



Sistemas Distribuídos

Interprocess Communication and Synchronization
Remote Objects - 2

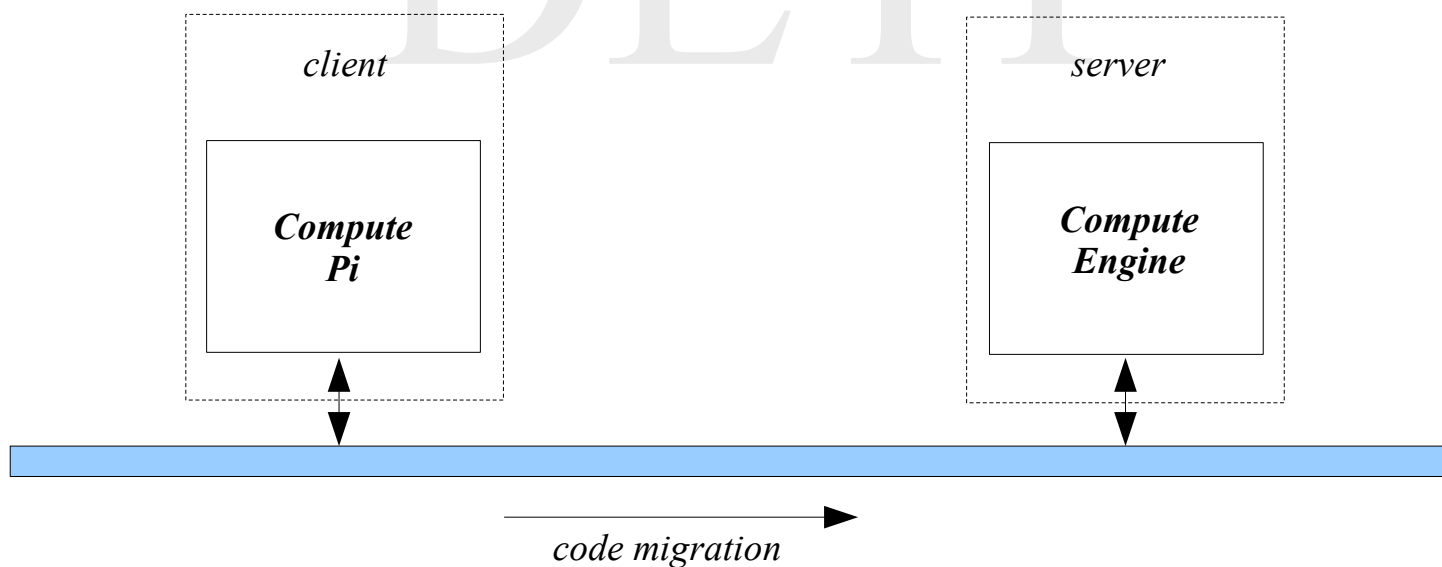
António Rui Borges

Summary

- *Characterization of the problem*
- *Code description*
- *Interaction diagrams*
- *Organization of the package BackEngine*
- *Local security policy*
- *Build and deploy*
- *Running the application*
- *Suggested reading*

Characterization of the problem - 1

- it is an example, adapted from the tutorial of Sun about *RMI*, to illustrate how code can be transferred between Java virtual machines, located on the same or on different hardware platforms, and be run in a JVM other than the one where it was formerly stored

