CSE 515 — Winter 2004

RPC & RMS

Class 4

In the beginning…

there were messages

- but the messages were without form!
  - just a string of bytes

  ⇒develop marshalling libraries
    - int2bytes(anInt) or writeInt(anInt, aStreamOrBuffer)
    - bytesToInt(aByteArray) or readInt(aStream)
- How do I know to unmarshall an int, not a string?

On the second day…

John White invented RPC (1976)

- Explored by Nelson in his Ph.D. (1981)
- Implemented efficiently at PARC (1982)

Idea:

- *Procedure Call* is well understood way of transferring data and control within a single computer
- extend it to 2 computers on a network

Goals

programs relatively easy. The existing communication mechanisms appeared to be a major factor constraining further development of distributed computing. Our hope is that by providing communication with almost as much ease as local procedure calls, people will be encouraged to build and experiment with distributed applications. RPC will, we hope, remove unnecessary difficulties, leaving only the fundamental difficulties of building distributed systems: timing, independent failure of components, and the coexistence of independent execution environments.

We had two secondary aims that we hoped would support our purpose. We wanted to make RPC communication highly efficient (within, say, a factor of

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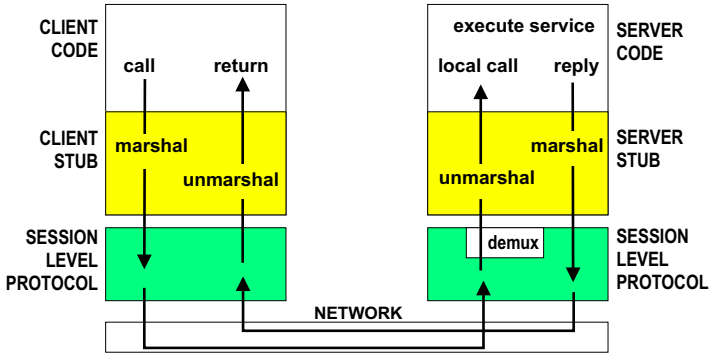
Goals

- "Make distributed computing easy"
  - By making communication as easy as a local procedure call, they hoped to encourage the writing of distributed applications
- RPC "removes unnecessary difficulties", leaving only the "fundamental difficulties"
  - timing
  - independent failure
  - coexistence of independent execution environments

Basic Architecture



Principle

The semantics of a remote call should be as close as possible to those of a local call

- Except:
  - You have to name the destination (binding)
  - Sharing of parameters is not possible
  - Independent failures
  - 3rd party references
- What works?
  -

What about Objects?

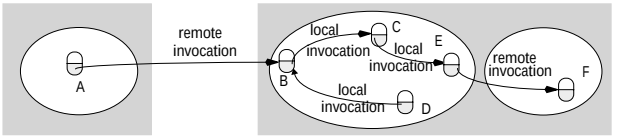
- *Coulouris et al.* claim that the Object Model is just right for distributed computing
- Object model:
  1. ubiquitous object reference mechanism
  2. send messages to objects, with objects as arguments
  3. objects respond autonomously by executing *method*
  4. objects export an interface
  5. state of an object is somewhat encapsulated
  6. objects are widely shared
  7. objects are ***not*** explicitly deallocated

On the third day…

came Remote Message Send (RMI)

- send an invocation message to a (possibly) remote object
- the identity of that object solves the *binding* problem
- life is good!

Figure 5.3 Remote and local method invocations



How good is the object model really?

- Object model:
  1. ubiquitous object reference mechanism
     - In a DS, this means that every object must have a global name!
     - Conceptually clean, but expensive to implement
     - Ingalls: the important thing about cheating is not to be caught (in implementing systems, *not* when doing homework!)
       - or at least, all objects must have the *potential* for a global name
       - cons up a global name only when it is needed

  2. send messages to objects, with objects as arguments
     - arguments can't *always* be object references
     - send copies of an object?
     - what are the consequences
  3. objects respond autonomously by executing a *method*
     - this is a great match for distributed systems
     - different objects at different locations can execute different code
  4. objects export an interface
     - this is a great match too

5. state of an object is somewhat encapsulated
   - In a DS, state is *really* encapsulated
   - *Object* encapsulation, not class encapsulation
   - no "friends"
6. objects are widely shared
   - In a distributed system, a message to a remote object is 1000 times slower than a message to a local object
   - what impact does this have on wide sharing
   - what impact does partial failure have on sharing?
7. objects are ***not*** explicitly deallocated
   - but global GC is hard (but memory is cheap)

What's Important in Distributed Systems?

