CprE 450/550X
Distributed Systems and Middleware

Inter-process Communication

Remote Procedure Call

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Readings for Today’s Lecture

- References
  - **Chapter 2 of “Distributed Systems: Principles and Paradigms”**
  - **Chapter 5 of “*Distributed Systems: Concepts and Design*”**

Remote Procedure Call (RPC)

- Paradigms in building distributed applications
- The RPC model
- Primitives
- Issues
- Case study: Sun RPC

Building Distributed Programs: Two Paradigms

Paradigms:

- Communication-Oriented Design
  - Start with communication protocol
  - Design message format and syntax
  - Design client and server components by specifying how they react to incoming messages

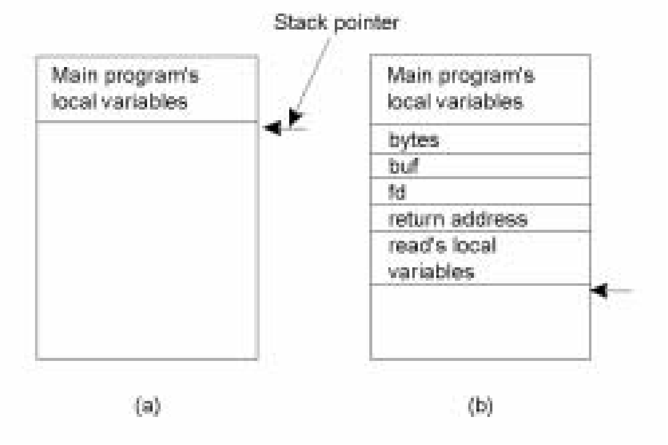
Problems:

- Protocol-design problems
- Application components as finite-state machines !?
- Focus on communication instead of application!

- Application-Oriented Design
  - Start with application
  - Design, build, test conventional implementation
  - Partition program

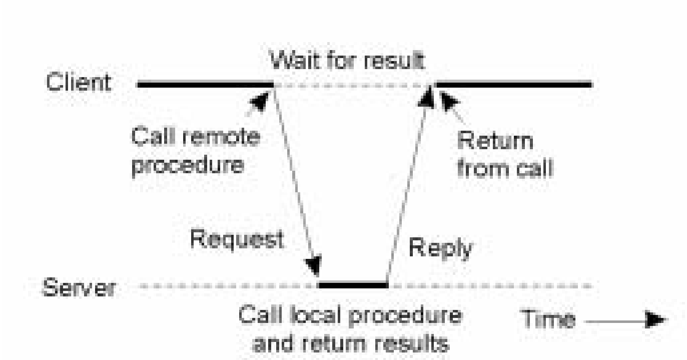
- Concurrency

Conventional Procedure Call



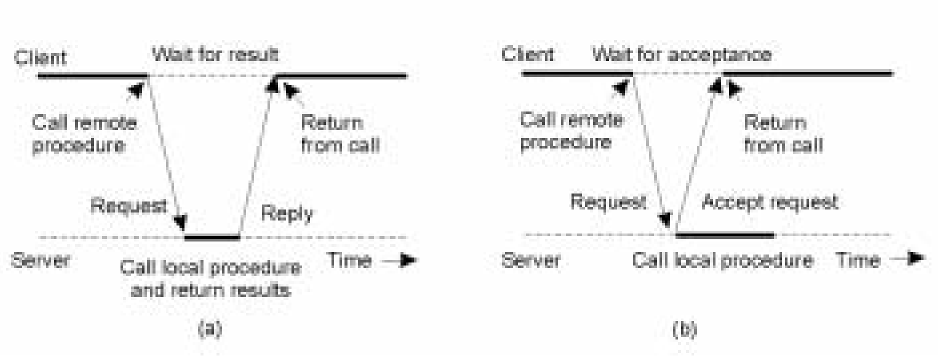
a) Parameter passing in a local procedure call: the stack before the call to read
b) The stack while the called procedure is active

RPC: Client and Server Stubs



- Principle of RPC between a client and server program.

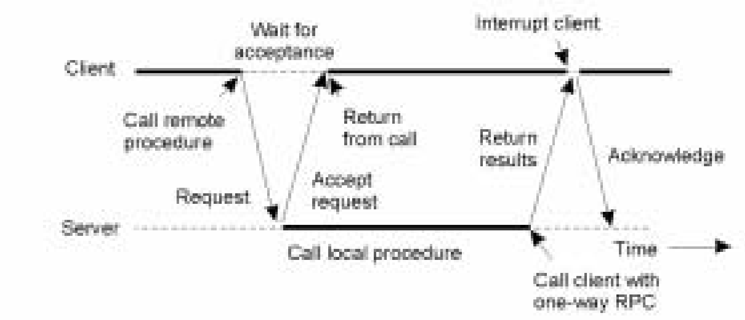
Asynchronous RPC (1)



a) The interconnection between client and server in a traditional RPC

b) The interaction using asynchronous RPC

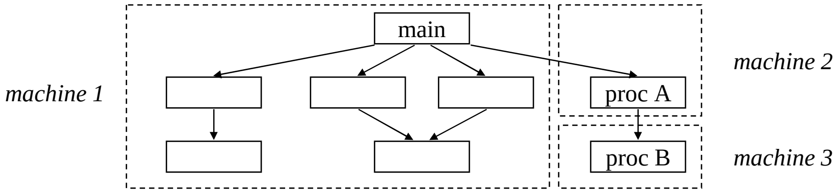
Asynchronous RPC (2)