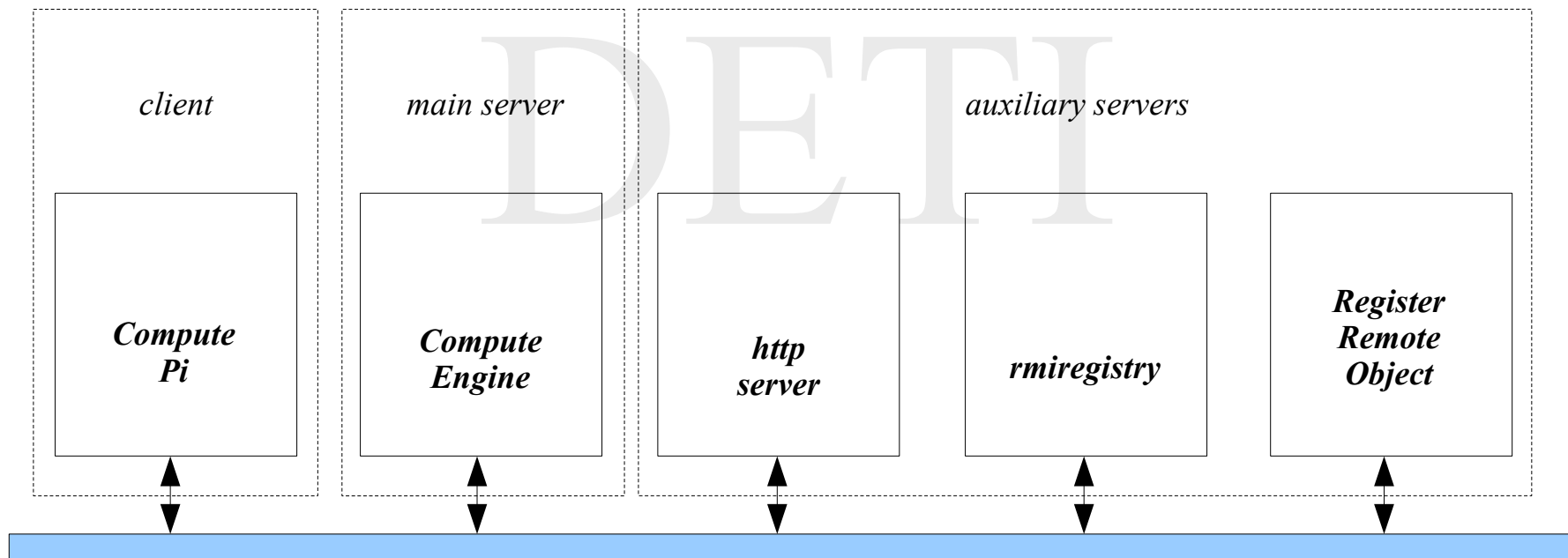


Characterization of the problem - 2

- two main classes of entities are considered
 - a *server object*, of type `ComputeEngine`, which provides a service for local execution of migrated code under remote control
 - several *client objects* to handle the local execution of migrated code under remote control (interfaces `Compute` and `Task`); in the present case, another object, of type `ComputePi`, transfers an object of type `Pi` (computation of π with a variable number of decimals) for remote execution
- and three auxiliary entities
 - a naming service for registering remote objects (`rmiregistry`)
 - a *server object*, of type `RegisterRemoteObject`, which provides support to register remote objects (those located in JVMs residing in hardware platforms other than the one the naming service is located)
 - a *http server* to assist the dynamic downloading of the data types used in remote calls.

Characterization of the problem - 3

Operational setup



Register Remote Object base thread - 1

```
public class ServerRegisterRemoteObject
{
    public static void main(String[] args)
    {
        /* get location of the registering service */

        String rmiRegHostName;
        int rmiRegPortNumb;

        GenericIO.writeString ("Name of the processing node where the registering service is located? ");
        rmiRegHostName = GenericIO.readLineString ();
        GenericIO.writeString ("Port number where the registering service is listening to? ");
        rmiRegPortNumb = GenericIO.readLineInt ();

        /* create and install the security manager */

        if (System.getSecurityManager () == null)
            System.setSecurityManager (new SecurityManager ());
        GenericIO.writelnString ("Security manager was installed!");

        /* instantiate a registration remote object and generate a stub for it */

        RegisterRemoteObject regEngine = new RegisterRemoteObject (rmiRegHostName, rmiRegPortNumb);
        Register regEngineStub = null;
        int listeningPort = 22001;                /* it should be set accordingly in each case */

        try
        { regEngineStub = (Register) UnicastRemoteObject.exportObject (regEngine, listeningPort);
        }
        catch (RemoteException e)
        { GenericIO.writelnString ("RegisterRemoteObject stub generation exception: " + e.getMessage ());
          System.exit (1);
        }
        GenericIO.writelnString ("Stub was generated!");
    }
}
```

