合肥學院
HEFEI UNIVERSITY

Distributed Computing
Lesson 14: Remote Method Invocation

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Outline

website

Overview

- How can we run procedures on a *different* computer?
- What are remote procedure calls and remote method invocation?
- What different technologies exist for that purpose?
- Example implementation in `Java`

Local Procedure Call

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  - Smaller programs
  - Separation of concerns (SoC) [3, 4]

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  - Centralized maintenance and updating
  - Platform independent binding of services
  - ...

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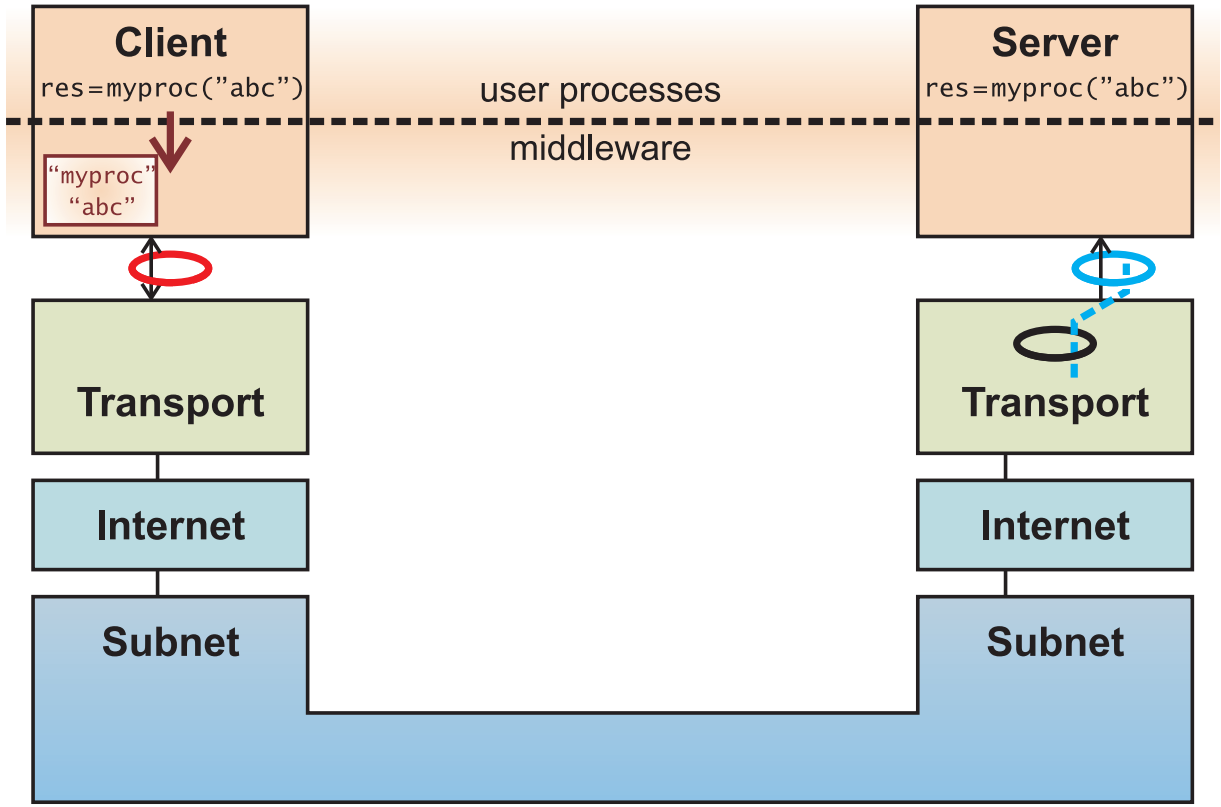
  - necessary communication offered by software framework
  - from programmer's perspective: looks exactly like local procedure call



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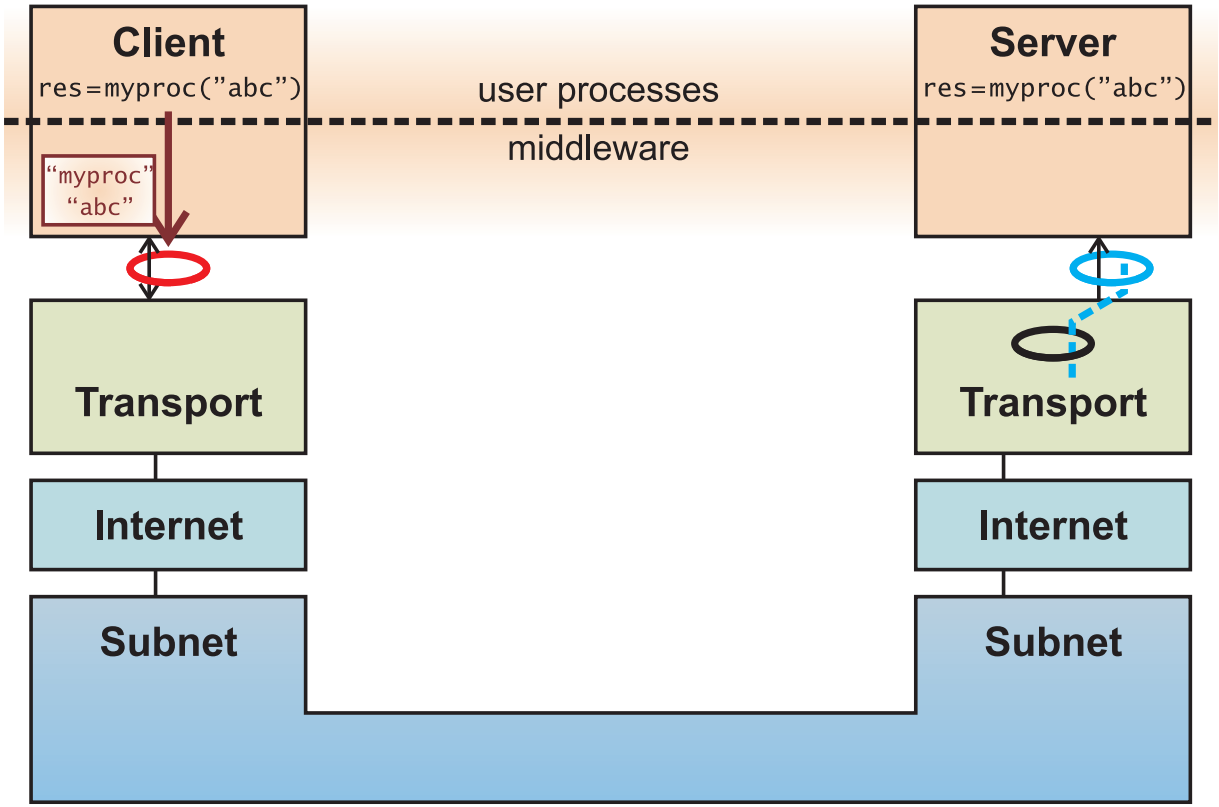

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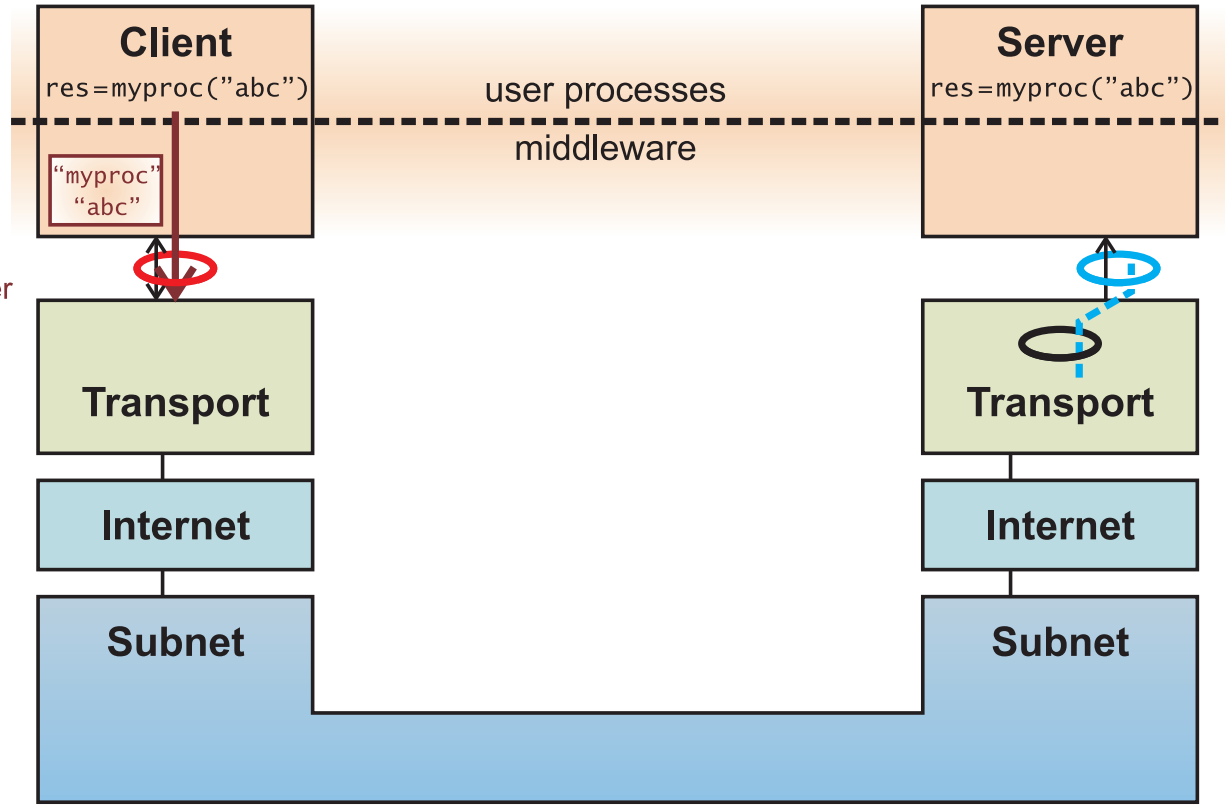

