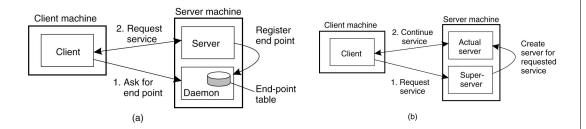
Server Design Issues



- Server Design
 - Iterative versus concurrent
- How to locate an end-point (port #)?
 - Well known port #
 - Directory service (port mapper in Unix)
 - Super server (inetd in Unix)



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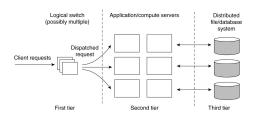
Stateful or Stateless?

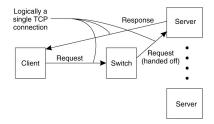
- Stateful server
 - Maintain state of connected clients
 - Sessions in web servers
- Stateless server
 - No state for clients
- Soft state
 - Maintain state for a limited time; discarding state does not impact correctness



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Server Clusters





- Web applications use tiered architecture
 - Each tier may be optionally replicated; uses a dispatcher
 - Use TCP splicing or handoffs



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Server Architecture

- Sequential
 - Serve one request at a time
 - Can service multiple requests by employing events and asynchronous communication
- Concurrent
 - Server spawns a process or thread to service each request
 - Can also use a pre-spawned pool of threads/processes (apache)
- Thus servers could be
 - Pure-sequential, event-based, thread-based, process-based
- Discussion: which architecture is most efficient?



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Scalability

- Question: How can you scale the server capacity?
- Buy bigger machine!
- Replicate
- Distribute data and/or algorithms
- Ship code instead of data
- Cache



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Today: Communication in Distributed Systems

- Message-oriented Communication
- Remote Procedure Calls
 - Transparency but poor for passing references
- Remote Method Invocation
 - RMIs are essentially RPCs but specific to remote objects
 - System wide references passed as parameters
- Stream-oriented Communication



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Communication Between Processes

- *Unstructured* communication
 - Use shared memory or shared data structures
- Structured communication
 - Use explicit messages (IPCs)
- Distributed Systems: both need low-level communication support (why?)

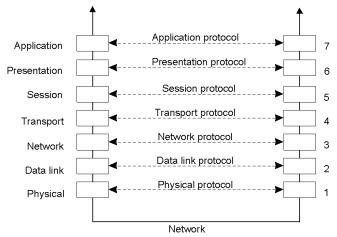


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Communication Protocols

- Protocols are agreements/rules on communication
- Protocols could be connection-oriented or connectionless

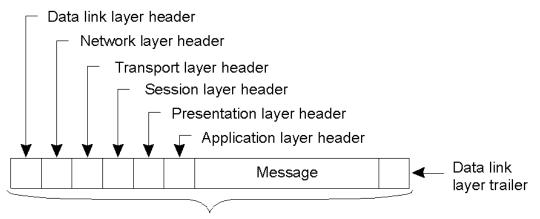


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Layered Protocols

A typical message as it appears on the network.



Bits that actually appear on the network

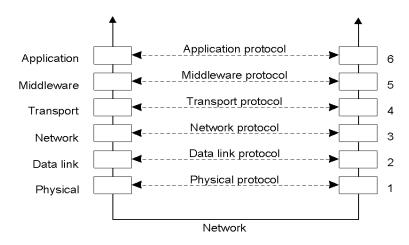


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Middleware Protocols

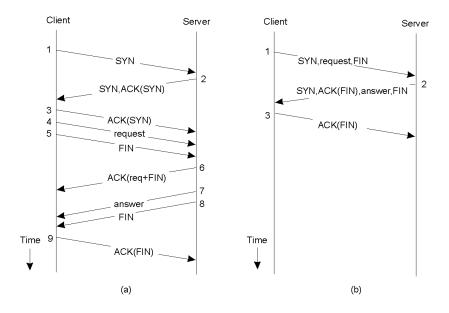
- Middleware: layer that resides between an OS and an application
 - May implement general-purpose protocols that warrant their own layers
 - Example: distributed commit



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Client-Server TCP





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To Push or Pull?

- Client-pull architecture
 - Clients pull data from servers (by sending requests)
 - Example: HTTP
 - Pro: stateless servers, failures are each to handle
 - Con: limited scalability
- Server-push architecture
 - Servers push data to client
 - Example: video streaming, stock tickers
 - Pro: more scalable, Con: stateful servers, less resilient to failure
- When/how-often to push or pull?



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Group Communication

- One-to-many communication: useful for distributed applications
- Issues:
 - Group characteristics:
 - Static/dynamic, open/closed
 - Group addressing
 - Multicast, broadcast, application-level multicast (unicast)
 - Atomicity
 - Message ordering
 - Scalability



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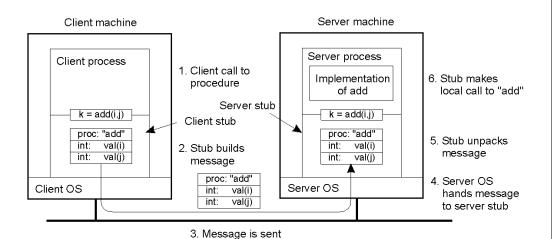
Remote Procedure Calls

- Goal: Make distributed computing look like centralized computing
- Allow remote services to be called as procedures
 - Transparency with regard to location, implementation, language
- Issues
 - How to pass parameters
 - Bindings
 - Semantics in face of errors
- Two classes: integrated into prog language and separate