Register Remote Object base thread - 2

```
/* register it with the local registry service */

String nameEntry = "RegisterHandler";
Registry registry = null;

try
{ registry = LocateRegistry.getRegistry (rmiRegHostName, rmiRegPortNumb);
}
catch (RemoteException e)
{ GenericIO.writelnString ("RMI registry creation exception: " + e.getMessage ());
  System.exit (1);
}
GenericIO.writelnString ("RMI registry was created!");

try
{ registry.rebind (nameEntry, regEngineStub);
}
catch (RemoteException e)
{ GenericIO.writelnString ("RegisterRemoteObject remote exception on registration: " +
                          e.getMessage ());
  System.exit (1);
}
GenericIO.writelnString ("RegisterRemoteObject object was registered!");
}
```

Register Remote Object and related interfaces - 1

```
public interface Register extends Remote
{
    public void bind (String name, Remote ref) throws RemoteException, AlreadyBoundException;
    public void unbind (String name) throws RemoteException, NotBoundException;
    public void rebind (String name, Remote ref) throws RemoteException;
}
```


Register Remote Object and related interfaces - 2

```
public class RegisterRemoteObject implements Register
{
    private String rmiRegHostName;
    private int rmiRegPortNumb = 1099;

    public RegisterRemoteObject (String rmiRegHostName, int rmiRegPortNumb)
    {
        if ((rmiRegHostName == null) || ("".equals (rmiRegHostName)))
            throw new NullPointerException ("RegisterRemoteObject: null pointer parameter on instantiation!");
        this.rmiRegHostName = rmiRegHostName;
        if ((rmiRegPortNumb >= 4000) && (rmiRegPortNumb <= 65535))
            this.rmiRegPortNumb = rmiRegPortNumb;
    }

    public void bind (String name, Remote ref) throws RemoteException, AlreadyBoundException
    {
        Registry registry;

        if ((name == null) || (ref == null))
            throw new NullPointerException ("RegisterRemoteObject: null pointer parameter(s) on on bind!");
        registry = LocateRegistry.getRegistry (rmiRegHostName, rmiRegPortNumb);
        registry.bind (name, ref);
    }
}
```

Register Remote Object and related interfaces - 3

```
public void unbind (String name) throws RemoteException, NotBoundException
{
    Registry registry;

    if ((name == null))
        throw new NullPointerException ("RegisterRemoteObject: null pointer parameter(s) on unbind!");
    registry = LocateRegistry.getRegistry (rmiRegHostName, rmiRegPortNumb);
    registry.unbind (name);
}
public void rebind (String name, Remote ref) throws RemoteException
{
    Registry registry;

    if ((name == null) || (ref == null))
        throw new NullPointerException ("RegisterRemoteObject: null pointer parameter(s) on rebind!");
    registry = LocateRegistry.getRegistry (rmiRegHostName, rmiRegPortNumb);
    registry.rebind (name, ref);
}
```

Compute Engine base thread - 1

```
public class ServerComputeEngine
{
    public static void main(String[] args)
    {
        /* get location of the registry service */

        String rmiRegHostName;
        int rmiRegPortNumb;

        GenericIO.writeString ("Name of the processing node where the registering service is located? ");
        rmiRegHostName = GenericIO.readlnString ();
        GenericIO.writeString ("Port number where the registering service is listening to? ");
        rmiRegPortNumb = GenericIO.readlnInt ();

        /* create and install the security manager */

        if (System.getSecurityManager () == null)
            System.setSecurityManager (new SecurityManager ());
        GenericIO.writelnString ("Security manager was installed!");

        /* instantiate a remote object that runs mobile code and generate a stub for it */

        ComputeEngine engine = new ComputeEngine ();
        Compute engineStub = null;
        int listeningPort = 22002;                /* it should be set accordingly in each case */

        try
        { engineStub = (Compute) UnicastRemoteObject.exportObject (engine, listeningPort);
        }
        catch (RemoteException e)
        { GenericIO.writelnString ("ComputeEngine stub generation exception: " + e.getMessage ());
          e.printStackTrace ();
          System.exit (1);
        }
        GenericIO.writelnString ("Stub was generated!")
    }
}
```

Compute Engine base thread - 2

```
/* register it with the general registry service */

String nameEntryBase = "RegisterHandler";
String nameEntryObject = "Compute";
Registry registry = null;
Register reg = null;

try
{ registry = LocateRegistry.getRegistry (rmiRegHostName, rmiRegPortNumb);
}
catch (RemoteException e)
{ GenericIO.writelnString ("RMI registry creation exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}
GenericIO.writelnString ("RMI registry was created!");

try
{ reg = (Register) registry.lookup (nameEntryBase);
}
catch (RemoteException e)
{ GenericIO.writelnString ("RegisterRemoteObject lookup exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}
catch (NotBoundException e)
{ GenericIO.writelnString ("RegisterRemoteObject not bound exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}
```

