CSCI 6730/ 4730 Operating Systems

RPC: Processes

Chapter 3: Processes: Outline

- Process Concept: views of a process
- Process Scheduling
- Operations on Processes
- Cooperating Processes
- Inter Process Communication (IPC)
  - » Local
    - – Pipe
    - – Shared Memory
    - – Messages (Queues)
  - » Remote
    - – Lower Level: Sockets, MPI, Myrinet
    - – Higher Level: RPC, RMI, WebServices, CORBA,

Client-Server Remote Machine Communication Mechanisms

- Socket communication (Possible bonus project)
- Remote Procedure Calls (Project next week).
- Remote Method Invocation (Briefly, on your own)

Remote Procedure Calls (RPC)

- Inter-machine process to process communication
  - » Abstract procedure calls over a network:
  - » rusers, rstat, rlogin, rup => daemons at ports
    - – Registered library calls (port mapper)
  - » Hide message passing I/O from programmer
- Looks (almost) like a procedure call -- but client invokes a procedure on a server.
  - » Pass arguments – get results
  - » Fits into high-level programming language constructs
  - » Well understood

Remote Procedure Calls (RPC)

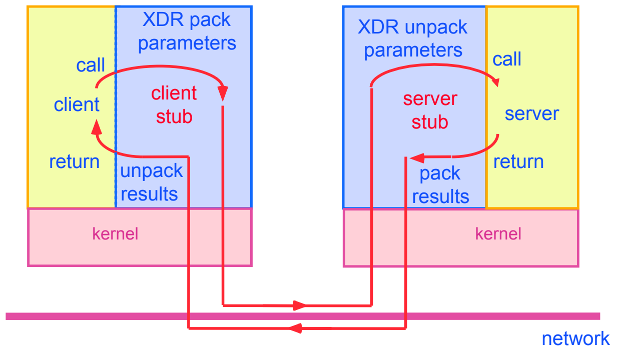
- **RPC High level view:**
  - » **Calling process attempt to call a 'remote' routine on server**
  - » **Calling process (client) is suspended**
  - » **Parameters are passed across network to a process server**
  - » **Server executes procedure**
  - » **Return results across network**
  - » **Calling process resumes**

Remote Procedure Calls

- **Usually built on top sockets (IPC)**
- **stubs – client-side proxy for the actual procedure on the server.**
- **The client-side stub locates the server and** marshalls **the parameters.**
- **The server-side stub receives this message, unpacks the marshalled parameters, and performs the procedure on the server.**

Association 5 tuple *{protocol, local-address, local-process, foreign-address, foreign-process}*

Client/Server Model Using RPC



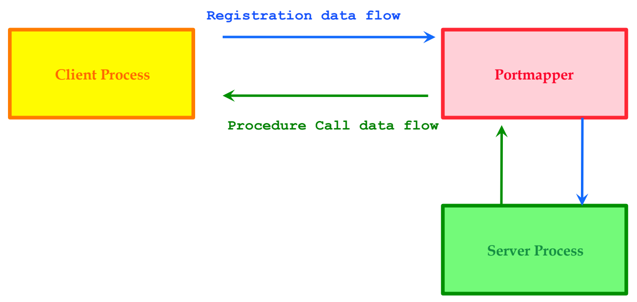
Each RPC invocation by a client process calls a ***client stub***, which builds a message and sends it to a ***server stub***

- **The server stub uses the message to generate a local procedure call to the server**
- **If the local procedure call returns a value, the server stub builds a message and sends it to the client stub, which receives it and returns the result(s) to the client**

RPC Association Between Machines

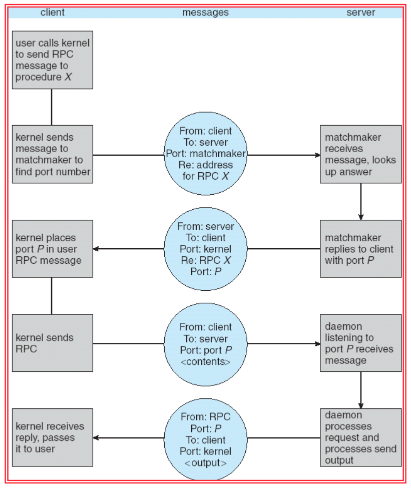
- **Association between remote and local host**
  - » **5 tuple**
    - – ***{protocol, local-address, local-process, foreign-address, foreign-process}***
    - – ***Protocol : transport protocol typically TCP or UDP, needs to be common between hosts***
    - – ***Local/foreign address: Typically the IP address***
    - – ***Local/foreign process: Typically the port number (not PID)***

Binding



- RPC application is packed into a program and is assigned an identifier (Port)
- Portmap : allocate port numbers for RPC programs

Execution of RPC


client
messages
server
user calls kernel to send RPC message to procedure X
kernel sends message to matchmaker to find port number
From: client To: server Port: matchmaker Re: address for RPC X
matchmaker receives message, looks up answer
kernel places port P in user RPC message
From: server To: client Port: kernel Re: RPC X Port: P
matchmaker replies to client with port P
kernel sends RPC
From: client To: server Port: port P <contents>
daemon listening to port P receives message
kernel receives reply, passes it to user
From: RPC Port: P To: client Port: kernel <output>
daemon processes request and processes send output