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Example of an RPC





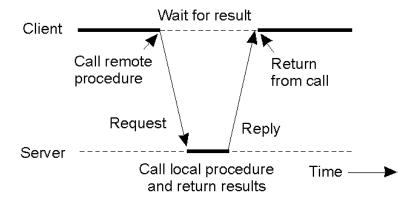
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across the network

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RPC Semantics

• Principle of RPC between a client and server program [Birrell&Nelson 1984]

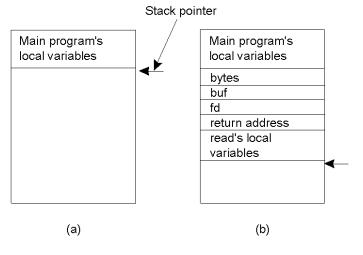




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Conventional Procedure Call

- Parameter passing in a local procedure call: the stack before the call to read
- b) The stack while the called procedure is active





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Parameter Passing

- Local procedure parameter passing
 - Call-by-value
 - Call-by-reference: arrays, complex data structures
- Remote procedure calls simulate this through:
 - Stubs proxies
 - Flattening marshalling
- Related issue: global variables are not allowed in RPCs



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Client and Server Stubs

- Client makes procedure call (just like a local procedure call) to the client stub
- Server is written as a standard procedure
- Stubs take care of packaging arguments and sending messages
- Packaging parameters is called marshalling
- Stub compiler generates stub automatically from specs in an Interface Definition Language (IDL)
 - Simplifies programmer task



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Steps of a Remote Procedure Call

- 1. Client procedure calls client stub in normal way
- 2. Client stub builds message, calls local OS
- 3. Client's OS sends message to remote OS
- 4. Remote OS gives message to server stub
- 5. Server stub unpacks parameters, calls server
- 6. Server does work, returns result to the stub
- 7. Server stub packs it in message, calls local OS
- 8. Server's OS sends message to client's OS
- 9. Client's OS gives message to client stub
- 10. Stub unpacks result, returns to client



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Marshalling

- Problem: different machines have different data formats
 - Intel: little endian, SPARC: big endian
- Solution: use a standard representation
 - Example: external data representation (XDR)
- Problem: how do we pass pointers?
 - If it points to a well-defined data structure, pass a copy and the server stub passes a pointer to the local copy
- What about data structures containing pointers?
 - Prohibit
 - Chase pointers over network
- Marshalling: transform parameters/results into a byte stream



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Binding

- Problem: how does a client locate a server?
 - Use Bindings
- Server
 - Export server interface during initialization
 - Send name, version no, unique identifier, handle (address) to binder
- Client
 - First RPC: send message to binder to import server interface
 - Binder: check to see if server has exported interface
 - Return handle and unique identifier to client



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Binding: Comments

- Exporting and importing incurs overheads
- Binder can be a bottleneck
 - Use multiple binders
- Binder can do load balancing



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Failure Semantics

- Client unable to locate server: return error
- Lost request messages: simple timeout mechanisms
- Lost replies: timeout mechanisms
 - Make operation idempotent
 - Use sequence numbers, mark retransmissions
- Server failures: did failure occur before or after operation?
 - At least once semantics (SUNRPC)
 - At most once
 - No guarantee
 - Exactly once: desirable but difficult to achieve



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Failure Semantics

- *Client failure:* what happens to the server computation?
 - Referred to as an orphan
 - Extermination: log at client stub and explicitly kill orphans
 - Overhead of maintaining disk logs
 - Reincarnation: Divide time into epochs between failures and delete computations from old epochs
 - Gentle reincarnation: upon a new epoch broadcast, try to locate owner first (delete only if no owner)
 - Expiration: give each RPC a fixed quantum T; explicitly request extensions
 - Periodic checks with client during long computations



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Implementation Issues

- Choice of protocol [affects communication costs]
 - Use existing protocol (UDP) 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
 - From client to NIC and from server NIC to server
 - As many as 7 copies
 - Stack in stub message buffer in stub kernel NIC medium – NIC – kernel – stub – server
 - Scatter-gather operations can reduce overheads



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Case Study: SUNRPC

- One of the most widely used RPC systems
- Developed for use with NFS
- Built on top of UDP or TCP
 - TCP: stream is divided into records
 - UDP: max packet size < 8912 bytes
 - UDP: timeout plus limited number of retransmissions
 - TCP: return error if connection is terminated by server
- Multiple arguments marshaled into a single structure
- At-least-once semantics if reply received, at-least-zero semantics if no reply. With UDP tries at-most-once
- Use SUN's eXternal Data Representation (XDR)
 - Big endian order for 32 bit integers, handle arbitrarily large data structures

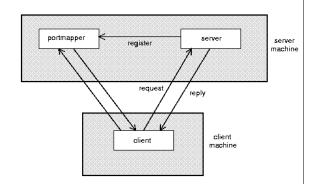


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Binder: Port Mapper

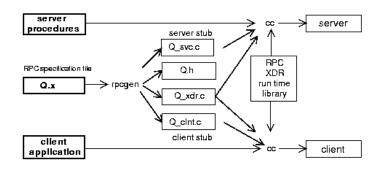
- •Server start-up: create port
- •Server stub calls *svc_register* to register prog. #, version # with local port mapper
- •Port mapper stores prog #, version #, and port
- •Client start-up: call *clnt_create* to locate server port
- •Upon return, client can call procedures at the server





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Rpcgen: generating stubs



- Q_xdr.c: do XDR conversion
- Detailed example: later in this course



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Summary

- RPCs make distributed computations look like local computations
- Issues:
 - Parameter passing
 - Binding
 - Failure handling
- Case Study: SUN RPC



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