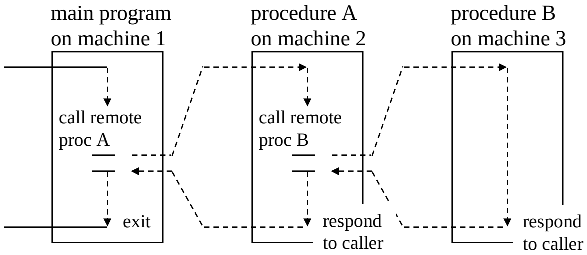
- A client and server interacting through two asynchronous RPCs

Model of Execution for RPCs

- Procedure-call structure of a program



- Model of execution with remote procedure call



RPC Properties

- Uniform call structure
- Type checking
- Full parameter functionality
- Distributed binding
- Recovery of orphan computations

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RPC Primitives

- Invocation at caller side

```
call service (value_args; result_args);
```

- Definition at server side
  - **declaration**

```
remote procedure service (in value_pars;
                          out result_pars);
begin body end;
```

  - **rendezvous statement**

```
accept service (in value_pars;
                out result_pars) -> body;
```

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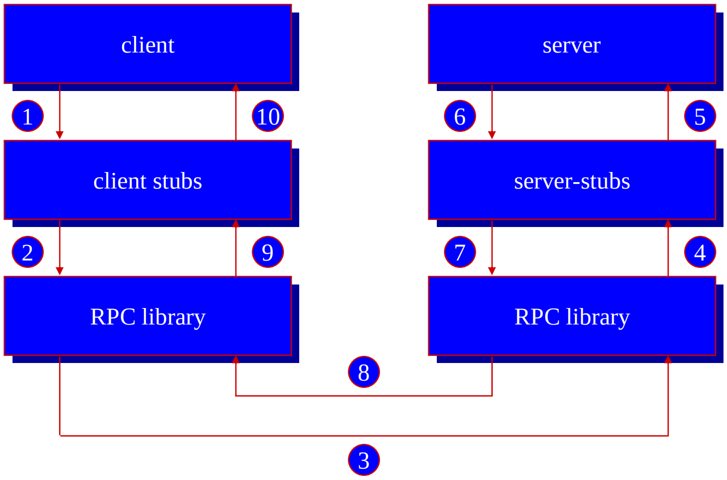
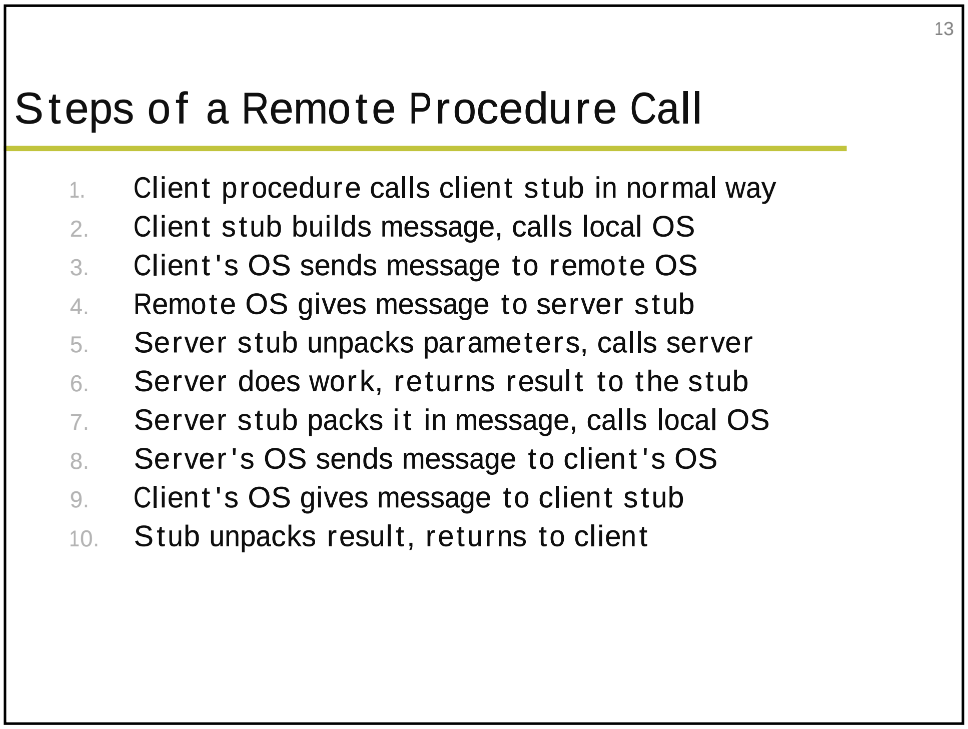
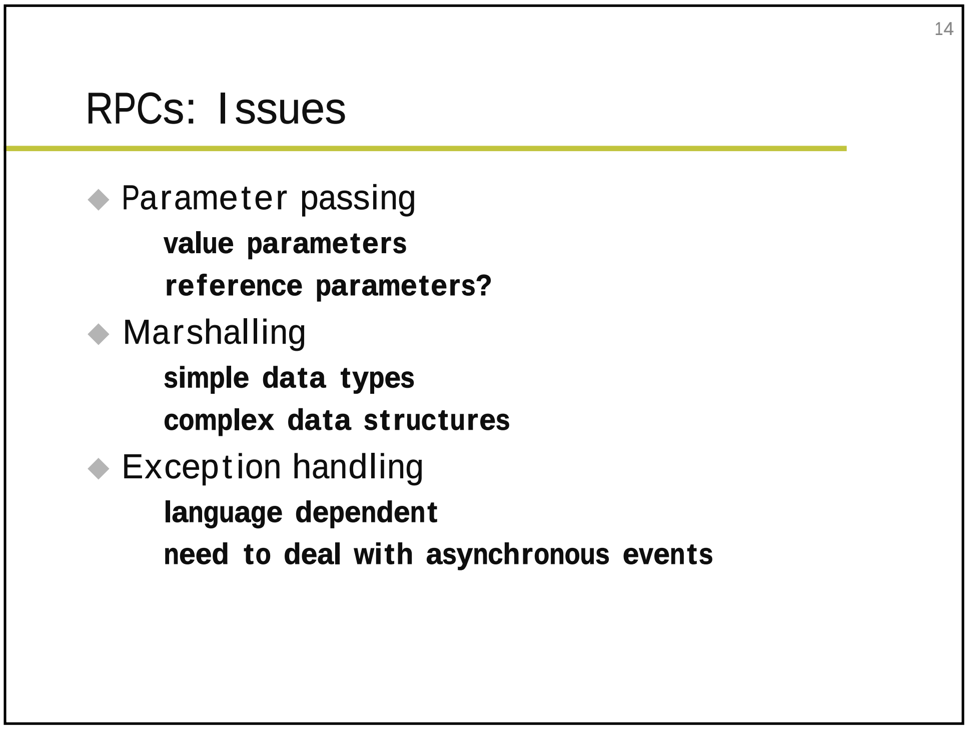
Structure of an RPC Call