Compute Engine base thread - 3

```
try
{ reg.bind (nameEntryObject, engineStub);
}
catch (RemoteException e)
{ GenericIO.writelnString ("ComputeEngine registration exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}
catch (AlreadyBoundException e)
{ GenericIO.writelnString ("ComputeEngine already bound exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}
GenericIO.writelnString ("ComputeEngine object was registered!");
}
```

Compute Engine remote object and related interfaces

```
public interface Compute extends Remote
{
    Object executeTask (Task t) throws RemoteException;
}

public interface Task extends Serializable
{
    public static final long serialVersionUID = 2021L;

    Object execute();
}

public class ComputeEngine implements Compute
{
    public Object executeTask (Task t)
    {
        return t.execute ();
    }
}
```

Compute Pi thread base - 1

```
public class ComputePi
{
    public static void main(String args[])
    {
        /* get location of the generic registry service */

        String rmiRegHostName;
        int rmiRegPortNumb;

        GenericIO.writeString ("Name of the processing node where the registering service is located? ");
        rmiRegHostName = GenericIO.readLineString ();
        GenericIO.writeString ("Port number where the registering service is listening to? ");
        rmiRegPortNumb = GenericIO.readLineInt ();

        /* look for the remote object by name in the remote host registry */

        String nameEntry = "Compute";
        Compute comp = null;
        Registry registry = null;

        try
        { registry = LocateRegistry.getRegistry (rmiRegHostName, rmiRegPortNumb);
        }
        catch (RemoteException e)
        { GenericIO.writelnString ("RMI registry creation exception: " + e.getMessage ());
          e.printStackTrace ();
          System.exit (1);
        }
    }
}
```

Compute Pi thread base - 2

```
try
{ comp = (Compute) registry.lookup (nameEntry);
}
catch (RemoteException e)
{ GenericIO.writelnString ("ComputePi look up exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}
catch (NotBoundException e)
{ GenericIO.writelnString ("ComputePi not bound exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}

/* instantiate the mobile code object to be run remotely */

Pi task = null;
BigDecimal pi = null;

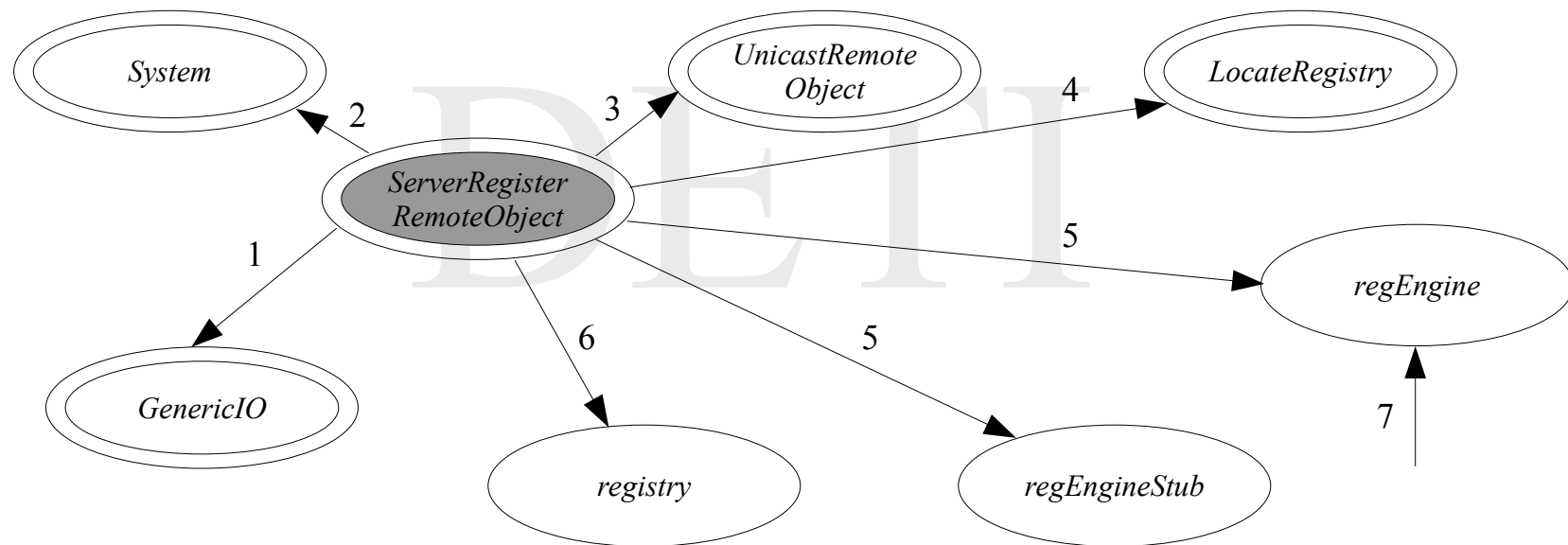
try
{ task = new Pi (Integer.parseInt (args[0]));
}
catch (NumberFormatException e)
{ GenericIO.writelnString ("Pi instantiation exception: " + e.getMessage ());
  e.printStackTrace ();
  System.exit (1);
}
```


