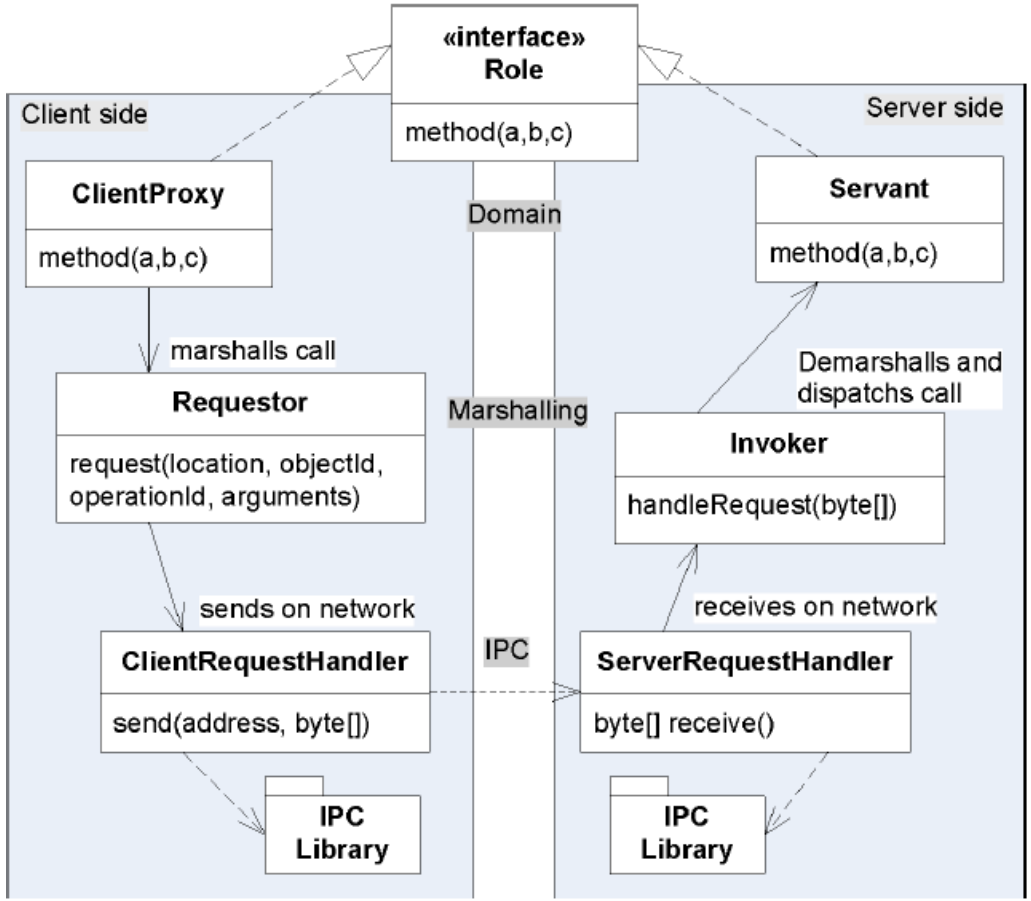
AARHUS UNIVERSITET

Software Engineering and Architecture

Broker Pattern
Architectural Pattern for
Remote Method Invocation

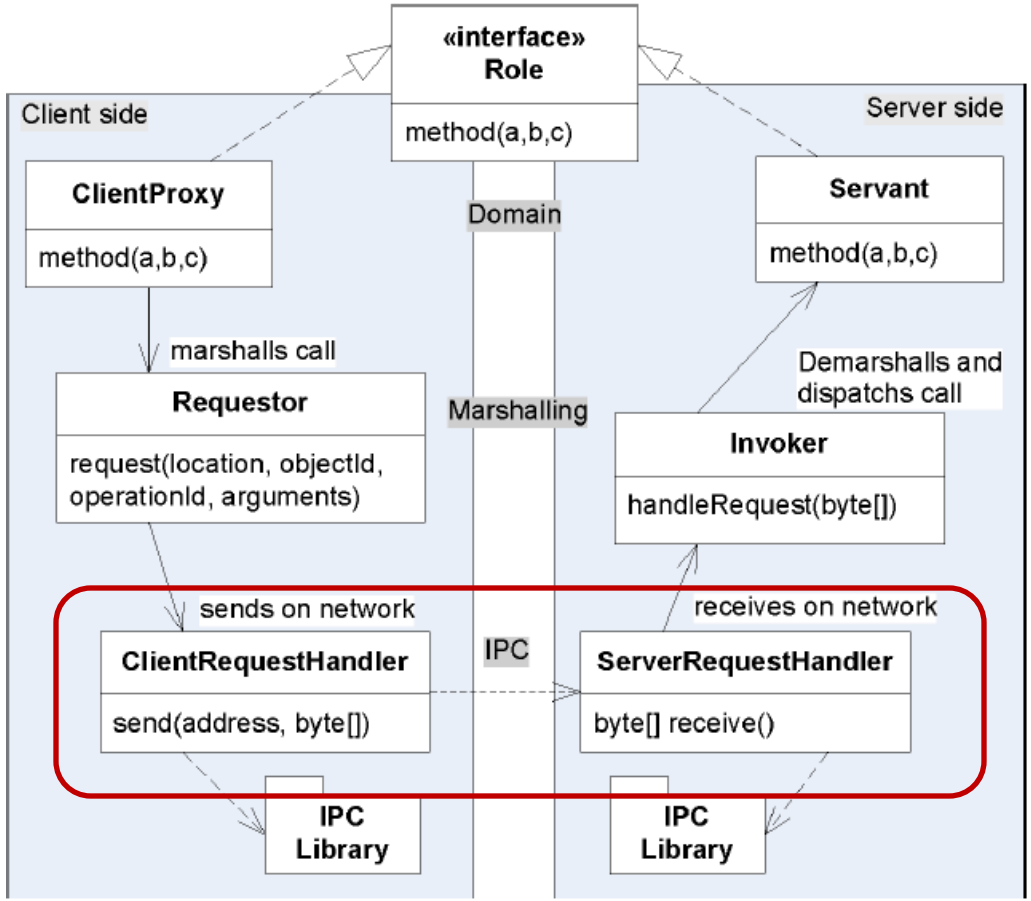
Broker

- Broker bundles the four elements:
- Solutions are
  - Request/Reply protocol
  - Marshalling
  - Proxy Pattern
  - Naming Systems



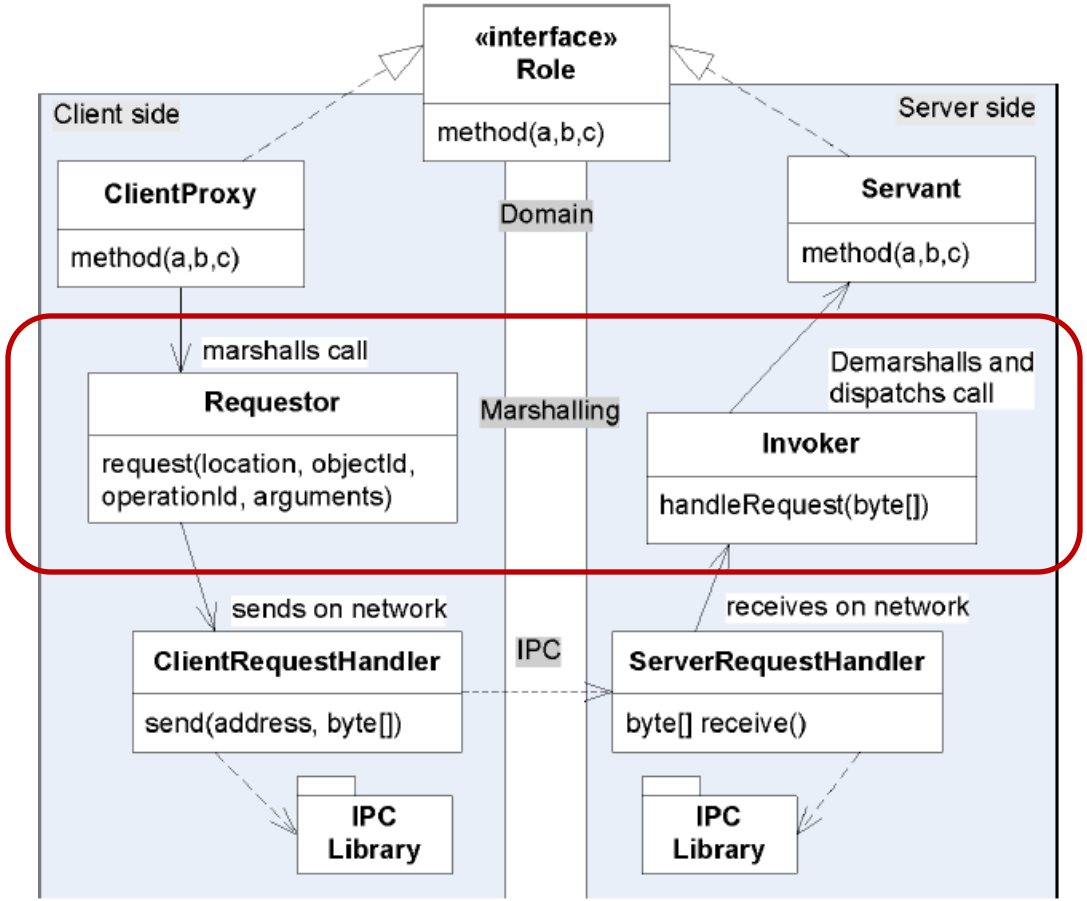
Broker

- Broker bundles the four elements:
- Solutions are
  - Request/Reply protocol
  - Marshalling
  - Proxy Pattern
  - Naming Systems