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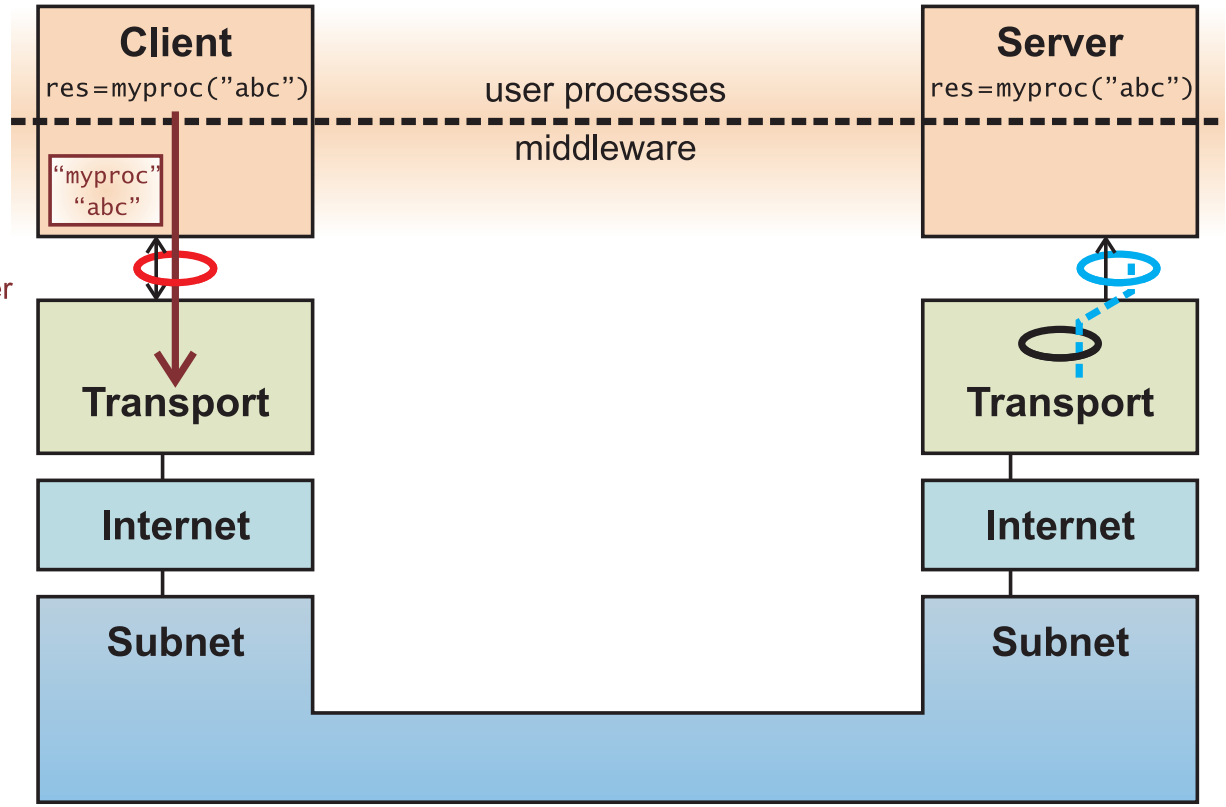

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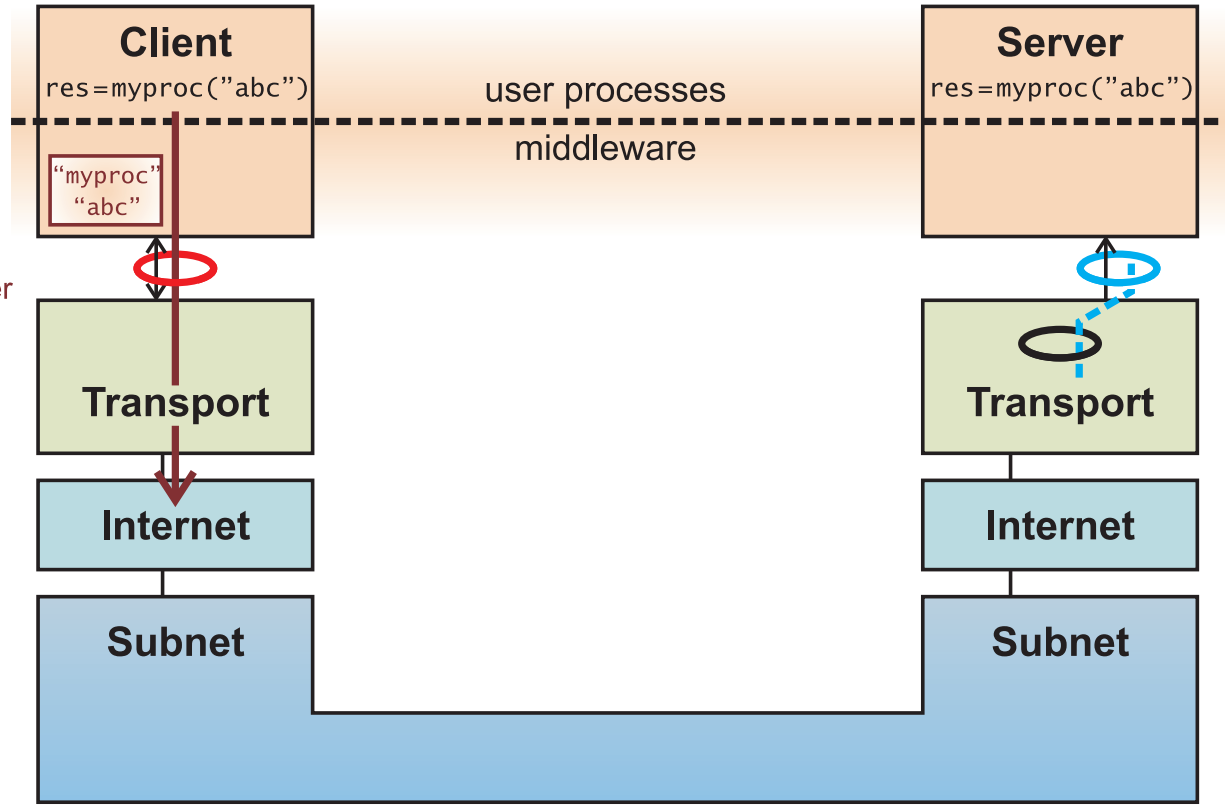

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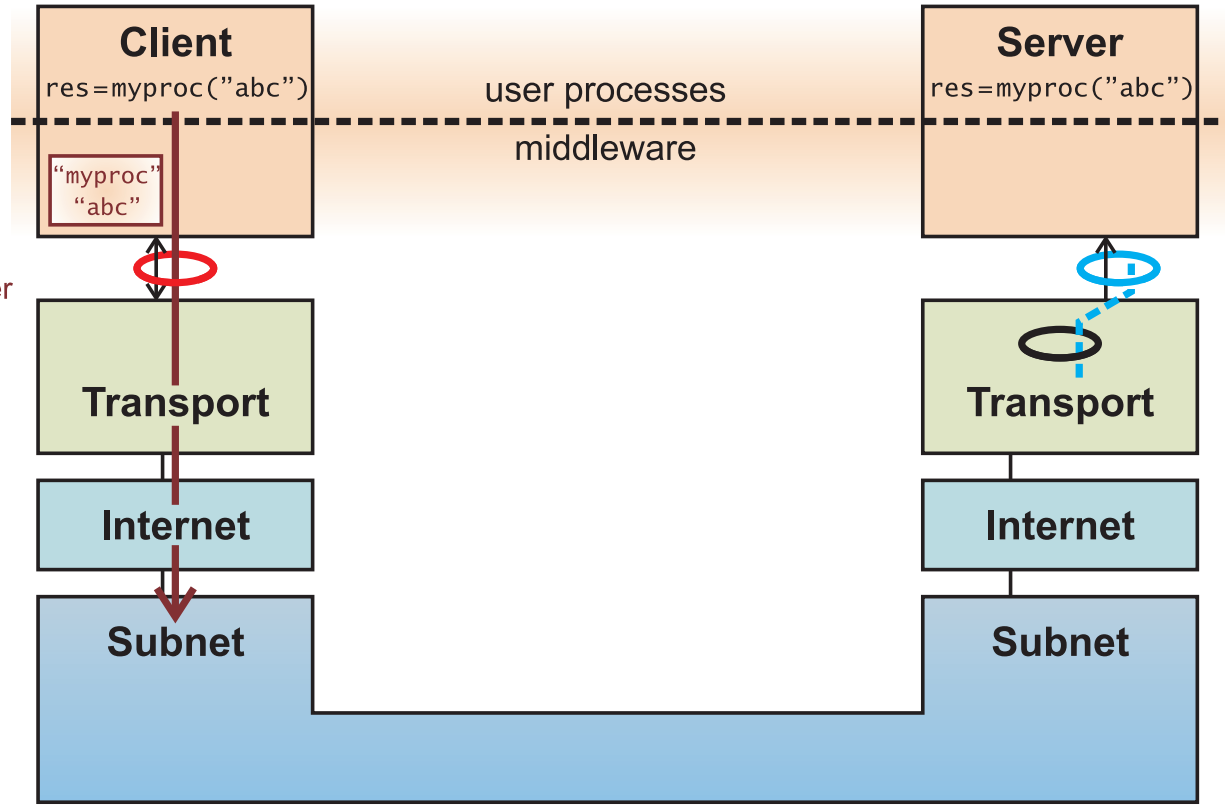

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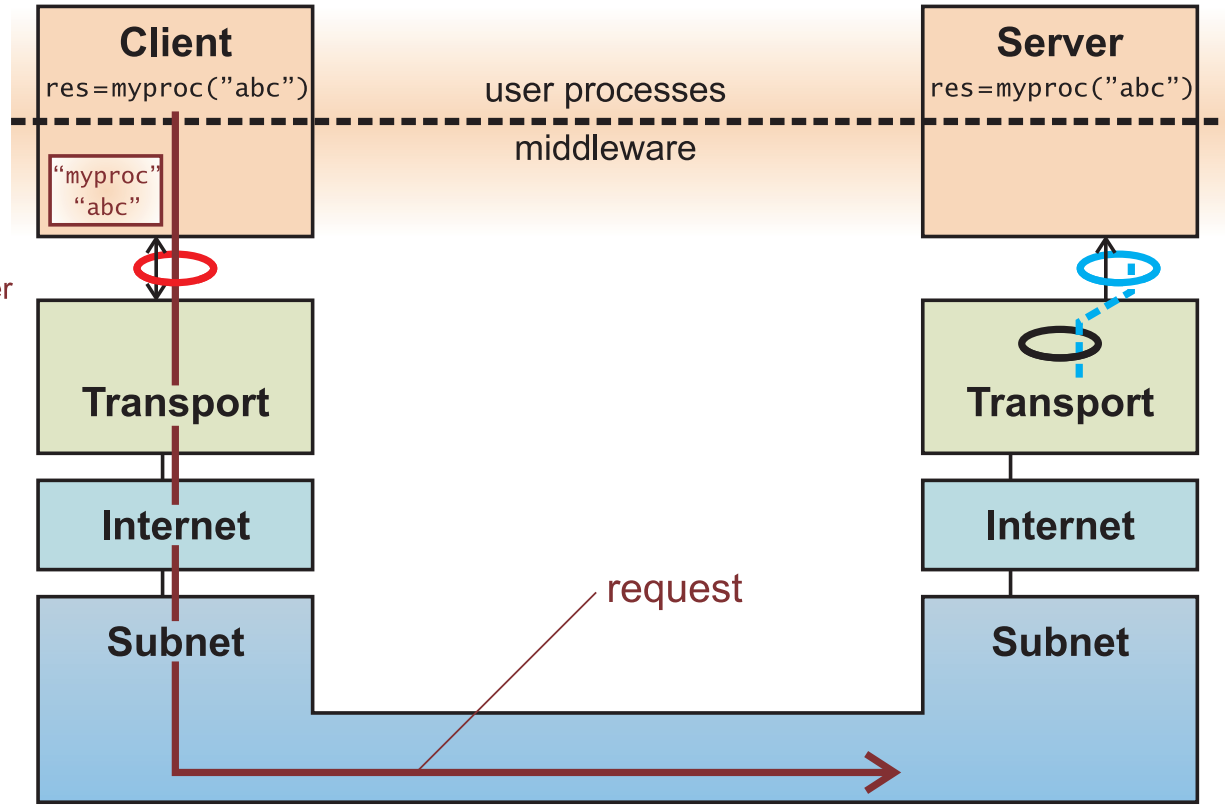