Compute Pi thread base - 3

```
/* invoke the remote method (run the code at a ComputeEngine remote object) */  
  
    try  
    { pi = (BigDecimal) (comp.executeTask (task));  
    }  
    catch (RemoteException e)  
    { GenericIO.writelnString ("ComputePi remote invocation exception: " + e.getMessage ());  
      e.printStackTrace ();  
      System.exit (1);  
    }  
  
    /* print the result */  
    GenericIO.writelnString (pi.toString ());  
}  
}
```

Interaction diagrams - 1

Remote object to support the registering of remote objects

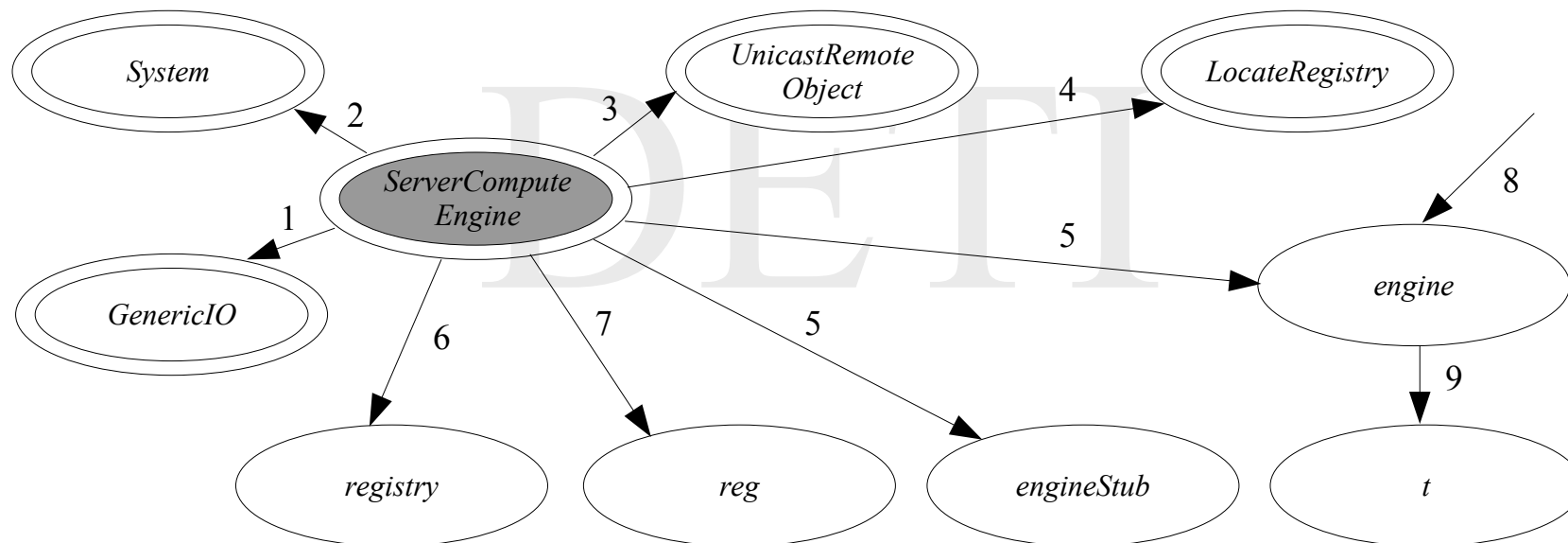


1 – readlnInt, readlnString, writeString, writelnString
2 – getSecurityManager, setSecurityManager
3 – exportObject
4 – getRegistry

