CSE 451: Operating Systems
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Lecture 16
RPC

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What's Interesting about RPC?

- RPC = Remote Procedure Call
  - the most common means for remote communication
  - used both by operating systems and applications
    - NFS is implemented as a set of RPCs
    - HTTP is essentially RPC
    - DCOM, CORBA, Java RMI, etc., are just RPC systems
- Someday you, too, will likely have to write an application that uses remote communications
  - you'll likely model your remote communications on RPC
- RPC is really, really simple under the covers

Client/Server Communication

- The prevalent model for structuring distributed computation is the client/server paradigm
  - a server is a program (or collection of programs) that provides a service to other programs
    - e.g., file server, name server, web server, …
    - server may span multiple nodes (clusters)
      - often, nodes are called servers too
      - e,g., the web server runs on a Dell server computer
  - a client is a program that uses the service
    - the client first binds to the server
      - locates it, establishes a network connection to it
    - the client then sends requests (with data) to perform actions, and the server sends responses (with data)
      - e.g., web browser sends a "GET" request, server responds with a web page

Messages

- Initially, people hand-coded messages to send requests and responses
  - but, this quickly gets tiresome
    - need to worry about message format
    - have to pack and unpack data from messages
    - servers have to decode messages and dispatch to handlers
    - messages are often asynchronous
      - after sending one, what do you do until response comes back?
  - messages aren't a natural programming model
    - maybe we could encapsulate messaging behind some abstraction that the OS provides…
      - then, we could just invoke library routines
      - the library routines would send messages for us, and wait for responses to come back.
        - » hmm….

Procedure Calls

- Procedure calls are a natural way to structure multiple modules inside a single program
  - every language supports procedure calls
  - semantics are well-defined and understood
  - programmers are used to them
- Idea: have servers export a set of procedures that can be called by client programs
  - similar to library API, class definitions, etc.
- Clients do a local procedure call, as though they were directly linked with the server
  - under the covers, the procedure call is converted into a message exchange with the server

Remote Procedure Calls

- So…now we know the main idea: use procedure calls as the model for distributed (remote) communication
- But, there are a bunch of hard issues:
  - how do we make the “remote” part of RPC invisible to the programmer?
    - and is that a good idea?
  - what are the semantics of parameter passing?
    - what if we try to pass by reference?
  - how do we bind (locate/connect-to) servers?
  - how do we handle heterogeneity?
    - OS, language, architecture, …
  - how do we make it go fast?

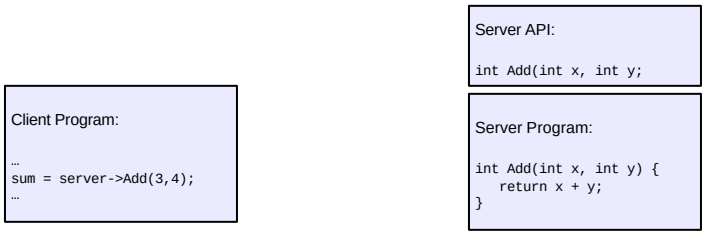
RPC model

- A server defines the service interface using an interface definition language (IDL)
  - the IDL specifies the names, parameters, and types for all client-callable server procedures
    - example: ASN.1 in the OSI reference model
    - example: Sun's XDR (external data representation)
- A "stub compiler" reads the IDL declarations and produces two stub procedures for each server procedure
  - the server programmer implements the service's procedures and links them with the server-side stubs
  - the client programmer implements the client program and links it with the client-side stubs
  - the stubs manage all of the details of remote communication between client and server

