# Communication (Part II)

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# Remote Procedure Call (RPC)

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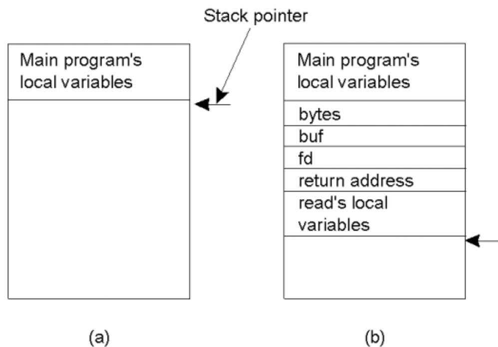
- Proposed solution: to allow programs to call procedures located on other machines: Remote Procedure Call (RPC).

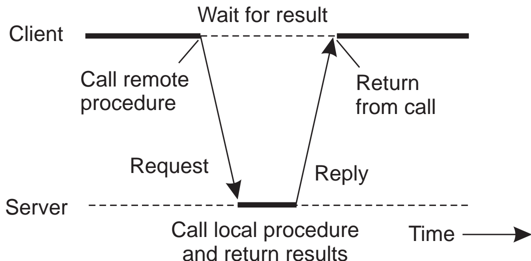
# Local Procedure Call

- a: Parameter passing in a local procedure call: the stack before the call to `read(fd, buf, bytes)`.
- b: The stack while the called procedure is active.



# Remote Procedure Call (RPC)

- Principle of RPC between a client and server program.



# Basics of RPCs

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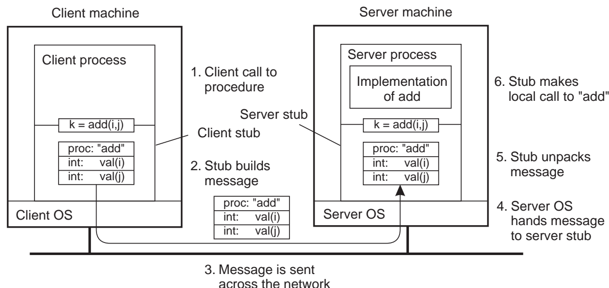
- The client-side stub
  - Locates the server
  - Marshalls the parameters
- The server-side stub
  - Receives the message from client-side stub
  - Unpacks the marshalled parameters
  - Performs the procedure on the server

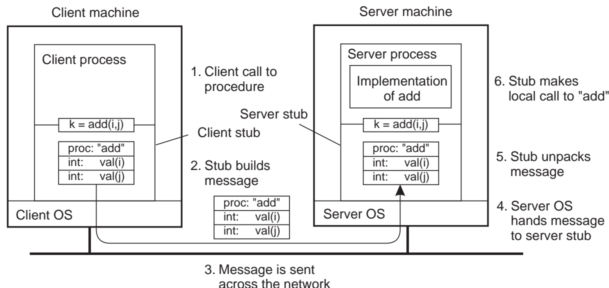
# Steps of a RPC (1/2)

1. Client procedure calls client stub.
2. Stub builds message, and calls local OS.
3. OS sends message to remote OS.
4. Remote OS gives message to server stub.
5. Server stub unpacks parameters and calls server.



# Steps of a RPC (2/2)

6. Server makes local call and returns result to stub.
7. Stub builds message, and calls OS.
8. OS sends message to client's OS.
9. Client's OS gives message to stub.
10. Client stub unpacks result and returns to the client.



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- Client and server machines may have different data representations (think of byte ordering).
- Wrapping a parameter means transforming a value into a sequence of bytes.
- Client and server have to agree on the same encoding:
  - How are basic data values represented (integers, floats, characters)
  - How are complex data values represented (arrays, unions)
- Client and server need to properly interpret messages, transforming them into machine-dependent representations.

# Parameter Passing (2/2)

- Some assumptions:
  - Copy in/copy out semantics: while procedure is executed, nothing can be assumed about parameter values.
  - All data that is to be operated on is passed by parameters. Excludes passing references to (global) data.

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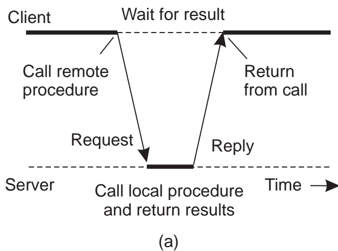
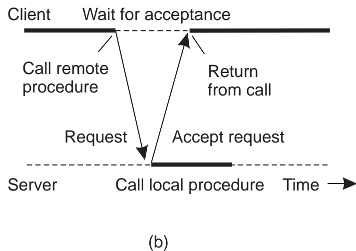
- Conclusion: full access transparency cannot be realized.

