CS 550:

Advanced Operating Systems

Remote Procedure Call & Remote Method Invocation & Web Services

Ioan Raicu
Computer Science Department
Illinois Institute of Technology

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Advanced Operating Systems
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Outline

- Wrap-up of RPC
- Case study: Sun RPC
- Extended RPC
  - Lightweight RPCs
  - Asynchronous RPC
  - One-way RPC
- Remote Method Invocation (RMI)
  - Design issues
  - Case study: JAVA RMI
- Web Services

Performance Issues

- Remember "performance" one of the most important requirements
- Performance depends on ?
- RPC Protocol (options)
  - connection vs connectionless oriented
  - standard vs. specialized

Implementation Issues

- Choice of protocol
  - Use existing protocol or design from scratch
  - Packet size restrictions
  - Reliability in case of multiple packet messages
  - Flow control
- Copying costs are dominant overheads
  - Need at least 2 copies per message
  - As many as 7 copies

Sun RPC

- One of the most widely used RPC systems
  - Also known as Open Network Computing (ONC)
- Originally developed by Sun, but now widely available on other platforms (including Digital Unix)
- Sun RPC package has an RPC compiler (rpcgen) that automatically generates the client and server stubs.
- RPC package uses XDR (eXternal Data Representation) to represent data sent between client and server stubs.
- Has built-in representation for basic types (int, float, char)
- Also provides a declarative language for specifying complex data types

Example: RPC Programming

1. Write RPC protocol specification file *foo.x*
2. Write server procedure *fooservices.c*
3. Write client application *foomain.c*

Example: RPCGEN

- There is a tool for automating the creation of RPC clients and servers.
- The program rpcgen does most of the work for you.
- The input to rpcgen is a protocol definition in the form of a list of remote procedures and parameter types.

Example: RPCGEN

4. rpcgen –C foo.x

foo_clnt.c	(client stubs)
foo_svc.c	(server main)
foo_xdr.c	(xdr filters)
foo.h	(shared header file)

Example: Client Creation

5. gcc -o fooclient foomain.c foo_clnt.c foo_xdr.c -lnsl

- foomain.c is the client main() (and possibly other functions) that call rpc services via the client stub functions in foo_clnt.c
- The client stubs use the xdr functions.

Example: Server Creation

6. gcc -o fooserver fooservices.c foo_svc.c foo_xdr.c –lrpcsvc -lnsl

- fooservices.c contains the definitions of the actual remote procedures.

Example: Execution

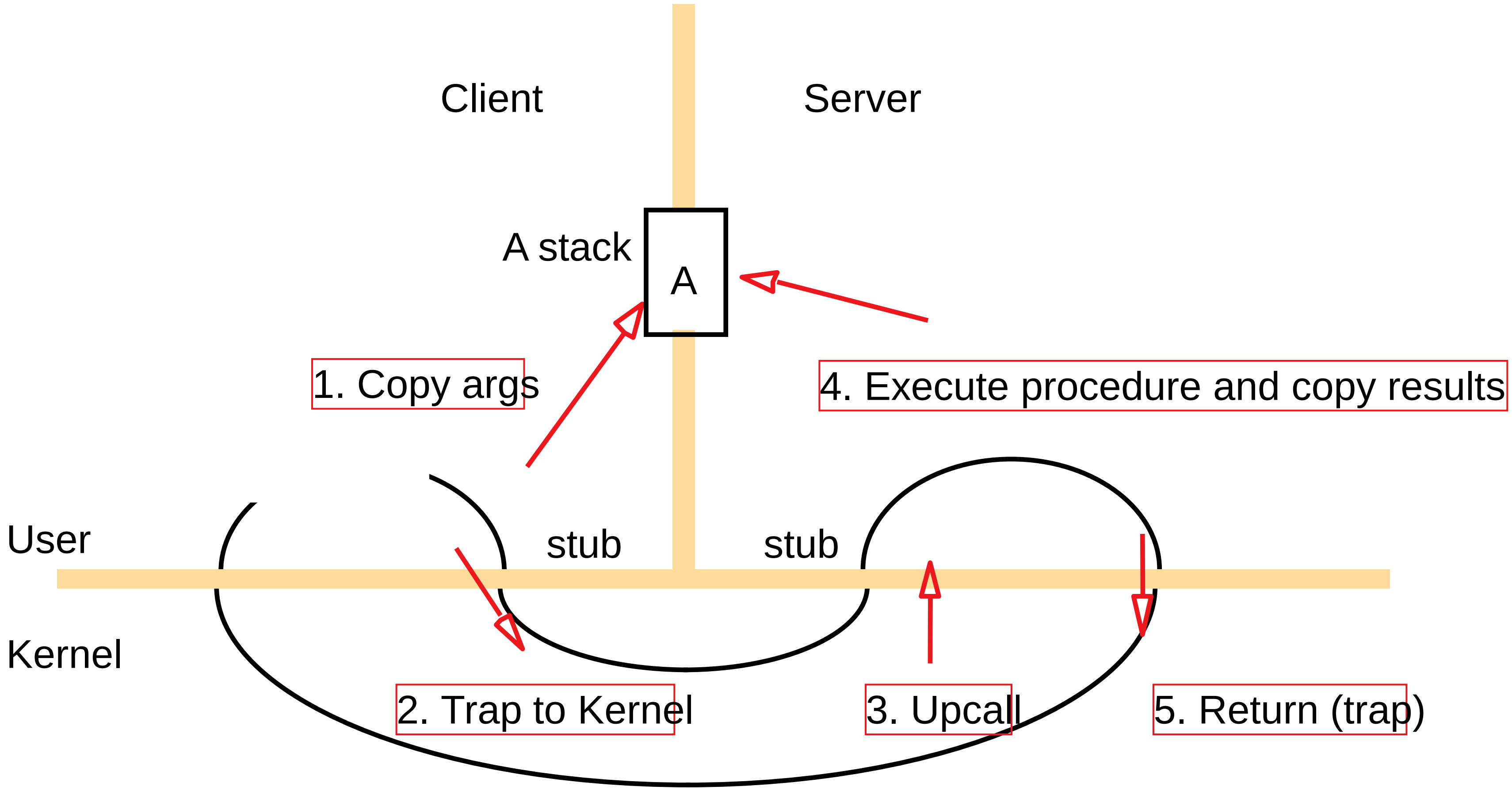
7. Copy the server fooserver to the remote machine, and run it in the background
8. Now you can call the remote procedure on a local machine