5 – instantiate
6 – instantiate, rebind
7 – bind, unbind, rebind

Interaction diagrams - 2

Remote object for local execution of migrated code under remote control

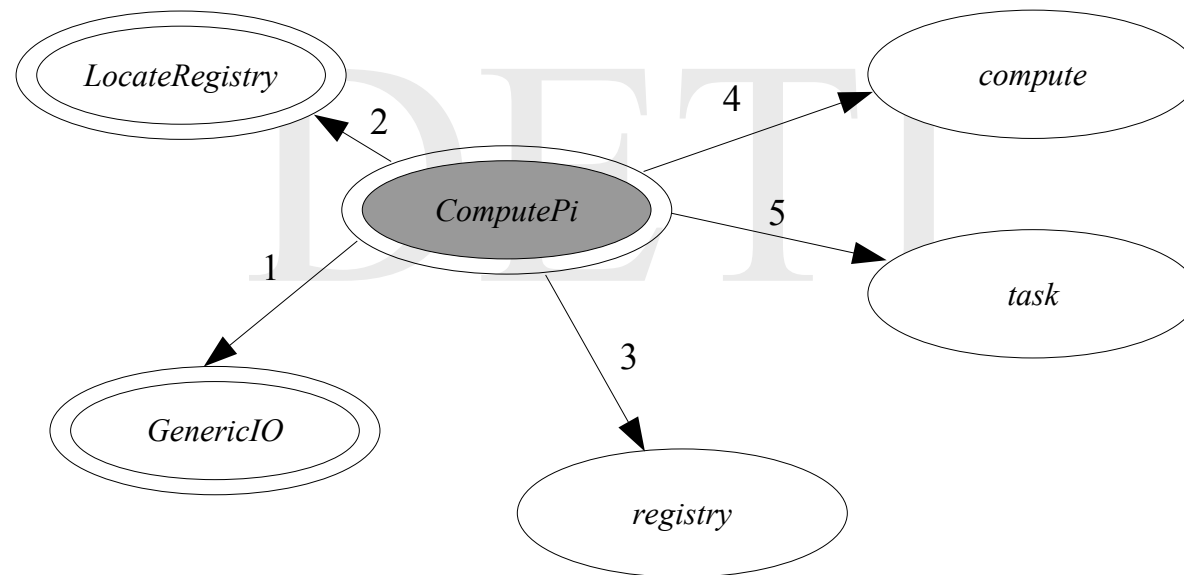


1 – readlnInt, readlnString, writeString, writelnString
2 – getSecurityManager, setSecurityManager
3 – exportObject
4 – getRegistry
5 – instantiate