- Observation: a remote reference mechanism enhances access transparency:
  - Remote reference offers unified access to remote data.
  - Remote references can be passed as parameter in RPCs.

# Asynchronous RPCs

- Try to get rid of the strict request-reply behavior, but let the client continue without waiting for an answer from the server.



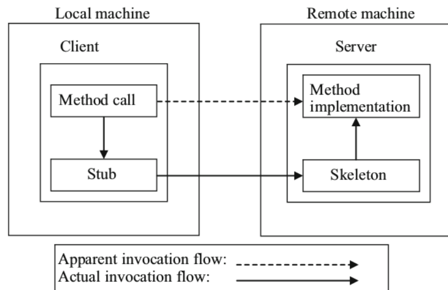
# Remote Method Invocation (RMI)

# Introduction

- Remote Method Invocation (RMI)
- RMI = RPC + object oriented
- RPC in C and RMI in Java

# Steps of a RMI (1/3)

1. The server program controls the remote objects.
2. The server registers an interface with a naming service: makes the interface accessible by clients.



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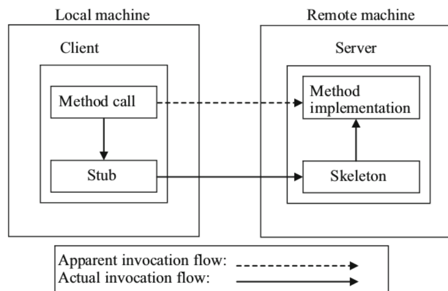

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1. The server program controls the remote objects.
2. The server registers an interface with a naming service: makes the interface accessible by clients.
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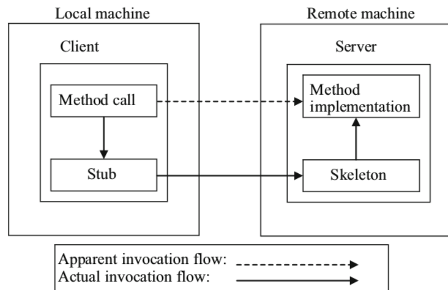
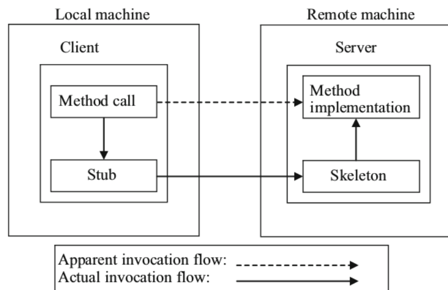
4. Clients use the naming service to obtain a reference to this interface: called a stub.



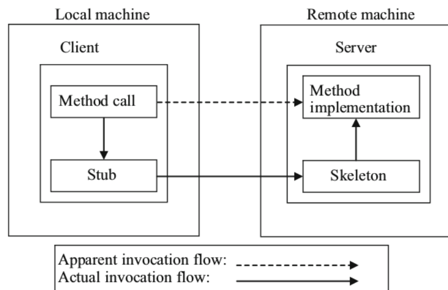
# Steps of a RMI (2/3)

5. The stub is a local surrogate for the remote object.
6. On the server system, there is another surrogate called a skeleton.



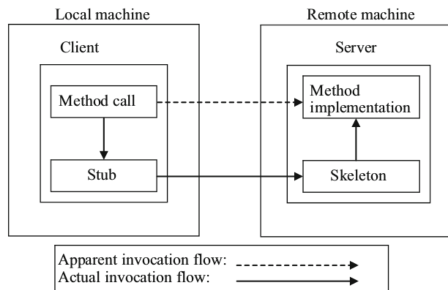
# Steps of a RMI (2/3)

5. The stub is a local surrogate for the remote object.
6. On the server system, there is another surrogate called a skeleton.
7. When the client program invokes a method of the remote object, it appears to the client as though the method is being invoked directly on the object.
8. What is actually happening, however, is that an equivalent method is being called in the stub.



