
            org.omg.CORBA.ORB orb = org.omg.CORBA.ORB.init(args,null);

            // initialize the BOA/POA
            POA rootPOA = POAHelper.narrow(orb.resolve_initial_references("RootPOA"));
            rootPOA.the_POAManager().activate();

            // creating the calculator object
            ReverseImpl rvr = new ReverseImpl();

            // get the object reference from the servant class
            org.omg.CORBA.Object ref = rootPOA.servant_to_reference(rvr);

            System.out.println("Step1");
            Reverse h_ref = ReverseModule.ReverseHelper.narrow(ref);
            System.out.println("Step2");

            org.omg.CORBA.Object objRef = orb.resolve_initial_references("NameService");

            System.out.println("Step3");
            NamingContextExt ncRef = NamingContextExHelper.narrow(objRef);
            System.out.println("Step4");

            String name = "Reverse";
            NameComponent path[] = ncRef.to_name(name);
            ncRef.rebind(path,h_ref);

            System.out.println("Reverse Server reading and waiting....");
            orb.run();
        }
        catch(Exception e)
        {
            e.printStackTrace();
        }
    }
}

```

### //ReverseClient.java

```
import ReverseModule.*;
import org.omg.CosNaming.*;
import org.omg.CosNaming.NamingContextPackage.*;
import org.omg.CORBA.*;
import java.io.*;

class ReverseClient
{
    public static void main(String args[])
    {
        Reverse ReverseImpl=null;

        try
        {
            // initialize the ORB
            org.omg.CORBA.ORB orb = org.omg.CORBA.ORB.init(args,null);

            org.omg.CORBA.Object objRef = orb.resolve_initial_references("NameService");
            NamingContextExt ncRef = NamingContextExtHelper.narrow(objRef);

            String name = "Reverse";
            //Helper class provides narrow method that cast corba object reference(ref) into the java interface
            // System.out.println("Step2");
            // Look ups "Reverse" in the naming context
            ReverseImpl = ReverseHelper.narrow(ncRef.resolve_str(name));

            System.out.println("Enter String="); BufferedReader br = new
            BufferedReader(new
InputStreamReader(System.in));
            String str= br.readLine();

            String tempStr= ReverseImpl.reverse_string(str)System.out.println(tempStr);
        }
        catch(Exception e)
        {
            e.printStackTrace();
        }
    }
}

//ReverseImpl.java
```

```
import ReverseModule.ReversePOA;
import java.lang.String;
class ReverseImpl extends ReversePOA
{
```

```

ReverseImpl()
{
    super();
    System.out.println("Reverse Object Created");
}

public String reverse_string(String name)
{
    StringBuffer str=new StringBuffer(name).reverse();
    return ("Server Send "+str);
}
}

//ReverseModule.idl

module ReverseModule           //module ReverseModule is the name of the module
{
    interface Reverse
    {
        string reverse_string(in string str);
    };
}

// ReverseServer.java

import ReverseModule.Reverse;import
org.omg.CosNaming.*;
import org.omg.CosNaming.NamingContextPackage.*;import
org.omg.CORBA.*;
import org.omg.PortableServer.*;

class ReverseServer
{
    public static void main(String[] args)
    {

        try
        {
            // initialize the ORB
            org.omg.CORBA.ORB orb = org.omg.CORBA.ORB.init(args,null);

            // initialize the portable object adaptor (BOA/POA) connects client
            request using object reference
                //uses orb method as resolve_initial_reference
                POA rootPOA =
                POAHelper.narrow(orb.resolve_initial_references("RootPOA"));
                rootPOA.the_POAManager().activate();

                // creating an object of ReverseImpl class
                ReverseImpl rvr = new
                    ReverseImpl();
                //server consist of 2 classes ,servent and server. The servent is the subclass of ReversePOA which is generated
                by the idlj compiler
    }
}

```

```

// The servant ReverseImpl is the implementation of the ReverseModuleIDL interface
// get the object reference from the servant class
//use root POA class and its method servant_to_reference org.omg.CORBA.Object ref=
rootPOA.servant_to_reference(rvr);

// System.out.println("Step1");
Reverse h_ref = ReverseModule.ReverseHelper.narrow(ref); // Helper class provides narrow method that cast
corba object reference (ref) into the java interface
// System.out.println("Step2");
// orb layer uses resolve_initial_references method to take initialreference as NameService
org.omg.CORBA.Object objRef = orb.resolve_initial_references("NameService");
//Register new object in the naming context under the Reverse

// System.out.println("Step3");
NamingContextExt ncRef = NamingContextExtHelper.narrow(objRef);
//System.out.println("Step4");

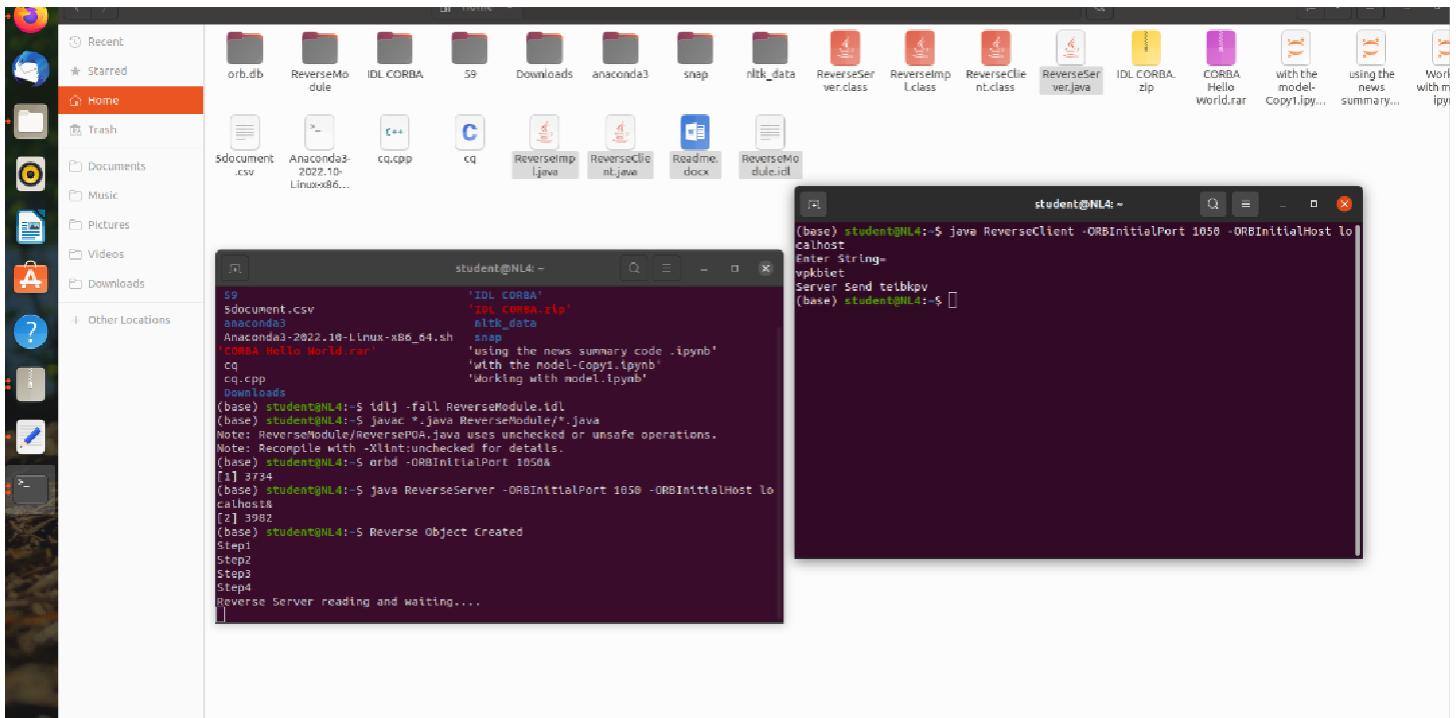
String name = "Reverse";
NameComponent path[] = ncRef.to_name(name);
ncRef.rebind(path,h_ref);
//Server run and waits for invocations of the new object from the client