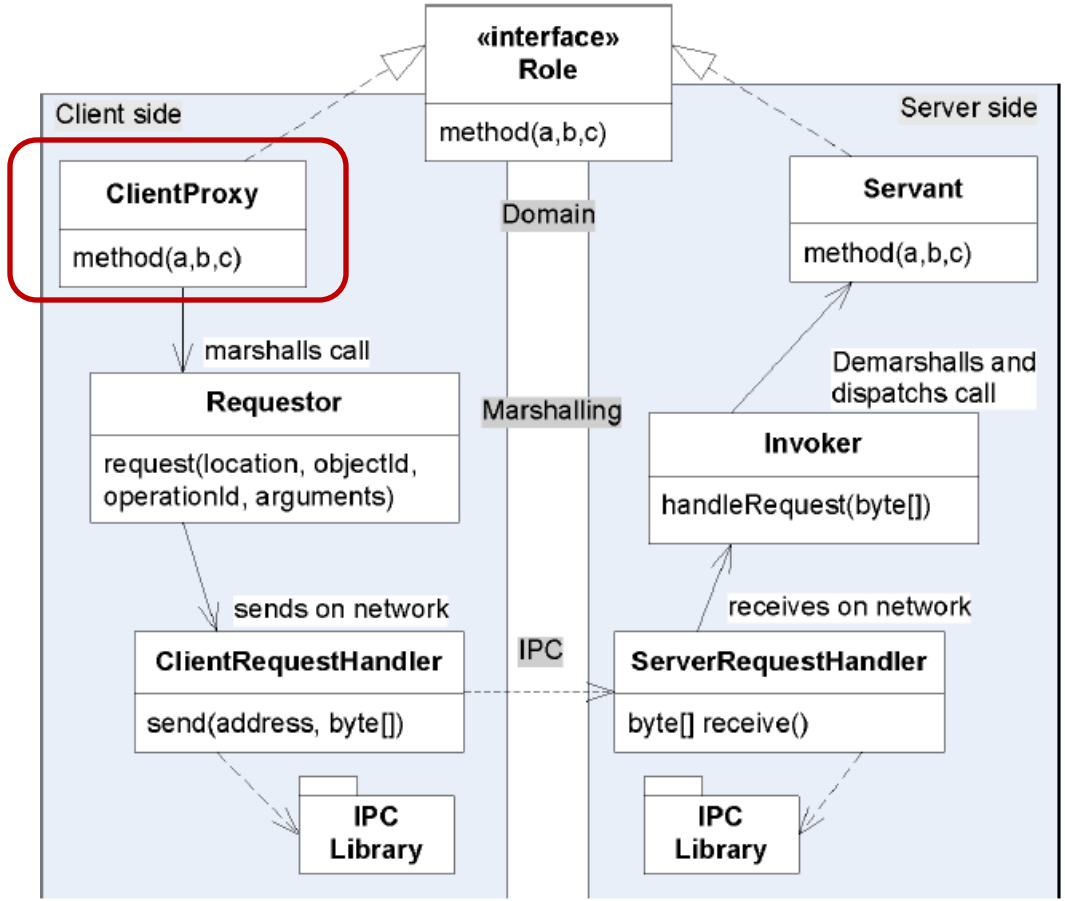
Broker

- Broker bundles the four elements:
- Solutions are
  - Request/Reply protocol
  - Marshalling
  - Proxy Pattern
  - Naming Systems



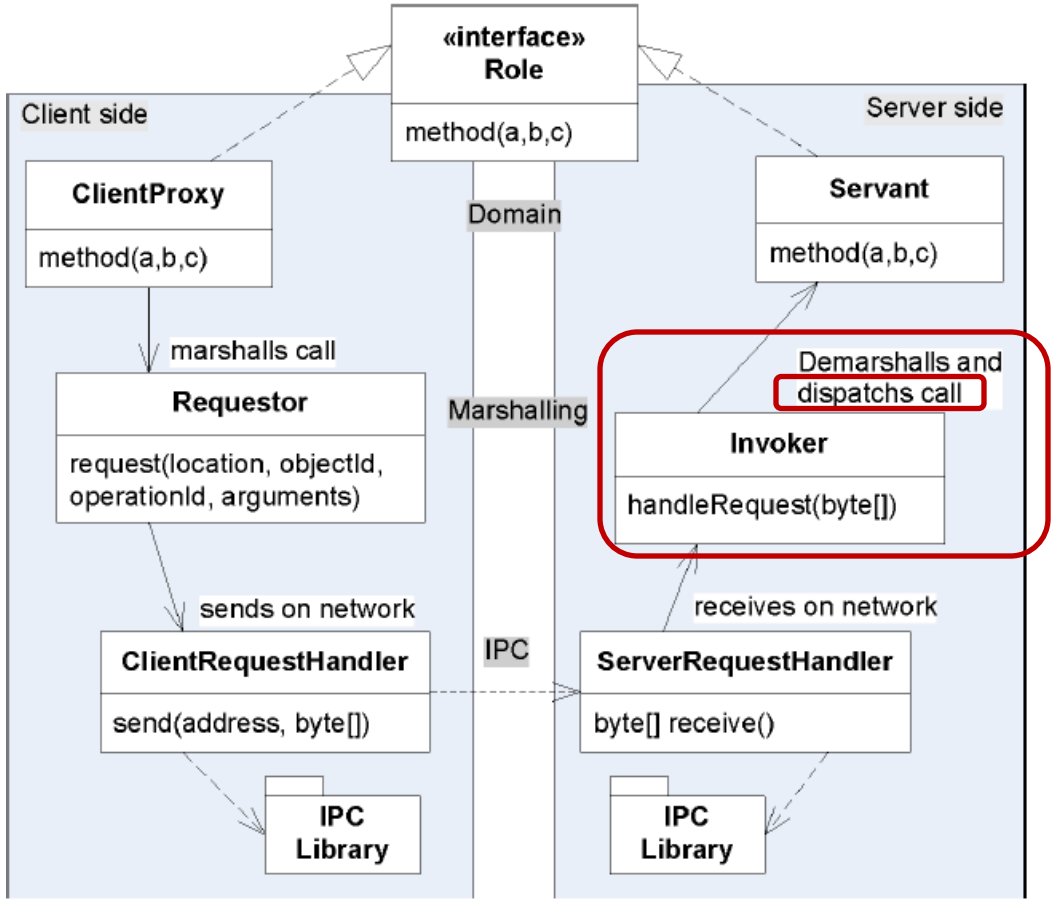
Broker

- Broker bundles the four elements:
- Solutions are
  - Request/Reply protocol
  - Marshalling
  - Proxy Pattern
  - Naming Systems