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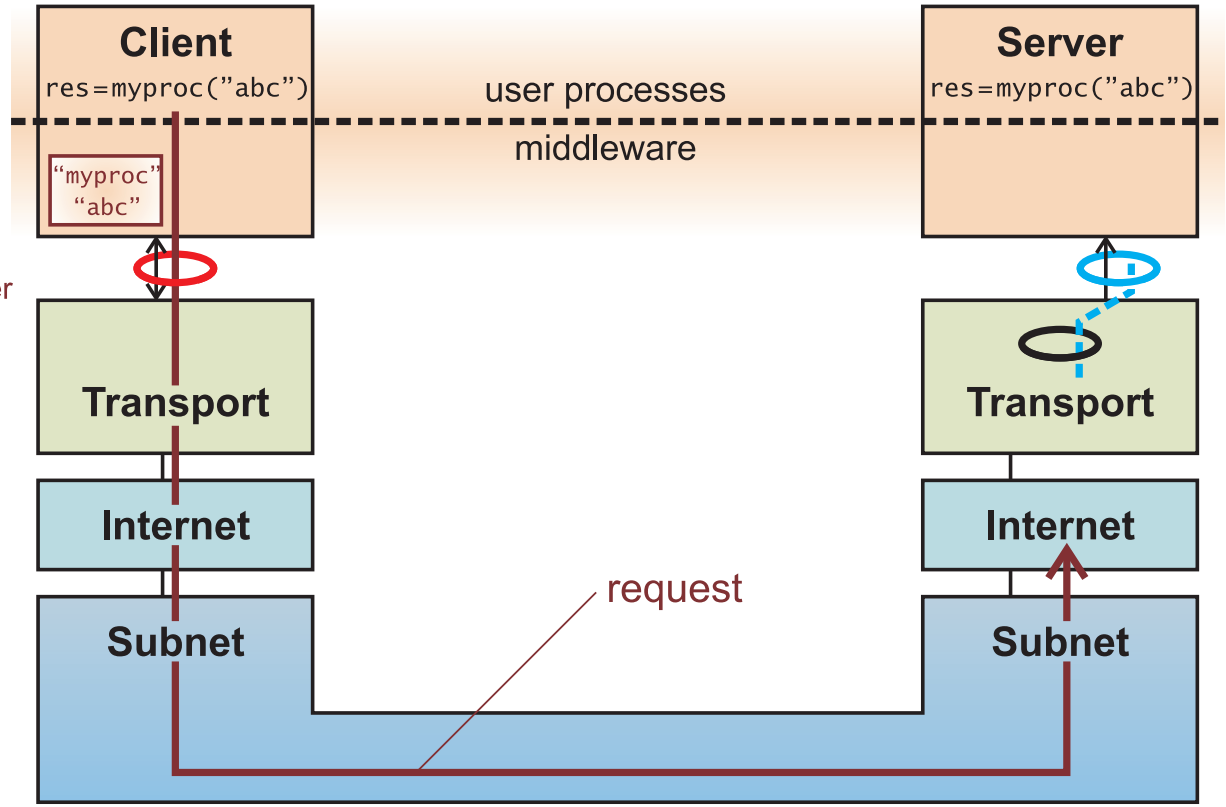

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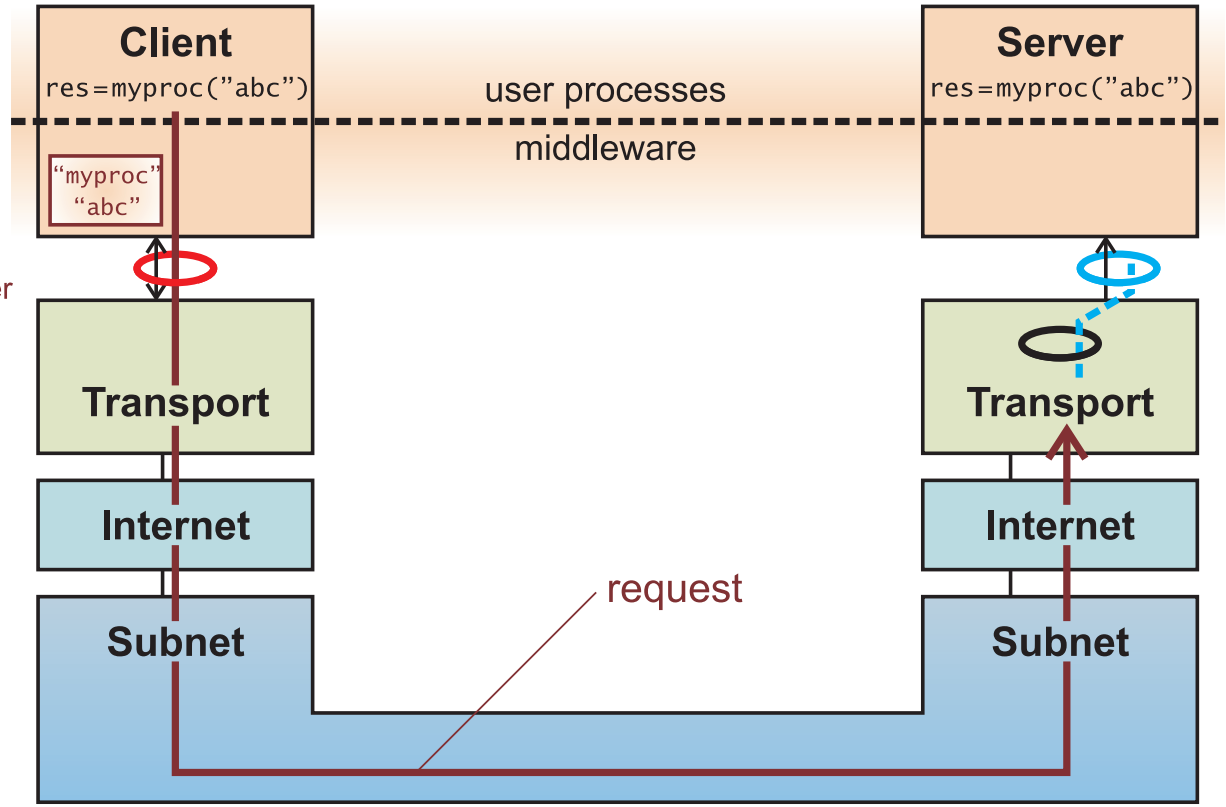

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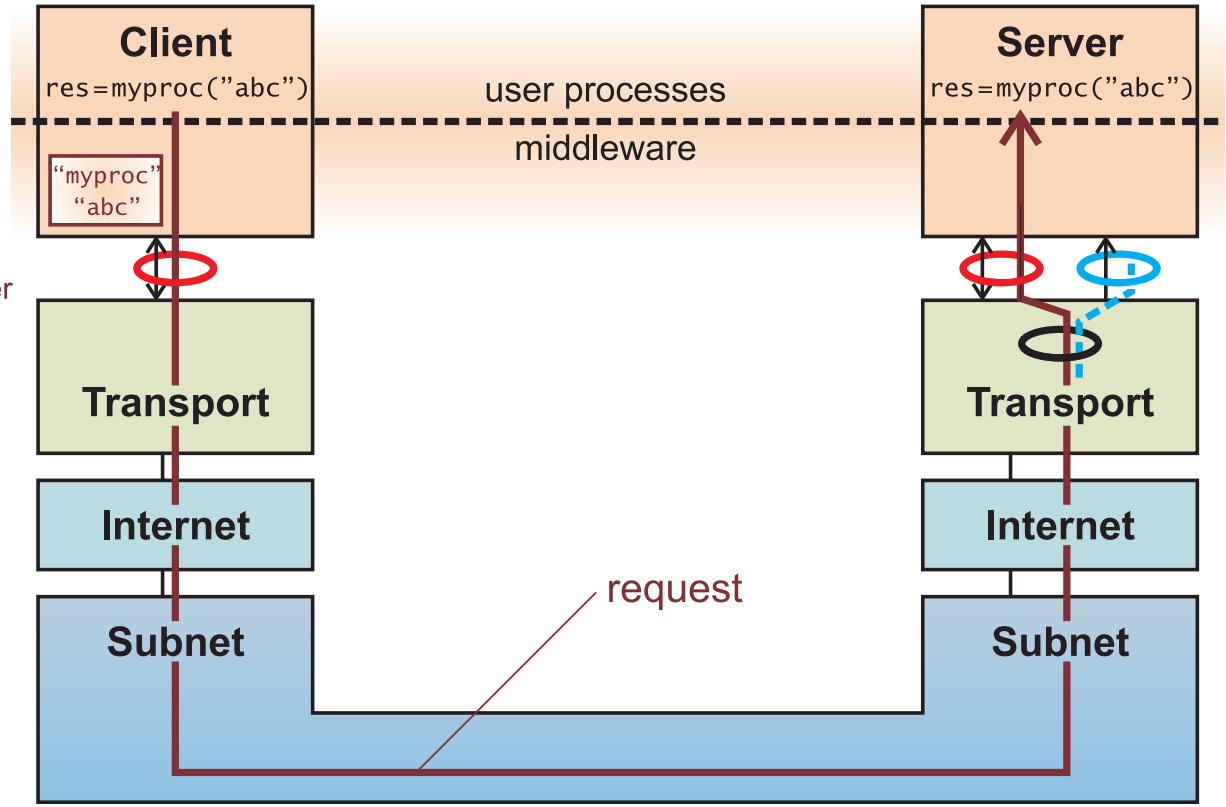

