Remote Procedure Call

Complex and Special RPCs

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A Case Study on Sun RPC

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Remote Procedure Call

Complex and Special RPCs

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Complex RPC

- Complex RPC refers to a collection of unusual types of RPC calls
- For example, Long RPC is used in two different perspectives
  - RPCs Involving long-duration Calls
  - RPCs Involving long messages
- Another case of complex RPC is when there's a long gap between two successive calls

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Long duration RPC

- There are two broad approaches to handle such RPC calls
  - Periodic probing of the server by the client
  - Periodic generation of acknowledgment messages by the server

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1. Periodic Probing of Server

- After a client sends request to the server, it periodically sends probe packets to the server.
- Server is expected to acknowledge these probes.
- The message identifier of the original request message is included in each probe packet.

1. Periodic Probing of Server

- If the original request is lost, the server detects the same on receipt of a probe packet corresponding to that request message.
- The server then intimates the client that the request message corresponding to the probe packet has not been received.

1. Periodic Probing of Server

- On receipt of such a reply from the server, the client retransmits the original request.
- This allows the client to detect a server's crash or a link failure and hence to notify the corresponding user on an exception.

2. Periodic Acknowledgement

- If the server is not able to generate the next reply within an expected retransmission interval, then it spontaneously generates an acknowledgment.
- Thus, for a long-duration call, the server may have to generate several acknowledgments.

2. Periodic Acknowledgement

- If the client does not receive either the reply or an acknowledgment within a predetermined timeout period, it assumes that either the server has crashed or a link has failed.
- Thus, it notifies the concerned user on an exception condition.

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RPCs with Long Messages

- In some RPCs, the messages are too large to fit in a single packet.
  - As for example, in a file server, large volume of data may be transferred as input arguments to a write operation or as result of a read operation.
- Some RPC systems too are limited to small size packets.
  - The Sun Micro System‘s RPC is limited to 8 kilobytes per message.

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RPCs with Long Messages

- A way of handling RPCs of this category is to use multi-datagram messages.
- In this method, a long message is fragmented and transmitted in multiple packets.
- To improve performance, a single acknowledgment is used for all the packets of a message.

Callback RPC

- In callback RPC, a process may play the role of either a client or a server.
- In the usual RPC protocol, the caller and called processes have a client-server relationship.
- Unlike this, the callback RPC facilitates a peer-to-peer paradigm among the participating processes.

Callback RPC

- Consider a remotely initiated interactive applications that need input from user time to time or under special conditions.
- Say, the client process makes an RPC and during procedure execution, the server makes a callback RPC to the client process.

Callback RPC

- Now, client process takes necessary action and returns a reply for the callback RPC to the server process.
- On receiving this reply, the server resumes execution and finally replies to the initial RPC from the client.
- Server may even callback the client multiple times before returning the result of the initial call to the client.

Requirements for Callback RPC

- The ability for a server to call its client back requires the following:
  - Providing the server with the client's handle
  - Making the client process wait for the callback RPC
  - Handling callback deadlocks

Providing Client's Handle to Server

- The server must have the client's handle to call the client back.
- Typically, the client process uses a transient program number for the callback service
- A client exports the callback service by registering its program number with the binding agent.

Providing Client’s Handle to Server

- Next, the program number is sent as part of RPC request to the server.
- To make a callback RPC, the server initiates a normal RPC request to the client using given program number.
- Instead of having the client just send the server the program number, it could also send its handle, such as the port number.

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Providing Client’s Handle to Server

- The client's handle could then be used by the server to directly communicate with the client.

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Making the Client Process Wait

- The client process must be waiting for the callback so that it can process the incoming RPC request from the server
- It must be ensured that a callback RPC from the server is not mistaken as the reply of the RPC call made by the client process.

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Challenges for Transparency in RPC

- Inefficient Parameter Passing:
  - Unlike local procedure, a remote procedure is executed in an address space that is disjoint from the calling program's address space.
  - Hence, the remote procedure cannot have access to any variables or data values in the calling program's environment.
  - In absence of shared memory, it is meaningless to pass addresses in arguments, thus making call by reference useless.