6 – instantiate, locate
7 – instantiate, bind
8 – executeTask
9 – execute

Interaction diagrams - 3

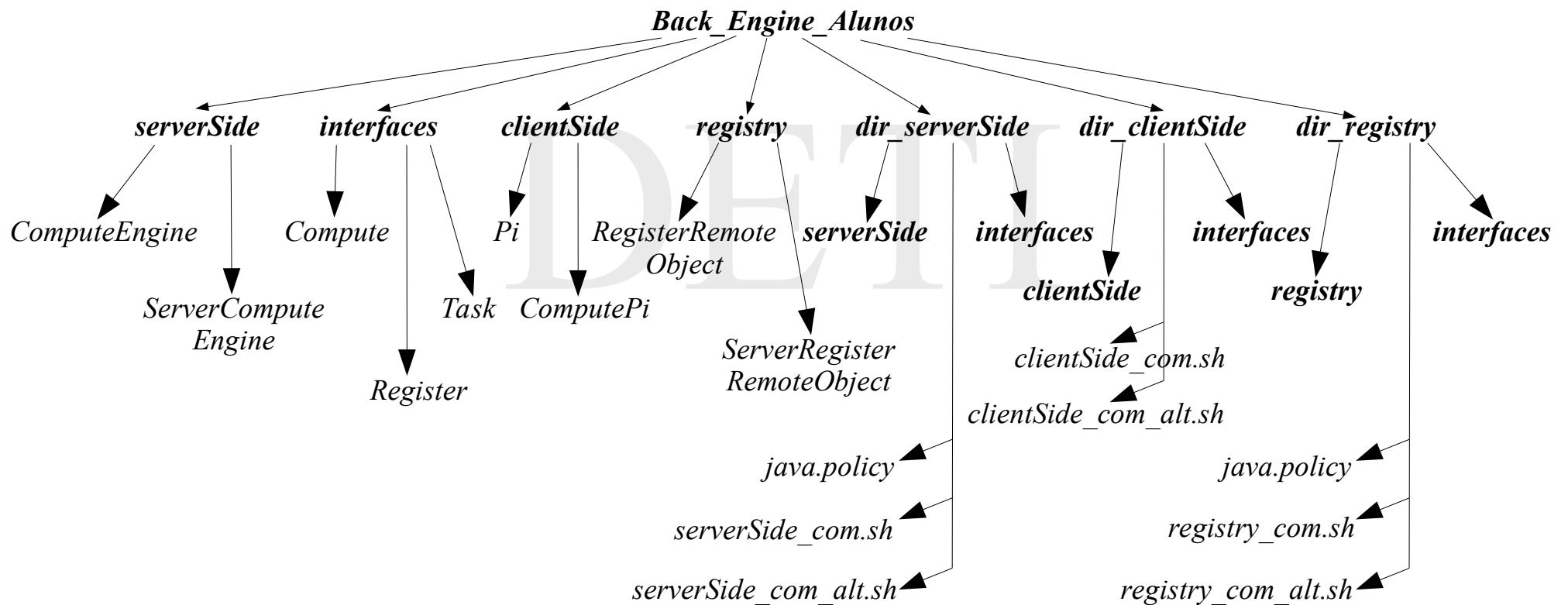
Client side



1 – readInt, readString, writeString, writeInt
2 – getRegistry
3 – instantiate, lookup

4 – instantiate, executeTask
5 – instantiate

Organization of the package BackEngine - 1



Organization of the package BackEngine - 2

Region for code development of the application

serverSide – directory with the main server code

ComputeEngine [.java] – remote object which provides local execution of migrated code under remote control

ServerComputeEngine [.java] – instantiation and registering of the remote object (service provided)

interfaces – directory with the interfaces to the remote objects

Compute [.java] – interface for access to the object that provides local execution of migrated code under remote control

Task [.java] – interface for local execution of migrated code

Register [.java] – interface for access to the object that provides support for registering remote objects

clientSide – directory the client code

Pi [.java] – code to be migrated and that it is going to be executed remotely under local control

ComputePi [.java] – access to the remote object which provides local execution of migrated code under remote control

registry – directory with the auxiliary server code to support the registering of remote objects

RegisterRemoteObject [.java] – remote object to support the registering of remote objects

ServerRegisterRemoteObject [.java] – instantiation and registering of the remote object (service provided)

Organization of the package BackEngine - 3

Region for deployment of the application

dir_serverSide – directory for running the main server code

serverSide – contains **ServerComputeEngine** [.class] and **ComputeEngine** [.class]

interfaces – contains **Register** [.class], **Compute** [.class] and **Task** [.class]

java.policy – file specifying the local security policy

serverSide_com.sh – shell script for the running code (data types are located with help of the http server)

serverSide_com_alt.sh – shell script for the running code (data types are located through the file system)

dir_clientSide – directory for running the client code

clientSide – contains **ComputePi** [.class] and **Pi** [.class]

interfaces – contains **Compute** [.class] and **Task** [.class]

clientSide_com.sh – shell script for the running code (data types are located with help of the http server)

clientSide_com_alt.sh – shell script for the running code (data types are located through the file system)

dir_registry – directory for running the auxiliary server code

registry – contains **ServerRegisterRemoteObject** [.class] and **RegisterRemoteObject** [.class]

interfaces – contains **Register** [.class]

java.policy – file specifying the local security policy

registry_com.sh – shell script for the running code (data types are located with help of the http server)

registry_com_alt.sh – shell script for the running code (data types are located through the file system)

