Programming with SUN RPC

CS 417

Distributed Systems

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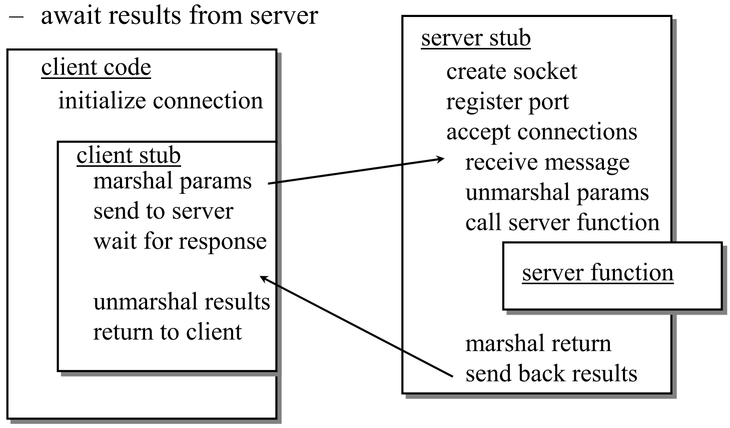
Remote Procedure Call

- remote procedures appear local through stub functions
- stub functions have the same functional interface
  - communicate with server
  - await results from server



Remote procedure calls appear local because a local procedure exists that provides the same interface.

This procedure gathers up the parameters and converts them into a **flat, pointerless** representation that is sent as a network message to a server. This data conversion is known as **marshaling**.

N.B.: pointers are useless on the remote side since they refer to local memory locations.

The server, upon receiving the message, reassembles the parameters into a form that is readable on that machine (correct byte ordering, word sizes, etc.) and calls the user-written **server function**. Upon return from the server function, any return value is marshaled into a network message and sent back to the client.

The client receives the return message, unmarshals the data, and returns it back to the calling client code.

Stub function generation

- Programming languages do not support Sun RPC.
  - A separate pre-compiler, **rpcgen**, must be used
- Input:
  - Interface definition language
- Output:
  - server main routine
  - client stub functions
  - header file
  - data conversion functions, if needed

RPC is a language construct, meaning it is a property of the programming language (since it deals with the semantics of function calls).

However, no languages support Sun RPC, so a pre-compiler must be used to generate the stub functions on the client and the server.

The Sun RPC compiler is called **rpcgen**. As input, it takes a list of remote procedures (interfaces) defined in an **interface definition language** (IDL).

The output from rpcgen is a set of files that include:

server code: main function that sets up a socket, registers the port with a name server, listens for and accepts connections, receives messages, unmarshals parameters, calls the user-written server function, marshals the return value, and sends back a network message.

client stub: code with the interface of the remote function that marshals parameters, sends the message to the server, and unmarshals the return value

header: contains definitions of symbols used by client and server as well as function prototypes

data conversion functions: a separate file may be generated if special functions need to be called to convert between local data types and their marshaled forms.

Interface Definition Language

- Used by *rpcgen* to generate stub functions
- defines an RPC *program*: collection of RPC procedures
- structure:

```
type definitions

program identifier {
        version version_id {
                procedure list
        } = value;
        …
} = value;
```

```
program PROG {
        version PROG1 {
                void PROC_A(int) = 1;
        } = 1;
} = 0x3a3afeeb;
```


The Interface Definition Language (IDL) is the one bit of input needed by **rpcgen** to generate the stub functions.

The structure of IDL is vaguely similar to a set of C prototype definitions.

Note that any similarity to C is essentially coincidental: RPC IDL is a separate definition language that is *not* C.

Each IDL program contains the following structure:

- optional constant definitions and typedefs may be present

- the entire *interface* is enveloped in a **program** block. The sample on the right gives a name PROG to the set of interfaces and a numeric value of 0x3a3afeeb. Sun decreed that each collection of RPC interfaces is identified by a 32 bit value that you have to select. The restrictions given are:

`0x00000000-0x1fffffff:`	defined by sun
`0x20000000-0x3fffffff`	defined by the user
`0x40000000-0x5fffffff`	transient processes
`0x60000000-0x7fffffff`	reserved

- within the program block, one or more sets of *versions* may be defined. A client program will always request an interface by asking for a {program#, version#} tuple. Each version contains a version name and number. In the sample on the right, the version name is PROG1 and the number is 1.

- within each version block, a set of functions is defined. These look similar to C prototypes and are tagged with a function number (each function gets a unique number within a version block).

Data types

- constants
  - may be used in place of an integer value - converted to #define statement by *rpcgen*

```
const MAXSIZE = 512;
```

- structures
  - similar to C structures - *rpcgen* transfers structure definition and adds a typedef for the name of the structure

```
struct intpair { int a, b };
```

is translated to:

```
struct intpair { int a, b };
typedef struct intpair intpair;
```

Data types

- **enumerations**
  - similar to C

```
enum state { BUSY=1, IDLE=2, TRANSIT=3 };
```

- **unions**
  - not like C
  - a union is a specification of data types based on some criteria:

```
union identifier switch (declaration) {
        case_list
}
```

  - for example:

```
const MAXBUF=30;
union time_results switch (int status) {
        case 0: char timeval[MAXBUF];
        case 1: void;
        case 2: int reason;
}
```


enumerations

- defines that state can have the value of one of the symbols: BUSY, IDLE, or TRANSIT. The symbols are defined to be the values 1, 2, and 3 respectively.

unions

- very different from C (similar to discriminated unions of Pascal or ADA)

The example shows that the union has a field of *status*. If *status* is set to 0, then the union also has a character array called *timeval*. If *status* is set to 1, then the union has no other fields, and if *status* is set to 2, then the union has an integer field called *reason*.