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Challenges for Transparency in RPC

- Vulnerability:
  - RPCs are more vulnerable to failure than local procedure calls, as RPCs involve two different processes in disjoint address spaces and possibly a network between two different nodes.
  - The need for the ability to handle processor crashes and/or communication failures makes it even more difficult to obtain the same semantics for RPCs as for local procedure calls.

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Challenges for Transparency in RPC

- Poor Response Time:
  - RPCs consume significantly more time (100-1000 times more) than local procedure calls.
  - This is mainly due to the involvement of a communication network in RPCs.
  - Hence, the applications using RPCs must also have the capability to handle the long delays that may possibly occur due to network congestion.

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Handling Deadlock in RPC

- Since a process may play the role of either a client or a server, deadlocks can occur.
- Consider a process X making an RPC call to a process Y. X waits for a reply from Y.
- In the meantime, Y makes an RPC call to another process Z and waits for a reply from Z.

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Handling Deadlock in RPC

- Now, say, Z makes an RPC call to X. So, Z waits for a reply from X.
- X cannot reply to Z's call until its request to Y is replied, and Y cannot process X's request until its call to Z is satisfied which is blocked by X.
- So X, Y, and Z are in deadlock.
- In RPC, care must be taken to handle deadlock.

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Case Study: SUN RPC

- Stub Generation
- Implementing SUN RPC applications
- Parameter Passing
- Call Semantics
- Client Server Binding
- Security
- Special Types of RPC
- Limitations of SUN RPC

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Case Study: SUN RPC

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SUN RPC: Stub Generation

- Sun RPC supports automatic stub generation, although users have the flexibility of writing the manual stubs.
- An application's interface definition is written in an IDL called RPC Language (RPCL).
- RPCL is an extension of the Sun XDR language, originally designed to specify external data representation.

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SUN RPC: Interface Definition

```
/*  File StatelessFS.x */
    const FILE_NAME_SIZE = 16
    const BUFFER_SIZE = 1024

    typedef string FileName<FILE_NAME_SIZE>;
    typedef long Position;
    typedef long Nbytes;

    struct Data {
          long n;
          char buffer(BUFFER_SIZE];
    };
```

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SUN RPC: Interface Definition

```
struct readargs {
      FIleName
      Position
      Nbytes
};
struct writeargs {
      FileName
      Position
      Data
};
program STATELESS_FS_PROG {
version STATELESS_FS_VERS {
      Data          READ (readargs) = 1;
      Nbytes        WRITE (writeargs) = 2;
} = 1 ;
} = 0x20000000;
```

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SUN RPC: Stub Generation

- An interface definition contains:
  - a program number (0x20000000 in our example)
  - a version number of the service (1 in our example),
  - the procedures supported by the service (READ and WRITE in our example),
  - the input and output parameters along with their types for each procedure, and
  - the supporting type definitions.

SUN RPC: Stub Generation

- Three numbers, program number (STATELESS_FS_PROG), version number (STATELESS_FS_ VERS), and procedure number (READ or WRITE) uniquely identify a RP.
- READ and WRITE procedures are numbered as 1 and 2, respectively.
- Extension of .x is used by interface definition files (e.g., StatelessFS.x).

SUN RPC: *rpcgen* Compiler

- The IDL compiler in SUN RPC is called *rpcgen*
- From a .x file, *rpcgen* produces the following:
  - Header files (with .h extension)
  - XDR filter files (with _xdr.c suffix)
  - A client stub file (with _clnt.c suffix)
  - A server stub file (with _svc.c suffix)

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SUN RPC: Header File by *rpcgen*

- The header file contains
  - definitions of common constants and types defined in the .x definition file.
  - external declarations for all XDR marshaling and un-marshaling procedures that are automatically generated.
- Name of a header file is formed by taking the name of input .x file and adding .h suffix (e.g. StatelessFS.h).

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SUN RPC: Header File by *rpcgen*

- This header file is to be manually included in client and server program files using #include preprocessor directive.
- The header file built by *rpcgen* compiler is automatically included in client stub, server stub, and XDR filters files.

SUN RPC: XDR filters by *rpcgen*

- The procedures in the XDR filter files built by *rpcgen* are used by the client and server stub procedures for encryption/decryption.
- The name of this file is formed by taking the name of the .x definition file and adding _xdr.c suffix (e.g., StatelessFS_xdr.c).