System.out.println("Reverse Server reading and waiting. ");
orb.run());
}

catch(Exception e)
{
e.printStackTrace();
}
}
}

```

### **Result-**



## Building and Executing the solution:

The Hello World program lets you learn and experiment with all the tasks required to develop almost any CORBA program that uses static invocation, which uses a client stub for the invocation and a server skeleton for the service being invoked and is used when the interface of the object is known at compile time.

This example requires a naming service, which is a CORBA service that allows **CORBA objects** to be named by means of binding a name to an object reference. The **name binding** may be stored in the naming service, and a client may supply the name to obtain the desired object reference. The two options for Naming Services with Java include **orbd**, a daemon process containing a Bootstrap Service, a Transient Naming Service,

To run this client-server application on the development machine:

1. Change to the directory that contains the file Hello.idl.
2. Run the IDL-to-Java compiler, idlj, on the IDL file to create stubs and skeletons. This step assumes that you have included the path to the java/bindirectory in your path.

**idlj -fall Hello.idl**

You must use the -falloption with the idljcompiler to generate both client and server- side bindings. This command line will generate the default server-side bindings, which assumes the POA Inheritance server-side model.

The files generated by the idljcompiler for Hello.idl, with the -fallcommand line

option, are:

- HelloPOA.java:  
This abstract class is the stream-based server skeleton, providing basic CORBA functionality for the server. It extends org.omg.PortableServer.Servant, and implements the InvokeHandler interface and the HelloOperations interface. The server class HelloImpl extends HelloPOA.
- HelloStub.java:  
This class is the client stub, providing CORBA functionality for the client. It extends org.omg.CORBA.portable.ObjectImpl and implements the Hellojavainterface.
- Hello.java:  
This interface contains the Java version of IDL interface written. The Hello.java interface extends org.omg.CORBA.Object, providing standard CORBA object functionality. It also extends the HelloOperations interface and org.omg.CORBA.portable.IDLEntity.

- HelloHelper.java

This class provides auxiliary functionality, notably the narrow() method required to cast CORBA object references to their proper types. **The Helper class is responsible for reading and writing the data type to CORBA streams, and inserting and extracting the data type from AnyS.** The Holder class delegates to the methods in the Helper class for reading and writing.

- HelloHolder.java

This final class holds a public instance member of type Hello. Whenever the IDL type is an outor an inoutparameter, the Holder class is used. It provides operations for org.omg.CORBA.portable.OutputStream and org.omg.CORBA.portable.InputStream arguments, which CORBA allows, but which do not map easily to Java's semantics. The Holder class delegates to the methods in the Helper class for reading and writing. It implements org.omg.CORBA.portable.Streamable.

- HelloOperations.java

This interface contains the methods sayHello() and shutdown(). The IDL-to-Java mapping puts all of the operations defined on the IDL interface into this file, which is shared by both the stubs and skeletons.

3. Compile the .java files, including the stubs and skeletons (which are in the directory directory HelloApp). This step assumes the java/bindirectory is included in your path.

```
javac *.java HelloApp/*.java
```

4. Start orbdb.

To start orbdb from a UNIX command shell, enter:

```
orbdb -ORBInitialPort 1050&
```

Note that 1050 is the port on which you want the name server to run. The -ORBInitialPort argument is a required command-line argument.

5. Start the HelloServer:

To start the HelloServer from a UNIX command shell, enter:

```
java HelloServer -ORBInitialPort 1050 -ORBInitialHost localhost&
```

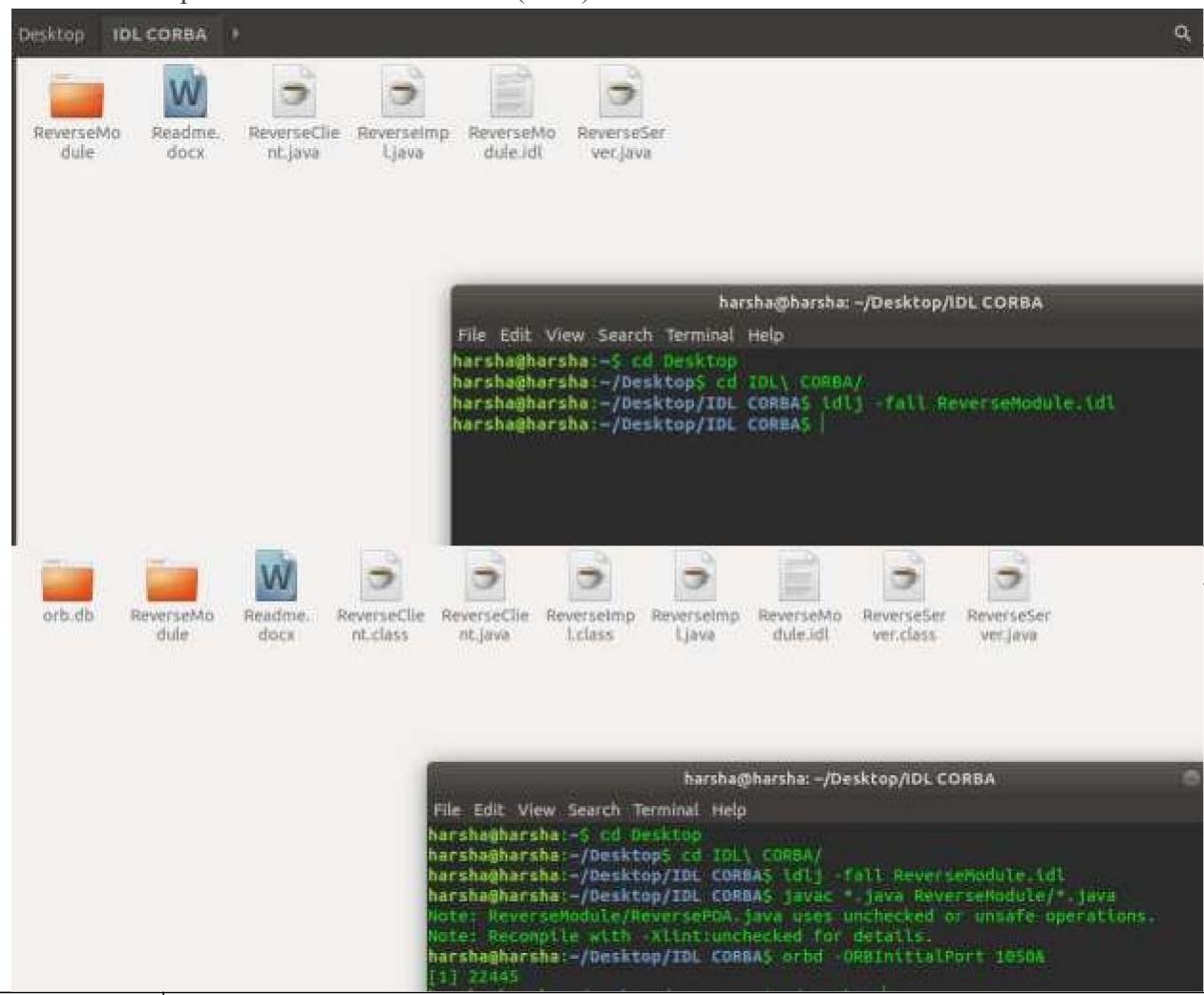
You will see HelloServer ready and waiting... when the server is started.

6. Run the client application:

```
java HelloClient -ORBInitialPort 1050 -ORBInitialHost localhost
```

When the client is running, you will see a response such as the following on your terminal: Obtained a handle on server object: IOR: (binary code)Hello World! HelloServer exiting...

After completion kill the name server (orbd).