- Caching and copying as alternatives to remote access
- Immutable objects are a ***secret weapon***
  - Which object models support them?
- Separating failures from exceptions
  - An *exception* is a result that falls within the specification of the object
  - A *failure* occurs when an object fails to meet its specification

The RPC Protocol

- Birrell & Nelson argue that using reliable streams for RPC is unacceptable
  - high set-up cost for each RPC (latency)
  - cost of maintaining state for each client
  - stream protocol does more than is required for the particular case of an RPC
  - since payload may be small, overhead is large
- Hence, they developed a special-purpose transport

Goals of PRC Transport

- minimize server load imposed per client
- "exactly once" semantics:
  - if the call returns, the procedure executed *once*
  - if there is no return, then a *failure* is indicated
    - procedure may have executed once, or not at all
  - client will wait indefinitely provided server has not crashed
- Efficient when all data will fit in a packet
  - common case is that packet will *not* be lost

Simple Calls

- One request pkt and one response pkt

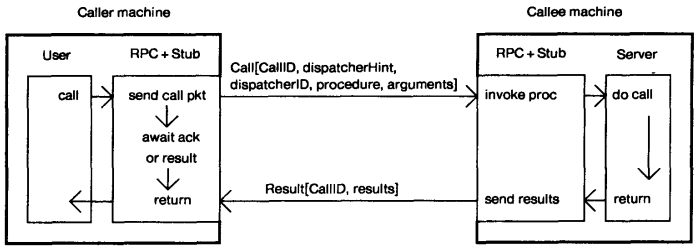


Fig. 3. The packets transmitted during a simple call.

  - Lost pkts?
  - Slow server?
  - Slow clients?

Features of the Protocol

- CallID
  1. Allows callee to eliminate duplicate requests
  2. Allows caller to match-up responses with requests
- Threading
  - No thread can have more than one call outstanding
- Required state:
  - Single counter on each client (what about reboots?)
  - "High water mark" CallID per client on the server
    - can eventually be discarded

Complicated Calls

- Transmitter responsible for retransmission
  - retransmitted request asks for explicit ack.
  - handles lost pkts, long calls, and long gaps
- If caller receives *ack* but no *response*
  - sends *probe* packet, which demands an ack
  - why?
- Caller will wait indefinitely so long as probes are ack'd
- Burden of this work is on client, not server

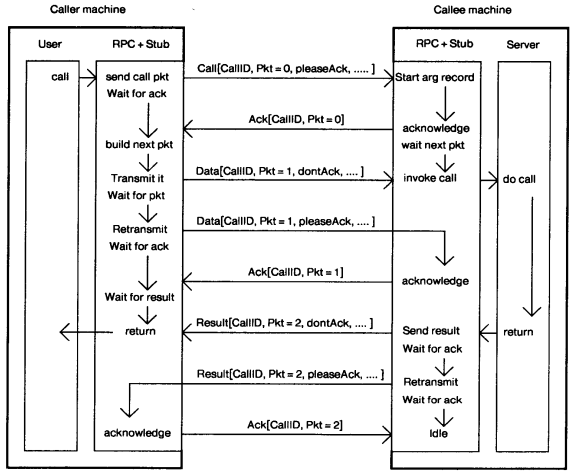


Fig. 4. A complicated call. The arguments occupy two packets. The call duration is long enough to require retransmission of the last argument packet requesting an acknowledgment, and the result packet is retransmitted requesting an acknowledgment because no subsequent call arrived.

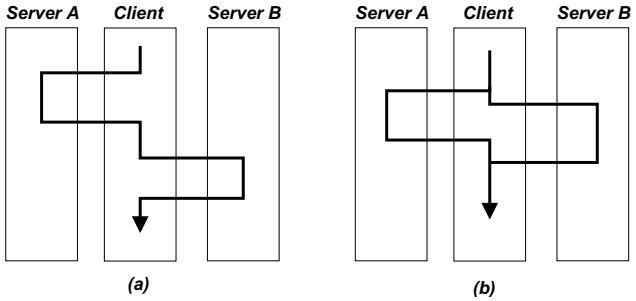
Performance

Procedure	Minimum	Median	Transmission	Local-only
no args/results	1059	1097	131	9
1 arg/result	1070	1105	142	10
2 args/results	1077	1127	152	11
4 args/results	1115	1171	174	12
10 args/results	1222	1278	239	17
1 word array	1069	1111	131	10
4 word array	1106	1153	174	13
10 word array	1214	1250	239	16
40 word array	1643	1695	566	51
100 word array	2915	2926	1219	98
resume except'n	2555	2637	284	134
unwind except'n	3374	3467	284	196

- all times in microseconds (μs)
- measured 12 000 calls in each case
- transmission times are calculated, not measured

Threading

- Client needs to be multi-threaded if it needs to continue working while waiting for a reply
  - *e.g.*, to be responsive to the UI



- Server needs to be multi-threaded if
  - Responding to calls is not CPU intensive
  - There is a desire to maximise throughput *or* minimize latency