RPC Stubs

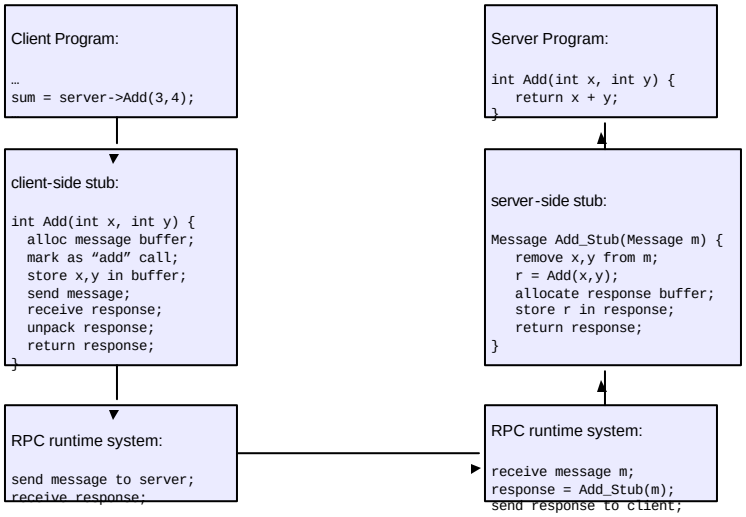
- A client-side stub is a procedure that looks to the client as if it were a callable server procedure
  - it has the same API as the server's implementation of the procedure
  - a client-side stub is just called a "stub" in Java RMI
- A server-side stub looks like a caller to the server
  - it looks like a hunk of code that invokes the server procedure
  - a server-side stub is called a "skeleton" or "skel" in Java RMI
- The client program thinks it's invoking the server
  - but it's calling into the client-side stub
- The server program thinks it's called by the client
  - but it's really called by the server-side stub
- The stubs send messages to each other to make the RPC happen transparently

RPC example



- If the server were just a library, then “Add” would just be a local procedure call

RPC example invocation



RPC Marshalling

- Marshalling is the packing of procedure parameters into a message packet
  - the RPC stubs call type-specific procedure to marshal or unmarshal the parameters of an RPC
    - the client stub marshals the parameters into a message
    - the server stub unmarshals the parameters and uses them to invoke the service's procedure
  - on return:
    - the server stub marshals the return value
    - the client stub unmarshals the return value, and returns them to the client program

RPC Binding

- Binding is the process of connecting the client to the server
  - the server, when it starts up, exports its interface
    - identifies itself to a network name server
      - "portmap" daemon on UNIX systems, sort of
    - tells RPC runtime that it is alive and ready to accept calls
  - the client, before issuing any calls, imports the server
    - RPC runtime uses the name server to find the location of the server and establish a connection
- The import and export operations are explicit in the server and client programs
  - a slight breakdown in transparency
    - more to come…

RPC Transparency

- One goal of RPC is to be as transparent as possible
  - make remote procedure calls look like local procedure calls
  - we've seen that binding breaks this transparency
- What else breaks transparency?
  - failures: remote nodes/networks can fail in more ways than with local procedure calls
    - network partition, server crash
    - need extra support to handle failures
    - server can fail independently from client
      - "partial failure": a big bugbear in distributed systems
      - if an RPC fails, was it invoked on the server?
  - performance: remote communication is inherently slower than local communication
    - if you're not aware you're doing a remote procedure call, your program might slow down an awful lot…

One more transparency problem

- What happens if my service interface looks like:
  - int Add(int *x, int *y);
- In other words, can I do pass-by-reference?
  - maybe, if we change it to:
    - Int Add(Int *x, Int *y);
  - in other words, pass remote references to remote procedures, and have the remote procedure do an RPC "callback"…
    - be careful about recursion here….
  - or, maybe we automatically convert pass-by-reference to pass-by-value
    - but changes semantics: if somebody modifies local copy while RPC is happening
- Sun XDR's solution
  - you can't do pass by reference

RPC and thread pools

- What happens if two client threads (or client programs) simultaneously invoke the same server procedure using RPC?
  - ideally, two separate threads will run on the server
  - so, the RPC run-time system on the server needs to spawn or dispatch threads into server-side stubs when messages arrive
    - is there a limit on the number of threads?
    - if so, does this change semantics?
    - if not, what if 1,000,000 clients simultaneously RPC into the same server?