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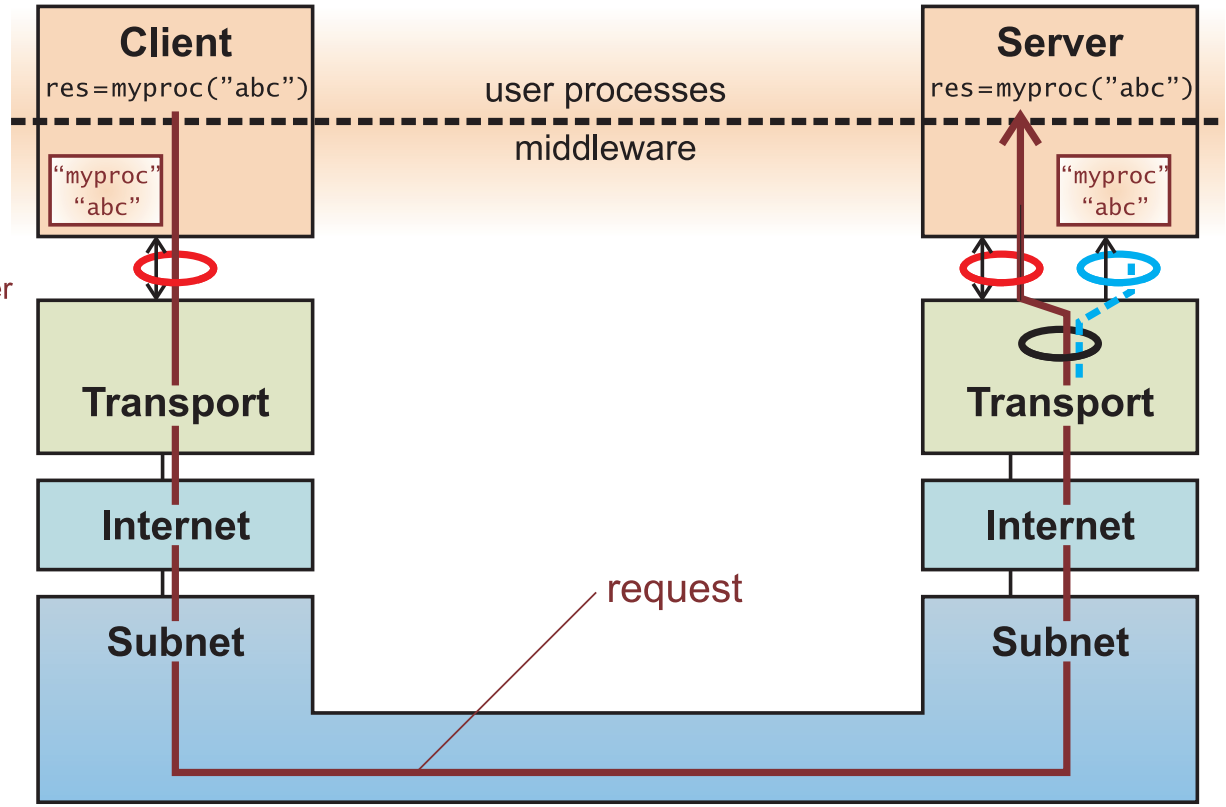

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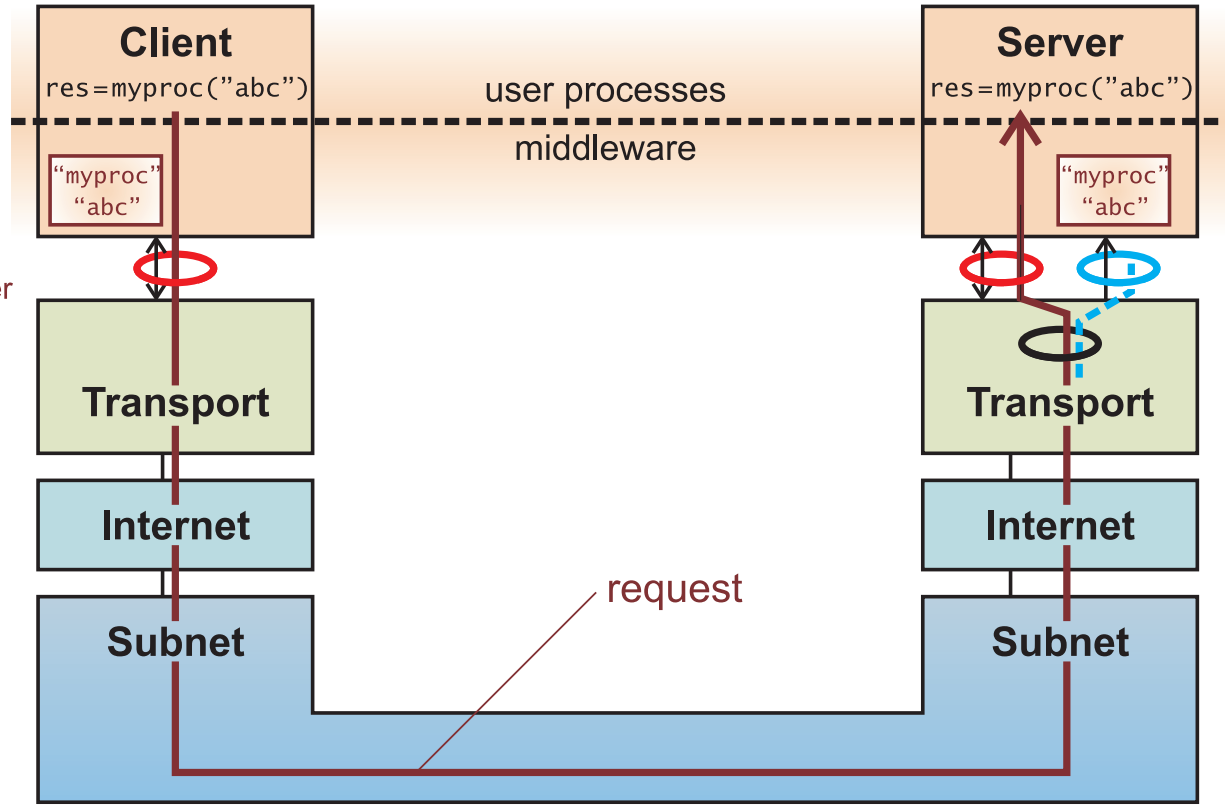

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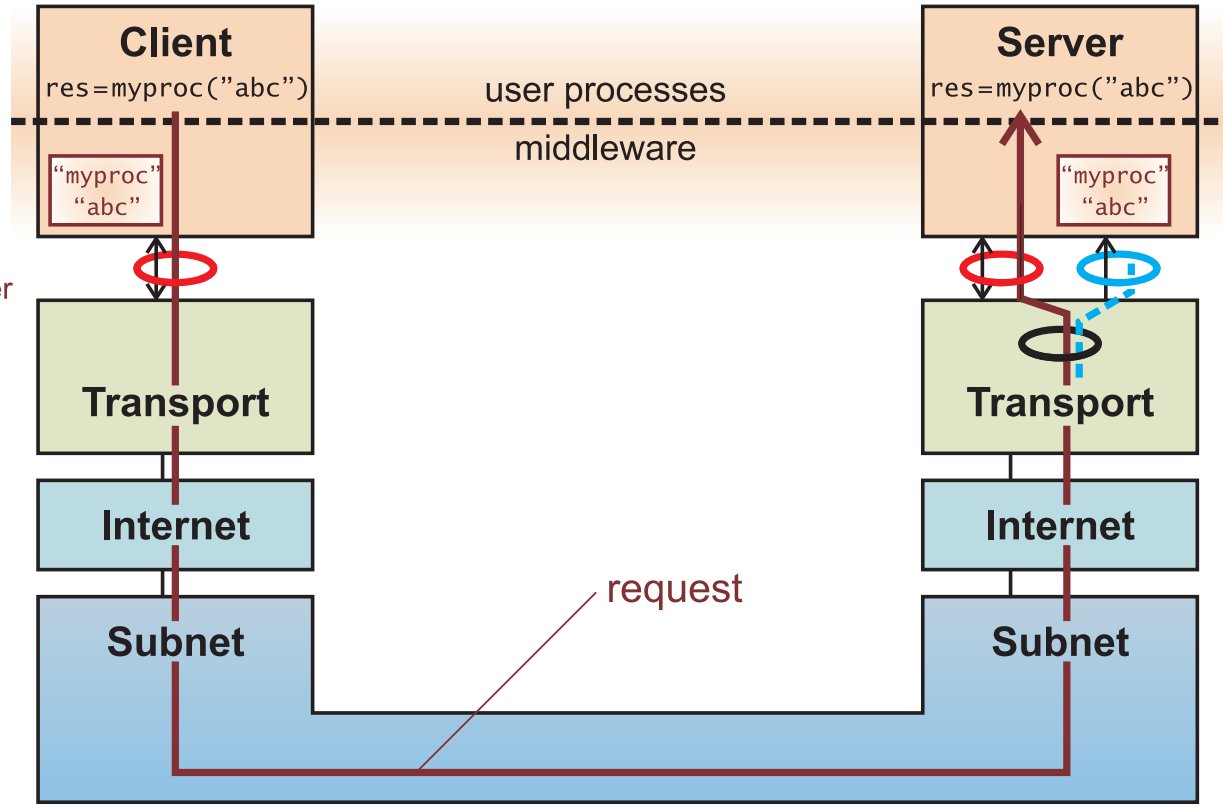

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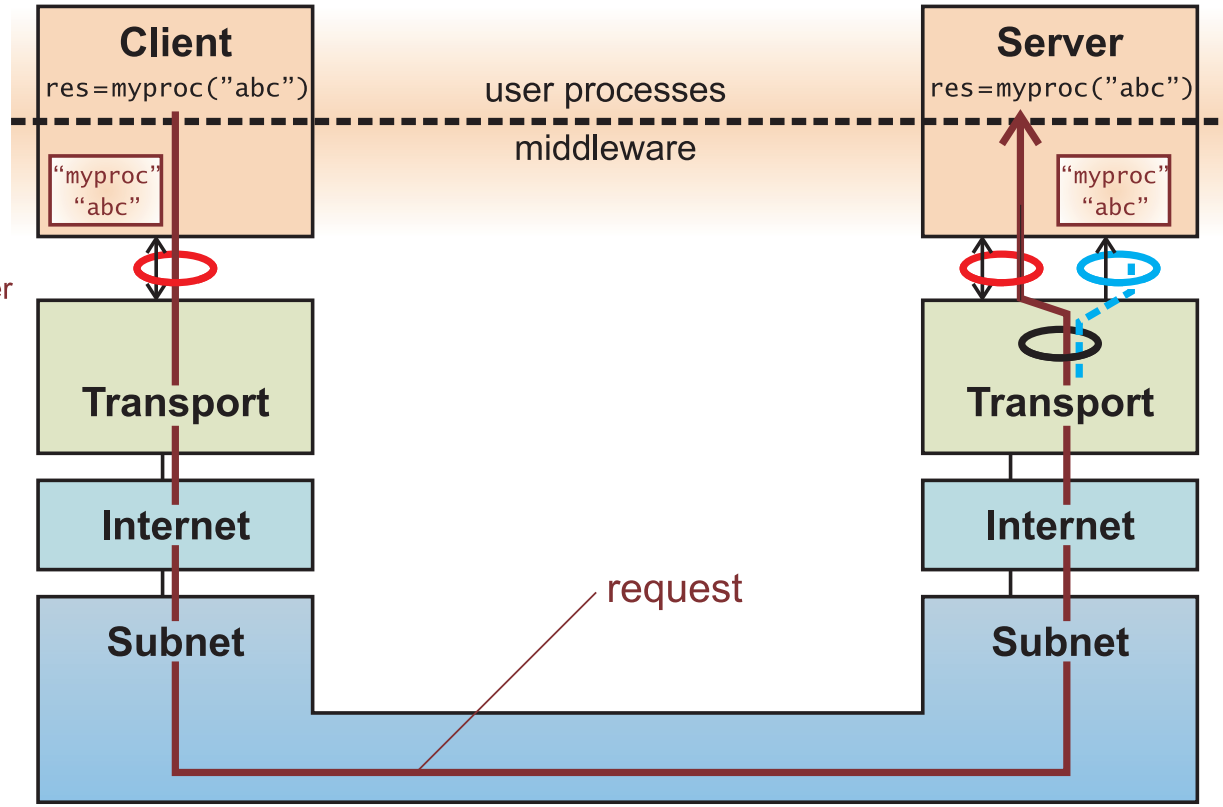