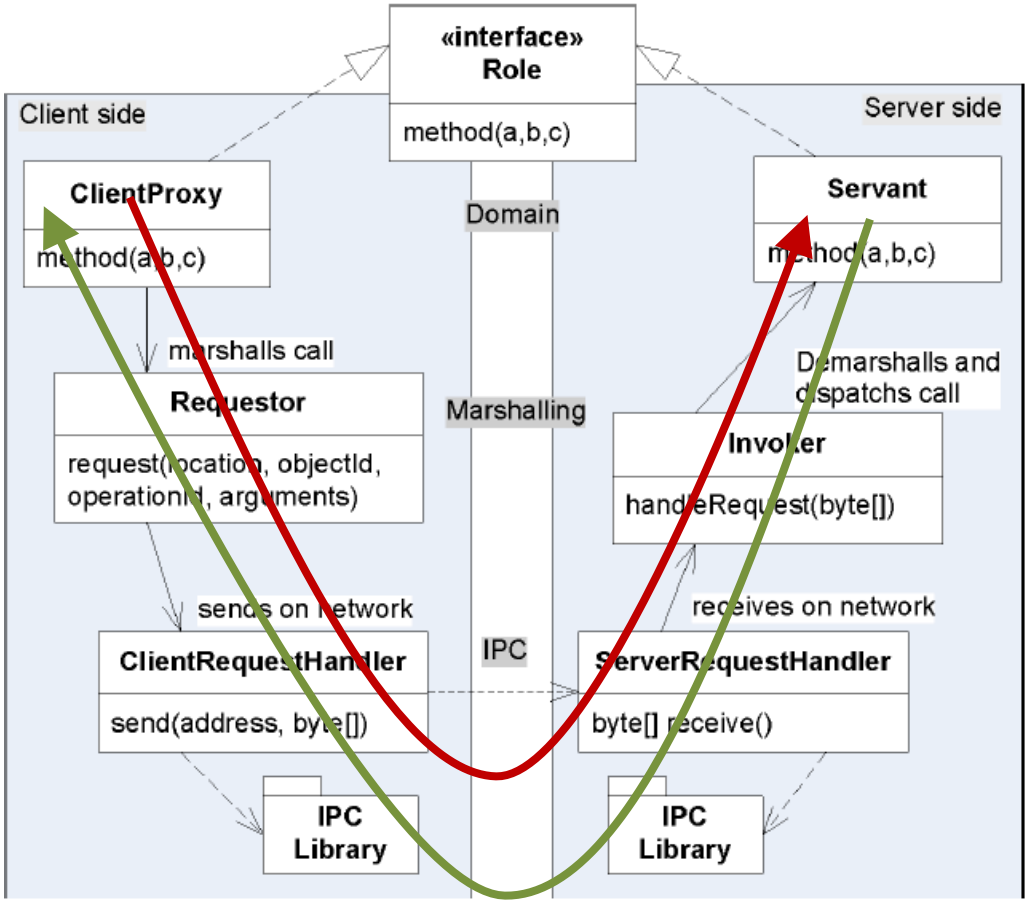
Broker

- Broker bundles the four elements:
- Solutions are
  - Request/Reply protocol
  - Marshalling
  - Proxy Pattern
  - Naming Systems



A Picture of the 'Flow'

- The method call *flows* from the client's ClientProxy, through intermediaries until it ends in the Servant
  - Each intermediate responsible for a transformation
    - domain-to-network and vice-versa
- … and back again…
  - "Chained calls"



The ‘Side’ Perspective

- Client side

ClientProxy

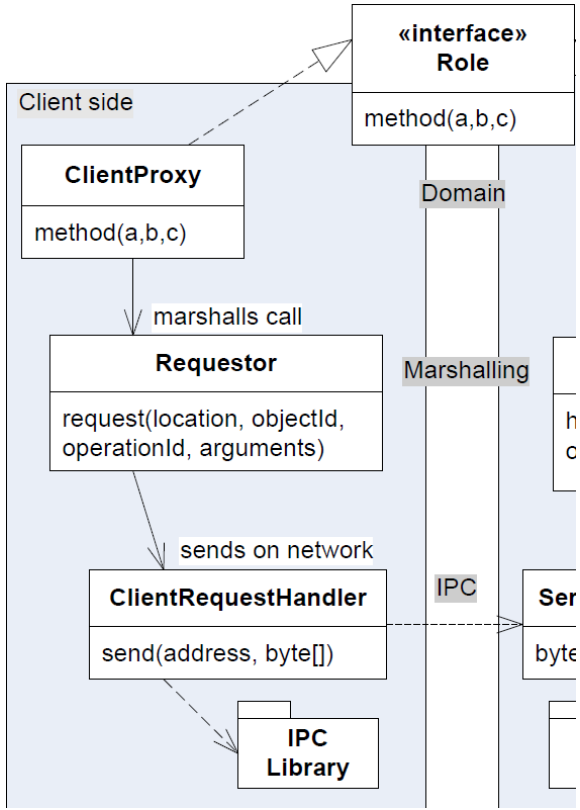
- *Proxy* for the remote servant object, implements the same interface as the servant.
- Translates every method invocation into invocations of the associated *requestors*’s `request()` method.

Requestor

- Performs marshalling of object identity, method name and arguments into a byte array.
- Invokes the **ClientRequestHandler**’s `send()` method.
- Demarshalls returned byte array into return value(s).
- Creates client side exceptions in case of failures detected at the server side or during network transmission.

ClientRequestHandler

- Performs all *inter process communication* on behalf of the client side, interacting with the server side’s **server request handler**.



The ‘Side’ Perspective

- Server side

Servant

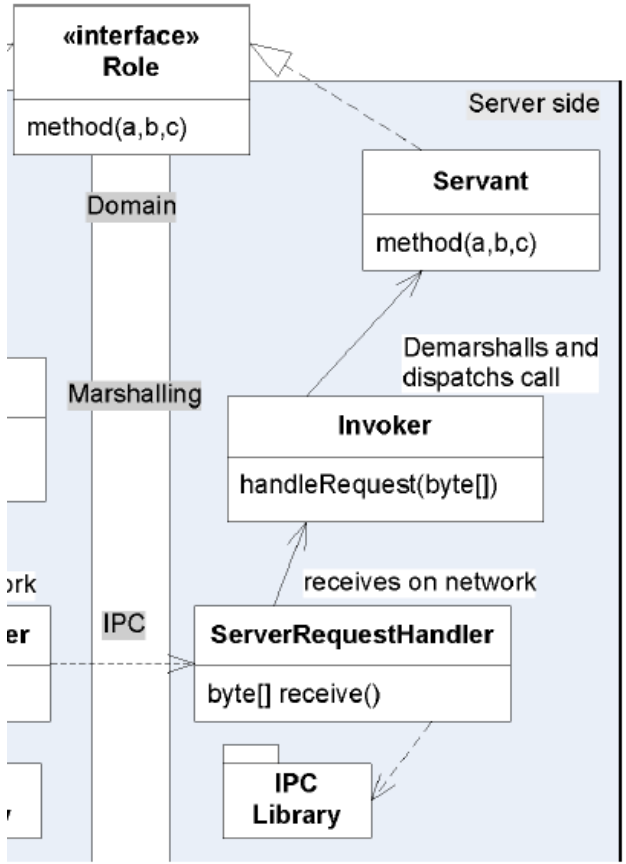
- Domain object with the domain implementation on the server side.

Invoker

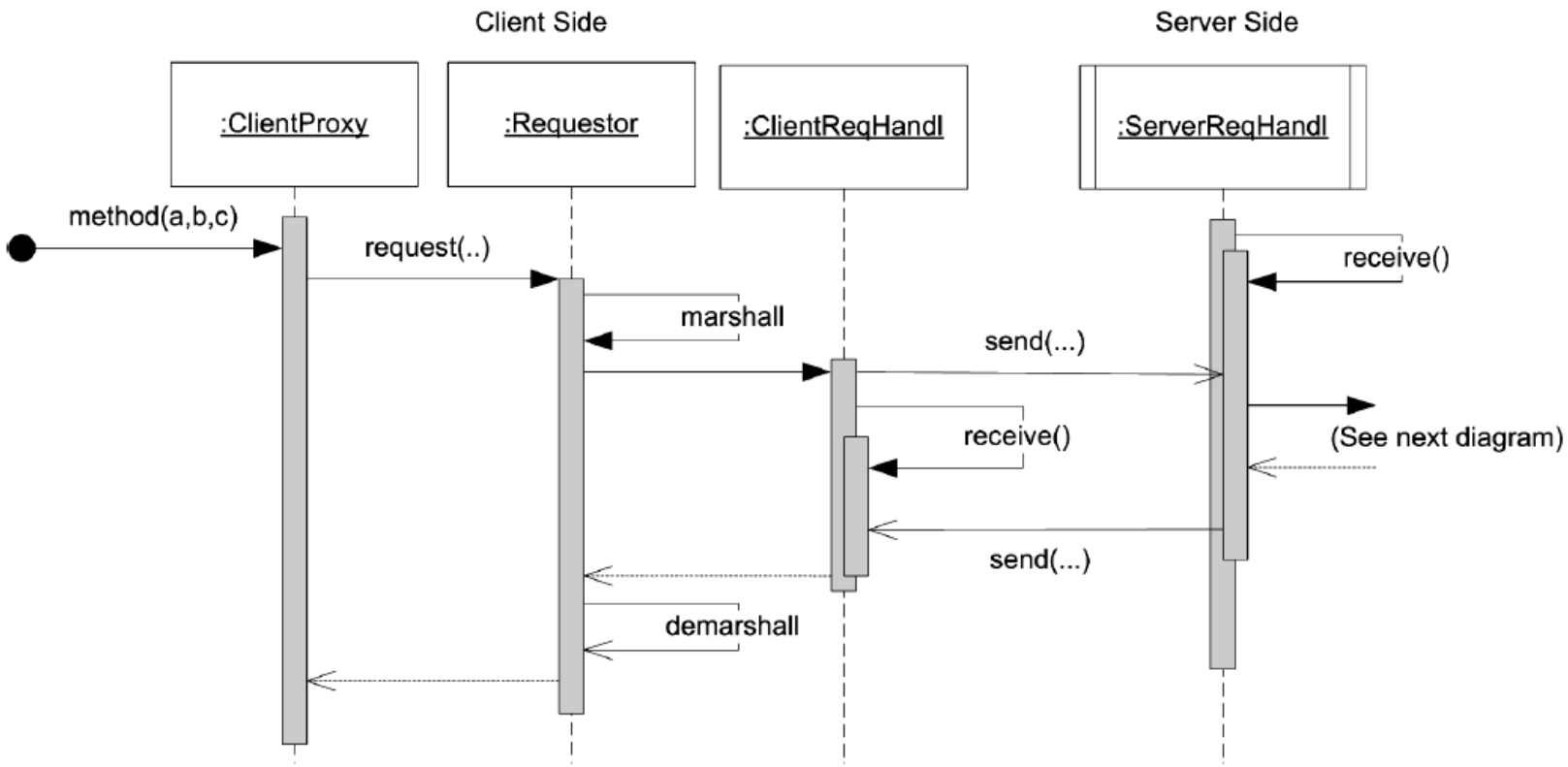
- Performs demarshalling of incoming byte array.
- Determines servant object, method, and arguments and calls the given method in the identified **Servant** object.
- Performs marshalling of the return value from the **Servant** object into a reply byte array, or in case of server side exceptions or other failure conditions, return error replies allowing the **Requestor** to throw appropriate exceptions.