Remote Procedure Calls

- Machine independent representation of data:
  - » Differ if most/least significant byte is in the high memory address
  - » External data representation (XDR)
    - – Allows more complex representation that goes beyond:
      - htonl() routines.
- Fixed or dynamic address binding
  - » Dynamic: Matchmaker daemon at a fixed address (given name of RPC returns port of requested daemon)

Tutorial (linux journal)

- `rpcgen` generates C code from a file written in 'RPC language' `<name>. x`, e.g., `avg.x`

Default output rpcgen	Syntax	Example
Header file	`<name>.h`	`avg.h`
XDR data type translate routines (from type in .h file)	`<name>_xdr.c`	`avg._xdr.c`
stub program for server	`<name>_svc.c`	`avg_svc.c`
stub program for client	`<name>_clnt.c`	`avg_clnt.c`

- Application programmer (you) write code for:
  - » Client routine (main program)
    - – `ravg <host> <parameters>`
  - » Server program (e.g., actual code to compute average)
    - – `avg_proc.c`

Application Routines of Interest

- **Server Routine:**
  - » average_1_svc(input_data,):
    - – A avg_proc.c routine that is called from the server stub that was generated by rpcgen
- **Client Routine:**
  - » average_prog_1()
    - – Local routine that parse parameter and that ultimately calls a ‘local’ average_1 routine from generated code in avg_clnt.c that packs parameters (also uses routines in avg_xdr.c and sends code to server.

avg.x : RPC language file

```
const MAXAVGSIZE  = 200;
struct input_data
  {
  double input_data<200>;
  };

typedef struct input_data input_data;

program AVERAGEPROG {
    version AVERAGEVERS {
        double AVERAGE(input_data) = 1;
    } = 1;
} = 22855; /* ‘port number’ */
```

ravg.c : Client Program(1)

```
/* client code - calls client stub, xdr client, xdr xerver, server stub, server routine */
#include "avg.h"        /* header file generated by rpcgen */
#include <stdlib.h>

/* local routine client prototype can be whatever you want */
void averageprog_1( char* host, int argc, char *argv[] )
{
   CLIENT       *clnt; /* client handle, rpc.h */
   double       f, kkkkkk  *result_1, *dp,
   char         *endptr;
   int i;
   input_data  average_1_arg; /* input_data rpc struct */

   average_1_arg.input_data.input_data_val = (double*) malloc(MAXAVGSIZE* sizeof(double));

   dp = average_1_arg.input_data.input_data_val;  /* ptr to beginning of data */
   average_1_arg.input_data.input_data_len = argc - 2;  /* set number of items */

   for( i = 1; i <= (argc - 2); i++ )
   {    /* str to d ASCII string to floating point nubmer */
        f = strtod( argv[i+1], &endptr);
        printf("value   = %e\n", f);
        *dp = f;
        dp++;
   }
```

ravg.c : Client Program (2)

```
   /*  clnt_create( host, program, version, protocol)
    *   generic client create routine from rpc library
    * program = AVERAGEPROG is the number 22855
    * version = AVERAGEVERS is 1
    * protocol = transfer protocol */
   clnt = clnt_create( host, AVERAGEPROG, AVERAGEVERS, "udp" );
   if (clnt == NULL)
   {  clnt_pcreateerror( host ); /* rpc error library */
      exit(1);
   }
   /* now call average routine 'just' like a local routine, but this will now go over network
    * average_1 is definined in the client stub in avg_clnt.c that was generated by rpcgen
    * send in ptr to the parameters or args  in first field, and client handle in second
    * field (created in clnt_create ) average_1 ultimately calls clnt_call() macro see
    * man rpc, then calls the remote routine associated with the client handle
    * so AVERAGEPROG, VERSION */
   result_1 = average_1( &average_1_arg, clnt );
   if (result_1 == NULL)
      {
      clnt_perror(clnt, "call failed:");
      }

   clnt_destroy( clnt );
   printf( "average = %e\n",*result_1 );
} /* end average_1 prodedure */ /* next slide main() */
```

ravg.c : Client Program (3)

```
int main( int argc, char* argv[] )
{
   char *host;

   /* check correct syntax */
   if( argc < 3 )
   {
        printf( "usage: %s server_host value ...\n", argv[0]);
        exit(1);
   }

   if( argc > MAXAVGSIZE + 2 )
   {
        printf("Two many input values\n");
        exit(2);
   }

   /* host name is in first parameter (after program name) */
   host = argv[1];
   averageprog_1( host, argc, argv);
}
```