```
harsha@harsha:~/Desktop/IDL-CORBA$ file EDT View Search Terminal Help
harsha@harsha:~/Desktop/IDL-CORBA$ java ReverseClient -ORBInitialPort 1090 -ORBInitialHost "localhost"
Enter String:
Hi hello there
server Send event done in
harsha@harsha:~/Desktop/IDL-CORBA$
```

```
harsha@harsha:~/Desktop/IDL-CORBA$ File Edit View Search Terminal Help
harsha@harsha:~/Desktop$ cd IDL-CORBA
harsha@harsha:~/Desktop/IDL-CORBA$ javac -fall ReverseModule.idl
harsha@harsha:~/Desktop/IDL-CORBA$ javac -r ReverseModule.java
Note: ReverseModule.java uses unchecked or unsafe operations.
Note: Recompile with -Xlint:unchecked for details.
harsha@harsha:~/Desktop/IDL-CORBA$ orb ORBInitialPort 1090
[1] 22445
harsha@harsha:~/Desktop/IDL-CORBA$ java ReverseServer -ORBInitialPort 1090 -ORBInitialHost "localhost"
[2] 22460
[3] 22467
harsha@harsha:~/Desktop/IDL-CORBA$ ORBInitialHost: command not found
Reverse Object Created
Step1
Step2
Step3
Step4
Reverse Server reading and waiting...
```

## Conclusion:

CORBA provides the network transparency, Java provides the implementation transparency. CORBA complements the Java™ platform by providing a distributed object framework, services to support that framework, and interoperability with other languages. The Java platform complements CORBA by providing a portable, highly productive implementation environment. The combination of Java and CORBA allows you to build more scalable and more capable applications than can be built using the JDK alone.

## ASSIGNMENT NO. 3

### Problem Statement:

To develop any distributed application using Message Passing Interface (MPI).

### Tools / Environment:

Java Programming Environment, JDK1.8 or higher, MPI Library (mpi.jar), MPJ Express (mpj.jar)

### Related Theory:

**Message passing** is a popularly renowned mechanism to implement parallelism in applications; it is also called MPI. The MPI interface for Java has a technique for identifying the user and helping in lower startup overhead. It also helps in collective communication and could be executed on both **shared memory and distributed systems**. MPJ is a familiar Java API for MPI implementation. mpiJava is the near flexible Java binding for MPJ standards. Currently developers can produce more efficient and effective parallel applications using message passing.

A basic prerequisite for message passing is a good communication API. Java comes with various ready-made packages for communication, notably an interface to BSD sockets, and the Remote Method Invocation (RMI) mechanism. The parallel computing world is mainly concerned with 'symmetric' communication, occurring in groups of interacting peers. This symmetric model of communication is captured in the successful Message Passing Interface standard (MPI).

### Message-Passing Interface Basics:

Every MPI program must contain the preprocessor directive:

```
#include <mpi.h>
```

The mpi.h file contains the definitions and declarations necessary for compiling an MPI program.

**MPI\_Init** initializes the execution environment for MPI. It is a “share nothing” modality in which the outcome of any one of the concurrent processes can in no way be influenced by the intermediate results of any of the other processes. Command has to be called before any other MPI call is made, and it is an error to call it more than a single time within the program. **MPI\_Finalize** cleans up all the extraneous mess that was first put into place by **MPI\_Init**.

The principal weakness of this limited form of processing is that the processes on different nodes run entirely independent of each other. It cannot enable capability or coordinated computing. **To get the different processes to interact, the concept of communicators is needed.** MPI programs are made up of concurrent processes executing at the same time that in almost all cases

are also communicating with each other. To do this, an object called the “communicator” is provided by MPI. Thus the user may specify any number of communicators within an MPI program, each with its own set of processes. “**MPI\_COMM\_WORLD**” communicator contains all the concurrent processes making up an MPI program.

The size of a communicator is the number of processes that makes up the particular communicator. The following function call provides the value of the number of processes of the specified communicator:

```
int MPI_Comm_size(MPI_Comm comm, int _size).
```

The function "MPI\_Comm\_size" required to return the number of processes; int size. `MPI_Comm_size(MPI_COMM_WORLD,&size);` This will put the total number of processes in the MPI\_COMM\_WORLD communicator in the variable size of the process data context. Every process within the communicator has a unique ID referred to as its “rank”. MPI system automatically and arbitrarily assigns a unique positive integer value, starting with 0, to all the processes within the communicator. The MPI command to determine the process rank is:

```
int MPI_Comm_rank (MPI_Comm comm, int _rank).
```

The sendfunction is used by the source process to define the data and establish the connection of the message. The send construct has the following syntax:

```
int MPI_Send (void _message, int count, MPI_Datatype datatype,int dest, int tag, MPI_Comm comm)
```

The first three operands establish the data to be transferred between the source and destination processes. The first argument points to the message content itself, which may be a simple scalar or a group of data. The message data content is described by the next two arguments. The second operand specifies the number of data elements of which the message is composed. The third operand indicates the data type of the elements that make up the message.

The receive command (MPI\_Recv) describes both the data to be transferred and the connection to be established. The MPI\_Recv construct is structured as follows:

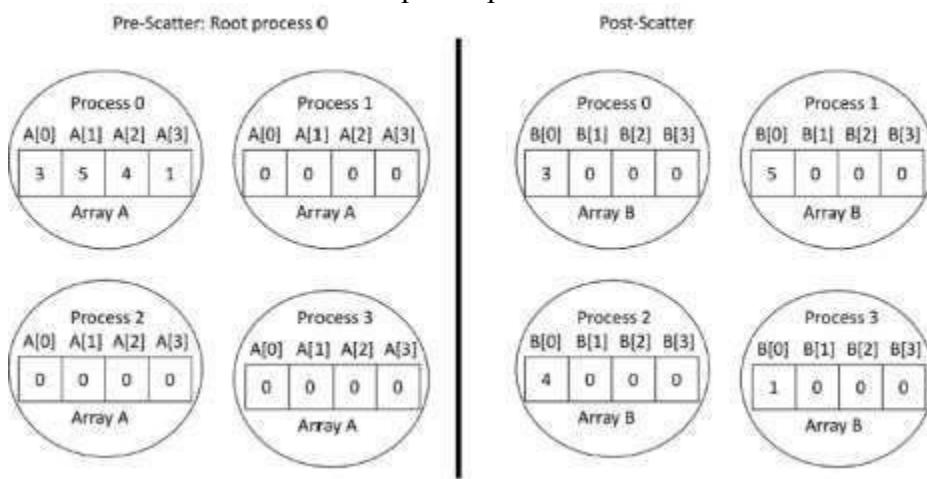
```
int MPI_Recv (void _message, int count, MPI_Datatype datatype,int source, int tag,  
MPI_Comm comm, MPI_Status _status)
```

The source field designates the rank of the process sending the message.

**Communication Collectives:** Communication collective operations can dramatically expand interprocess communication from point-to-point to n-way or all-way data exchanges.

**The scatter operation:** The scatter collective communication pattern, like broadcast, shares data of one process (the root) with all the other processes of a communicator. But in this case it partitions a set of data of the root process into subsets and sends one subset to each of the processes. Each receiving process gets a different subset, and there are as many subsets as there are processes. In this example the send array is A and the receive array is B. B is initialized to 0. The root process (process 0 here) partitions the data into subsets of length

1 and sends each subset to a separate process.



**MPJ Express** is an open source Java message passing library that allows application developers to write and execute parallel applications **for multicore processors and compute clusters / clouds**. The software is distributed under the MIT (a variant of the LGPL) license. MPJ Express is a message passing library that can be used by application developers to execute their parallel Java applications on compute clusters or network of computers.

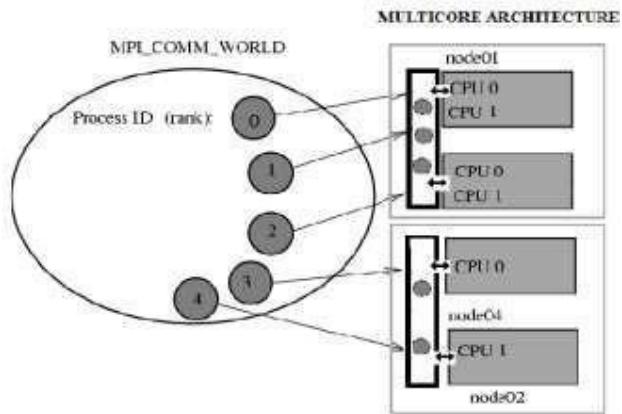
MPJ Express is essentially a middleware that supports communication between individual processors or clusters. **The programming model followed by MPJ Express is Single Program Multiple Data (SPMD).**

The multicore configuration is meant for users who plan to write and execute parallel Java

applications using MPJ Express on their desktops or laptops which contains shared memory and multicore processors. In this configuration, users can write their message passing parallel application using MPJ Express and it will be ported automatically on multicore processors. We expect that users can first develop applications on their laptops and desktops using multicore configuration, and then take the same code to distributed memory platforms

### Designing the solution:

While designing the solution, we have considered the multi-core architecture as per shown in the diagram below. The communicator has processes as per input by the user. MPI program will execute the sequence as per the supplied processes and the number of processor cores available for the execution.



### Implementing the solution:

1. For implementing the MPI program in multi-core environment, we need to install MPJ express library.
  - a. Download MPJ Express (mpj.jar) and unpack it.
  - b. Set MPJ\_HOME and PATH environment variables:
  - c. export MPJ\_HOME=/path/to/mpj/
  - d. export PATH=\$MPJ\_HOME/bin:\$PATH
2. Write Hello World parallel Java program and save it as HelloWorld.java (Asign2.java).
3. Compile a simple Hello World (Asign)parallel Java program
4. Running MPJ Express in the Multi-core Configuration.

### Writing the source code:

**Asign2.java**