SUN RPC: Client Stub by *rpcgen*

- A client stub file contains one stub procedure for each procedure defined in the .x definition file.
- A client stub procedure name is the name of the procedure given in the interface definition, converted to lowercase appended with an underscore and the version number.

SUN RPC: Client Stub by *rpcgen*

- In our example, the client stub procedure names for READ and WRITE procedures will be read_1 and write_1 respectively.
- The name of the client stub file is formed by taking the name of the .x file to *rpcgen* and adding a _clnt.c suffix to it. (e.g., StatelessFS_clnt.c).

SUN RPC: Server Stub by *rpcgen*

- Server stub file contains the main routine, the dispatch routine, and one stub procedure for each procedure defined in the interface definition file plus a null procedure.
- The dispatch routine dispatches incoming calls to the appropriate procedure.

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SUN RPC: Server Stub by *rpcgen*

- The dispatch routine is named by taking the .x program name to lowercase characters and appending an underscore followed by version number (e.g., stateless_fs_prog_1) .
- The name of the server stub file is formed by taking the base name of the .x input file and adding _svc. c suffix to it (e.g., StatelessFS_svc.c).

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Implementing SUN RPC applications

- Application programmer manually writes the client and server programs
- Client program is compiled to get a client object file.
- Server program is compiled to get a server object file.
- The client stub file and the XDR filters file are compiled and linked to get a client stub object file

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Implementing SUN RPC applications

- Server stub and XDR filter files are compiled and linked to get a server stub object file.
- Client object file, client stub object file, and client-side RPCRuntime library are linked together to get the client executable file.
- Server object file, server stub object file, and server-side RPCRuntime library are linked together to get the server executable file.

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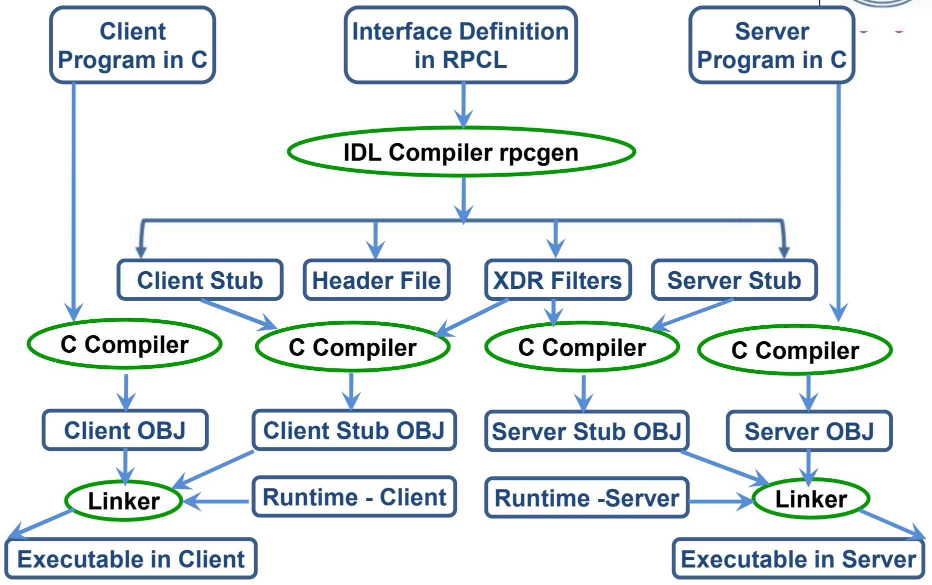
Implementing SUN RPC Applications



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SUN RPC: Implementing File Server

```
#include <Stdio.h>
#include <rpc.h>
#include "StatelessFS.h“

/* READ PROCEDURE •/
Data   *read_1 (args)
       readargs      •args;
{
   static Data          result;
   /* Statements for reading args.n bytes of data from
   the file args.filename starting from args.position, and
   for putting the data read in &result.buffer and the
   actual number of bytes read in result.n */
   Return (&result);
}
```

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SUN RPC: Implementing File Server

```
/* WRITE PROCEDURE •/
Nbytes         •wnte_ 1 (args)
               writeargs •args;
{
   static Nbytes       result;
   /* Statements for writingargs.data.n bytes of data
   from the buffer &args.data.buffer into the file
   args.filename starting at position args.position */
   /* Statement for putting the actual number of bytes
   written in result */
   Return (&result);
}
```

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SUN RPC: Parameter Passing

- In Sun RPC, a called procedure can accept only one data argument and return only one result.
- Therefore, procedures requiring multiple parameters as input or as output must include them as components of a single structure.
- This is why structures *Data*, *readargs* and *writeargs* are defined.