avg_proc.c : Server Program (1)

```
#include <rpc/rpc.h>
#include "avg.h”  /* avg.h generated rpcgen */
#include <stdio.h>

/* run locally on 'server' called by a remote client. */
static double sum_avg;

/* routine notice the _1 the version number and  notice the client handle, not used here, but
 * still needs to be  a parameter */
double * average_1( input_data *input, CLIENT *client)
  {
  /* input is parameters were marshaled by generated routine */
  /*  a pointer to a double, set to beginning of data array  */
  double *dp = input->input_data.input_data_val;
  u_int i;
  sum_avg = 0;
  for( i = 1; i <= input->input_data.input_data_len; i++ ) /* iterate over input */
    {
    sum_avg = sum_avg + *dp;  /* add what ptrs points  to ( '*' gets content ) */
    dp++;
    }

  sum_avg = sum_avg / input->input_data.input_data_len;
  return( &sum_avg );
} /* end average_1 */ /* next is routine called from server stub generated by rpcgen */
```

avg_proc.c : Server Program (1)

```
#include <rpc/rpc.h>
#include "avg.h”  /* avg.h generated rpcgen */
#include <stdio.h>

/* run locally on 'server' called by a remote client. */
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  for( i = 1; i <= input->input_data.input_data_len; i++ ) /* iterate over input */
    {
    sum_avg = sum_avg + *dp;  /* add what ptrs points  to ( '*' gets content ) */
    dp++;
    }

  sum_avg = sum_avg / input->input_data.input_data_len;
  return( &sum_avg );
} /* end average_1 */ /* next is routine called from server stub generated by rpcgen */
```

avg_proc.c : Server Program (2)

```
/*
 * server stub 'average_1_svc function handle called in avg_svc that was
 * generated by rpcgen
 * FYI:
 *    result = (*local)((char *)&argument, rqstp);
 *    where local is (char *(*)(char *, struct svc_req *)) average_1_svc;
 */

double * average_1_svc(input_data *input, struct svc_req *svc)
  {
  CLIENT *client;
  return( average_1( input, client) );
  }
```

Compilation on client

```
rpcgen avg.x  # generates:
  # avg_clnt.c, avg_svc.c, avg_xdr.c, avg.h
gcc ravg.c –c       # -c generates .o files
gcc avg_clnt.c –c
gcc avg_xdr.c –c
gcc –c ravg ravg.o avg_clnt.o avg_xdr.o -lnsl
```

Compilation on server

```
rpcgen avg.x  # generates:
  # avg_clnt.c, avg_svc.c, avg_xdr.c, avg.h
gcc avg_proc.c –c
gcc avg_svc.c –c
gcc –o avg_svc avg_proc.o avg_svc.o avg_xdr.o -lnsl
```

.rhost

- Directly under your home directory on each machine (client and server) create a file named:

  .rhost
- Add two or more lines in the format:

  `<machine_name>   <loginname>`
- For example I added 3 lines:

```
odin maria
herc maria
atlas maria
```

Running

```
{maria:herc} avg_svc
```

```
{maria:odin} ravg atlas.cs.uga.edu 1 2 3 4 5
```

Resources

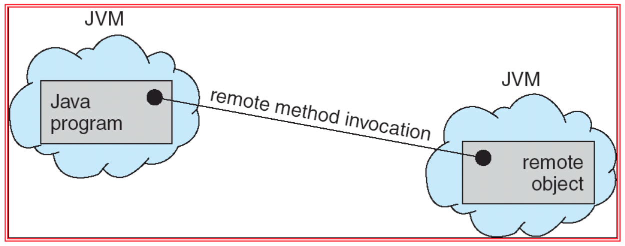
1. http://www.cs.cf.ac.uk/Dave/C/node34.html (RPCgen)
2. http://www.cs.cf.ac.uk/Dave/C/node27.html (Sh. Mem)
3. http://www.linuxjournal.com/article/2204?page=0,2
4. https://beej.us/guide/bgipc/output/html/singlepage/bgipc.html

(1) Nice tutorial on RPC
(2) (2) Shared Memorh
(3) Linux journal tutorial uses avg.x
(4) Beej's Guide

See Textbook i.e., reading assignment

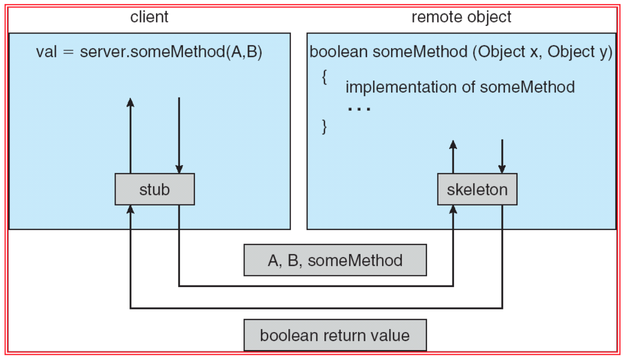
Remote Method Invocation

- Remote Method Invocation (RMI) is a Java mechanism similar to RPCs.
- RMI allows a Java program on one machine to invoke a method on a remote object.
- Possible to Pass Objects(remote, local) as parameters to remote methods (via serialization).



Marshalling Parameters

- Client invoke method: someMethod on a remote object Server


client
remote object
val = server.someMethod(A,B)
boolean someMethod (Object x, Object y)
{
implementation of someMethod
. . .
}
stub
skeleton
A, B, someMethod
boolean return value