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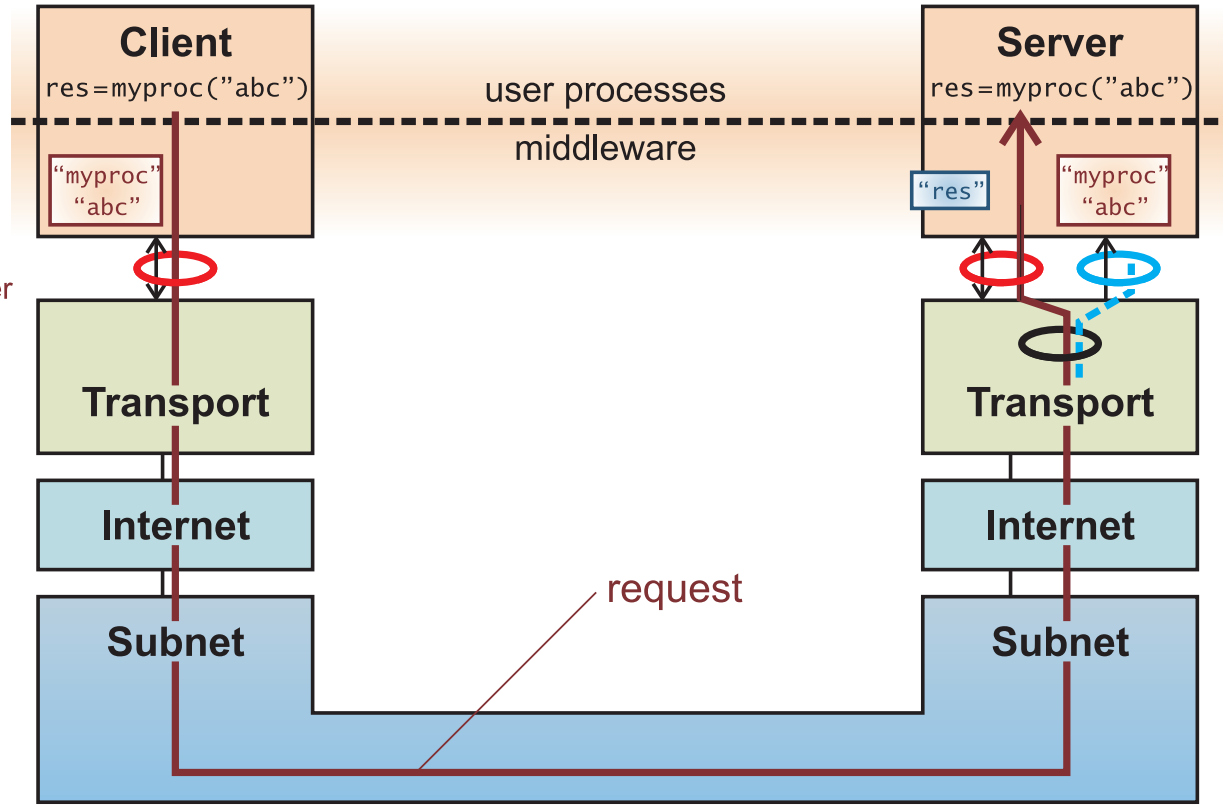

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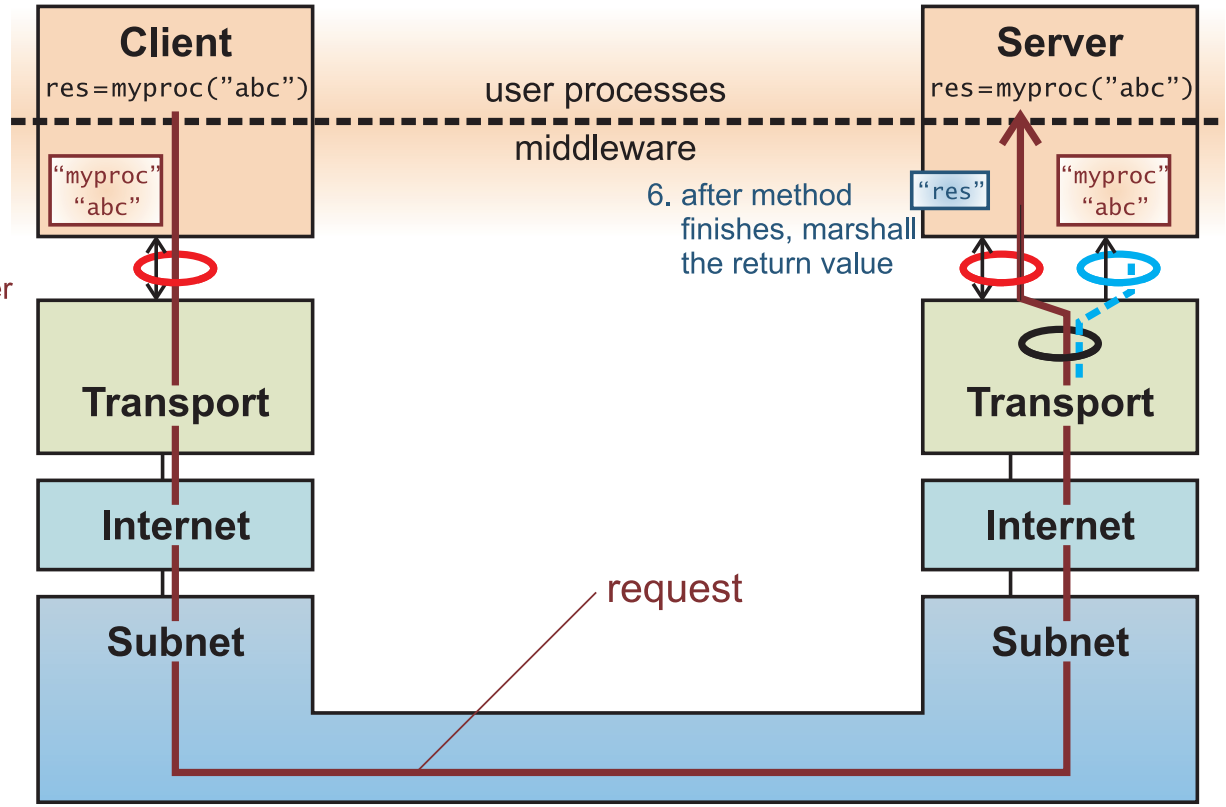

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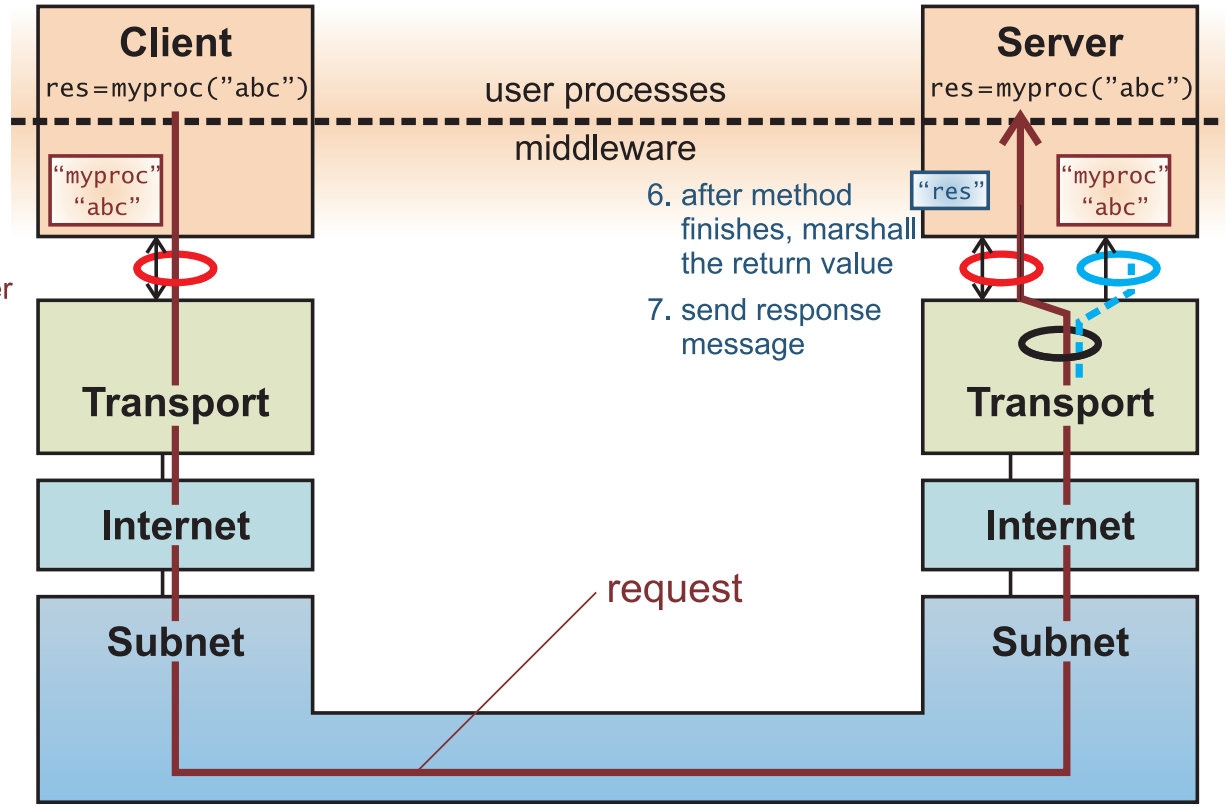

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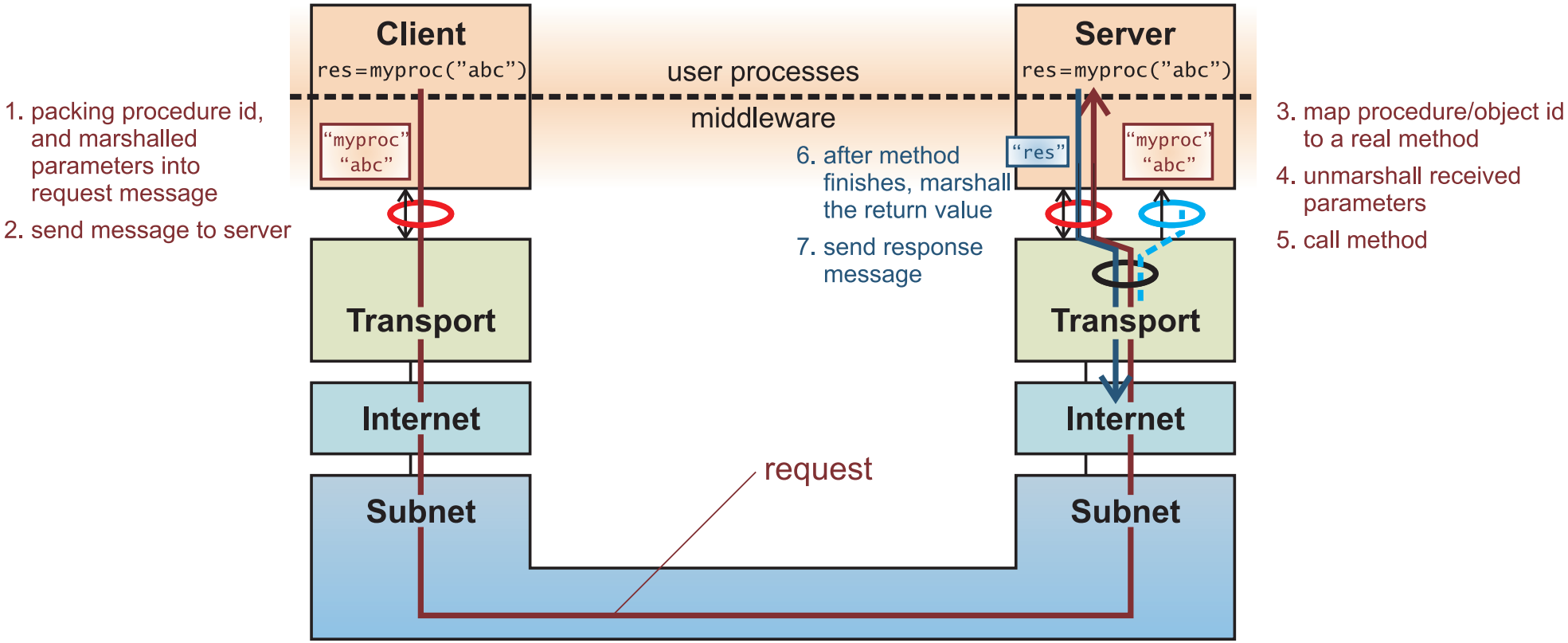

