CS 555: Distributed Systems [RPC]

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Frequently asked questions from the previous class survey

- Publish/subscribe
  - Twitter
  - Does producer store the data?
  - Pub/sub and P2P
  - Can a **new** subscriber receive an **old** event?
  - Are broker nodes connected to all publishers?
  - NDNs and publish/subscribe?
  - Event vs Topic based subscriptions?

Topics covered in this lecture

- RPC
  - Persistence/transience
  - Synchronous/asynchronous communications
  - Parameters in RPC settings

RPCs and Distributed Objects

RPCs and Distributed Objects

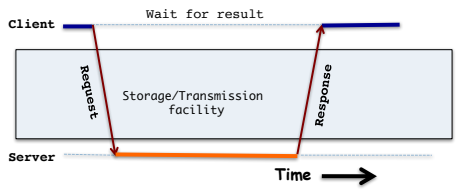
- Why are we looking at this?
- What we will cover in the next few lectures:
  - Middleware based interactions
  - Remote Procedure Calls
  - How to design your own distributed objects framework
  - Java RMI

Middleware based interactions

Viewing the middleware as an additional service in client-server computing: E-mail

- Sender passes mail to mail-server
- Hope that server will *eventually* deliver to client
- Receiver connects to mail server to see if mail is available
  - If so, **pull** it

The middleware as an intermediary for application-level communications



Persistent communications

- Message handed-off to a middleware is **held as long as it takes** to deliver to receiver
- Sending application need not execute *after* message submission
- Receiver application need not execute *when* message is being submitted
- **Time-decoupled** interactions

Transient communications

- Message stored only as long as the sender and receiver *are executing*
  - **At the same time**
- Transport level communications are transient
  - E.g. if a router cannot deliver to a host, simply drop the message

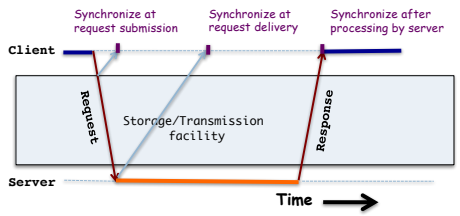
Asynchronous communication

- **Do not block**
- Proceed to the next thing, once a message has been submitted

Synchronous communications

- Sender can **block**
- Until request is known to be accepted

Synchronization points



Synchronicity and persistence options can be combined

- Persistence + synchronization?
  - Message queuing systems
- Transience + synchronization?
  - Remote procedure calls

Discrete and streaming communications

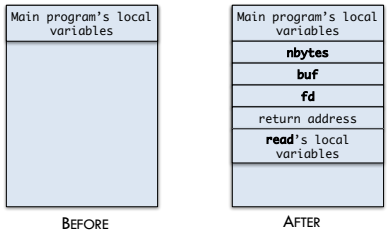
- Discrete
  - Each message is a complete unit of information
- Streaming
  - *Multiple* messages; one after another
  - *Related* by sending order or temporal relationships

Remote Procedure Calls

Conventional procedure calls

- Consider a call:
  `count = read(fd, buf, nbytes);`
- `fd` indicates a file
- `buf` is an array of characters
- `nbytes` tells us how many bytes to read

Caller pushes parameters onto stack (last one first) in order



Parameter passing in C

- Call-by-value
- Call-by-reference

Parameter passing in C: Call-by-value

- Values parameters simply **copied** on to stack
  - Scalar types
  - In our example? `fd` and `nbytes`
- In the called procedure?
  - Value parameters = *initialized* local variables
- Changes made <u>do not affect</u> original value at the caller

Parameter passing in C: Call-by-reference

- Reference parameter
  - Pointer (address) to a variable
  - Not the value
  - When used to store something
    - Results in modifications at the caller
- Arrays are passed by reference
  - Address of our character array **`buf`** pushed on stack

Another parameter passing scheme: Call-by-copy/restore

- Caller will copy variable on to the stack
  - Similar to call-by-value
- **Copy back after call**
  - Overwrite original value at the caller
- In most settings has the same effect as call-by-reference

Distributed systems often have explicit message exchanges

- Rely on **`send`** and **`receive`** primitives
- Do not *conceal communications*
  - Needed to achieve access **transparency**

Origins of RPC

- RFC 707 (1976).
  - First use was at Xerox in 1981 (Courier)
- 1984 paper by Birell and Nelson
  - Introduced a different way of handling communications
  - Allow programs to call procedures located on remote machines

Remote procedure call (RPC)

- Process on **A** calls procedure on machine **B**
- Calling process on **A** is *suspended*
- Execution of called procedure takes place on **B**
- Results are *transported*
- Message passing **not visible** to the programmer

Goal of RPC is to make a remote procedure call *look like* a local one

- Objective is **transparency**
- Calling procedure should *not be aware* that called procedure is remote
  - The other way around too

Reading data from a file on a single processor system

- Use the API's `read` in the code
- The `read` routine is *extracted* from library by a linker
  - Inserted into program
- The routine is implemented by an equivalent `read` system call
- The `read` call is an *interface* between user-code and the local OS