ServerRequestHandler

- Performs all *inter process communication* on behalf of the server side, interacting with the client side’s **ClientRequestHandler**.
- Contains the event loop thread that awaits incoming requests from the network.
- Upon receiving a message, calls the **Invoker**’s `handleRequest` method with the received byte array. Sends the reply back to the client side.

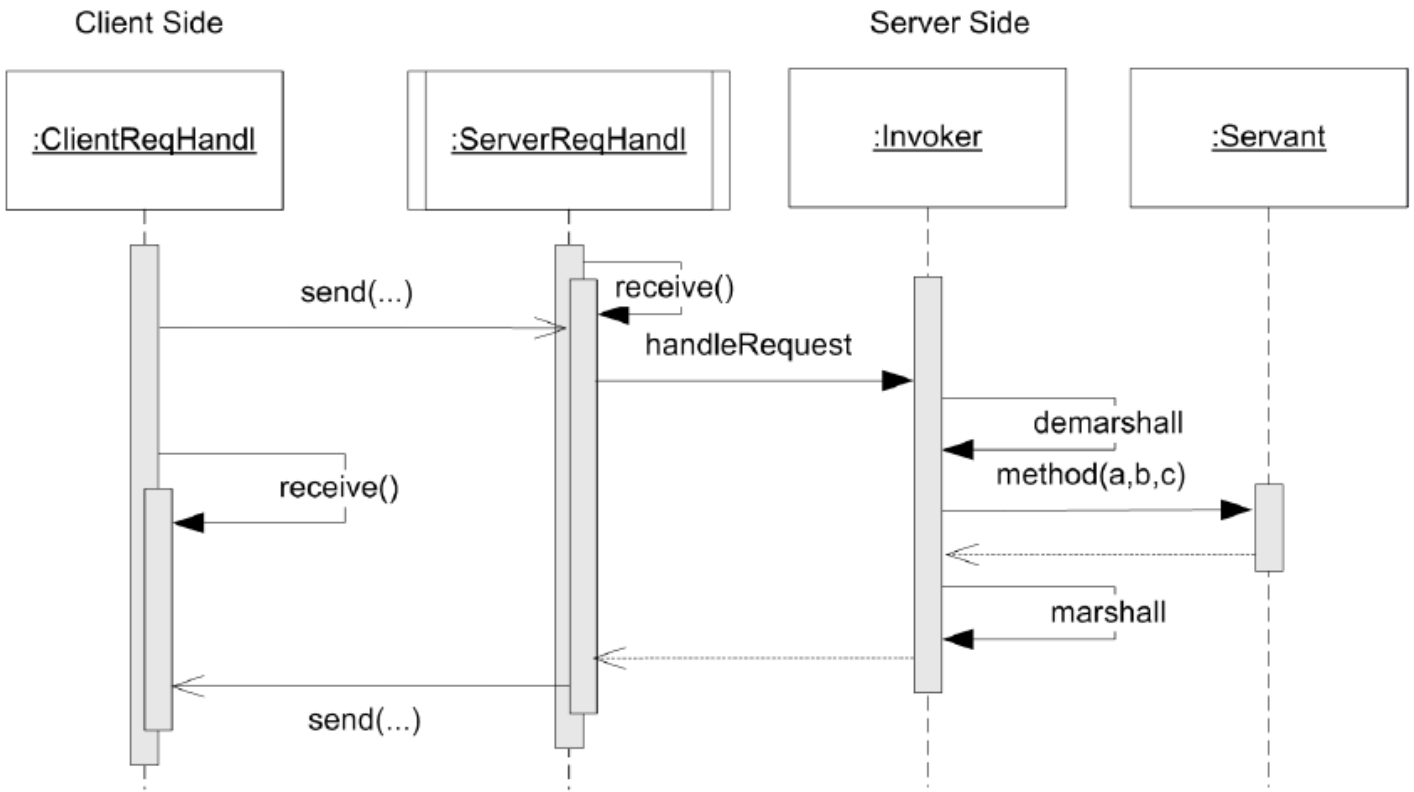


Dynamics (Client)



Broker client side dynamics.

Dynamics (Server)



Broker server side dynamics.

Domain Level

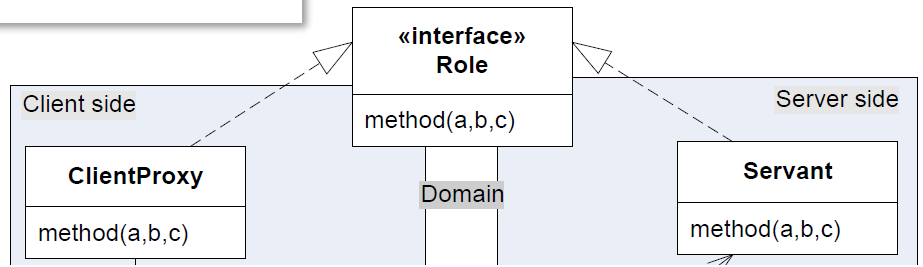
- Domain level represents the actual **Role**

Servant

- Domain object with the domain implementation on the server side.

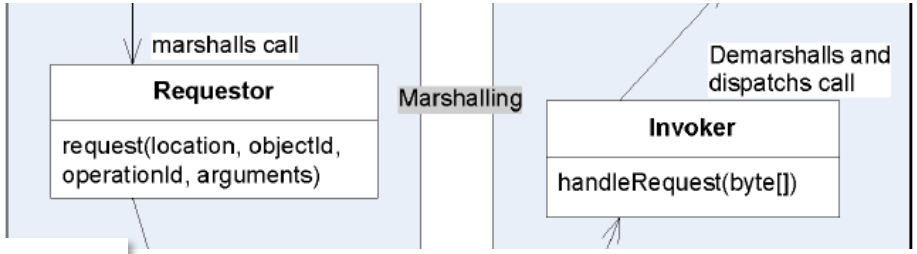
ClientProxy

- *Proxy* for the remote servant object, implements the same interface as the servant.
- Translates every method invocation into invocations of the associated **Requestor**'s `request()` method.



Marshalling Level

- Encapsulate translation to/from bits and objects



Requestor

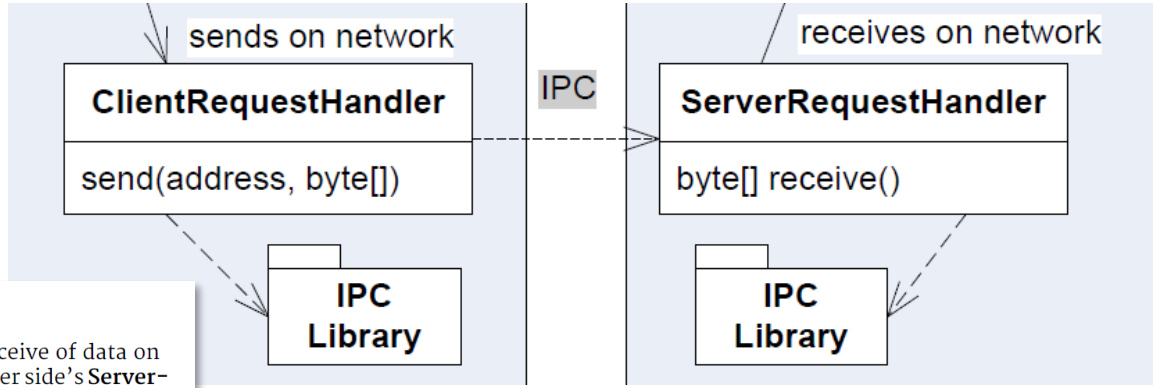
- Performs marshalling of object identity, method name and arguments into a byte array.
- Invokes the **ClientRequestHandler**'s `send()` method.
- Demarshalls returned byte array into return value(s).
- Creates client side exceptions in case of failures detected at the server side or during network transmission.