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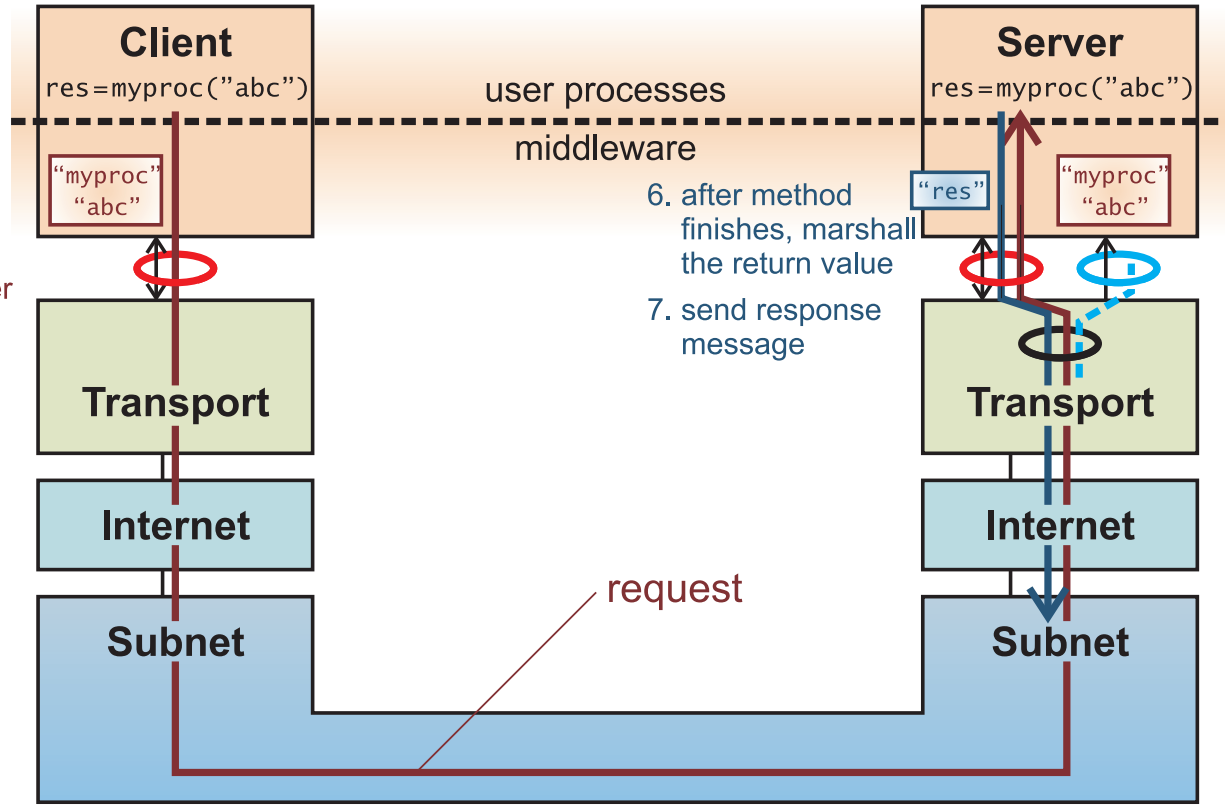

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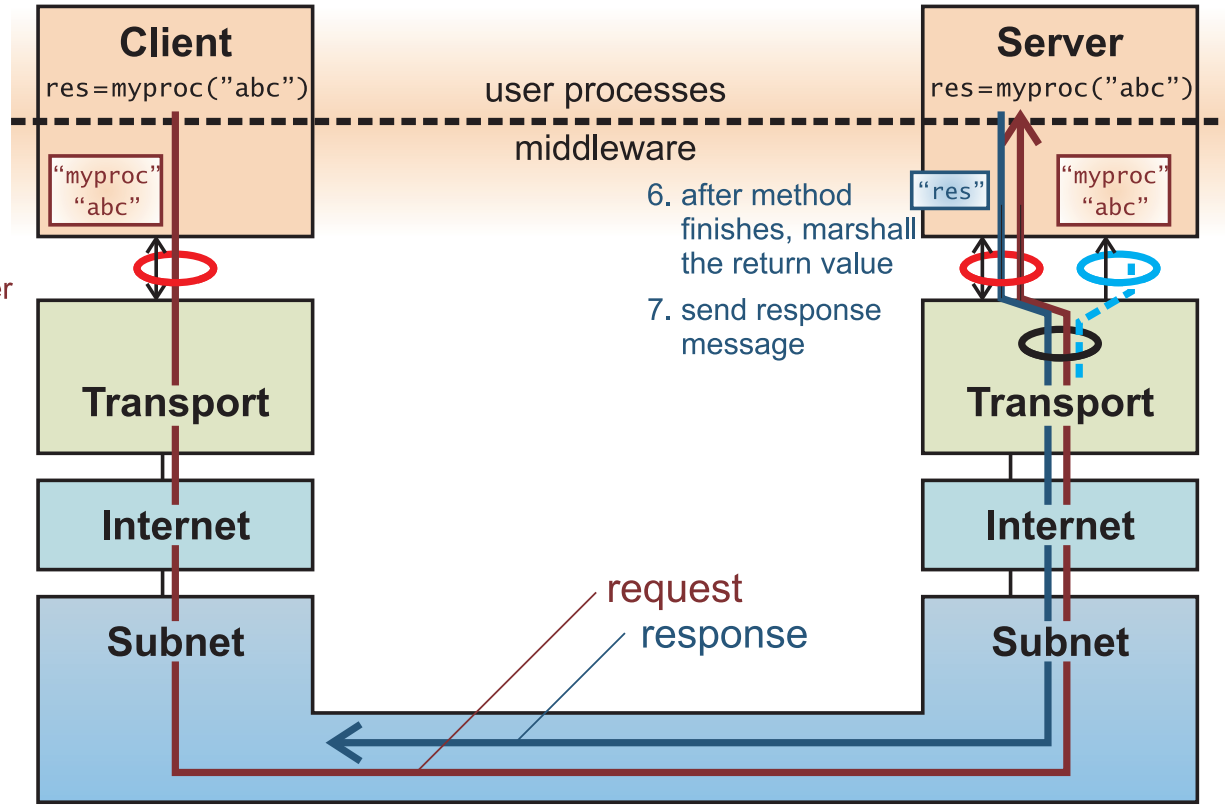

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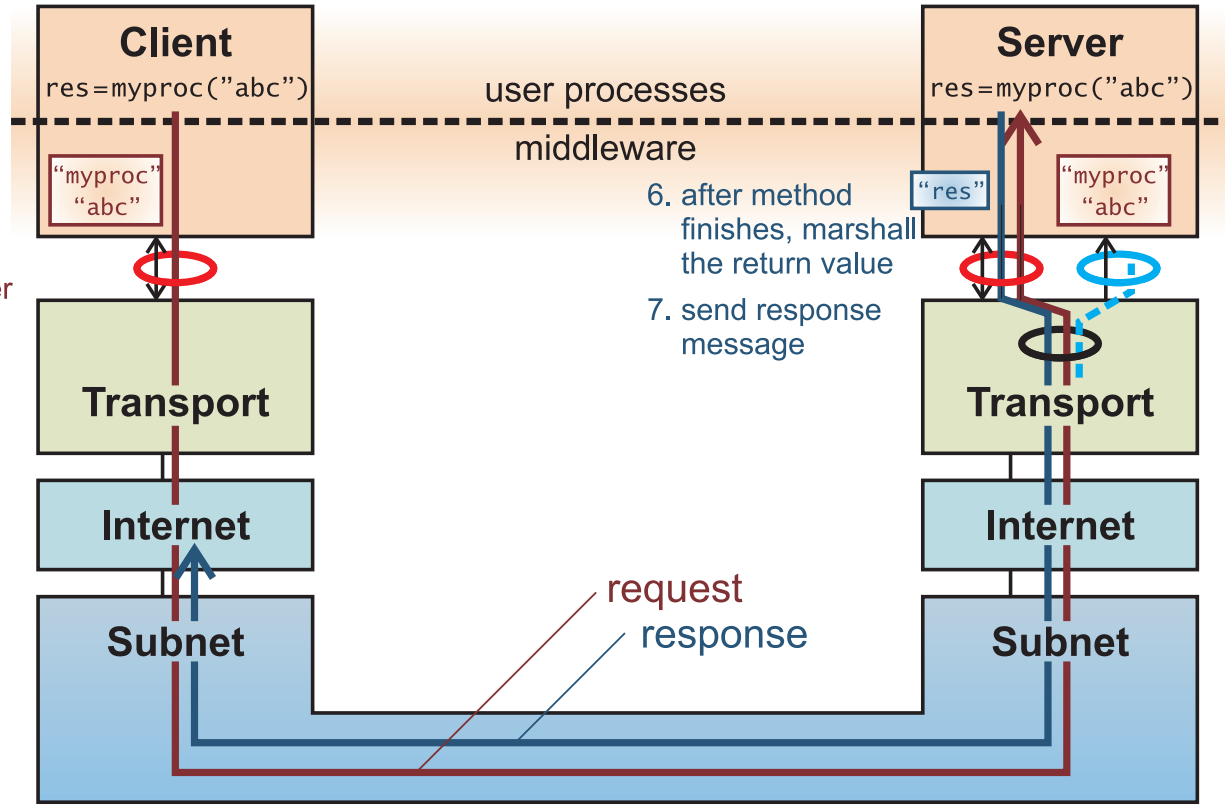