- Useful reference:
  - http://tools.ietf.org/html/rfc1831

Lightweight RPCs

- Many RPCs occur between client and server on same machine
  - use a lightweight RPC mechanism (LRPC)
- Server *S* exports interface to remote procedures
- Client *C* on same machine imports interface
- OS kernel creates data structures including an **argument stack** shared between *S* and *C*

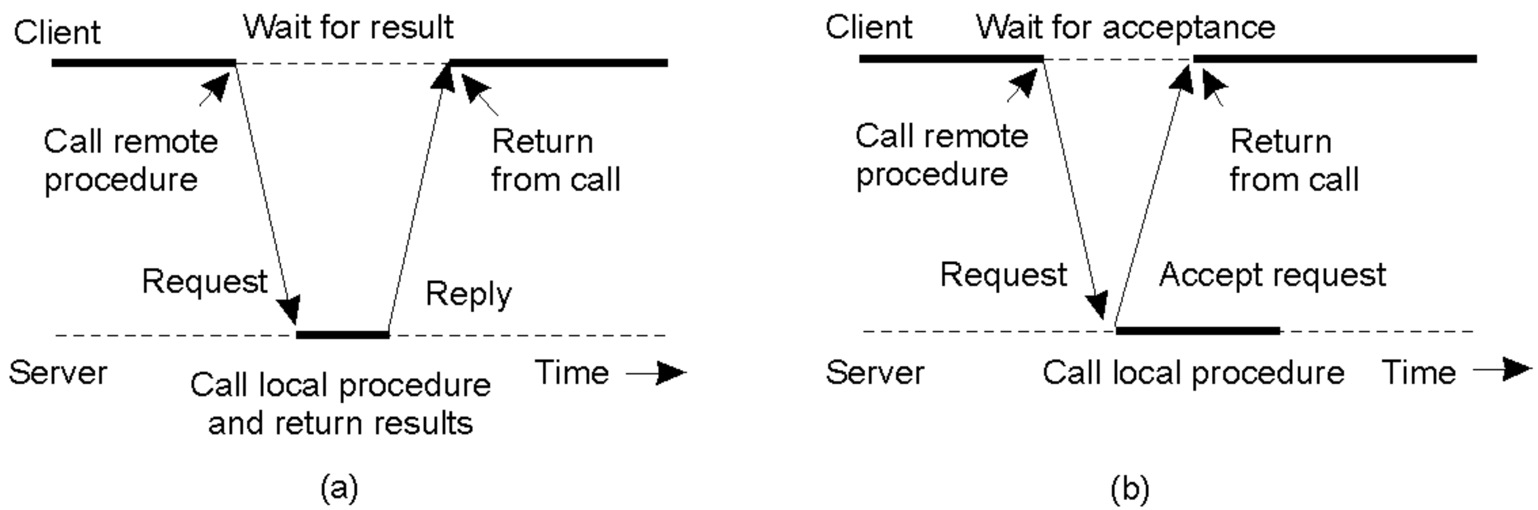
Lightweight RPCs



Other RPC Models

- Asynchronous RPC
  - Server can reply as soon as request is received and execute procedure later
- Deferred-synchronous RPC
  - Use two asynchronous RPCs
  - Client needs a reply but can’t wait for it; server sends reply via another asynchronous RPC
- One-way RPC
  - Client does not even wait for an ACK from the server

