CSE 486/586 Distributed Systems
Remote Procedure Call

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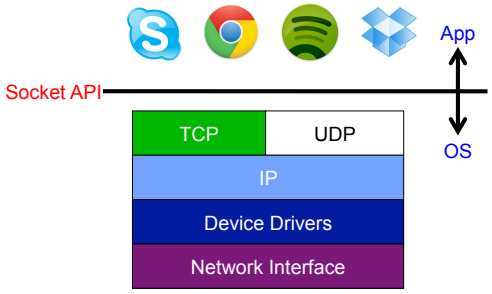
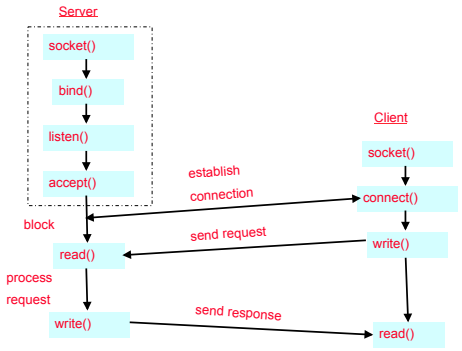
Recap

- Paxos phase 1
  - A proposer sends a prepare message.
  - Acceptors reply with the highest-numbered proposal
- Paxos phase 2:
  - The proposer waits for a majority of acceptors.
  - The proposer chooses the value from the highest-numbered proposal.
  - Upon receiving a new prooposal, acceptors either:
    - » Accept it
    - » Or, reject it if there was another prepare request with N' higher than N, and it replied to it (due to the promise in phase 1).

Recall?



Socket API



What's Wrong with Socket API?

- Low-level read/write
- Communication oriented
- Same sequence of calls, repeated many times
- Etc, etc…
- Not programmer friendly

Another Abstraction

- RPC (Remote Procedure Call)
  - Goal: it should appear that the programmer is calling a local function
  - Mechanism to enable function calls between different processes
  - First proposed in the 80's
- Examples
  - Sun RPC
  - Java RMI
  - CORBA
- Other examples that borrow the idea
  - XML-RPC
  - Android Bound Services with AIDL
  - Google Protocol Buffers

RPC

- Client

```
int main (…)
{
  …
  rpc_call(…);
  …
}
```

- Server

```
…

void rpc_call(…) {
  …
}

…
```


Local Procedure Call

- E.g., x = local_call("str");
- The compiler generates code to *transfer necessary things* to local_call
  - Push the parameters to the stack
  - Call local_call
- The compiler also generates code to *execute the local call*.
  - Assigns registers
  - Adjust stack pointers
  - Saves the return value
  - Calls the return instruction

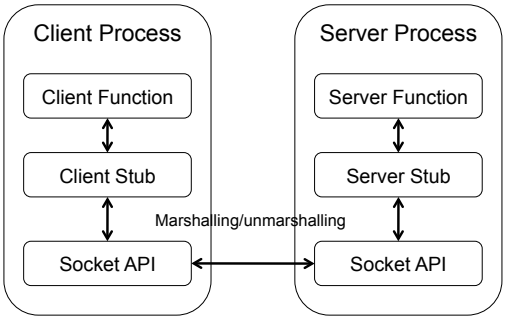
Remote Procedure Call

- Give an illusion of doing a local call by using whatever the OS gives
- Closer to the programmers
  - Language-level construct, not OS-level support
- What are some of the challenges?
  - How do you know that there are remote calls available?
  - How do you pass the parameters?
  - How do you find the correct server process?
  - How do you get the return value?

Stub, Marshalling, & Unmarshalling

- Stub functions: local interface to make it appear that the call is local.
- Marshalling: the act of taking a collection of data items (platform dependent) and assembling them into the external data representation (platform independent).
- Unmarshalling: the process of disassembling data that is in external data representation form, into a locally interpretable form.

RPC Process



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How Do You Generate Stubs?

- Ever heard of C/C++, Java, Python syntax for RPC?
  - None!
- Language compilers don't generate client and server stubs.
- Common solution: use a separate language and a pre-compiler

Interface Definition Language (IDL)

- Allow programmers to express remote procedures, e.g., names, parameters, and return values.
- Pre-compilers take this and generate stubs, marshalling/unmarshalling mechanisms.
- Similar to writing function definitions

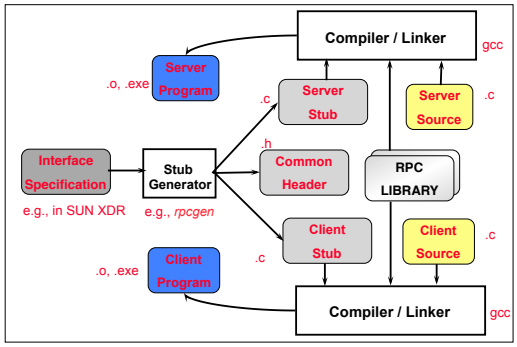
Example: SUN XDR

```
const MAX = 1000;
typedef int FileIdentifier;
typedef int FilePointer;
typedef int Length;
struct Data {
    int length;
    char buffer[MAX];
};
struct writeargs {
    FileIdentifier f;
    FilePointer position;
    Data data;
};
```

```
struct readargs {
    FileIdentifier f;
    FilePointer position;
    Length length;
};

program FILEREADWRITE {
  version VERSION {
    void WRITE(writeargs)=1;
    Data READ(readargs)=2;
  }=2;
} = 9999;
```

