Implementing Remote Procedure Calls

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Lecture 3

Today's Reminders

- Enroll in Piazza (31 have as of class time)
- Waitlist (33 currently enrolled)

Implementing Remote Procedure Calls
Andrew Birrell & Bruce Nelson 1984

- Andrew Birrell known for Grapevine (1981), with first distributed naming system (SigOps HoF paper); Dryad; was part of MSR-SV 2001-2014

- Bruce Nelson (CMU PhD'81), Dissertation "Remote Procedure Call"

- Awarded ACM Software System Award in 1994

SigOps HoF citation (2007): "This is THE paper on RPC, which has become the standard for remote communication in distributed systems and the Internet. The paper does an excellent job laying out the basic model for RPC and the implementation options."

Remote Procedure Calls

- Procedure calls are a well-known & well-understood mechanism for transfer of program control and data
- Not a new idea: e.g., discussed in 1976 paper
- Major issues facing the designer of an RPC facility:
  - Precise semantics of a call in the presence of failures
  - Semantics of address-containing arguments in the absence of a shared address space
  - Integration of remote calls into existing programming systems
  - Binding (how caller determines location/identity of callee)
  - Suitable protocols for transfer of data & control between caller and callee
  - How to provide data integrity and security in an open communication network

Aims

- **Make distributed computation easy**
- **"We wanted to make RPC communication highly efficient (within, say, a factor of five beyond the necessary transmission times of the network)."**
- **Make semantics of RPC package as powerful as possible, w/o loss of simplicity or efficiency**
- **Provide secure communication with RPC**

Components of the System

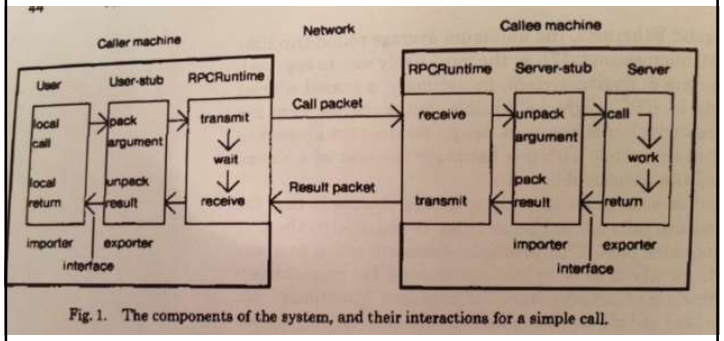


Fig. 1. The components of the system, and their interactions for a simple call.

Stubs

- **User-stub and server-stub are automatically generated, using Mesa interface modules (basis for separate compilation)**
  - Specification Interface: List of procedure names, together with the types of the arguments and results
- **Lupine stub generator checks that user avoids specifying arguments or results that are incompatible with the lack of a shared address space**

Binding

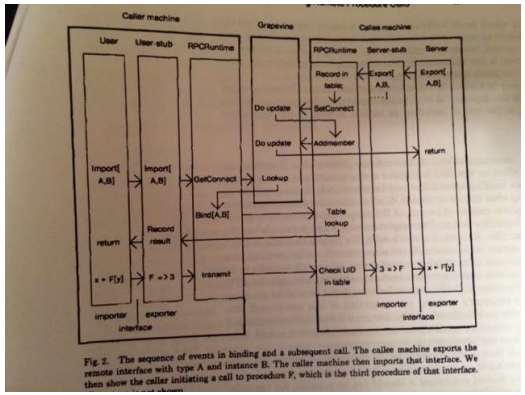


Fig. 2. The sequence of events in binding and a subsequent call. The callee machine exports the remote interface with type A and instance B. The caller machine then imports that interface. We then show the caller initiating a call to procedure F, which is the third procedure of that interface.

