(Q) Describe: ...

Dr. Barry Porter
SCC.311: Remote Invocation
Lecture starts at 15:00 BST

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Housekeeping...

- Our lab stream starts this week
- Lab work is based on Java, using RMI as an example middleware
- We've posted an "RMI primer", for you to start this week, and will

(2) shortly post the first two coursework stages

- We have a practice marking session for stage 1 in week 4, with a real

(2) marking session for stage 1 + stage 2 in week 7

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Overview

- Remote invocation in the general sense is just accessing any remote

(2) resource, using a particular protocol

- We'll look at general protocol variations, then focus on:
- RPC as a particular protocol
- Java RMI as one possible implementation of RPC
- REST as a different remote invocation protocol

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Remote Invocation

- This is the act of accessing a remote "thing" (procedure / object)
- Achieved through the use of message passing over a network
- Message exchange is handled through an agreed protocol
- The semantics of this protocol depend on the context of your application
- Different protocols will offer different reliability, scalability, and performance
- The implementation of this protocol, and associated tools, is a

(2) communication middleware

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Protocol styles

- R: no value needs to be returned from the server / no confirmation is

(2) needed; client can "fire and forget" in a non-blocking way

- RR: typical "request-reply" protocol: if reply from server is lost in

(2) transit, request may be repeated by client

- RRA: server needs to know the client got its reply, e.g. to allow

(2) resources to be released or coordinate with other communications
Style Messages sent by
Client Server Client
R Request - -
RR Request Reply -
RRA Request Reply Acknowledgement

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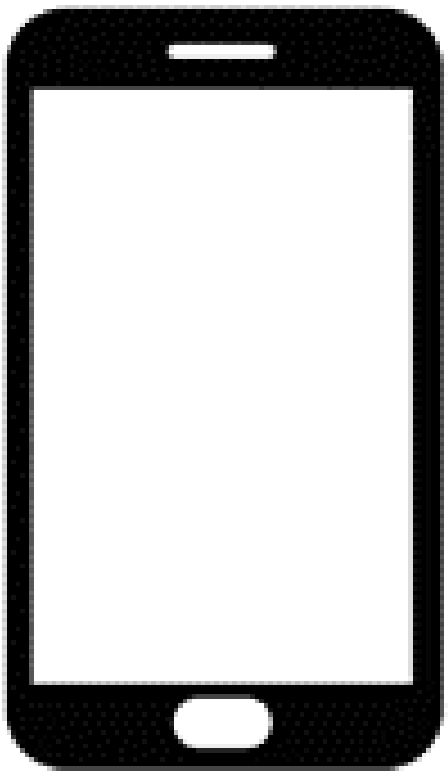
Let's build a text chat server...
socket = new Socket(serverName, serverPort);
console = new DataInputStream(System.in);
streamOut = new DataOutputStream(socket.getOutputStream());
line = console.readLine();
streamOut.writeUTF(line);
streamOut.flush();
console.close();
streamOut.close();
socket.close();
client



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Let's build a text chat server...
server = new ServerSocket(port);
socket = server.accept();
streamIn = new DataInputStream(new
BufferedInputStream(socket.getInputStream()));
boolean done = false;
while (!done) {
String line = streamIn.readUTF();
System.out.println(line);
}
socket.close();
streamIn.close();
server

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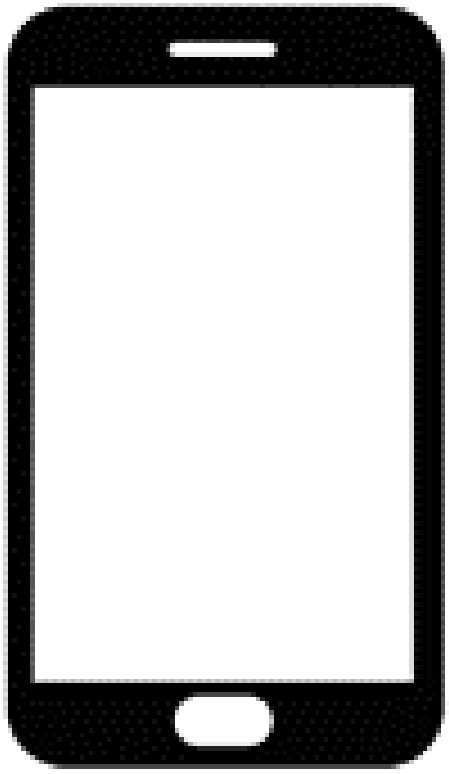
An RPC chat server
server = ChatServer.connect(serverName);
line = console.readLine();
server.sendMessage(line);
void sendMessage(String line) {
System.out.println(line)
}
main(...)
server = new ChatServer();
server
client

- Build from the top down, not bottom-up
- Directly call a remote procedure, rather

(2) than handing all of the piping yourself



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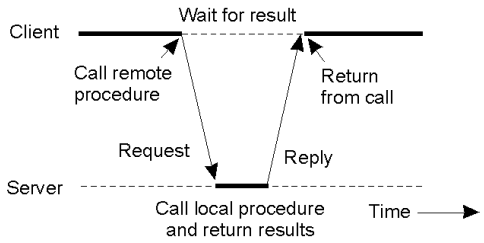
What is RPC?