```

import mpi.*;
public class Asign2 {

    public static void main(String args[]) throws Exception {
        MPI.Init(args);
        int me = MPI.COMM_WORLD.Rank();
        int size = MPI.COMM_WORLD.Size();
        System.out.println("Hi from <" + me + ">");
        MPI.Finalize();
    }
}

```

**Compile:** javac -cp \$MPJ\_HOME/lib/mpj.jar Asign2.java  
(mpj.jar is inside lib folder in the downloaded MPJ Express)

**Execute:** \$ MPJ\_HOME/bin/mpjrun.sh -np 4 Asign2

```
dos@dospc ~ /Desktop/Junaid/Asign2    mpjrun.sh -np 2 Asign2
MPJ Express (0.44) is started in the multicore configuration
Hi from <0>
Hi from <1>
dos@dospc ~ /Desktop/Junaid/Asign2    mpjrun.sh -np 4 Asign2
MPJ Express (0.44) is started in the multicore configuration
Hi from <3>
Hi from <1>
Hi from <2>
Hi from <0>
```

## ASSIGNMENT NO.4

### Problem Statement:

Berkeley algorithm for clock synchronization.

Implement

### Tools / Environment:

Anaconda(Jupiter Notebook/Spyder/Visual studio),Python Language ,

### Related Theory:

Berkeley's Algorithm is an algorithm that is used for clock Synchronisation in distributed systems. This algorithm is used in cases when some or all systems of the distributed network have one of these issues –

- A. The machine does not have an accurate time source.
- B. The network or machine does not have a UTC server.

The algorithm is designed to work in a network where clocks may be running at slightly different rates, and some computers may experience intermittent communication failures.

The basic idea behind Berkeley's Algorithm is that each computer in the network periodically sends its local time to a designated "master" computer, which then computes the correct time for the network based on the received timestamps. The master computer then sends the correct time back to all the computers in the network, and each computer sets its clock to the received time.

Distributed system contains multiple nodes that are physically separated but are linked together using a network.

### Berkeley's Algorithm

In this algorithm, the system chooses a node as master/ leader node. This is done from pool nodes in the server.

The algorithm is –

- An election process chooses the master node in the server.
- The leader then polls followers that provide their time in a way similar to Cristian's Algorithm, this is done periodically.
- The leader then calculates the relative time that other nodes have to change or adjust to synchronize to the global clock time which is the average of times that are provided to the leader node.

Let's sum-up steps followed to synchronize the clock using the Berkeley algorithm,

Nodes in the distributed system with their clock timings –

N1 -> 14:00 (master node)

N2 -> 13: 46

N3 -> 14: 15

Step 1 – The Leader is elected, node N1 is the master in the system.

Step 2 – leader requests for time from all nodes.

N1 -> time : 14:00

N2 -> time : 13:46

N3 -> time : 14:20

Step 3 – The leader averages the times and sends the correction time back to the nodes.

N1 -> Corrected Time 14:02 (+2)

N2 -> Corrected Time 14:02 (+16)

N3 -> Corrected Time 14:02 (-18)

This shows how the synchronization of nodes of a distributed system is done using Berkeley's algorithm.

### # Python3 program imitating a clock server

```
from functools import reduce
from dateutil import parser
import threading
import datetime
import socket
import time

# datastructure used to store client address and clock data
client_data = {}

""" nested thread function used to receive clock time from a connected
    client """
def startReceivingClockTime(connector, address):

    while True:
        # receive clock time
        clock_time_string = connector.recv(1024).decode()
        clock_time = parser.parse(clock_time_string)
        clock_time_diff = datetime.datetime.now() - \
            clock_time

        client_data[address] = {
            "clock_time" : clock_time,
            "time_difference" : clock_time_diff,
            "connector" : connector
        }

        print("Client Data updated with: " + str(address),
              end = "\n\n")
        time.sleep(5)

""" master thread function used to open portal for accepting clients over given
    port """
def startConnecting(master_server):

    # fetch clock time at slaves / clients
```

```

while True:
    # accepting a client / slave clock client master_slave_connector, addr =
    master_server.accept($slave_address = str(addr[0]) + ":" + str(addr[1]))

    print(slave_address + " got connected successfully")current_thread =
        threading.Thread(
            target = startReceivingClockTime,
            args = (master_slave_connector,
                    slave_address, ))
    current_thread.start()

# subroutine function used to fetch average clock difference
def getAverageClockDiff():

    current_client_data = client_data.copy() time_difference_list =
        list(client['time_difference'])

        for client_addr, client
            in client_data.items())

    sum_of_clock_difference = sum(time_difference_list, \
                                    datetime.timedelta(0, 0))

    average_clock_difference = sum_of_clock_difference \
                                / len(client_data)

    return average_clock_difference

"""

 master sync thread function used to generate cycles of clock synchronization
 in the network "
def synchronizeAllClocks()while True:

    print("New synchronization cycle started.") print("Number of clients to be
    synchronized: " + \
    str(len(client_data)))

    if len(client_data) > 0:

        average_clock_difference = getAverageClockDiff()for client_addr,
        client in client_data.items():
            try:
                synchronized_time = \ datetime.datetime.now()
                +
                average_clock_difference

```

```

        client['connector'].send(str(
            synchronized_time).encode())

    except Exception as e:
        print("Something went wrong while " + \ "sending
              synchronized time " + \ "through " +
              str(client_addr))

    else :
        print("No client data." + \
              " Synchronization not applicable.")

        print("\n\n")ime.sleep(5)

# function used to initiate the Clock Server / Master Node
def initiateClockServer(port =
8080):

    master_server = socket.socket() master_server.setsockopt(socket.SOL_SOCKET,
                                                    socket.SO_REUSEADDR, 1)

    print("Socket at master node created successfully\n") master_server.bind(("",
port))