Data types

- type definitions
  - like C:
    ```
    typedef long counter;
    ```
- arrays
  - like C but may have a fixed or variable length:
    ```
    int proc_hits[100];
    ```
    defines a fixed size array of 100 integers.

    ```
    long x_vals<50>
    ```
    defines a variable-size array of a maximum of 50 longs
- pointers
  - like C, but nit sent over the network. What is sent is a boolean value (true for pointer, false for null) followed by the data to which the pointer points.

Data types

- **strings**
  - declared as if they were variable length arrays
    ```
    string name<50>;
    ```
    declares a string of at most 50 characters.
    ```
    string anyname<>;
    ```
    declares a string of any number of characters.
- **boolean**
  - can have the value of TRUE or FALSE:
    ```
    bool busy;
    ```
- **opaque data**
  - untyped data that contains an arbitrary sequence of bytes - may be fixed or variable length:
    ```
    opaque extra_bytes[512];
    opaque more<512>;
    ```
  - latter definition is translated to C as:
    ```
    struct {
            uint more_len;    /* length of array */
            char *more_val;   /* space used by array */
    }
    ```

Writing procedures using Sun RPC

- create a procedure whose name is the name of the RPC definition
  - in lowercase
  - followed by an underscore, version number, underscore, “svc”
  - for example, `BLIP` → `blip_1_svc`
- argument to procedure is a *pointer* to the argument data type specified in the IDL
- default behavior: only *one* parameter to each function
  - if you want more, use a struct
  - this was relaxed in later versions of rpcgen but remains the default
- procedure must return a *pointer* to the data type specified in the IDL
- the server stub uses the procedure’s return value after the procedure returns, so the return address must be that of a **static** variable

Sample RPC program

- Start with stand-alone program that has two functions:
  - bin_date returns system date as # seconds since Jan 1 1970 0:00 GMT
  - str_date takes the # of seconds as input and returns a formatted data string
- Goal
  - move bin_date and str_date into server functions and call them via RPC.

Stand-alone program

```
#include <stdio.h>

long bin_date(void);
char *str_date(long bintime);

main(int argc, char **argv) {
        long lresult; /* return from bin_date */
        char *sresult; /* return from str_date */
        if (argc != 1) {
                fprintf(stderr, "usage: %s\n", argv[0]);
                exit(1);
        }
        /* call the procedure bin_date */
        lresult = bin_date();
        printf("time is %ld\n", lresult);
        /* convert the result to a date string */
        sresult = str_date(lresult);
        printf("date is %s", sresult);
        exit(0);
}
```

Stand-alone program: functions

```
/* bin_date returns the system time in binary format */
long bin_date(void) {
        long timeval;
        long time();  /* Unix time function; returns time */

        timeval = time((long *)0);
        return timeval;
}

/* str_date converts a binary time into a date string */
char *str_date(long bintime) {
        char *ptr;
        char *ctime();  /* Unix library function that does the work */

        ptr = ctime(&bintime);
        return ptr;
}
```

Define remote interface (IDL)

- Define two functions that run on server:
  - bin_date has no input parameters and returns a long.
  - str_date accepts a long as input and returns a string
- IDL:

```
program DATE_PROG {
        version DATE_VERS {
                long BIN_DATE(void) = 1;
                string STR_DATE(long) = 2;
        } = 1;
} = 0x31423456;
```

function numbers

version number

program number

- IDL convention is to suffix the file with .x
  - we name the file date.x
  - it can be compiled with:
    `rpcgen -C date.x`

We have to envelope our two functions in a version block. This in turn has to be enveloped in a program block.

Each function is assigned an arbitrary number.

We pick a number for the program number and hope that nobody on our server will pick the same one.

When the file (date.x) is compiled with rpcgen -C date.x (the -C is to produce ANSI C function declarations), we get:

date.h: header file

date_clnt.c: client stub

date_svc.c: server stub

Generating server functions: templates from rpcgen

- We can have *rpcgen* generate a template for the server code using the interface we defined:

```
rpcgen -C -Ss date.x >server.c
```

- This produces:

```
#include "date.h"
long *
bin_date_1_svc(void *argp, struct svc_req *rqstp)
{
     static long result;
     /* insert server code here */
     return &result;
}

char **
str_date_1_svc(long *argp, struct svc_req *rqstp)
{
     static char *result;
     /* insert server code here */
     return &result;
}
```


Note:

- the names we selected for the procedures have been modified: converted to lower-case and suffixed with an underscore, version, underscore, "svc".