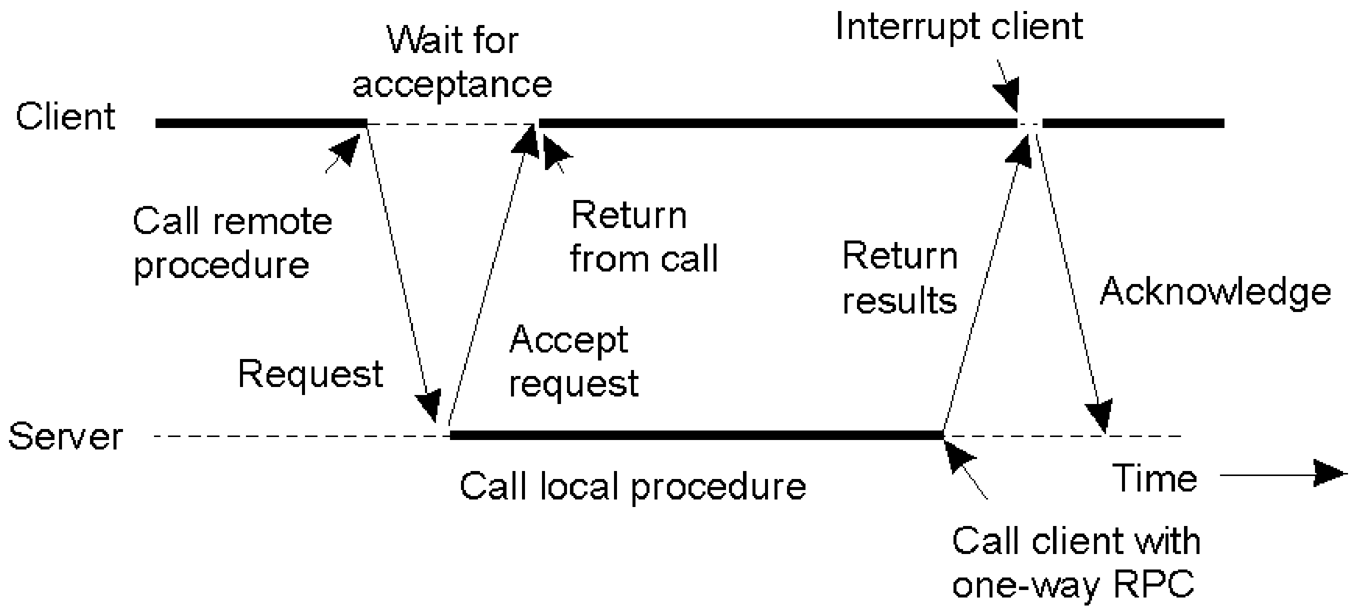
Asynchronous RPC



a) The interconnection between client and server in a traditional RPC
b) The interaction using asynchronous RPC