    # Start listening to requests master_server.listen(10)
    print("Clock server started...\n")

    # start making connections
    print("Starting to make connections...\n")master_thread =
threading.Thread(
        target = startConnectingargs =
(master_server, ))
    master_thread.start()

    # start synchronization
    print("Starting synchronization parallelly...\n")sync_thread = threading.Thread(
        target = synchronizeAllClocksargs = ())
    sync_thread.start()

# Driver function
if __name__ == '__main__':

    # Trigger the Clock Server initiateClockServer(port =
8080)

```

## **Output:**

**New synchronization cycle started. Number of clients to be synchronized: 3**

**Client Data updated with: 127.0.0.1:57284**

**Client Data updated with: 127.0.0.1:57274**

**Client Data updated with: 127.0.0.1:57272**

## **Client:**

```
# Python3 program imitating a client process

from timeit import default_timer as timefrom dateutil import
parser
import threadingimport
datetime import socket
import time

# client thread function used to send time at client sidedef
startSendingTime(slave_client):

    while True:
        # provide server with clock time at the client
        slave_client.send(str(
            datetime.datetime.now()).encode())

        print("Recent time sent successfully",
              end = "\n\n")
        time.sleep(5)

# client thread function used to receive synchronized timedef
startReceivingTime(slave_client):

    while True:
        # receive data from the server
        Synchronized_time =
        parser.parse(
```

```

        slave_client.recv(1024).decode()

    print("Synchronized time at the client is: " + \
          str(Synchronized_time) + "\n\n")

# function used to Synchronize client process time
def initiateSlaveClient(port = 8080):

    slave_client = socket.socket()

    # connect to the clock server on local computer
    slave_client.connect(('127.0.0.1', port))

    # start sending time to server
    print("Starting to receive time from server\n")
    send_time_thread = threading.Thread(
        target = startSendingTime,
        args = (slave_client, ))
    send_time_thread.start()

    # start receiving synchronized from server
    print("Starting to receiving
    " + \
          "synchronized time from server\n")
    receive_time_thread = threading.Thread(
        target = startReceivingTime,
        args = (slave_client, ))
    receive_time_thread.start()

# Driver function
if __name__ == '__main__':
    # initialize the Slave / Client
    initiateSlaveClient(port =
8080)

```

**output:**

**Recent time sent successfully**

**Synchronized time at the client is: 2018-11-23 18:49:31.166449**

## ASSIGNMENT NO.5

### Problem Statement:

Bully and Ring algorithm for leader election.

Implement

### Tools / Environment:

Programming Environment, JDK 1.8, Eclipse Neon(EE).

Java

### Related Theory:

Election

#### Algorithm:

1. Many distributed algorithms require a process to act as a coordinator.
2. The coordinator can be any process that organizes actions of other processes.
3. A coordinator may fail.
4. How is a new coordinator chosen or elected?

#### Assumptions:

Each process has a unique number to distinguish them. Processes know each other's process number.

There are two types of Distributed Algorithms:

1. Bully Algorithm
2. Ring Algorithm

#### Bully Algorithm:

##### A. When a process, P, notices that the coordinator is no longer responding to requests, it initiates an election.

1. P sends an ELECTION message to all processes with higher numbers.
2. If no one responds, P wins the election and becomes a coordinator.
3. If one of the higher-ups answers, it takes over. P's job is done.

##### B. When a process gets an ELECTION message from one of its lower-numbered colleagues:

1. Receiver sends an OK message back to the sender to indicate that he is alive and will take over.
2. Eventually, all processes give up apart of one, and that one is the new coordinator.
3. The new coordinator announces its victory by sending all processes a CO-ORDINATOR message telling them that it is the new coordinator.

##### C. If a process that was previously down comes back:

1. It holds an election.
2. If it happens to be the highest process currently running, it will win the election and take over the coordinators job.

"Biggest guy" always wins and hence the name bully algorithm.

## **Ring Algorithm:**

### **Initiation:**

1. When a process notices that coordinator is not functioning:
2. Another process (initiator) initiates the election by sending "ELECTION" message (containing its own process number)

### **Leader Election:**

3. Initiator sends the message to it's successor (if successor is down, sender skips over it and goes to the next member along the ring, or the one after that, until a running process is located).
4. At each step, sender adds its own process number to the list in the message.
5. When the message gets back to the process that started it all: Message comes back to initiator.

In the queue the **process with maximum ID Number wins**.

Initiator announces the winner by sending another message around the ring.

## **Designing the solution:**

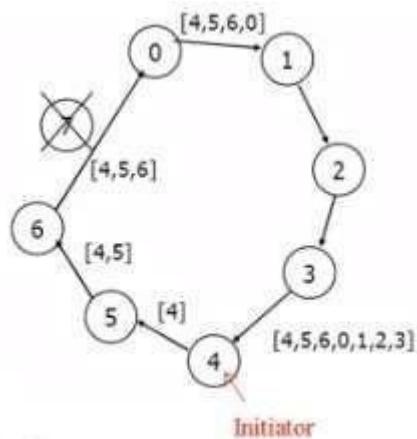
### **A. For Ring Algorithm**

#### **Initiation:**

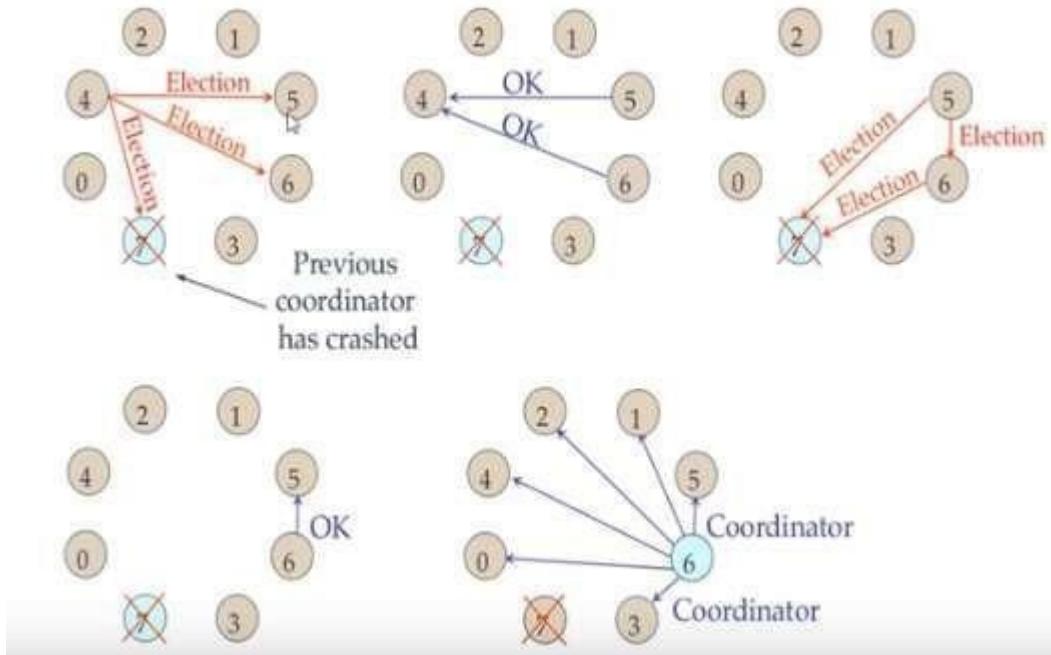
1. Consider the Process 4 understands that Process 7 is not responding.
2. Process 4 initiates the Election by sending "ELECTION" message to it's successor (or next alive process) with it's ID.

#### **Leader Election:**

3. Messages comes back to initiator. Here the initiator is 4.
4. Initiator announces the winner by sending another message around the ring. Here the process with highest process ID is 6. The initiator will announce that Process 6 is Coordinator.



## B. For Bully Algorithm:



### Implementing the solution:

#### For Ring Algorithm:

1. Creating Class for Process which includes
  - i) State: Active / Inactive
  - ii) Index: Stores index of process.
  - iii) ID: Process ID
2. Import Scanner Class for getting input from Console
3. Getting input from User for number of Processes and store them into object of classes.
4. Sort these objects on the basis of process id.
5. Make the last process id as "inactive".
6. Ask for menu 1.Election 2.Exit
7. Ask for initializing election process.
8. These inputs will be used by Ring Algorithm.

## **Writing the source code:**

Bully.java

The screenshot shows the Eclipse IDE interface with the following details:

- File Bar:** File, Edit, Source, Refactor, Navigate, Search, Project, Run, Window, Help.
- Toolbar:** Standard Eclipse toolbar icons.
- Left Panel:** Shows the file structure for "Bully.java" and its contents.
- Right Panel:** A multi-tabbed view with tabs for Problems, Javadoc, Declaration, Console, and another Console tab.
- Console Tab Content:**
  - Bally (1) [Java Application] /usr/lib/jvm/java-8-openjdk-amd64/bin/java [28-Dec-2018, 7:35:55 AM]
  - 5 active process are:
  - Process up = p1 p2 p3 p4 p5
  - Process 5 is coordinator
  - .....
  - 1 up a process.
  - 2.down a process
  - 3 send a message
  - 4.Exit
  - .....
  - bring down any process..
  - 5
  - .....
  - 1 up a process.
  - 2.down a process
  - 3 send a message
  - 4.Exit
  - .....
  - which process will send message
  - processSelection
  - election send from process2to process 3
  - election send from process2to process 4
  - election send from process2to process 5
  - Coordinator message send from process4to all
  - .....
  - 1 up a process.
  - 2.down a process
  - 3 send a message
  - 4.Exit

## Ring.java

The screenshot shows the Eclipse IDE interface with the Ring.java file open in the editor. The code implements a ring-based election algorithm. In the console view, the program prompts for the number of processes (5), their IDs (5, 6, 8), and initializes them. It then sorts the processes by ID and performs a series of messages between processes 5, 6, and 8, eventually selecting process 8 as the coordinator. The final output shows the program terminating.