- **Naming**
  - Use Mesa interface module name + instance

Discussion of Binding

- **Use Grapevine distributed database**
  - Maps type to set of instances
  - Maps instance to network address
- **Importing an interface has no effect on data structures**
- **Unique identifier means bindings broken on server crash**
- **Can only call explicitly exported procedures**
- **Grapevine enforces access control**
- **Options include importer specifies type and gets nearest**

Packet-level Transport Protocol

- **Up to factor of 10 faster than using general protocols**
  - Not doing large data transfers
  - Goals: Minimize latency to get result & Server load under many users (minimize state info & handshaking costs)
- **Guarantee: If call returns, procedure invoked exactly once**
- **Do not abort on server code deadlock or infinite loop**
- **When connection is idle, only a single machine-wide counter**
- **Rate of calls on ExportInterface in a single machine limited to an average rate of less than one per second**

Packets Transmitted in Simple Call

- **Arguments & Return result each fit in a single packet**

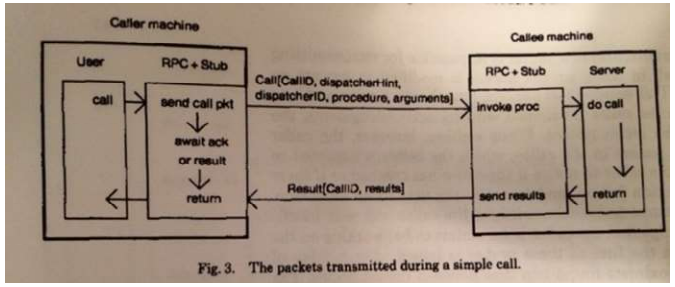


Fig. 3. The packets transmitted during a simple call.

- **Caller periodically probes, and callee acks**
  - Less work for server vs. pushing "I'm alive" messages
  - Callee can get "called failed" exception

Minimizing Process Swap Cost

- **Maintain at each machine idle server processes ready to handle incoming packets (avoid process creates)**
- **Only 4 process swaps in each call**
- **Also, bypass SW layers for intranet RPCs**
  - Modularity vs. performance trade-off
  - Today: RDMA

Performance

Table I. Performance Results for Some Examples of Remote Calls

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

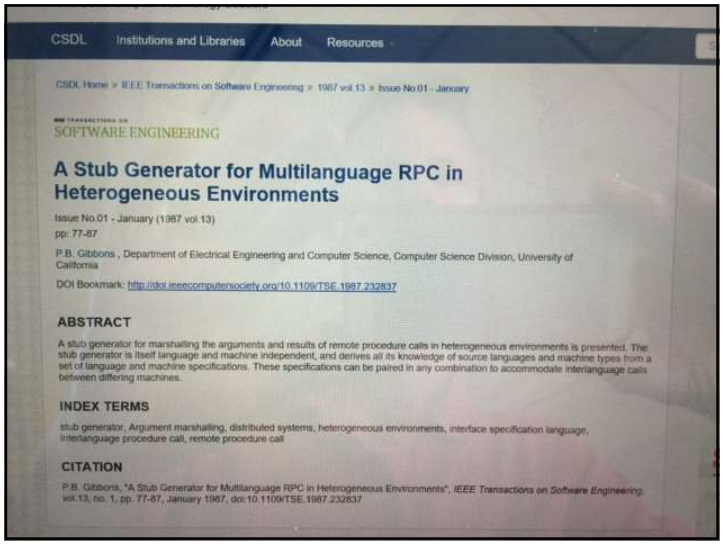
in microseconds

Alternatives

- **Message passing – but procedure calls already in high-level languages**
  - HPC community uses MPI (messages)
- **Remote fork – would encounter same design problems**
  - Also, what do you return, entire contents of memory??
- **Distributed Shared Memory: need to extend address width, not as efficient, done at page granularity, not in their language (Mesa)**
  - Long history of research into general DSM
  - Specialized DSM: key-value stores, parameter servers

Discussion

- **Multicasting or broadcasting can be better than RPCs**
- **"At present it is hard to justify some of our insistence on good performance because we lack examples demonstrating the importance of such performance."**
- **Today:**
  - Remote Method invocation
  - Naming via key-value store containing hostname (or IP address) and port number
  - RPC over UDP/IP (unreliable, but more efficient); IP handles multi-packet arguments
  - Sun's RPC (ONC RPC) system, with stub compiler rpcgen, is widely used, e.g., in Linux; provides XDR, a common data representation in messages



Wednesday's Paper

Using Threads in Interactive Systems: A Case Study

Carl Hauser, Christian Jacobi, Marvin Theimer, Brent Welch, Mark Weiser 1993