Invoker

- Performs demarshalling of incoming byte array.
- Determines servant object, method, and arguments and calls the given method in the identified **Servant** object.
- Performs marshalling of the return value from the **Servant** object into a reply byte array, or in case of server side exceptions or other failure conditions, return error replies allowing the **Requestor** to throw appropriate exceptions.

IPC Level

- Interprocess Communication
  - Encapsulate low-level OS/Network communication



ClientRequestHandler

- Performs all *inter process communication* send/receive of data on behalf of the client side, interacting with the server side's **ServerRequestHandler**.

ServerRequestHandler

- Performs all *inter process communication* on behalf of the server side, interacting with the client side's **ClientRequestHandler**.
- Contains the event loop thread that awaits incoming requests from the network.
- Upon receiving a message, calls the **Invoker**'s `handleRequest` method with the received byte array. Sends the reply back to the client side.

Relating to ③ ① ②

- Broker pattern and ③ ① ② ?
  - Yes, yes, and yes

- ③ *Encapsulate what varies*
  - *We would like to vary marshalling format: Requestor+Invoker*
  - *We would like to vary IPC method: xRequestHandler*

- ② *Object composition*
  - *We delegate to the requestor. We delegate to the RequestHandl.*

AARHUS UNIVERSITET

In Practice

How Does It Look Then…

The TeleMed Interface

- Will only look at the two methods to
  - Upload
    - *processAndStore*
  - Download
    - *getObservationsFor*

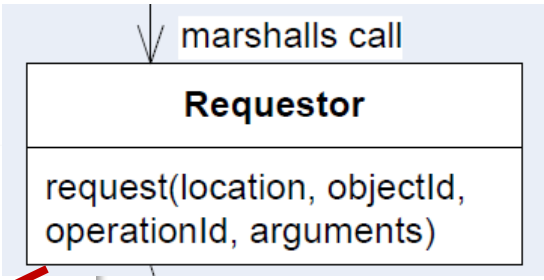
```java
public interface TeleMed {

  /**
   * Process a tele observation into the HL7 format and store it
   * in the XDS database tier.
   *
   * @param teleObs
   *          the tele observation to process and store
   * @return the id of the stored observation
   * @throws IPCException in case of any IPC problems
   */
  String processAndStore(TeleObservation teleObs);

  /**
   * Retrieve all observations for the given time interval for the
   * given patient. If no observations exists return a 0 sized
   * list.
   *
   * @param patientId
   *          the ID of the patient to retrieve observations for
   * @param interval
   *          define the time interval that measurements are
   *          wanted for
   * @return list of all observations
   * @throws IPCException in case of any IPC problems
```

```java
List<TeleObservation> getObservationsFor(String patientId,
  TimeInterval interval);
```

TeleMed Proxy

- ClientProxy = Proxy calls

```java
public class TeleMedProxy implements TeleMed, ClientProxy {
  public static final String TELEMED_OBJECTID = "singleton";

  private final Requestor requestor;
  public TeleMedProxy(Requestor requestor) {
    this.requestor = requestor;
  }

  @Override
  public String processAndStore(TeleObservation teleObs) {
    String uid =
      requestor.sendRequestAndAwaitReply(TELEMED_OBJECTID, OperationNames.PROCESS_AND_STORE_OPERATION,
      String.class, teleObs);
    return uid;
  }

  @Override
  public List<TeleObservation> getObservationsFor(String patientId, TimeInterval interval) {
    Type collectionType =
      new TypeToken<List<TeleObservation>>(){}.getType();
    List<TeleObservation> returnedList;
    try {
      returnedList = requestor.sendRequestAndAwaitReply(TELEMED_OBJECTID,
              OperationNames.GET_OBSERVATIONS_FOR_OPERATION,
              collectionType, patientId, interval);
```



Note: *There is only a single TeleMed servant object. Thus the objectId is 'not applicable'*

Note: *location = server, is provided as a global parameter, and not part of parameter list…*

Identity of Methods

- Remember: *We can only send byte arrays aka. Strings*
- Need to Marshall method names as well.

```java
public class OperationNames {
  // Method names are prefixed with the type of the method receiver ('telemed') which
  // can be used in when serveral different types of objects are present at the server side
  // and is also helpful in case of failure on the server side where log files can be
  // inspected.
  public static final String PROCESS_AND_STORE_OPERATION = "telemed-process-and-store";
  public static final String GET_OBSERVATIONS_FOR_OPERATION = "telemed-get-observation-for";
  public static final String CORRECT_OPERATION = "telemed-correct";
  public static final String GET_OBSERVATION_OPERATION = "telemed-get-observation";
  public static final String DELETE_OPERATION = "telemed-delete";
```

- ”Mangling” = Concatenate class name and method name

AARHUS UNIVERSITET

Requestor

General Implementation!
Use JSON and the GSON library

Generic return type is pretty helpful…

And Object… = arrays of mixed types are really nasty that required some googling to find out how.

This is code provided by the FRDS.Broker library!

```java
@Override
public <T> T sendRequestAndAwaitReply(String objectId, String operationName,
                                      Type typeOfReturnValue, Object... arguments) {
  // Perform marshalling, first arguments, next full request
  String marshalledArgumentList = gson.toJson(arguments);
  RequestObject request = new RequestObject(objectId, operationName, marshalledArgumentList);
  String marshalledRequest = gson.toJson(request);
  // Ask CRH to do the network call
  String marshalledReply = clientRequestHandler.sendToServerAndAwaitReply(marshalledRequest);
  // Demarshall the reply
  ReplyObject reply = gson.fromJson(marshalledReply, ReplyObject.class);
  // First, verify that the request succeeded
  if (!reply.isSuccess()) {
    throw new IPCException(reply.getStatusCode(),
        "Failure during client requesting operation '"
                + operationName
                + "'. ErrorMessage is: "
                + reply.errorDescription());
  }
  // No errors - so get the payload of the reply
  String payload = reply.getPayload();
  // and demarshall the returned value
  T returnValue = null;
  if (typeOfReturnValue != null)
    returnValue = gson.fromJson(payload, typeOfReturnValue);
  return returnValue;
}
```

```java
public class RequestObject {
  private final String operationName;
  private final String payload;
  private final String objectId;
```

Request Handlers

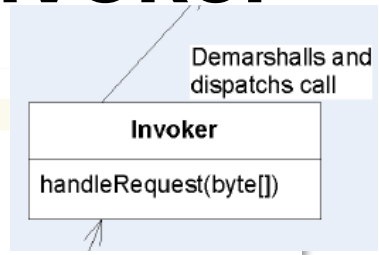
- Let us skip them for the moment…
- Basically they are responsible for the request/reply protocol
- Broker Library code base come with two variants:
  - Socket: Raw Java TCP/IP network implementations
  - HTTP: Use as a raw transport (URI Tunneling)

AARHUS UNIVERSITET

Invoker

Basically you need a *large switch* on each method name to do the 'upcall', and extract the relevant parameters for the method

For multi-object system, you need something more complex. Stay tuned – we will look at it next week...




```java
public class TeleMedJSONInvoker implements Invoker {
  private final TeleMed teleMed;
  private final Gson gson;

  public TeleMedJSONInvoker(TeleMed teleMedServant) {
    teleMed = teleMedServant;
    gson = new Gson();
  }

  @Override
  public String handleRequest(String request) {
    // Do the demarshalling
    RequestObject requestObject =  gson.fromJson(request, RequestObject.class);
    JsonArray array = JsonParser.parseString(requestObject.getPayload()).getAsJsonArray();

    ReplyObject reply;
    /* As there is only one TeleMed instance (a singleton)
       the objectId is not used for anything in our case.
     */
    try {
      // Dispatching on all known operations
      // Each dispatch follows the same algorith
      // a) retrieve parameters from json array
      // b) invoke servant method
      // c) populate a reply object with return values

      if (requestObject.getOperationName().equals(OperationNames.
              PROCESS_AND_STORE_OPERATION)) {
```