# Steps of a RMI (3/3)

9. The stub forwards the call and any parameters to the skeleton on the remote machine.



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9. The stub forwards the call and any parameters to the skeleton on the remote machine.
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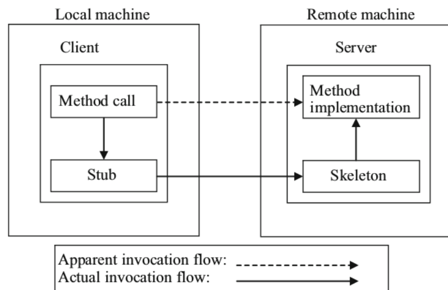

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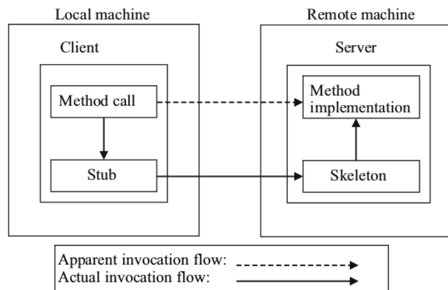

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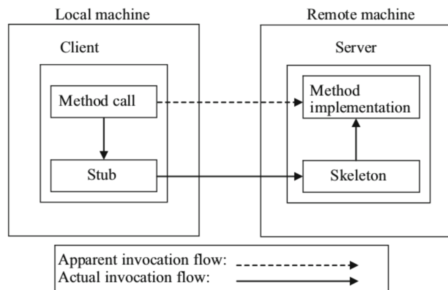
12. The skeleton calls the implementation of the method on the server.



# RMI Implementation

- Setting up a RMI connection four steps:
  1. Create the interface.
  2. Define a class that implements this interface.
  3. Create the server process.
  4. Create the client process.

# Setting up a RMI Connection (1/4)

- Create the interface.
- This interface should extend interface `Remote`.

```
import java.rmi.*;

public interface Hello extends Remote {
  public String getGreeting() throws RemoteException;
}
```

# Setting up a RMI Connection (2/4)

- Define a class that implements this interface.
- The implementation class must extend class RemoteObject or one of RemoteObject's subclasses.
  - E.g., UnicastRemoteObject that supports TCP point-to-point communication.
- We must provide a constructor for our implementation object.

```
import java.rmi.*;
import java.rmi.server.*;

public class HelloImpl extends UnicastRemoteObject implements Hello {
  public HelloImpl() throws RemoteException { ... }

  public String getGreeting() throws RemoteException {
    return ("Hello there!");
  }
}
```

# Setting up a RMI Connection (3/4) - Part 1

- Create the server process.
- The server creates object(s) of the above implementation class and registers them with a naming service called the registry.
- Establishes a connection between the object's name and its reference, by using method `rebind` that takes two arguments:
  1. a string that holds the name of the remote object as a URL with protocol `rmi`.
  2. a reference to the remote object.
- Clients will then be able to use the remote object's name to retrieve a reference to that object via the registry.

# Setting up a RMI Connection (3/4) - Part 2

```
import java.rmi.*;
public class HelloServer {
  private static fi nal String HOST = "localhost";
  public static void main(String[] args) throws Exception {
    //Create a reference to an implementation object...
    HelloImpl temp = new HelloImpl();

    //Create the string URL holding the object's name...
    String rmiObjectName = "rmi://" + HOST + "/Hello";

    //'Bind' the object reference to the name...
    Naming.rebind(rmiObjectName, temp);

    System.out.println("Binding complete...\n");
  }
}
```

# Setting up a RMI Connection (4/4)

- Create the client process.
- The client obtains a reference to the remote object from the registry, by calling method `lookup`.

```
import java.rmi.*;
public class HelloClient {
  private static fi nal String HOST = "localhost";
  public static void main(String[] args) {
  try {
    //Obtain a reference to the object from the registry
    Hello greeting = (Hello)Naming.lookup("rmi://" + HOST + "/Hello");

    //Use the above reference to invoke the remote object's method...
    System.out.println("Message received: " + greeting.getGreeting());
  } catch(Exception ex) { ... }
}
```

# RMI Implementation

- Compiling and running a RMI application consists of four steps:
  1. Compile all files with `javac`.
  2. Start the RMI registry: `rmiregistry`.
  3. Run the server.
  4. Run the client.

# Summary

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- Send and receive methods do not hide provide access transparency.
- Remote Procedure Call (RPC) - in C
- Client stub and server stub (skeleton)
- Parameter passing: marshaling
- Remote Method Invocation (RMI) - in Java

# Reading

- Chapter 4 of the Distributed Systems: Principles and Paradigms.
- Chapter 5 of An Introduction to Network Programming with Java.

Questions?