Deferred Synchronous RPC

- A client and server interacting through two asynchronous RPCs

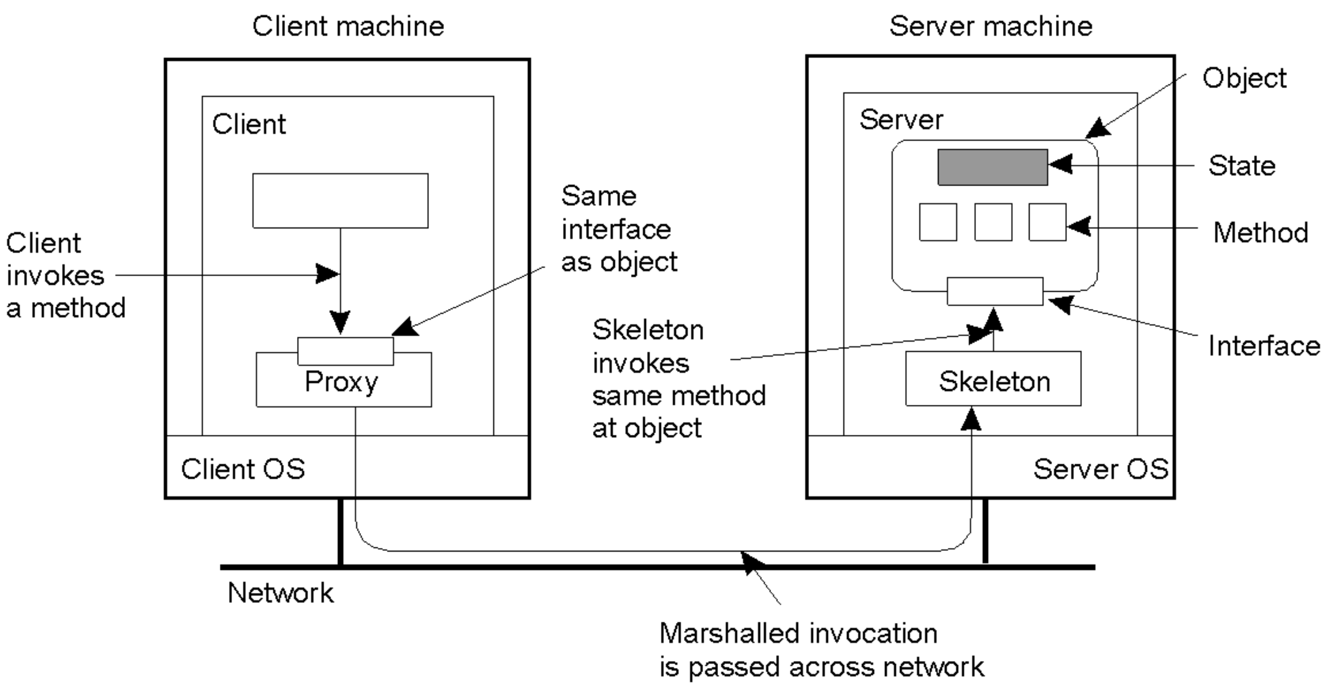


Remote Method Invocation (RMI)

- RPCs applied to objects
  - Class: object-oriented abstraction; module with data and operations
  - Separation between **interface** and **implementation**
  - Interface resides on one machine, implementation on another

- RMIs support system-wide object references
  - Parameters can be object references

Distributed Objects



- When a client binds to a distributed object, load the interface ("**proxy**") into client address space
- Server stub is referred to as a **skeleton**

Proxies and Skeletons

- Proxy: client stub
  - Maintains server ID, endpoint, object ID
  - Sets up and tears down connection with the server
  - Does serialization of local object parameters
  - In practice, can be downloaded/constructed on the fly
- Skeleton: server stub
  - Does deserialization and passes parameters to server and sends result to proxy

Binding a Client to an Object

- An object reference must contain enough information to allow a client to bind to an object
  - Object reference include server ID, endpoint, and object ID
  - Have a local daemon per machine that keeps track of the server-to-endpoint assignments
  - Use a location server
  - Include an implementation handle in the object reference

Static vs. Dynamic RMI

- Static invocation
  - Use predefined interface definitions
  - Require that the interfaces of an objects are known when client application is being developed

- Dynamic invocation
  - A method invocation is composed at runtime
  - An application selects at runtime which method it will invoke at a remote objects

Java RMI

- Server
  - Defines interface and implements interface methods
  - Server program
    - Creates server object and registers object with “remote object” registry
- Client
  - Looks up server in remote object registry
  - Uses normal method call syntax for remote methods
- Java tools
  - rmic: java RMI stub compiler
  - rmiregistry: java remote object registry
  - rmid: java RMI activation system daemon
- Useful reference:
  - http://java.sun.com/j2se/1.4/docs/guide/rmi/

Java RMI

- Java supports Monitors: synchronized objects
  - Serializes accesses to objects
- Options: block at the client or the server
  - Block at server
    - Can synchronize across multiple proxies
    - Problem: what if the client crashes while blocked?
  - Block at proxy
    - Need to synchronize clients at different machines
    - Explicit distributed locking necessary

Web Services

"Web services" is an effort to build a distributed computing platform for the Web

Yet another one!

Designing Web Services

- Goals
  - Enable universal interoperability
  - Widespread adoption, ubiquity: fast!
  - Enable (Internet scale) dynamic binding
    - Support a service oriented architecture (SOA)
  - Efficiently support both open (Web) and more constrained environments
- Requirements
  - Based on standards. Pervasive support is critical
  - Minimal amount of required infrastructure is assumed
    - Only a minimal set of standards must be implemented
  - Very low level of application integration is expected
    - But may be increased in a flexible way
  - Focuses on messages and documents, not on APIs

Web Services Model

Web service applications are encapsulated, loosely coupled Web "components" that can bind dynamically to each other

Web Services Summary

- Web Services are logically simple
  - Standard mechanisms for describing, discovering, and accessing services
  - Encourage loose coupling; service-oriented architecture
- Web Services are complex in practice
  - Due to the wide variety of interactions that can occur
- Broad adoption is encouraging.
- For more information
  - Web Services Architecture: http://www.w3.org/TR/ws-arch/

Questions

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