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SUN RPC: Parameter Passing

- A Sun RPC call message has two parameters
  - the first is a pointer to the single argument of the remote procedure
  - the second is a pointer to a client handle.
    - read_result=read_1(&read_args, client_handle);
    - write_result=write_1(&write_args, client_handle);
- The return argument for a procedure is a pointer to the single result.

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SUN RPC: Parameter Passing

- The returned result must be declared as a static variable in the server program.
- Otherwise, the value of the returned result becomes undefined when the procedure returns.

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SUN RPC: Call Semantics

- Sun RPC supports at-least-once semantics.
- After sending a request message, the RPC Runtime library waits for a timeout period for the server to reply before retransmitting the request.
- The number of retries is the total time to wait divided by the timeout period.

SUN RPC: Call Semantics

- The default time to wait and the timeout period are 25 and 5 seconds respectively. These default values can be reset by the users.
- Eventually, if no reply is received from the server within the total time to wait, the RPC Runtime returns a timeout error.

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SUN RPC: Client-Server Binding

- Sun RPC does not have a network-wide client-server binding.
- Each node has a local binding agent called port-mapper that maintains a database of mapping of all local services and their port numbers.
- The port-mapper runs at a well-known port number on every node.

SUN RPC: Client-Server Binding

- When a server starts up, it registers its program number, version number, and port number with the local port-mapper.
- When a client wants to do an RPC, it must first find out the port number of the server that supports the remote procedure.

SUN RPC: Client-Server Binding

- For this, the client makes a remote request to the port-mapper at the server's host, specifying the program number and version number.
- Thus, a client must specify host name of the server to import a service.
- In effect, this means that Sun RPC has no location transparency.

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SUN RPC: Security

- SUN RPC supports three types of authentication models:
  - No Authentication: Default type
  - Unix Style Authentication: Restricted access to a service to a certain set of users based on user and group ids.
  - DES Style Authentication: User can access the service encrypted *with* DES

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SUN RPC: Special Types of RPC

- SUN RPC supports some special types of RPCS including
  - Asynchronous RPC
  - Callback RPC
  - Broadcast RPC, and
  - Batch-mode RPC.

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SUN RPC: Special Types of RPC

- Asynchronous RPC is realized by setting the timeout value of an RPC to 0 and writing the server such that no reply is generated for the request.
- To facilitate callback RPC, the client registers the callback service using a transient program number with the local port-mapper.

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SUN RPC: Special Types of RPC

- The program number is then sent as part of the RPC request to the server.
- The server initiates a normal RPC request to the client using the given program number when it is ready to do the callback RPC.

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Case Study: Limitations of SUN RPC

- Sun RPC lacks location transparency as a client requires to specify the host name of the server when it imports a service interface.
- Sun RPC supports at-least-once or may-be call semantics, which may not be acceptable for many applications.

Case Study: Limitations of SUN RPC

- The IDL of Sun RPC does not allow a general specification of arguments and results.
- It allows only a single argument and a single result.
- This forces multiple arguments or return values to be packaged as a single structure.

Case Study: Limitations of SUN RPC

- Sun RPC is not transport independent and the transport protocol is limited to either UDP or TCP.
- In UDP, Sun RPC messages are limited to 8 kilobytes in length.
- Sun RPC does not have a network-wide client-server binding.

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Case Study: Limitations of SUN RPC

- A transport-independent version of Sun RPC, known as TI-RPC (transport-independent RPC), has been developed by Sun-Soft.
- TI-RPC provides a simple and consistent way in which transports can be dynamically selected depending upon user preference.

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Case Study: Limitations of SUN RPC

- We know that threads in client or server can improve performance of an RPC-based application.
- Sun RPC does not include any integrated facility for threads in the client or server, although Sun OS has a separate thread package.

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Thanks for your kind attention

Questions??

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