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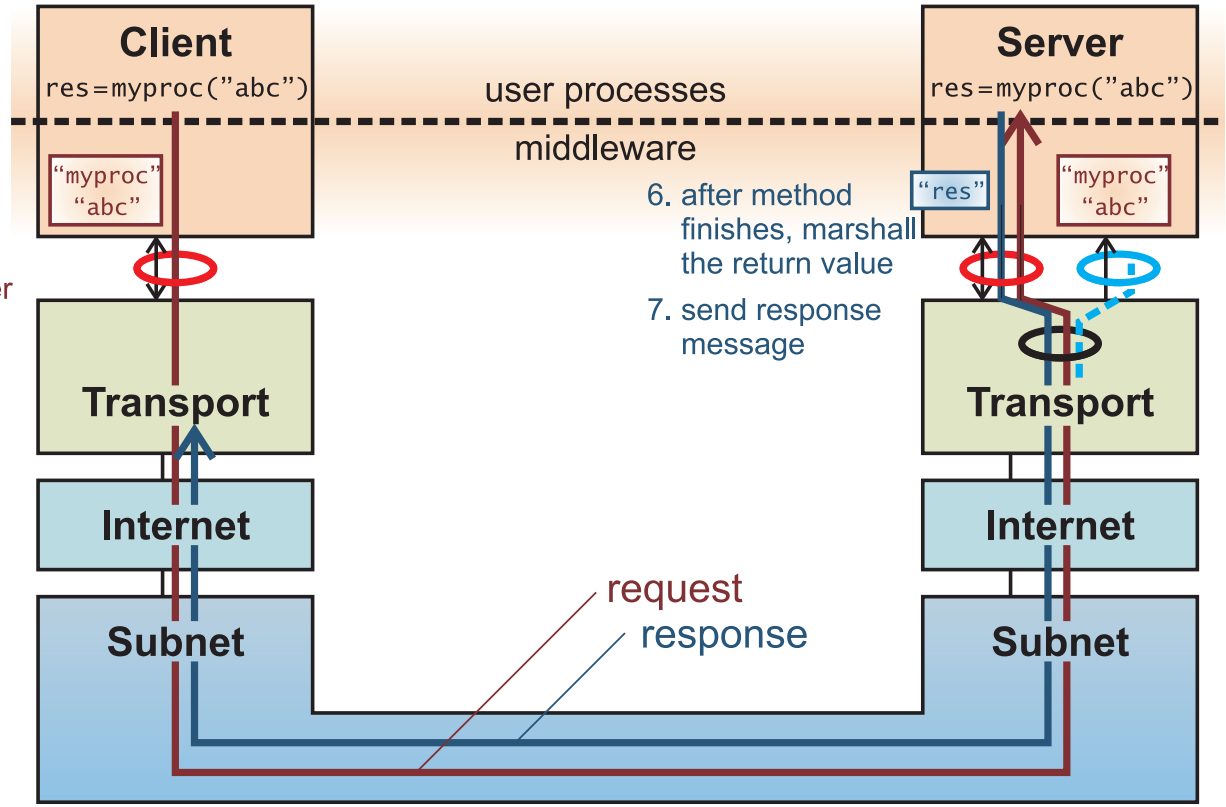

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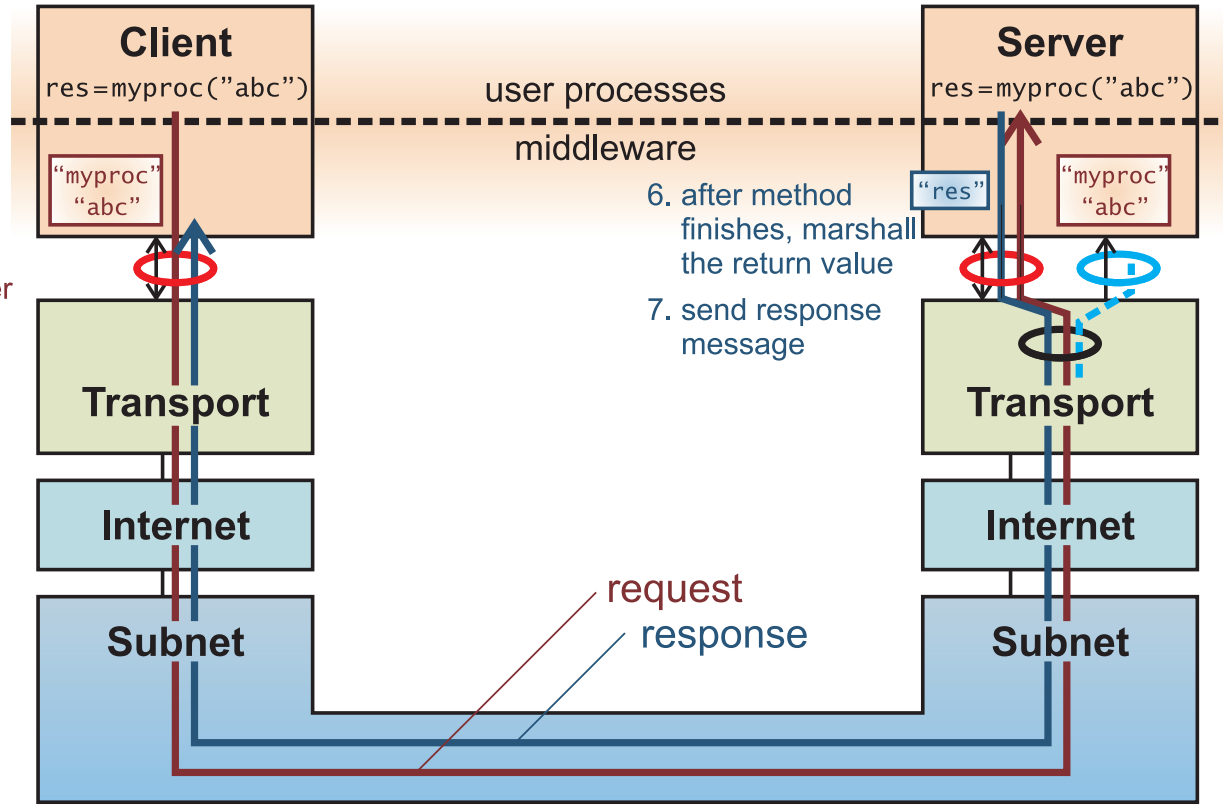

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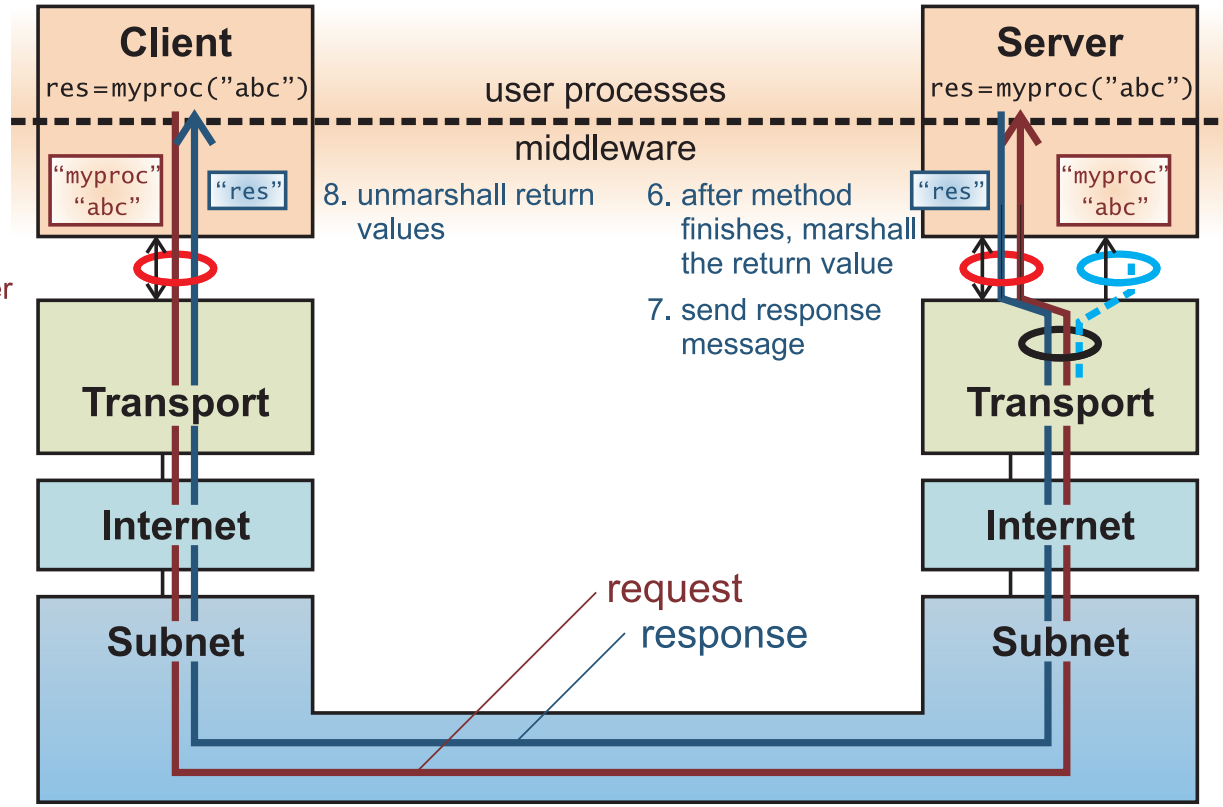

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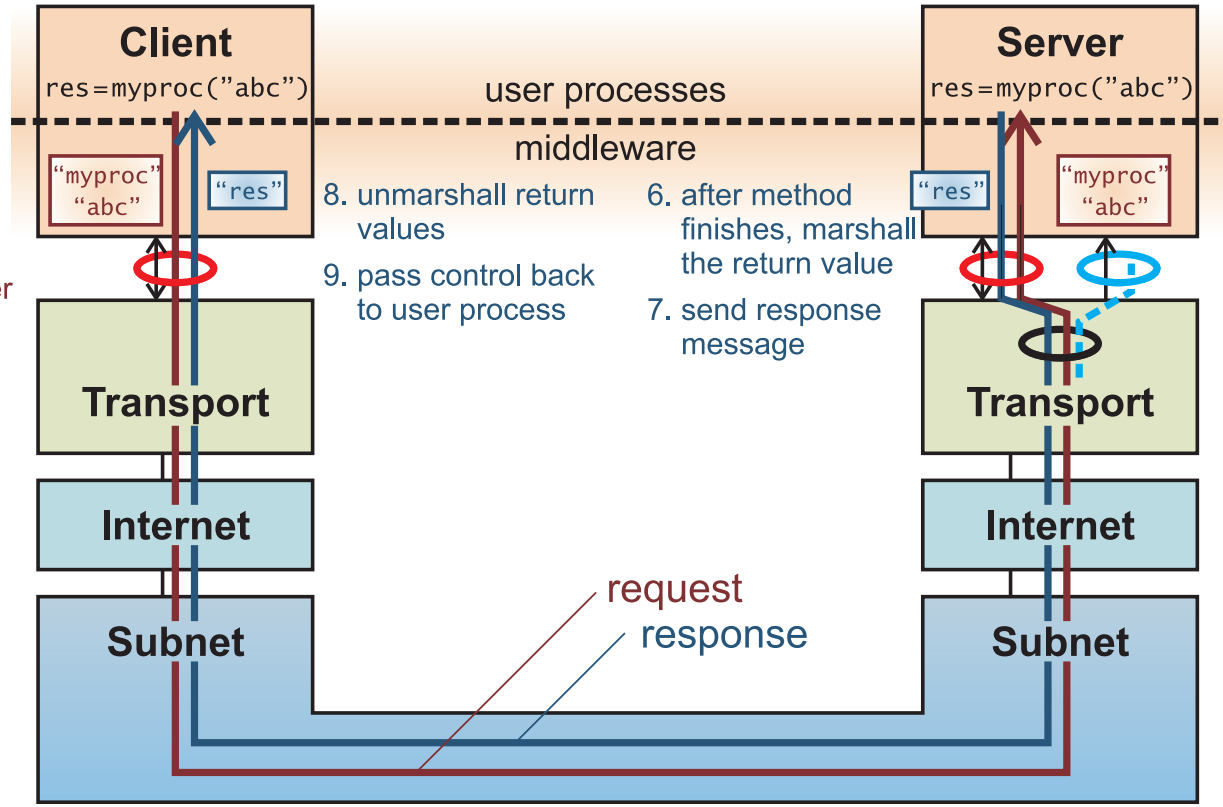

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double calculate(double x, double y)
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- Goals
  - Function which is implemented on another computer is actually executed on that other computer, but triggered by our process
  - From the programmer's and program's perspective, it looks like it is called in the current process

Remember

- We can use sockets to realize some sort of *remote* procedure call...