Local security policy

- there is a single security rule in Java: *everything is forbidden, unless it explicitly allowed*

grant

```
{ permission java.util.PropertyPermission "user.dir", "read";  
  permission java.net.SocketPermission "*:1024-65535",  
                                         "listen,resolve,connect,accept";  
  permission java.net.SocketPermission "*:80", "connect";  
  permission java.io.FilePermission "/-", "read,write";  
};
```


Local security policy

- there is a single security rule in Java: *everything is forbidden, unless it explicitly allowed*

grant

```
{ permission java.util.PropertyPermission "user.dir", "read";  
  permission java.net.SocketPermission "*:1024-65535",  
                                         "listen,resolve,connect,accept";  
  permission java.net.SocketPermission "*:80", "connect";  
  permission java.io.FilePermission "/-", "read,write";  
};
```

Build and deploy - 1

- create a *shell* window
- position inside the directory `Back_Engine_Alunos`
- replace in `buildAndDeploy.sh` all instances of `ruib` by your login
- do the same in the files `set_rmiregistry.sh`, `clientSide_com_alt.sh`, `serverSide_com_alt.sh`, `serverSide_com.sh`, `registry_com_alt.sh`, `registry_com.sh`
- run the shell script `buildAndDeploy.sh`

```
[ruib@ruib-laptop Back_Engine_alunos]$ pwd
/home/ruib/Teaching/SD/exemplos demonstrativos/BackEngine/Back_Engine_alunos
[ruib@ruib-laptop Back_Engine_Alunos]$ ./buildAndDeploy.sh
Compiling source code.
Distributing intermediate code to the different execution environments.
Compressing execution environments.
Deploying and decompressing execution environments.
[ruib@ruib-laptop Back_Engine_alunos]$
```

Build and deploy - 2

```
[ruib@ruib-laptop Back_Engine_alunos]$ cat buildAndDeploy.sh
echo "Compiling source code."
javac interfaces/*.java registry/*.java serverSide/*.java clientSide/*.java
echo "Distributing intermediate code to the different execution environments."
cp interfaces/Register.class dir_registry/interfaces/
cp registry/*.class dir_registry/registry/
cp interfaces/*.class dir_serverSide/interfaces/
cp serverSide/*.class dir_serverSide/serverSide/
cp interfaces/Compute.class interfaces/Task.class dir_clientSide/interfaces/
cp clientSide/*.class dir_clientSide/clientSide/
mkdir -p /home/ruib/Public/classes
mkdir -p /home/ruib/Public/classes/interfaces
mkdir -p /home/ruib/Public/classes/clientSide
cp interfaces/*.class /home/ruib/Public/classes/interfaces/
cp clientSide/Pi.class /home/ruib/Public/classes/clientSide/
echo "Compressing execution environments."
rm -f dir_registry.zip dir_serverSide.zip dir_clientSide.zip
zip -rq dir_registry.zip dir_registry
zip -rq dir_serverSide.zip dir_serverSide
zip -rq dir_clientSide.zip dir_clientSide
echo "Deploying and decompressing execution environments."
cp set_rmiregistry_alt.sh /home/ruib
cp set_rmiregistry.sh /home/ruib
mkdir -p /home/ruib/test/BackEngine
rm -rf /home/ruib/test/BackEngine/*
cp dir_registry.zip dir_serverSide.zip dir_clientSide.zip /home/ruib/test/BackEngine
cd /home/ruib/test/BackEngine
unzip -q dir_registry.zip
unzip -q dir_serverSide.zip
unzip -q dir_clientSide.zip
[ruib@ruib-laptop Back_Engine_alunos]$
```

Running the application

- a *http* server is not required to run the version where the data types are located through the file system
- four shell windows are required
 - window 1: base directory, execute `set_rmiregistry[_alt].sh`
 - window 2: `dir_registry`, execute `registry_com[_alt].sh`
 - window 3: `dir_serverSide`, execute `serverSide_com[_alt].sh`
 - window 4: `dir_clientSide`, execute `clientSide_com[_alt].sh`

Suggested reading

- *On-line* support documentation for Java program developing environment by Oracle (Java Platform Standard Edition 8)