6 Remote Procedure Call (RPC)

- RFC 1831 (Sun)
- invoke procedure on remote host in analogy to local procedure call
- programming interface: (local) procedure call
- remote procedure call
  - active client calls
  - server sends reply
- network service = collection of remote programs
- remote program implements several remote procedures
- more than one version of remote program active on server

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Differences RPC vs local calls

1. Error handling: failures of the remote server or network
2. Global variables and side-effects: not available
3. Performance: RPC usually one or more orders of magnitude slower
4. Authentication: may be necessary for RPC

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RPC Overview

- client: calls *stub* for remote procedure
- client *stub*:
  - marshals (*converts*) parameters to external representation (XDR)
  - builds request from procedure id and parameters
  - sends request to server (UDP or TCP)
  - waits for result (synchronous)
- server: determines local procedure from id, calls its skeleton
- *procedure skeleton*:
  - unmarshals parameters from external representation
  - makes local call to procedure
  - marshals result to XDR
  - returns datagram to client
- client stub:
  - receives result
  - unmarshals from XDR
  - returns result to local procedure call

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XDR

- RFC 1832 (Sun)
- language for describing data
- semantics: data representation in terms of octet stream
- a data item of n bytes is represented by $4 * i$ octets
  where $r = 4 * i - n < 4$ (padding)
- fixes “network” byte order:
  big-endian (most significant byte sent first)

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XDR data types

- signed/unsigned 32 bit integer (`int`)
- C-style enumeration; represented as signed 32 bit integer
- Boolean (`bool`); equivalent to
  `enum { FALSE = 0; TRUE = 1 } ident;`
- signed/unsigned 64 bit integer (`hyper`)
- floating point number: `float`, `double`, `quadruple`
- fixed length opaque data; length is `n`
  `opaque ident[n];`
- variable length opaque data; max length is `n` or $2^{32} - 1$ if unspecified
  `opaque ident1<n>; opaque ident2<>;`
- string type, like opaque, but with ASCII characters
  `string str1<n>; string str2<>;`

- arrays:
  - fixed length `typename obj[n];`
  - variable length `typename obj<n>`
- structure

```
struct {
     component-declaration-A;
     component-declaration-B;
     ...
} identifier;
```

- discriminated union

```
union switch (discriminant-declaration) {
      case discriminant-value-A:
        arm-declaration-A;
      case discriminant-value-B:
        arm-declaration-B;
      ...
      default:
        default-declaration;
} identifier;
```


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- `void` (no elements, no space)
- constant declaration

  ```
  const name-identifier = n;
  ```

- type definition, modifies declaration to bind the type to a name, rather than binding a variable to a type

  ```
  typedef declaration;
  ```

- optional data

  ```
  typename *identifier;
  ```

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XDR Example

```
const MAXUSERNAME = 32;     /* max length of a user name */
const MAXFILELEN = 65535;   /* max length of a file      */
const MAXNAMELEN = 255;     /* max length of a file name */

/*
 * Types of files:
 */
enum filekind {
   TEXT = 0,        /* ascii data */
   DATA = 1,        /* raw data   */
   EXEC = 2         /* executable */
};

/*
 * File information, per kind of file:
 */
union filetype switch (filekind kind) {
case TEXT:
   void;                           /* no extra information */
case DATA:
   string creator<MAXNAMELEN>;     /* data creator         */
case EXEC:
   string interpretor<MAXNAMELEN>; /* program interpretor  */
};
```

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```
/*
 * A complete file:
 */
struct file {
   string filename<MAXNAMELEN>; /* name of file    */
   filetype type;               /* info about file */
   string owner<MAXUSERNAME>;   /* owner of file   */
   opaque data<MAXFILELEN>;     /* file data       */
};
```

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Requirements for RPC protocol

1. unique specification of called procedure; by triple
   (program number, version number, procedure number)

2. matching responses to requests

3. authentication
   opaque to the RPC protocol:

```
enum auth_flavor {
   AUTH_NONE       = 0,
   AUTH_SYS        = 1,
   AUTH_SHORT      = 2
   /* and more to be defined */
};

struct opaque_auth {
   auth_flavor flavor;
   opaque body<400>;
};
```

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RPC message

```
struct rpc_msg {
  unsigned int xid;
    /* message id; used to match request/reply */
  union switch (msg_type mtype) {
  case CALL:
     call_body cbody;
  case REPLY:
     reply_body rbody;
  } body;
};
```

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RPC calls

```
struct call_body {
   unsigned int rpcvers;       /* must be 2 */
   unsigned int prog;
   unsigned int vers;
   unsigned int proc;
   opaque_auth  cred;
   opaque_auth  verf;
   /* procedure specific parameters start here */
};
```

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RPC replies

```
union reply_body switch (reply_stat stat) {
  case MSG_ACCEPTED:
     accepted_reply areply;
  case MSG_DENIED:
     rejected_reply rreply;
  } reply;
```

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RPC accepted replies

```
struct accepted_reply {
   opaque_auth verf;
   union switch (accept_stat stat) {
   case SUCCESS:
      opaque results[0];
      /*
       * procedure-specific results start here
       */
    case PROG_MISMATCH:
       struct {
          unsigned int low;
          unsigned int high;
       } mismatch_info;
    default:
       /*
        * Void.  Cases include PROG_UNAVAIL, PROC_UNAVAIL, GARBAGE_ARGS, and SYSTEM_ERR.
        */
       void;
    } reply_data;
};
```

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RPC rejected replies