Listing: [TCPServerStructuredData.java]: A server perform a specific "method".

```
import java.io.DataInputStream;   import java.io.DataOutputStream;
import java.net.ServerSocket;     import java.net.Socket;

public class TCPServerStructuredData {
  public static final void main(final String[] args) {
    ServerSocket       server;       Socket             client;
    DataOutputStream   dos;          DataInputStream    dis;
    String             s;            long               a, b,r;

    try {
      server = new ServerSocket(9996);//1 + 2)

      for (int j = 5; (--j) >= 0;) { //process only 5 clients, so I can show 5) below
        client = server.accept();    //3)

        dis = new DataInputStream(client.getInputStream()); //4 + 3
        s   = dis.readUTF();       //read an UTF-encoded string: the operation
        r   = a = dis.readLong(); //read a 64 bit long integer
        b   = dis.readLong();      //read another 64 bit long int
        if ("add".equalsIgnoreCase(s)) { r += b; } else { // add
          if ("sub".equalsIgnoreCase(s)) { r -= b;  }     // subtract
        }  //4 + 3)

        System.out.println(s + "(" + a + ",␣" + b + ")␣=␣" + r + "␣to␣" +
            client.getRemoteSocketAddress());

        dos = new DataOutputStream(client.getOutputStream()); //marshall output
        dos.writeLong(r); //write 64bit long integer: 4 + 3)
        dos.close(); // flush and close

        client.close(); //4)
      }
      server.close(); //5)
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

Client Part of the Example

Listing: [TCPClientStructuredData.java]: A client asking the server to perform a specific "method".

```
import java.io.DataInputStream;   import java.io.DataOutputStream;
import java.net.InetAddress;      import java.net.Socket;

public class TCPClientStructuredData {

  public static final void main(final String[] args) {
    Socket           client;     InetAddress       ia;
    DataOutputStream dos;        DataInputStream   dis;

    try {
      ia = InetAddress.getByName("localhost");

      client = new Socket(ia, 9996); //1+2)

      dos = new DataOutputStream(client.getOutputStream()); //marshall data
      dos.writeUTF("sub"); //send operation name 3)
      dos.writeLong(9876); //send 64bit long integer
      dos.writeLong(1234); //send another 64bit long integer
      dos.flush();  //flush is important, otherwise stuff may just be buffered!

      dis = new DataInputStream(client.getInputStream()); // unmashall input
      System.out.println("Result: " + dis.readLong());    //3)

      client.close(); //4)
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

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- Client side

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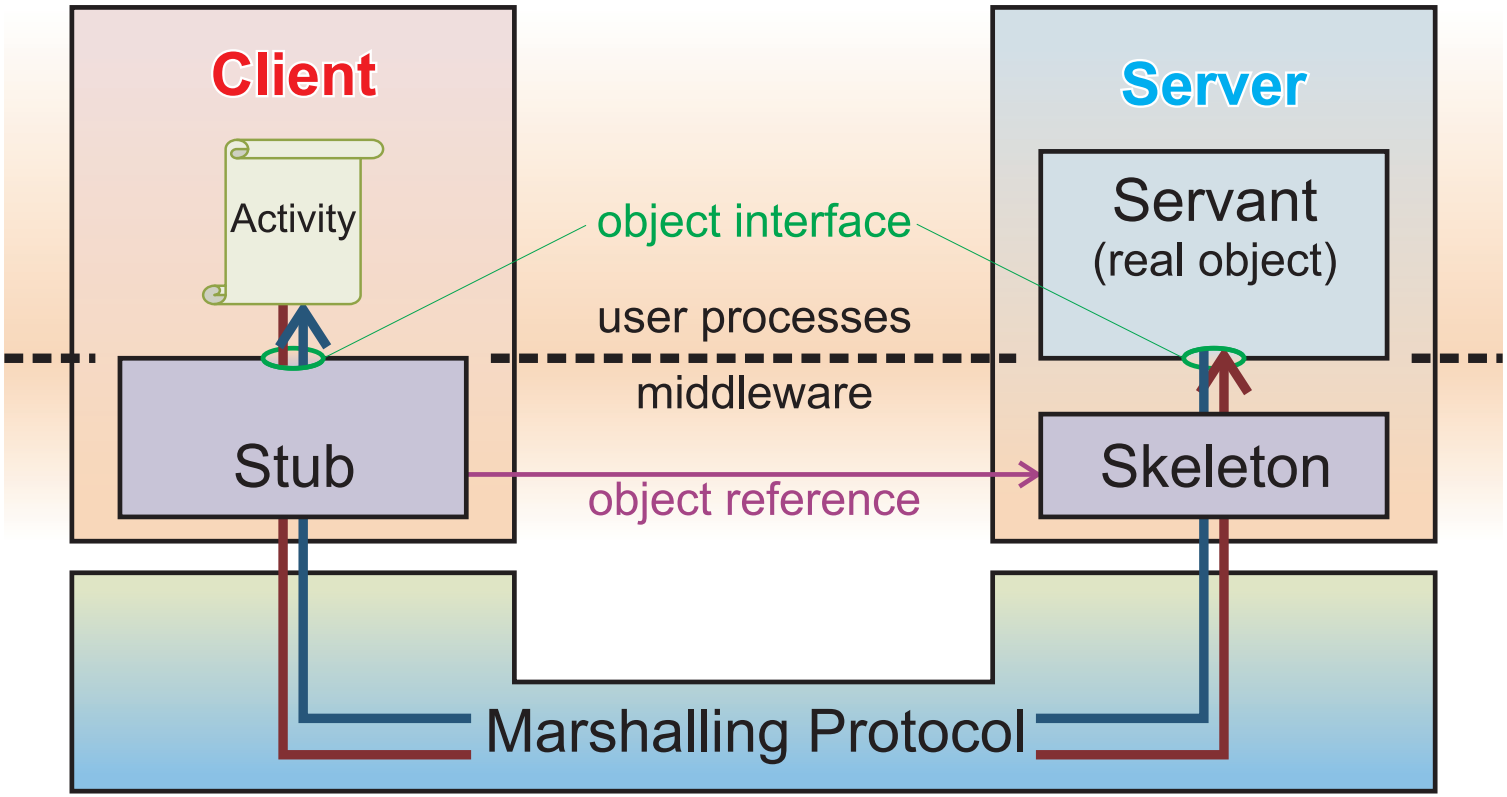
- Remote Method Invocation (RMI): RPC for distributed objects
- Stub: implements object interface [6, 7] and marshalls calls
- Skeleton: unmarshalls calls and delegates them to real object



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- Functionality specified as `interface`
- Servant object (on server side) implements the functionality
- A name is assigned to the Servant and managed by a registry
- Client can request access to the object from the registry
- Stub on client side is an automatically generated instance of the interface
- Client can now access the object exactly as if it was a local object

RemotePrintInterface

Listing: [RemotePrintInterface.java]: The interface specifying the functionality.

```
import java.rmi.Remote;
import java.rmi.RemoteException;

// the RemotePrint interface
public interface RemotePrintInterface extends Remote {

  /** A method to be remote-accessible
   * @param what the string to print
   * @throws RemoteException a possible exception */
  public abstract void print(final String what) throws
      RemoteException;

}
```

RemotePrintServer

Listing: [RemotePrintServer.java]: The server implementing the functionality.

```
import java.rmi.RemoteException;          import java.rmi.registry.LocateRegistry;
import java.rmi.registry.Registry;        import java.rmi.server.UnicastRemoteObject;

public class RemotePrintServer extends UnicastRemoteObject implements
    RemotePrintInterface {
  RemotePrintServer() throws RemoteException {
    super();
  }

 // the actual implementation of the method specified by RemotePrintInterface
  @Override
  public void print(final String what) throws RemoteException {
    System.out.println(what);
  }

  public static final void main(final String args[]) {
    Registry registry;

    try {
      // create the (local) object registry
      registry = LocateRegistry.createRegistry(9999);
      // bind the object to the name "server"
      registry.rebind("server", new RemotePrintServer());
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

RemotePrintClient

Listing: [RemotePrintClient.java]: The client remotely using the functionality.

```
import java.rmi.registry.LocateRegistry;      import java.rmi.registry.Registry;

public class RemotePrintClient { // the remote print rmi client
  public static final void main(final String args[]) {
    RemotePrintInterface rmiServer;         Registry registry;

    try {
      // find the (local) object registry
      registry = LocateRegistry.getRegistry(9999);

      // find the server object
      rmiServer = (RemotePrintInterface) (registry.lookup("server"));

      rmiServer.print("Hello World"); //$NON-NLS-1$
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
}
```

RemotePrintClientErroneous

Listing: [RemotePrintClientErroneous.java]: The client remotely using the functionality wrongly.

```
import java.rmi.registry.LocateRegistry;      import java.rmi.registry.Registry;

public class RemotePrintClientErroneous { // the erroneous remote print client
  public static final void main(final String args[]) {
    RemotePrintInterface rmiServer;         Registry registry;

    try {
      // find the (local) object registry
      registry = LocateRegistry.getRegistry(9999);

      //! invalid cast to server class !
      rmiServer = ((RemotePrintServer)(registry.lookup("server")));

      rmiServer.print("Hello World"); //$NON-NLS-1$
    } catch (Throwable t) {
      t.printStackTrace();
    }
  }
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```

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- Why?

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- The real object instance (servant) exists in another JVM / on another computer
- The proxy on the client side is a dynamically created object implementing the `RemotePrintInterface` interface
- It has a class different from `RemotePrintServer`
- And thus, cannot be cast to `RemotePrintServer`

Summary

- RPC: call a procedure on another computer
- RMI: call a method (i.e., access an object) on a different computer
- Many different technologies
- Java RMI: quite simple to use

谢谢

Thank you

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