```
Ring.java
1 import java.util.Scanner;
2
3 public class Ring {
4
5     public static void main(String[] args) {
6
7         // TODO Auto-generated method stub
8
9         int temp, i, j;
10        char str[] = new char[10];
11        Rr proc[] = new Rr[10];
12
13        // object initialisation
14        for (i = 0; i < proc.length; i++)
15            proc[i] = new Rr();
16
17        // scanner used for getting input from console
18        Scanner in = new Scanner(System.in);
19        System.out.println("Enter the number of process : ");
20        int num = in.nextInt();
21
22        // getting input from users:
23        for (i = 0; i < num; i++) {
24            proc[i].index = i;
25            System.out.println("Enter the id of process : ");
26            proc[i].id = in.nextInt();
27            proc[i].state = "active";
28            proc[i].f = 8;
29        }
30
31
32        // sorting the processes from on the basis of id
33        for (i = 0; i < num - 1; i++) {
34            for (j = 0; j < num - 1; j++) {
35                if (proc[j].id > proc[j + 1].id) {
36                    temp = proc[j].id;
37                    proc[j].id = proc[j + 1].id;
38                    proc[j + 1].id = temp;
39                }
40            }
41        }
42    }
43}
```

```
<terminated> Ring (1) [Java Application] /usr/lib/jvm/java-8-openjdk-amd64/bin/java [28]
Enter the number of process :
5
Enter the id of process :
5 6 8
Enter the id of process :
Enter the id of process :
[0] 5 [1] 6 [2] 8
process 8 select as co-ordinator
1.election 2.quit
1

Enter the Process number who initialised election :
2

Process 8 send message to 5
Process 5 send message to 6
Process 6 send message to 8
process 8 select as co-ordinator
1.election 2.quit
2