Demarshall into (objectId, operation name, arguments)

```java
public class RequestObject {
  private final String operationName;
  private final String payload;
  private final String objectId;
```

Invoker

- Once the method is determined, parameter list can be demarshalled, and the *upcall* made…

```
if (requestObject.getOperationName().equals(OperationNames.
        PROCESS_AND_STORE_OPERATION)) {
  // Parameter convention: [0] = TeleObservation
  TeleObservation ts = gson.fromJson(array.get(0),
          TeleObservation.class);

  String uid = teleMed.processAndStore(ts);
  reply = new ReplyObject(HttpServletResponse.SC_CREATED,
          gson.toJson(uid));
```

```
} else if (requestObject.getOperationName().equals(OperationNames.
        GET_OBSERVATIONS_FOR_OPERATION)) {
  // Parameter convention: [0] = patientId
  String patientId = gson.fromJson(array.get(0), String.class);
  // Parameter convention: [1] = time interval
  TimeInterval interval = gson.fromJson(array.get(1),
          TimeInterval.class);

  List<TeleObservation> tol =
          teleMed.getObservationsFor(patientId, interval);
  int statusCode =
```

```
// And marshall the reply
return gson.toJson(reply);
```

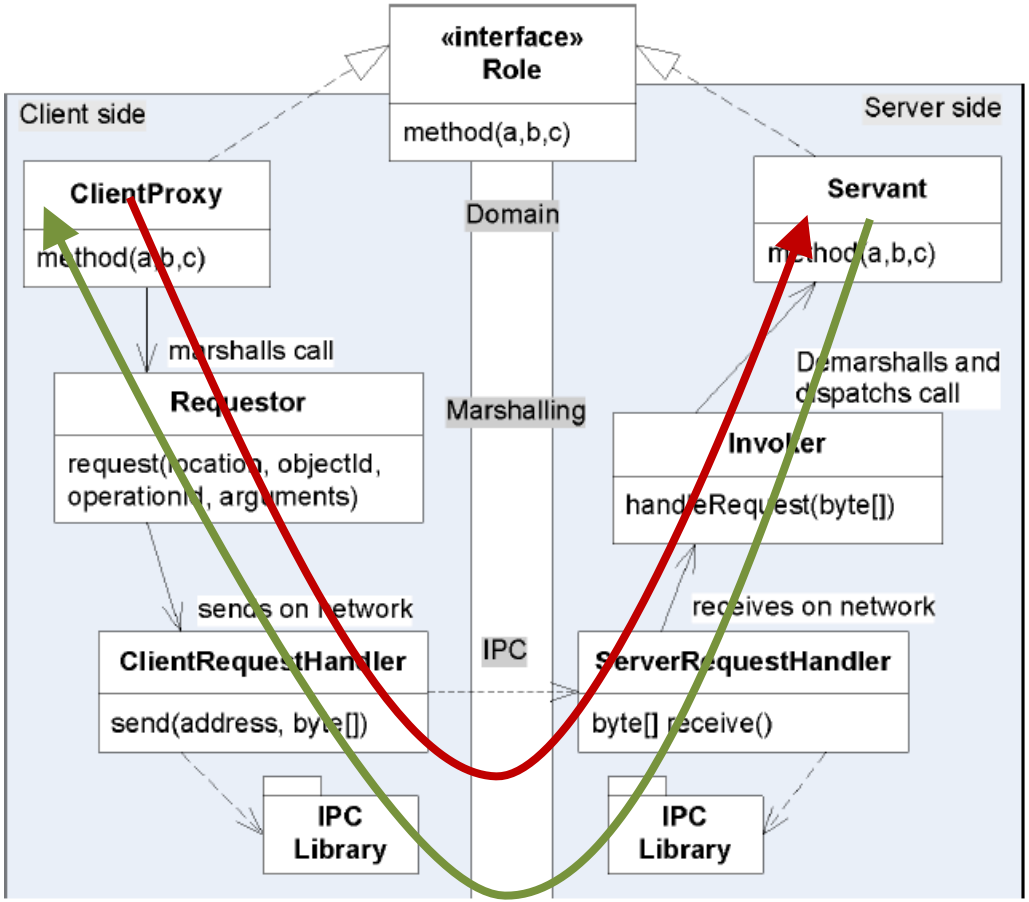
TeleMed Servant

- Servant = Domain implementation
- Not really relevant for Broker, but for the system ☺

```
public class TeleMedServant implements TeleMed, Servant {

  private XDSBackend xds;

  public TeleMedServant(XDSBackend xds) {
    this.xds = xds;
  }

  @Override
  public String processAndStore(TeleObservation teleObs) {
    // Generate the XML document representing the
    // observation in HL7 (HealthLevel7) format.
    HL7Builder builder = new HL7Builder();
    Director.construct(teleObs, builder);
    Document hl7Document = builder.getResult();

    // Generate the metadata for the observation
    MetadataBuilder metaDataBuilder = new MetadataBuilder();
    Director.construct(teleObs, metaDataBuilder);
    MetaData metadata = metaDataBuilder.getResult();

    // Finally store the document in the XDS storage system
    String uniqueId = null;
    uniqueId = xds.provideAndRegisterDocument(metadata, hl7Document);

    return uniqueId;
  }
```

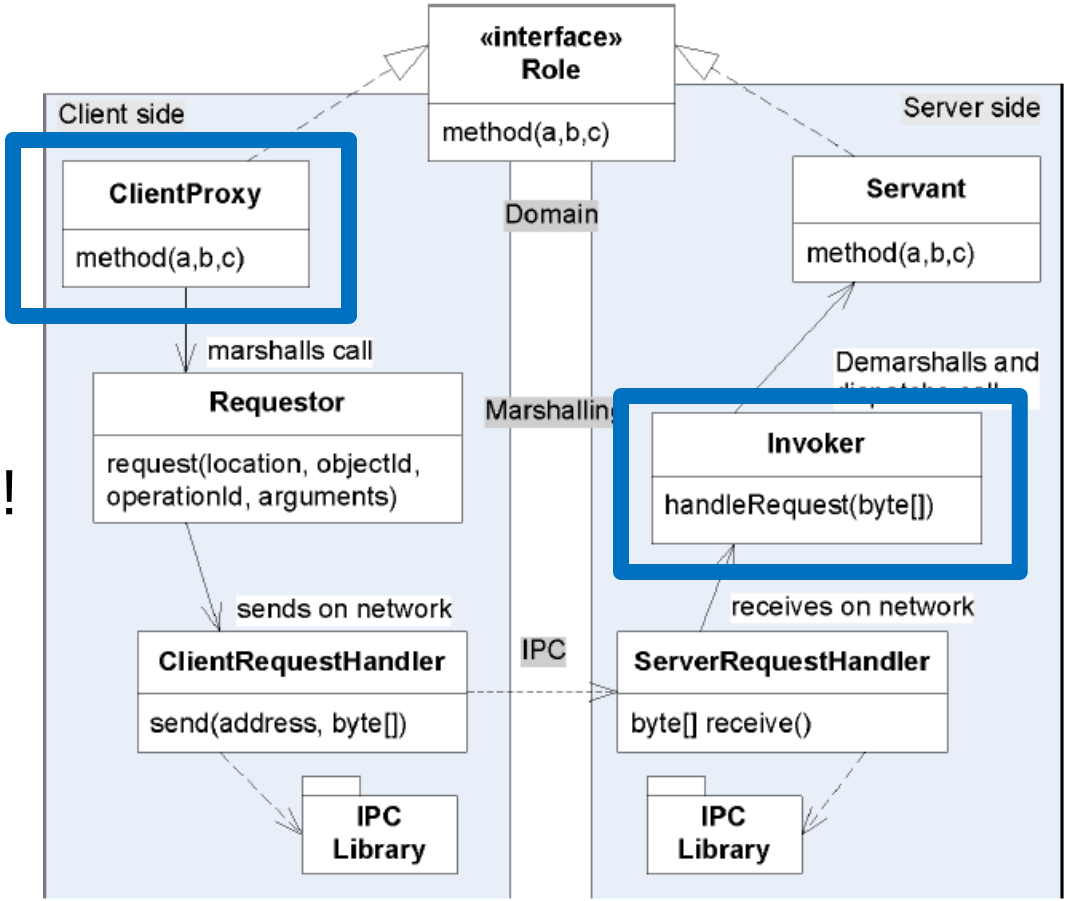
Summary

- The flow



Summary

- It is a Framework !
- Only roles
  - ClientProxy
  - Invoker
- … are TeleMed specific!
- (… and HotStone specific!)