```
union rejected_reply switch (reject_stat stat) {
case RPC_MISMATCH:
   struct {
      unsigned int low;
      unsigned int high;
   } mismatch_info;
case AUTH_ERROR:
   auth_stat stat;
};
```

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The RPC Language

```
program PING_PROG {
   /*** Latest and greatest version */
   version PING_VERS_PINGBACK {
      void
      PINGPROC_NULL(void) = 0;

      /*
       * Ping the client, return the round-trip time
       * (in microseconds). Returns -1 if the operation
       * timed out.
       */
      int
      PINGPROC_PINGBACK(void) = 1;
   } = 2;

   /*** Original version */
   version PING_VERS_ORIG {
      void
      PINGPROC_NULL(void) = 0;
   } = 1;
} = 1;

const PING_VERS = 2;      /* latest version */
```

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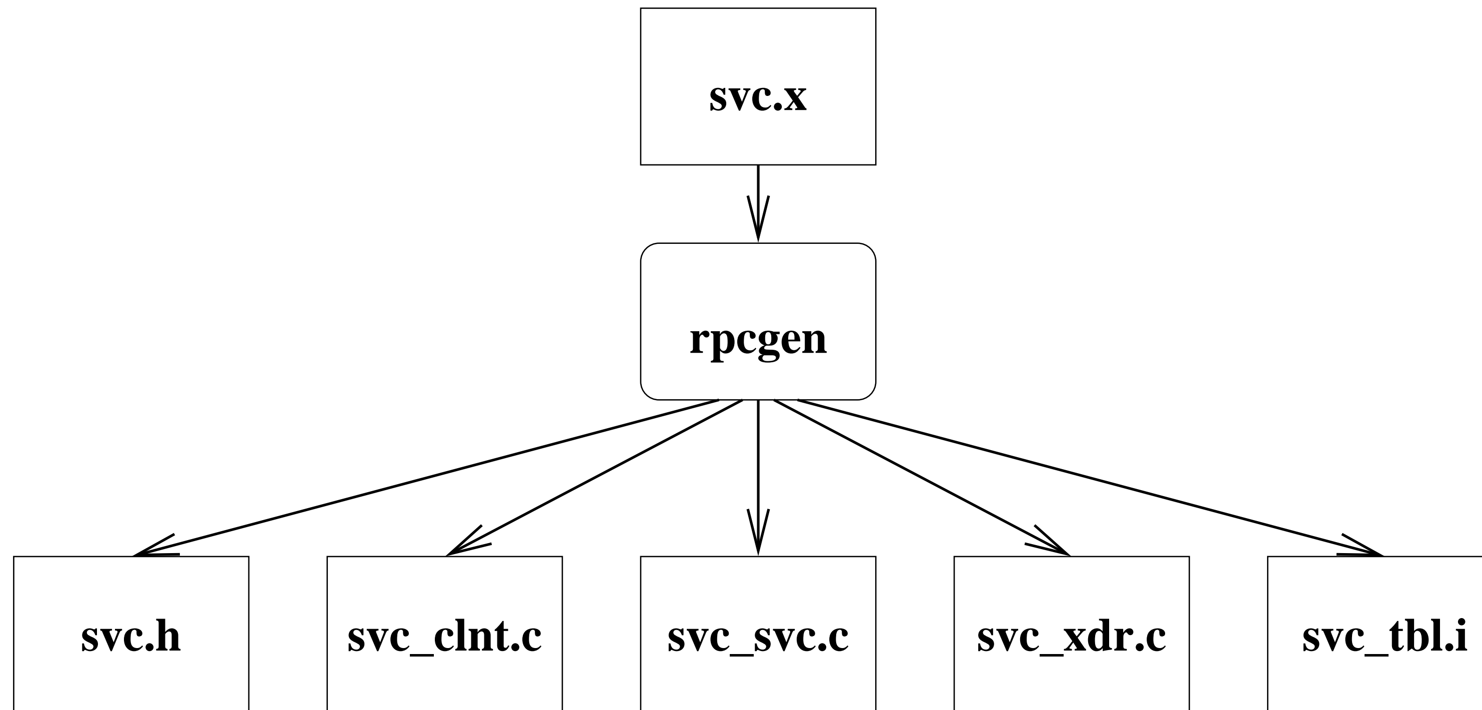
RPC programming



RPC example client code

```
#include "ping.h"

void
ping_prog_2(char *host)
{
	CLIENT *clnt;
	void  *result_1;
	char *pingproc_null_2_arg;
	int  *result_2;
	char *pingproc_pingback_2_arg;

	clnt = clnt_create (host, PING_PROG, PING_VERS_PINGBACK, "udp");
	if (clnt == NULL) { clnt_pcreateerror (host); exit (1);}

	result_1 = pingproc_null_2((void*)&pingproc_null_2_arg, clnt);
	if (result_1 == (void *) NULL) {
		clnt_perror (clnt, "call failed");
	}
	result_2 = pingproc_pingback_2((void*)&pingproc_pingback_2_arg, clnt);
	if (result_2 == (int *) NULL) {
		clnt_perror (clnt, "call failed");
	}
	clnt_destroy (clnt);
}
```

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