Program terminated ...
```

## Compiling and Executing the solution:

1. Create Java Project in Eclipse
2. Create Package
3. Add class in package Ring.java.
4. Compile and Execute in Eclipse.

The output is associated in the above section.

**Conclusion:** Election algorithms are designed to choose a coordinator. We have two election algorithms for two different configurations of distributed system. The **Bully** algorithm applies to system where every process can send a message to every other process in the system and **The Ring** algorithm applies to systems organized as a ring (logically or physically). In this algorithm we assume that the link between the process are unidirectional and every process can message to the process on its right only.

## ASSIGNMENT NO. 6

### Problem Statement:

To create a simple web service and write any distributed application to consume the web service.

### Tools / Environment:

Java Programming Environment, JDK 8, Netbeans IDE with GlassFish Server

### Related Theory:

**Web Service:**  
A web service can be defined as a collection of open protocols and standards for exchanging information among systems or applications.

A service can be treated as a web service if:

- The service is discoverable through a simple lookup
- It uses a standard XML format for messaging
- It is available across internet/intranet networks.
- It is a self-describing service through a simple XML syntax
- The service is open to, and not tied to, any operating system/programming language

### Types of Web Services:

There are two types of web services:

1. **SOAP:** SOAP stands for Simple Object Access Protocol. SOAP is an XML based industry standard protocol for designing and developing web services. Since it's XML based, it's platform and language independent. So, our server can be based on JAVA and client can be on .NET, PHP etc. and vice versa.
2. **REST:** REST (Representational State Transfer ) is an architectural style for developing web services. It's getting popularity recently because it has small learning curve when compared to SOAP. Resources are core concepts of Restful web services and they are uniquely identified by their URIs.

### Web service architectures:

As part of a web service architecture, there exist three major roles.

**Service Provider** is the program that implements the service agreed for the web service and exposes the service over the internet/intranet for other applications to interact with.

**Service Requestor** is the program that interacts with the web service exposed by the Service Provider. It makes an invocation to the web service over the network to the Service Provider and exchanges information.

**Service Registry** acts as the directory to store references to the web services.

The following are the steps involved in a basic SOAP web service operational behavior:

1. The client program that wants to interact with another application prepares its request content as a SOAP message.
2. Then, the client program sends this SOAP message to the server web service as an HTTP POST request with the content passed as the body of the request.
3. The web service plays a crucial role in this step by understanding the SOAP request and converting it into a set of instructions that the server program can understand.
4. The server program processes the request content as programmed and prepares the output as the response to the SOAP request.
5. Then, the web service takes this response content as a SOAP message and reverts to the SOAP HTTP request invoked by the client program with this response.
6. The client program web service reads the SOAP response message to receive the outcome of the server program for the request content it sent as a request.

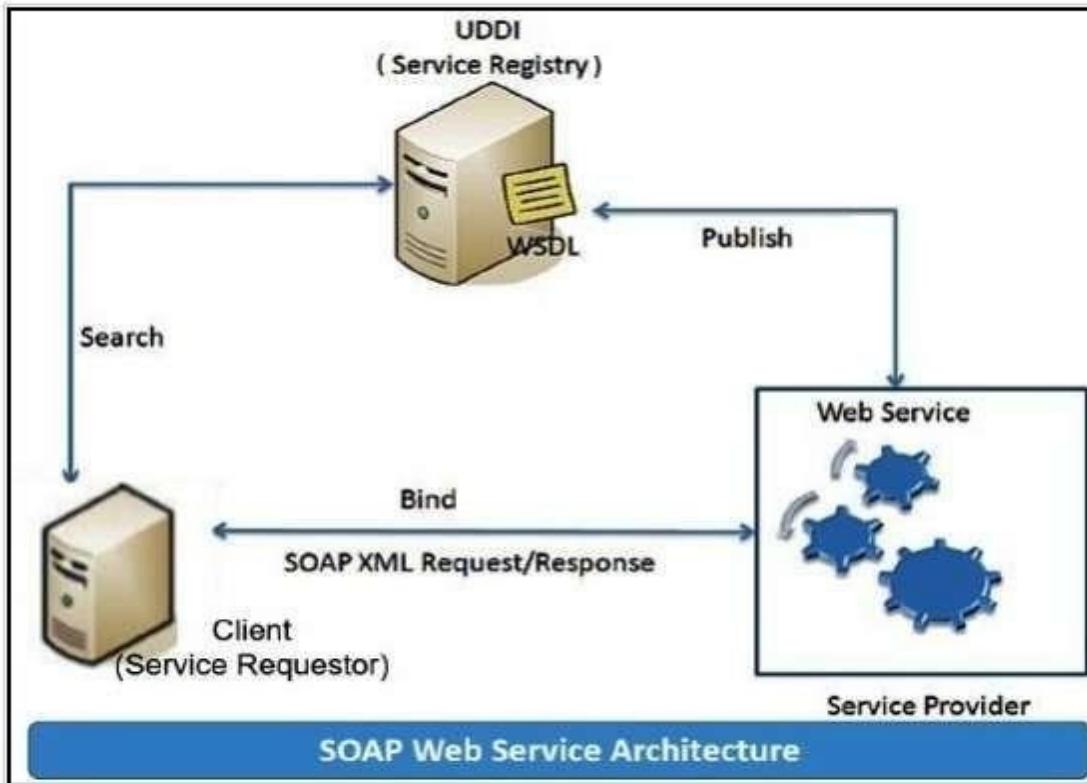
#### **SOAP web services:**

**Simple Object Access Protocol (SOAP)** is an XML-based protocol for accessing web services. It is a W3C recommendation for communication between two applications, and it is a platform- and language-independent technology in integrated distributed applications.

While XML and HTTP together make the basic platform for web services, the following are the key components of standard SOAP web services:

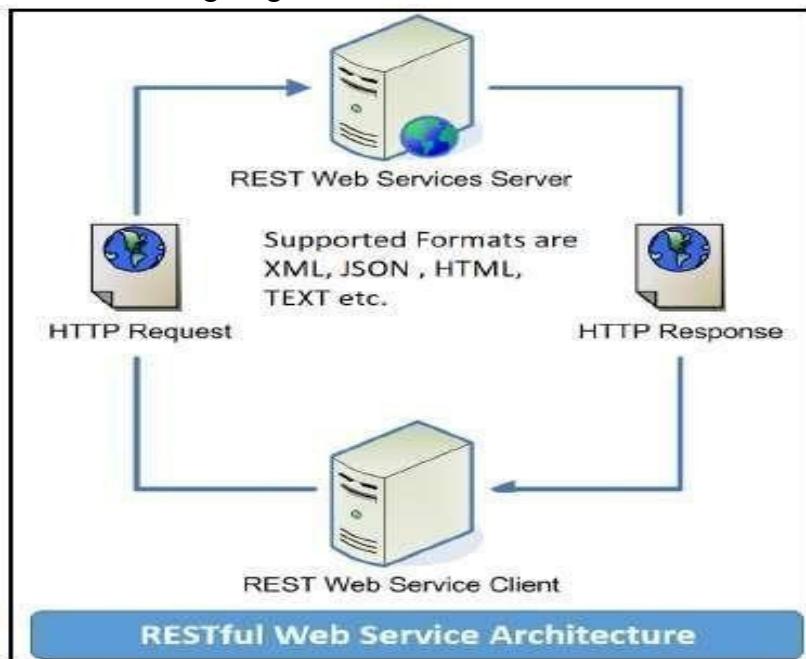
**Universal Description, Discovery, and Integration (UDDI):** UDDI is an XML-based framework for describing, discovering, and integrating web services. It acts as a directory of web service interfaces described in the WSDL language.

**Web Services Description Language (WSDL):** WSDL is an XML document containing information about web services, such as the method name, method parameters, and how to invoke the service. WSDL is part of the UDDI registry. It acts as an interface between applications that want to interact based on web services. The following diagram shows the interaction between the UDDI, Service Provider, and service consumer in SOAP web services:



## RESTful web services

**REST** stands for **R**epresentational **S**tate **T**ransfer. RESTful web services are considered a performance-efficient alternative to the SOAP web services. REST is an architectural style, not a protocol. Refer to the following diagram:



While both SOAP and RESTful support efficient web service development, the difference between these two technologies can be checked out in the following table :

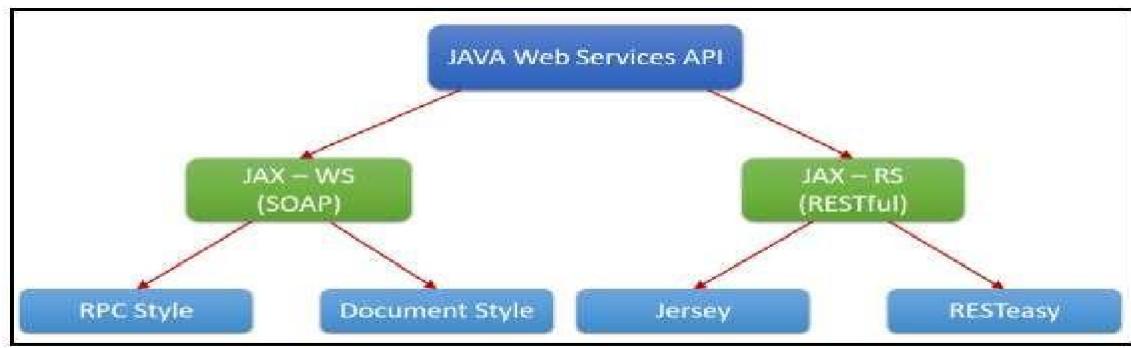
SOAP	REST
SOAP is a protocol.	REST is an architectural style.
SOAP stands for Simple Object Access Protocol.	REST stands for REpresentational State Transfer.
SOAP can't use REST because it is a protocol.	REST can use SOAP web services because it is a concept and can use any protocol like HTTP, SOAP.
SOAP uses services interfaces to expose the business logic.	REST uses URI to expose business logic.
JAX-WS is the java API for SOAP web services.	JAX-RS is the java API for RESTful web services.
SOAP defines standards to be strictly followed.	REST does not define too much standards like SOAP.
SOAP requires more bandwidth and resource than REST.	REST requires less bandwidth and resource than SOAP.
SOAP defines its own security.	RESTful web services inherits security measures from the underlying transport.
SOAP permits XML data format only.	REST permits different data format such as Plain text, HTML, XML, JSON etc.
SOAP is less preferred than REST.	REST more preferred than SOAP.

### Designing the solution:

Java provides it's own API to create both SOAP as well as RESTful web services.

1. **JAX-WS:** JAX-WS stands for Java API for XML Web Services. JAX-WS is XML based Java API to build web services server and client application.
2. **JAX-RS:** Java API for RESTful Web Services (JAX-RS) is the Java API for creating REST web services. JAX-RS uses annotations to simplify the development and deployment of web services.

Both of these APIs are part of standard JDK installation, so we don't need to add any jars to work with them.



## Implementing the solution:

### 1. Creating a web service CalculatorWSApplication:

Create New Project for CalculatorWSApplication. Create a package org.calculator. Create class CalculatorWS.

Right-click on the CalculatorWS and create New Web Service.

IDE starts the glassfish server, builds the application and deploys the application on server.

### 2. Consuming the Webservice:

Create a project with an CalculatorClient

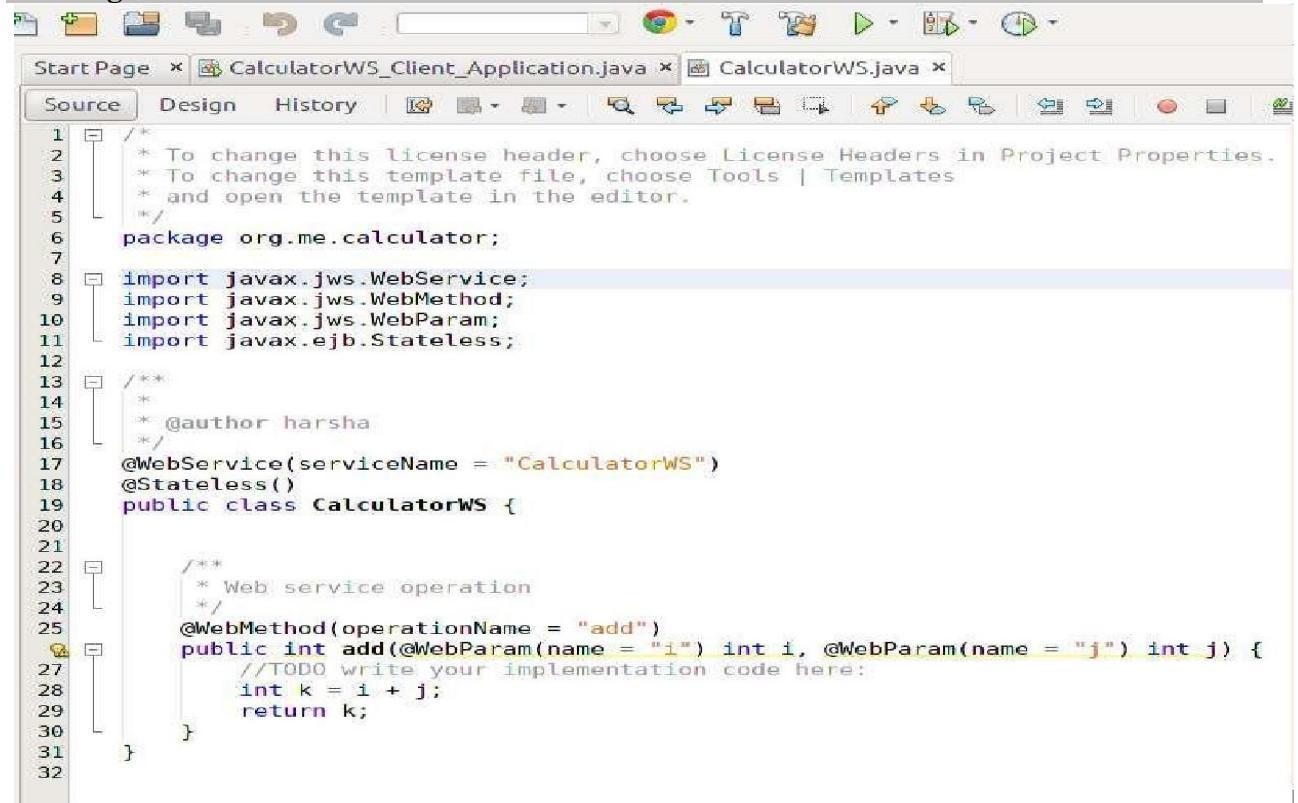
Create package org.calculator.client;

add java class CalculatorWS.java, addresponse.java, add.java, CalculatorWSService.java and ObjectFactory.java

### 3. Creating servlet in web application

Create new jsp page for creating user interface.

## Writing the source code:



```
1  /*
2  * To change this license header, choose License Headers in Project Properties.
3  * To change this template file, choose Tools | Templates
4  * and open the template in the editor.
5  */
6  package org.me.calculator;
7
8  import javax.jws.WebService;
9  import javax.jws.WebMethod;
10 import javax.jws.WebParam;
11 import javax.ejb.Stateless;
12
13 /**
14 *
15 * @author harsha
16 */
17 @WebService(serviceName = "CalculatorWS")
18 @Stateless()
19 public class CalculatorWS {
20
21
22     /**
23      * Web service operation
24      */
25     @WebMethod(operationName = "add")
26     public int add(@WebParam(name = "i") int i, @WebParam(name = "j") int j) {
27         //TODO write your implementation code here:
28         int k = i + j;
29         return k;
30     }
31 }
32 }
```

The screenshot shows the NetBeans IDE interface with the following details:

- Code Editor:** Displays the `CalculatorWS_Client_Application.java` file. The code implements a Java application that uses a web service to add two integers. The `main` method calls the `add` method of the `CalculatorWS_Service` to print the result.
- Output Window:** Shows the build and deployment logs for the `CalculatorWSApplication`. It indicates a successful build and deployment to GlassFish Server 4.1.1.
- Navigator:** Shows the members of the `CalculatorWS_Client_Application` class, including the `add` method and the `main` method.
- Project Explorer:** Shows the project structure under the `CalculatorWS_Client_Application` node, including source packages, libraries, and configuration files.

```
/*
 * To change this license header, choose License Headers in Project Properties.
 * To change this template file, choose Tools | Templates.
 * and open the template in the editor.
 */
package calculatorws_client_application;

/**
 *
 * @author harsha
 */
public class CalculatorWS_Client_Application {

    /**
     * @param args the command line arguments
     */
    public static void main(String[] args) {
        // TODO code application logic here
        try {
            int i = 3;
            int j = 4;
            int result = add(i, j);
            System.out.println("Result = " + result);
        } catch (Exception ex) {
            System.out.println("Exception: " + ex);
        }
    }

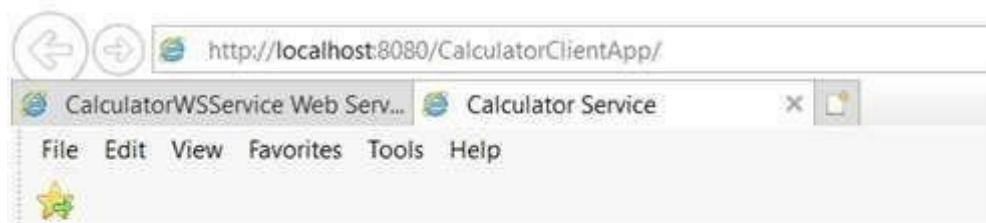
    private static int add(int i, int j) {
        org.me.calculator.CalculatorWS_Service service = new org.me.calculator.CalculatorWS_Service();
        org.me.calculator.CalculatorWS port = service.getCalculatorWSPort();
        return port.add(i, j);
    }
}
```

```
try {
    int i = 3;
    int j = 4;
    int result = add(i, j);
    System.out.println("Result = " + result);
} catch (Exception ex) {
    System.out.println("Exception: " + ex);
}

private static int add(int i, int j) {
    org.me.calculator.CalculatorWS_Service service = new org.me.calculator.CalculatorWS_Service();
    org.me.calculator.CalculatorWS port = service.getCalculatorWSPort();
    return port.add(i, j);
}
```

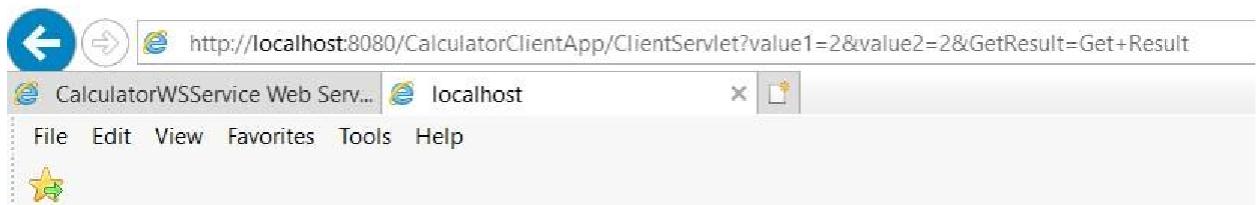
### Compiling and Executing the solution:

Right Click on the Project and Choose Run.



## Calculator Service

2	+	2	=	Get Result
---	---	---	---	------------



## Servlet ClientServlet at /CalculatorClientApp

Result:  $2 + 2 = 4$

### Conclusion:

This assignment, described the Web services approach to the Service Oriented Architecture concept. Also, described the Java APIs for programming Web services and demonstrated examples of their use by providing detailed step-by-step examples of how to program Web services in Java.