Limitations

- No Name Service / Registry required for TeleMed
  - Parameterized which machine the servant object resides on
    - Use DNS as kind of registry, defaults to ‘localhost’
  - More RPC than RMI
    - Remote Procedure Call on ‘single type object’, not on multiple objects
- Only Value types can be passed, not Reference types
  - No object references ever pass **from client to server!**
- Asymmetric
  - Client-server protocol, no ‘callback’ **from** server possible
  - I.e. The Observer pattern **can not** be implemented

We treat String as pass-by-value

Why No Call Backs to Clients?

- Because *server calling clients is* ***BAD ☺!***

- No no no. Nothing is every ‘good’ or ‘bad’ in science ☺
  - WarpTalk is all about ‘call back from server to clients’ ☺

- We will return to why ‘servers should not call clients’ in next week…

Deployment

- In the code bases distributed, the client and server side classes are pooled into one big source tree
  - src/

Simply easier in our teaching

- In *real* deployments you need to split'em
  - Server: Server side specific classes
  - Core: Core domain *interfaces* and *PODOs*
  - Client: Client side specific classes

- The client side deployment (Core + Client)
- The server side deployment (Core + Server)

AARHUS UNIVERSITET

The Process?

How did I get there?

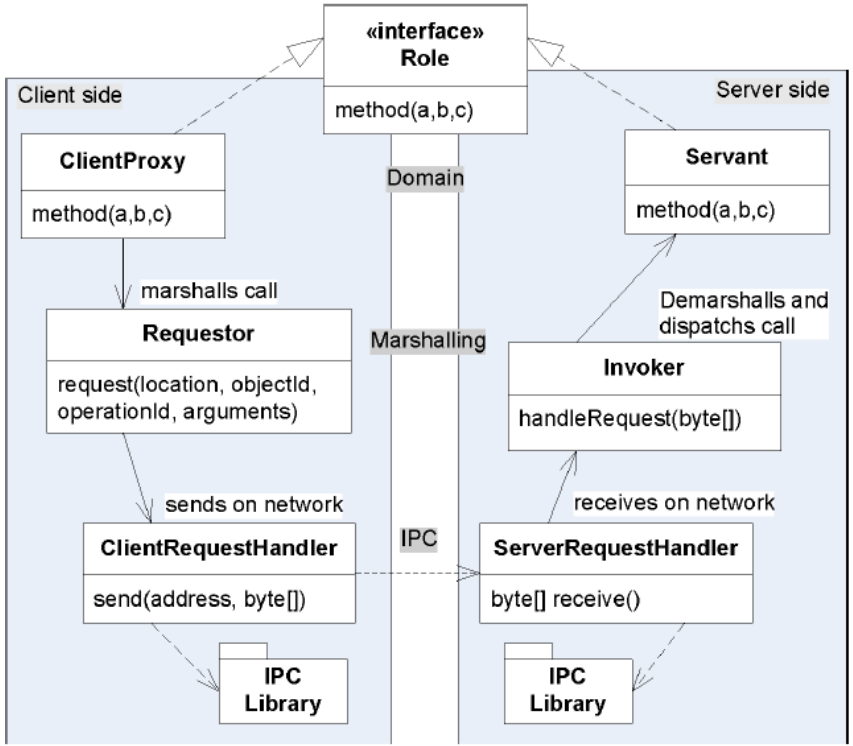
Developing it

- All well – you see the *final picture* but how was it painted?

- Challenge: **TDD of a distributed system?**
  - I cannot (easily) automate that a server needs to be running on some remote machine, can I?
    - (Well we can, but that is another course…)

Exercise

- Which level hinders TDD???
  - Or rather *automated testing*



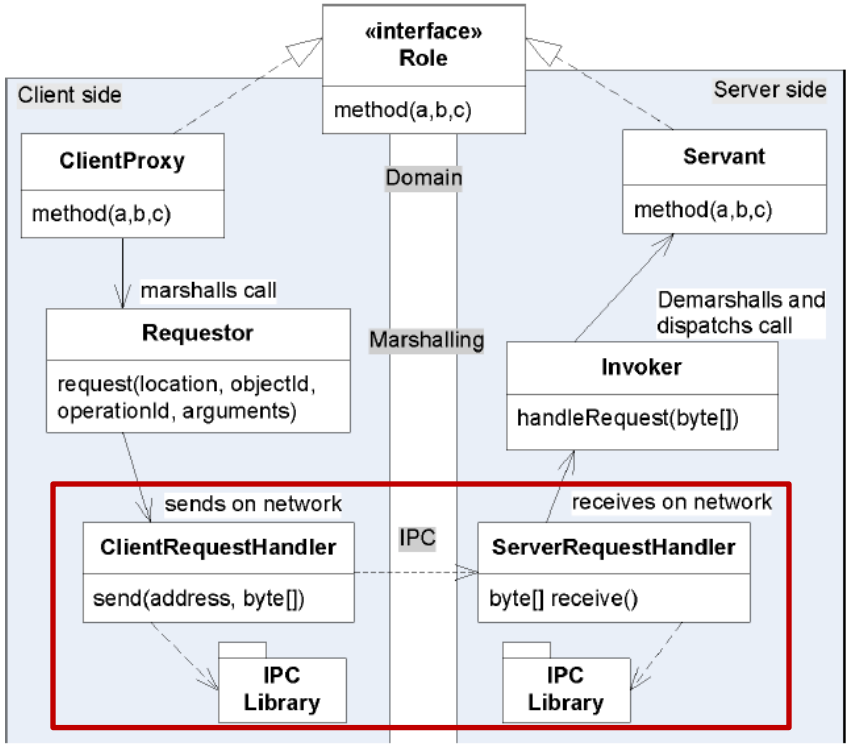
- And **you know** how to deal with it, right?!?

- **What is the answer???**

Principle 1+2+Doubles

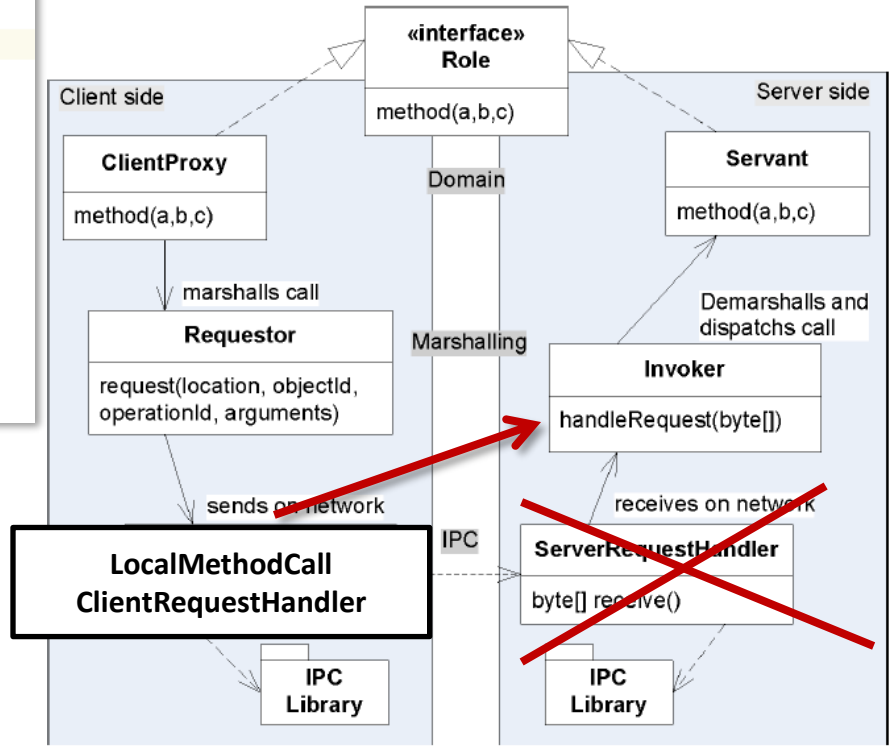
- *It is the IPC Level that hinders TDD*

- *But*
  - *Programmed to an interface*
  - *Object compose a Test Double into place instead!!!*
    - *A Fake Object IPC*



Faking the IPC

```java
public class LocalMethodCallClientRequestHandler implements ClientRequestHandler {

  private final Invoker invoker;
  private String lastRequest; private String lastReply;

  public LocalMethodCallClientRequestHandler(Invoker invoker) {
    this.invoker = invoker;
  }

  @Override
  public String sendToServerAndAwaitReply(String request) {
    lastRequest = request;
    String reply = invoker.handleRequest(request);
    lastReply = reply;
    return reply;
  }
```



No need to start server.
No concurrency.