- each function has an extra parameter: **struct svc_req *rstp**. We generally won't use this, but it's the request structure that allows us to find out about where the request is coming from.

- the input parameter is a **pointer** to the type we asked for.

- the return parameter is also a **pointer** to the type we asked for.

- static results are generated. This is important because we return the *address* of the result. The address of a local variable lives on the stack and may be overwritten once a function has returned.

Generating server functions: plug in the code

- Now just copy the functions from the original stand-alone code

```
long *
bin_date_1_svc(void *argp, struct svc_req *rqstp)
{
    static long result;
    long time();
    result = time((long *)0);
    return &result;
}

char **
str_date_1_svc(long *bintime, struct svc_req *rqstp)
{
    static char *result;
    char *ctime();

    result = ctime(bintime);
    return &result;
}
```

we don't need to use &bintime here because we get the address as a parameter

For the first function, we don't use any incoming parameters, so we ignore the argument.

As guided by the template code, we return a *pointer* to the return type. The auto-generated code made *result* static so that the data won't be out of scope when bin_date_1_svc returns.

For the second function, the first parameter is a *pointer* to the binary time (we renamed it to bintime, which is more meaningful than argp). The return value is stored in result.

Once again, we return a *pointer* to the data type we're interested in. In this case, we want a char *, so we return a pointer to that – a char **.

Generating the client: get the server name

- We need to know the name of the server
  - use *getopt* library function to accept a **-h hostname** argument on the command line.

```
extern char *optarg;
extern int optind;
char *server = "localhost";  /* default */
int err = 0;

while ((c = getopt(argc, argv, "h:")) != -1)
        switch (c) {
        case 'h':
                server = optarg;
                break;
        case '?':
                err = 1;
                break;
        }
/* exit if error or extra arguments */
if (err || (optind < argc)) {
        fprintf(stderr, "usage:  %s [-h hostname]\n", argv[0]);
        exit(1);
}
```


We now modify our main program (client) to accept a parameter *–h hostname*.

We'll use *getopt* just to make life easier in the future when we may want to add more options.

Generating the client: add headers and create client handle

- We need a couple of extra #include directives:

```
#include <rpc/rpc.h>
#include "date.h"
```

- Before we can make any remote procedure calls, we need to initialize the RPC connection via *clnt_create*:

```
CLIENT *cl;  /* rpc handle */
cl = clnt_create(server, DATE_PROG, DATE_VERS, "netpath");
```

- Program and version numbers are defined in date.h.
- "netpath" directs to read the NETPATH environment variable to decide on using TCP or UDP
- The server's RPC name server (port mapper) is contacted to find the port for the requested program/version/transport.

The main program needs a couple of headers: rpc/rpc.h, which defines rpc structures (such as the client handle) and date.h, which defines our remote functions.

Then we need to establish a connection with the server. To do this, we define a client handle and call *clnt_create*. This will contact the RPC name server to find the port number on the server for the requested program and version.

The "netpath" transport tells clnt_create to use look at the NETPATH environment variable to select the transport protocol (Linux does not support this). You can also explicitly state "tcp" or "udp".

Generating the client: modify calls to remote functions

- Client's calls to bin_date and str_date have to be modified:
  - add version number to the function
  - add a client handle as a parameter (from *clnt_create*)
  - *always* pass a single parameter (NULL if there is none)

```
bin_date_1(NULL, cl);
str_date_1(&value, cl);
```


The names of the remote functions are changed to reflect the version number and to reflect the restriction of passing a single parameter and a client handle. Sun RPC now supports multiple parameters but the default is to use the original behavior – if you need multiple parameters, put them into a struct.

Generating the client: check for RPC errors

- Remember: remote procedure calls may fail!
  - add code to check return value
  - a remote procedure call returns a *pointer* to the result we want
  - if the pointer is null, then the call failed.

```
long *lresult;       /* return from bin_date_1 */
if ((lresult=bin_date_1(NULL, cl))==NULL) {
       clnt_perror(cl, server);   /* failed! */
       exit(1);
}
```

- if *bin_date_1* succeeds, the result can be printed:

```
printf("time on %s is %ld\n", server, *lresult);
```

Generating the client: check for RPC errors (2)

- Same for the call to *str_date*:

```
char **sresult;   /* return from str_date_1 */
if ((sresult=str_date_1(lresult, cl)) == NULL) {
    /* failed ! */
    clnt_perror(cl, server);
    exit(1);
}
```

- if the call to *str_date_1* succeeds, then print the result:

```
printf("date is %s", *sresult);
```

Compile - link - run

- Generate stubs

```
rpcgen -C date.x
```

- Compile & link the client and client stub

```
cc -o client client.c date_clnt.c -lnsl
```

- Compile & link the server and server stub

```
cc -o server -DRPC_SVC_FG server.c date_svc.c -lnsl
```

  – Note: defining RPC_SVC_FG compiles the server such that it will run in the foreground instead of running as a background process

- Run the server (e.g. on remus)

```
$ ./server
```

- Run the client

```
$ ./client -h remus
time on localhost is 970457832
date is Sun Oct  1 23:37:12 2000
```