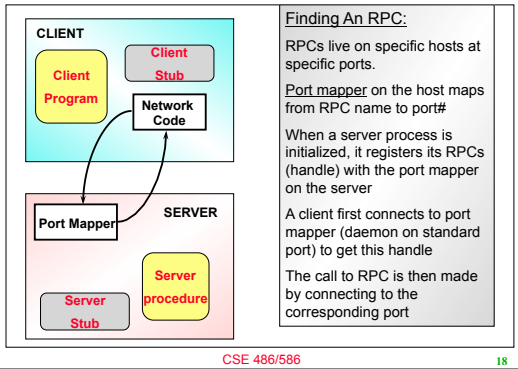

Stub Generation



How Do You Find the Server Process?

- Solution 1
  - Central DB (the first solution proposed)
- Solution 2
  - Local DB with a well-known port (SUN RPC)

Local DB with Well-Known Port



Finding An RPC:

RPCs live on specific hosts at specific ports.

Port mapper on the host maps from RPC name to port#

When a server process is initialized, it registers its RPCs (handle) with the port mapper on the server

A client first connects to port mapper (daemon on standard port) to get this handle

The call to RPC is then made by connecting to the corresponding port

How to Pass Parameters?

- Pass by value: no problem
  - Just copy the value
- What about pointers/references?
  - Need to copy the actual data as well
  - Marshall them at the client and unmarshall them at the server
  - Pass the local pointers/references
- What about complex data structures? struct, class, etc.
  - Need to have a platform independent way of representing data

External Data Representation

- Communication between two heterogeneous machines
  - Different byte ordering (big-endian & little-endian)
  - Different sizes of integers and other types
  - Different floating point representations
  - Different character sets
  - Alignment requirements
- Used in general contexts, not just in RPCs

Example: Google Protocol Buffers

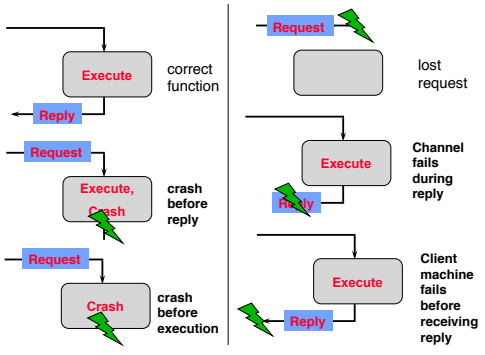
- Goal: language- and platform-neutral way to specify and serialize data
- Provides syntax & pre-compiler (open-source)
  - Pre-compiler generates code to manipulate objects for a specific language, e.g, C++, Java, Python.
  - The runtime support applies a fast & sloppy compression algorithm.

```
message Book {
   required string title = 1;
   repeated string author = 2;
   optional BookStats statistics = 3;
   message BookStats {
         required int32 sales =1;
   }
}
```


What About Failures?

- Local calls do not fail.
- Remote calls might fail.
- Programmers should deal with this.
  - No transparency here

Failure Modes of RPC



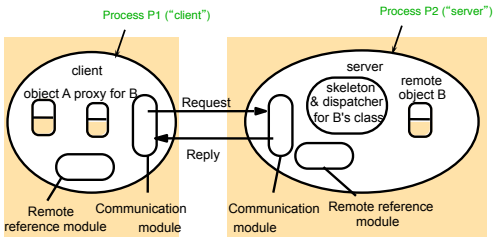
Invocation Semantics

- Local procedure call: exactly-once
- Remote procedure call:
  - 0 times: server crashed or server process died before executing server code
  - 1 time: everything worked well, as expected
  - 1 or more: excess latency or lost reply from server and client retransmission
- When do these make sense?
  - Idempotent functions: OK to run any number of times
  - Non-idempotent functions: cannot do it
- What we can offer
  - At least once
  - At most once

Invocation Semantics

Fault tolerance measures			*Invocation semantics*
Retransmit request message	*Duplicate filtering*	*Re-execute procedure or retransmit reply*	
No	Not applicable	Not applicable	*Maybe*
Yes	No	Re-execute procedure	*At-least-once*
Yes	Yes	Retransmit old reply	*At-most-once*

Remote Method Invocation (RMI)



Summary

- RPC enables programmers to call functions in remote processes.
- IDL (Interface Definition Language) allows programmers to define remote procedure calls.
- Stubs are used to make it appear that the call is local.
- Semantics
  - Cannot provide exactly once
  - At least once
  - At most once
  - Depends on the application requirements

Acknowledgements

- These slides contain material developed and copyrighted by Indranil Gupta (UIUC).