All aspects (except IPC) can be TDD'ed

@BeforeEach

- Binding the Broker / Coupling the delegates together

```
@Before
public void setup() {
  teleObs1 = HelperMethods.createObservation120over70forNancy();
  // Create server side implementations
  xds = new FakeObjectXDSDatabase();
  TeleMed teleMedServant = new TeleMedServant(xds);

  // Server side broker implementations
  Invoker invoker = new StandardJSONInvoker(teleMedServant);

  // Create client side broker implementations
  ClientRequestHandler clientRequestHandler = new LocalMethodCallClientRequestHandler(invoker);
  Requestor requestor = new StandardJSONRequestor(clientRequestHandler);

  // Finally, create the client proxy for the TeleMed
  teleMed = new TeleMedProxy(requestor);
}
```

The *only* test double!
The rest are production code!

- That is
  - Link proxy to requestor, requestor to CRH double, CRH to invoker, and the Invoker to the servant object

Fun Fact

- Nancy?
  - A fictive person which exists in all Danish medical systems

2512489996	25-12-1948	K	Berggren	Nancy Ann Test	Testpark Allé 48	3400	219	84		Sønnerne Max og Ruddi. Døtrene Kirsten og Britta.

- She even has a face book profile ☺

https://da-dk.facebook.com › nancy.a.berggren ▾

Nancy Ann Berggren | Facebook

Nancy Ann **Berggren** er på Facebook. Bliv medlem af Facebook, og få kontakt med **Nancy** Ann **Berggren** og andre, du måske kender. ... **MedCom**, profile picture.

Make a Test Case

- Call client proxy, assert something stored in XDS

```
@Test
public void shouldStoreFromClient() {
  // Nancy uploads a single observation
  teleMed.processAndStore(teleObs1);

  // And the proper HL7 document is stored in the backend XDS
  Document stored = xds.getLastStoredObservation();
  HelperMethods.assertThatDocumentRepresentsObservation120over70forNancy(stored);
}
```

'xds' is both Spy and FakeObject

```
@Before
public void setup() {
  teleObs1 = HelperMethods.createObservation120over70forNancy();
  // Create server side implementations
  xds = new FakeObjectXDSDatabase();
  TeleMed teleMedServant = new TeleMedServant(xds);
```

AARHUS UNIVERSITET

The IPC Level

Talking network'ish

Choosing IPC

- The most fundamental level
  - Sockets

- More modern approach
  - URI Tunneling using HTTP web servers

Rule #1

- Find stuff on the internet ☺
  - Jakob Jenkov has fine tutorials on socket server programming
    - Single thread
    - Multi thread
    - Thread pooled

- Question of concurrency
  - Single thread — Only one call at the time
  - Multi thread — Unlimited => Memory exhausted!
  - Thread pool — N threads = Best of both worlds

Client Request Handler

- Socket
  - “modificed EchoClient"
- The old HTTP protocol
  - Create socket
  - Send request
  - Read reply
  - Close socket
- Inefficient but reliable

```java
@Override
public String sendToServerAndAwaitReply(String request) {
  Socket clientSocket = null;

  // Create the socket connection to the host
  PrintWriter out;
  BufferedReader in;
  try {
    clientSocket = new Socket(hostname, port);
    out = new PrintWriter(clientSocket.getOutputStream(), true);
    in = new BufferedReader(new InputStreamReader(
            clientSocket.getInputStream()));
  } catch (IOException e ) {
    throw new IPCException("Socket creation problems", e);
  }

  // Send it to the server (= write it to the socket stream)
  out.println(request);

  // Block until a reply is received
  String reply;
  try {
    reply = in.readLine();

  } catch (IOException e) {
    throw new IPCException("Socket read problems", e);
  } finally {
    try {
      clientSocket.close();
    } catch (IOException e) {
      throw new IPCException("Socket close problems (1)", e);
    }
  }
  // ... and close the connection
  try {
    clientSocket.close();
  } catch (IOException e) {
    throw new IPCException("Socket close problems (2)", e);
  }

  return reply;
}
```

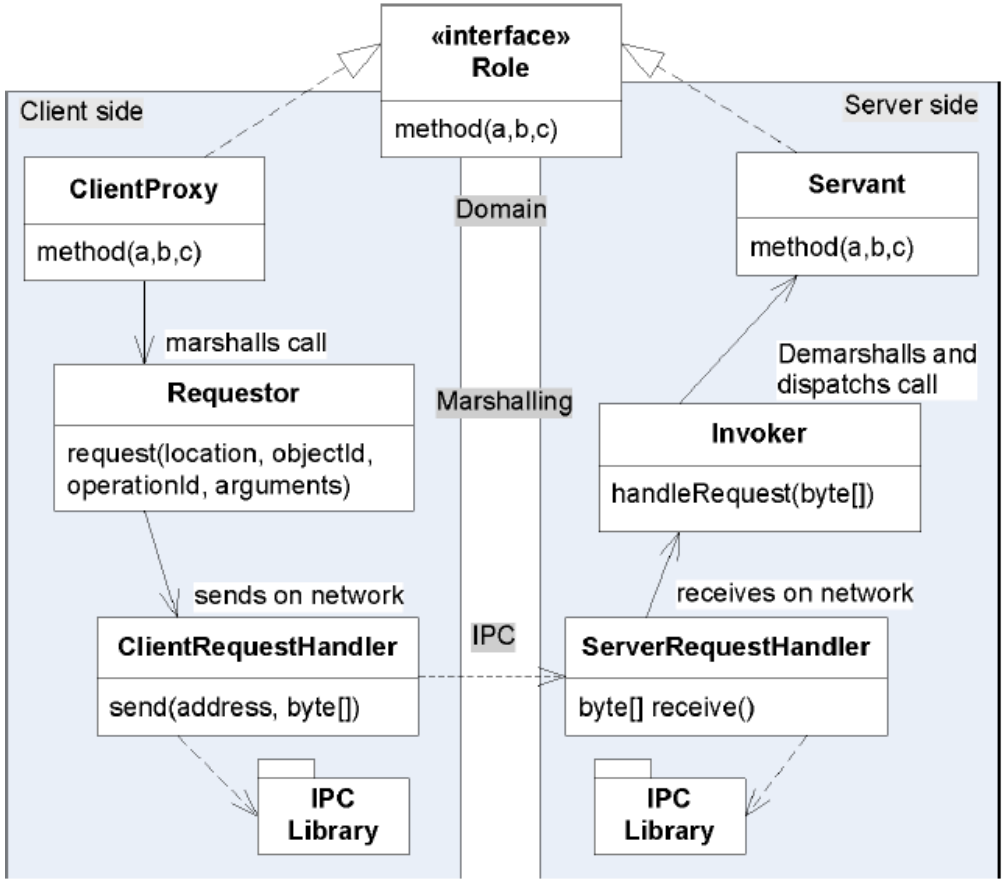
Server Request Handler

- Jenkov single thread
  - Accept incoming socket
  - Read request
  - Call invoker
  - Send reply
  - Close socket

```java
@Override
public void run() {
  openServerSocket();

  System.out.println("*** Server socket established ***");

  isStopped = false;
  while (!isStopped) {

    System.out.println("--> Accepting...");
    Socket clientSocket;
    try {
      clientSocket = serverSocket.accept();
    } catch(IOException e) {
      if(isStopped) {
        System.out.println("Server Stopped.") ;
        return;
      }
      throw new RuntimeException(
          "Error accepting client connection", e);
    }

    try {
      readMessageAndDispatch(clientSocket);
    } catch (IOException e) {
      System.out.println("ERROR: IOException encountered: "
              + e.getMessage());
    }
  }
  System.out.println("Server Stopped.");
}
```

```java
private void readMessageAndDispatch(Socket clientSocket)
        throws IOException {
  PrintWriter out =
          new PrintWriter(clientSocket.getOutputStream(), true);
  BufferedReader in = new BufferedReader(new InputStreamReader(
      clientSocket.getInputStream()));

  String inputLine;
  String marshalledReply = null;

  inputLine = in.readLine();
  System.out.println("--> Received " + inputLine);
  if (inputLine == null) {
    System.err.println(
            "Server read a null string from the socket???");
  } else {
    marshalledReply = invoker.handleRequest(inputLine);

    System.out.println("--< replied: " + marshalledReply);
  }
  out.println(marshalledReply);

  System.out.println("Closing socket...");
  in.close();
  out.close();
}
```

Summary


«interface»
Role
method(a,b,c)
Client side
Server side
ClientProxy
method(a,b,c)
Domain
Servant
method(a,b,c)
marshalls call
Requestor
request(location, objectId, operationId, arguments)
Marshalling
Demarshalls and dispatchs call
Invoker
handleRequest(byte[])
sends on network
receives on network
ClientRequestHandler
send(address, byte[])
IPC
ServerRequestHandler
byte[] receive()
IPC Library
IPC Library