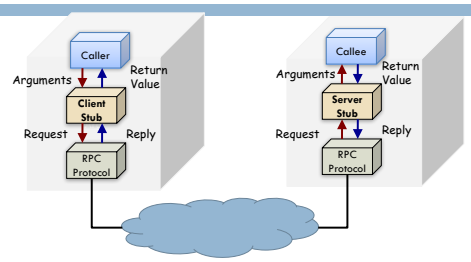
RPC transparency is similar

- If `read` is a remote procedure?
  - A different version, called a **stub**, is put into library
- When it is invoked:
  - Does not ask the OS for data, but …
  - Creates a **request message** to be *sent to server*
- Client stub does a `send`
  - Then calls `receive` (blocking itself) until reply comes

The server's OS passes message to a server stub

- **Transforms** network requests into local invocations
- Stub usually calls `receive`
  - Is *blocked* awaiting incoming messages
- Perform remote work to get results
  - Return result to the client

RPC Mechanism



What makes RPCs tick?

- Blissful ignorance at the clients
- Remote services accessed by making ordinary procedure calls
  - No need for `send` and `receive` primitives

Parameter passing

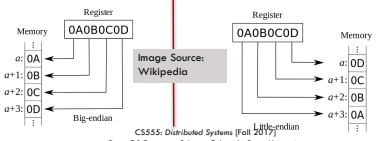
- Stubs *pack* and *unpack* request parameters
- Packing parameters into a message
  - Parameter **marshaling**

Challenges in passing parameters in distributed systems

- Multiple machine *types* are present
- Each has its *own representation* for
  - Numbers, characters, etc.
- Examples
  - IBM mainframes use EBCDIC character codes
    - PCs use ASCII
  - Integer representations
    - One's or Two's complement

The endian issue

- Big endian: SPARC
  - Number their bytes from left to right
- Little endian: INTEL
  - Number their bytes from right to left



An example of two parameters: 32 bits
(a) Integer - 5 **(b)** 4 character string JILL

0 [3]	0 [2]	0 [1]	5 [0]
L [7]	L [6]	I [5]	J [4]

On **INTEL**: Little endian

How are messages sent?

- Messages are transferred byte-for-byte
- First byte sent is the first to arrive
- Big-endian is typically the convention in data networking (including IPv6)
  - Network byte order

Message sent from INTEL to SPARC

0 [3]	0 [2]	0 [1]	5 [0]
L [7]	L [6]	I [5]	J [4]

On **INTEL**:
Little endian

5 [0]	0 [1]	0 [2]	0 [3]
J [4]	I [5]	L [6]	L [7]

On **SPARC**:
Big endian

The integer is now 5×2^{24}
The String is correct "JILL" ☹

Message sent from Intel to Sparc:
How about we invert the bytes of each word

0 [3]	0 [2]	0 [1]	5 [0]
L [7]	L [6]	I [5]	J [4]

On **INTEL**:
Little endian

5 [0]	0 [1]	0 [2]	0 [3]
J [4]	I [5]	L [6]	L [7]

On **SPARC**:
Big endian

0 [0]	0 [1]	0 [2]	5 [3]
L [4]	L [5]	I [6]	J [7]

☹
integer is 5
String is "LLIJ"

PARAMETERS IN RPC SETTINGS

Passing reference parameters

- Pointers are meaningful only within a process
  - Address 1000 in process **A** may be start of an array
  - Address 1000 in process **B** is something else
- Forbid pointers and reference parameters?
  - These are highly important
  - Not having them is not an option

Passing reference parameters: Our read example

- Copy array into message and send to server
  - Server stub calls server with a pointer to the array
- Changes made by server using the pointer?
  - Affects the array
- Send array back to the client
- Call-by-reference replaced by **copy/restore**

Optimizing the copy/restore

- If the buffer is an *input* or *output* parameter?
  - **One of the copies can be eliminated**
- If it is input to server?
  - No need to copy back to client
- If it is output from the server?
  - No need to send from client in the first place

Parameter specification and stub generation

- Agree on the **format** of the messages
- Similar **actions** for passing complex data structures

Parameter agreements: An example
`foobar(char x; float y; int z[5])`

- WORD = 4 bytes
- `Character` in *rightmost* byte of a word
  - Leave the leftmost 3 bytes empty
- `Float` as a whole word
- `Array` as group of words
  - Precede this by word indicating the array length

Parameter agreements: An example
`foobar(char x; float y; int z[5])`

foobar's local variables			
			x
y			
5			
z[0]			
z[1]			
z[2]			
z[3]			
z[4]			

Besides message format, there needs to be agreement on representation

- `integers`, `characters`, `Boolean`, etc
- For e.g.:
  - `integers` could be 2's complements
  - `characters` are 16-bit Unicode
  - `floats` in IEEE #754 standard
  - Store everything in big-endian

The contents of this slide-set are based on the following references

- *Distributed Systems: Principles and Paradigms. Andrew S. Tanenbaum and Maarten Van Steen. 2nd Edition. Prentice Hall. ISBN: 0132392275/978-0132392273.* [Chapter 6]
- *Distributed Systems: Concepts and Design.* George Coulouris, Jean Dollimore, Tim Kindberg, Gordon Blair. 5th Edition. Addison Wesley. ISBN: 978-0132143011.
- *Java Distributed Computing. Jim Farley. O'Reilly. ISBN 1-56592-206-9*