- Remote Procedure Call
- In essence, the idea is:
- it's nice that we can define and call functions for local programs
- why not extend this to a distributed system, so that we can call an apparently

(2) local function and that function call actually happens on a remote computer?



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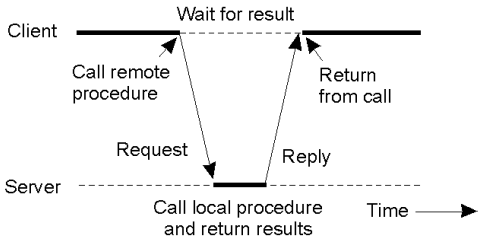
What is RPC?

- Remote Procedure Call
- One of the simplest forms of communication middleware
- Provides a high-level request-response mechanism to build distributed apps
- Usually synchronous, meaning that the client blocks while waiting for

(2) the procedure (cf. function) call to complete



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RPC and Middleware

- Examples: XML-RPC, JSON-RPC, SOAP
- Interaction between processes is done using defined interfaces

(2) Application
RMI, RPC and indirect comm.
Request reply protocol
External Data Representation
Operating System
Middleware
layers

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Programming with Interfaces

- Separation of interface and implementation
- IDL (Interface Definition Language): programming language-independent

(2) notation of parameters and types

- Client software does not need to know the details of the implementation,

(2) cf. abstraction

- Important for platform and language independence
- Also important to support the evolution of software

(2) myObject:myClass
myInterface

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Implementing RPC
N.B. Proxies, stubs, dispatchers are generated
automatically by an appropriate IDL compiler
Request
Reply
Communication modules
Object A
Remote
Object B
Proxy
Client Stub
Server Stub
Dispatcher

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Key components: client side

- Proxies
- Masquerade as a local version of the remote interface
- Redirect calls to client stubs
- May perform other actions (see smart proxies)
- Client stub
- Carries out marshalling (flattening) of a call into a request message sent to

(2) remote end

- Also unmarshalls returning replies
- One stub per interface procedure

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Key components: server side

- Dispatchers
- Receive incoming messages and direct them to an appropriate server stub
- Server stubs (skeletons)
- Unmarshalls message and then invokes appropriate code body
- Also marshals reply values and initiates transmission back to the client

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What we get from this...
obj = RPCService.getRemoteObject(serverName);
obj.callFunction("hi") After the initial acquisition of this object, from the middleware, use of the object then looks
exactly like a normal local call – neat!

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...but there might be a dragon or two...

- A lot of our current understanding on the theory of RPC comes from

(2) the original researchers and designers of the Java language1

- Remote calls have different latency to local calls
- Memory access models are different if we pass references around
- Partial failures are possible

(2) [1] J. Waldo, G. Wyant, A. Wollrath, and S. Kendall. A note on distributed computing. Technical report, 1994

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Protocol guarantees

- What delivery guarantees does the exchange protocol give?
- Referred to as 'call semantics' in the book
- Local procedure calls = 'exactly once' guarantee
- But for RPC?
- Different guarantee types are possible depending on the protocol implementation

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Focus on the underlying protocol

- Let's focus on the communications module for RPC which will provide

(2) a protocol that mimics the semantics of a local call

- For the sake of this discussion let's assume the underlying protocol is UDP
- (note RPC is more commonly implemented with TCP in modern middleware)
- Problems
- Request message may get lost
- Reply message may get lost
- Client may crash
- Server may crash

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Lightweight protocol semantics

- Maybe semantics
- Send request to server; which sends back a reply
- No guarantees at all if anything goes wrong
- At least once semantics
- Sends message and if reply not received after a given time, the message is re-sent (failure

(2) assumed after n re-sends)

- Will guarantee the call is made "at least once", but possibly multiple times
- Ideal for idempotent operations (i.e. same effect)

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Lightweight protocol semantics

- At most once semantics Client Server

(2) Call
Re-send
Log
results
Execute code
Detect
duplicate
Request (#1473)
Request (#1473)
Reply (#1473)
Reply (#1473)

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Lightweight protocol semantics

- Local procedure calls have an even stronger exactly once semantic
- So far, for RPC, we have:

(2) Semantics Fault tolerance measures
Retransmit request Duplicate filtering Re-execute procedure or retransmit reply
Maybe No No N/A
At least once Yes No Re-execute procedure
At most once Yes Yes Retransmit reply

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RPC protocol semantics

- Exactly once semantics
- In this case the procedure will be carried out once (completely) or not at all

(2) (operation aborted)

- This builds on the "at most once" protocol, but also adds support for

(2) atomicity

- We'll cover this topic in our lectures on fault tolerance and

(2) dependability

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From RPC to RMI

- Remote Method Invocation (RMI) is the Java-specific built-in

(2) middleware technology which implements the RPC concept, integrating it seamlessly with the Java language

- RMI implements remote objects in an almost transparent way: you

(2) can pass object references into remote function calls to create complex object reference graphs which span continents

- The "almost" part is that RMI chooses to expose a new class of exceptions on

(2) all remote calls, via RemoteException, which must be caught in the caller

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RMI Basics
Example: You need to develop a Java mobile app to access the Google Maps Service
Your Mobile @ Lancaster
Google Servers @ Dublin

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RMI Basics

- RMI allows one Java object to call methods on another Java object in

(2) a different JVM

- The intention is to make distributed programming as easy as standard

(2) Java programming
Local
Object
Remote
Object
Client JVM
Server JVM
Method parameters
Result or exception


AT&T 3G
12:41 PM
89 %
Back
Contact
Map
Satellite
Austin
Downtown
Austin Convention Center
The Paramount Theatre
1
2
3
4
5

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RMI Basics

- RMI uses interfaces to specify a remote object: we define an interface

(2) which extends from java.rmi.Remote

- We define a class which implements this interface; we can then

(2) instantiate an object from this class which can be advertised for remote access

- A client program only needs access to the interface type (not the

(2) class), and can then acquire a reference to the remote object of this type via the RMI middleware service

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RMI Basics

- The advertisement (at the server) and lookup (at the client) of remote

(2) objects is done through a special service called the RMI registry

- We execute the registry at the command line using the command rmiregistry
- This service associates names with object references
- The registry often runs on the same host as a server system, but

(2) does not need to

- A server and client both need to talk to the same registry service,

(2) on the same host, to advertise and look up a named object

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RMI Basics
RMIRegistry
Server
naming.rebind(“rmi://www.google.com/Map
Service”, RemoteObjectReference)
Client
naming.lookup(“rmi://www.google.com
/MapService”)
Interface Remote Object
Client Program Server Program
Step1: Bind to nameStep2: Lookup name
Step3: Method Invocation

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REST

- ...and now for something different!
- So far we've covered remote procedure call and RMI
- These are not the only forms of remote invocation

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REST

- Representational State Transfer (REST) is a set of resource-oriented

(2) architectural principles

- RPC/RMI are operation-/transaction-oriented
- RPC: readStudent(1234)
- REST: GET /students/1234
- Properties:
- Every resource is addressable using a Uniform Resource Identifier (URI)
- To change the state of the system: transition resources
- HTTP-based: basic HTTP verbs and status codes (universal interface)
- Self-descriptive: responses include description and next step(s) links
- Stateless: data required to transition between states is in request

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HTTP Methods (verbs)
The universal/uniform interface of REST
•https://www.restapitutorial.com/lessons/httpmethods.html
Verb CRUD Safe? Idempotent?
POST Create
GET Read
PUT Update/Replace
PATCH Modify
DELETE Delete

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HTTP Methods (verbs)

- Read specific student

(2) GET /students/1234

- Read all students

(2) GET /students

- Create a student

(2) POST /students

- Update specific student

(2) PUT /students/1234

- Delete specific student

(2) DELETE /students/1234

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HTTP Methods (verbs)

- Read specific student email address(es)

(2) GET /students/1234/email

- Update specific student email address

(2) PUT /students/1234/email/1

- Delete specific student email address

(2) DELETE /students/1234/email/2

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HTTP Content Types

- The content type used by each verb, in both the request and

(2) the response message, is configurable

- This is done using headers which can be included in the

(2) request and response

- Common content types are text/html, text/xml, text/json,

(2) image/jpeg, etc.

- The sender of a request can also specify the content types that it is

(2) expecting and can process, as part of its request message

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HTTP Status Codes
1xx Informational
2xx Success
200 Resource was read, updated, or deleted
201 Resource was created
3xx Redirection
301 Resource has permanently moved to a new URI
4xx Client Error
400 Bad request
403 Not authorized to perform this action
404 Resource not found
5xx Server Error

- https://www.restapitutorial.com/httpstatuscodes.html

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HTTP Semantics

- The most obvious feature of REST is that servers do not hold any per-

(2) client state

- Instead, the client sends the current state with every request (this is

(2) what cookies are)

- This allows servers to consume fewer memory resources, and also

(2) allows a client request to hit any server, because the request carries all of the state

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HTTP Semantics

- REST also has a general assumption of idempotence, meaning that an

(2) operation will only ever have a single effect (repeating the same operation, with the same state, has no effect)

- Keeps servers slender
- Very useful in distributed environments
- Multiple 'servers'
- Unreliable network

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HTTP Summary

- Because it is a text-based format, is very simple, and is not language-
(2) specific, HTTP has become a kind of general interoperability protocol

- A wide range of other protocols have been designed which can
(2) operate on top of HTTP, taking advantage of this common carrier

- Linking back to RPC, the Web Services framework is a language-
(2) independent RPC solution which is built on top of HTTP

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Further reading

- CDKB, ch 5
- also optionally ch 4 for background
- TvS, pp. 145-158, 68-98, 99-134
- REST API Tutorial: https://www.restapitutorial.com/

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