Steps of a Remote Procedure Call

1. Client procedure calls client stub in normal way
2. Client stub builds message, calls local OS
3. Client's OS sends message to remote OS
4. Remote OS gives message to server stub
5. Server stub unpacks parameters, calls server
6. Server does work, returns result to the stub
7. Server stub packs it in message, calls local OS
8. Server's OS sends message to client's OS
9. Client's OS gives message to client stub
10. Stub unpacks result, returns to client



RPCs: Issues

- Parameter passing
  - **value parameters**
  - **reference parameters?**
- Marshalling
  - **simple data types**
  - **complex data structures**
- Exception handling
  - **language dependent**
  - **need to deal with asynchronous events**

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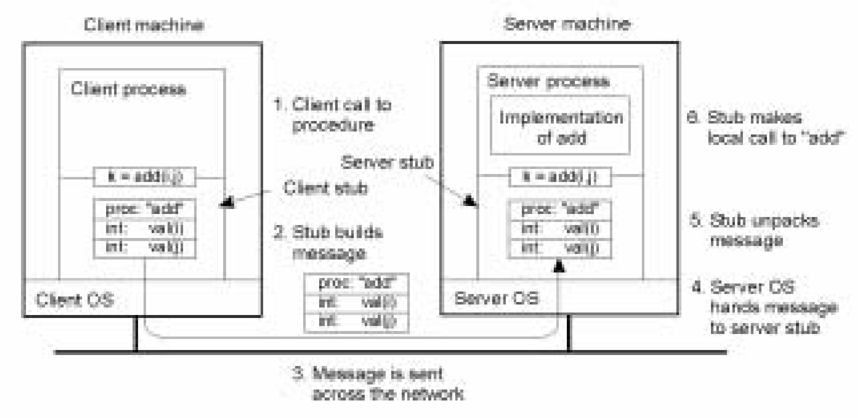
Passing Value Parameters



- Steps involved in doing remote computation through RPC

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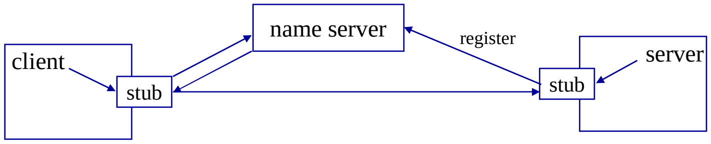
Locating Servers

- Broadcast requests

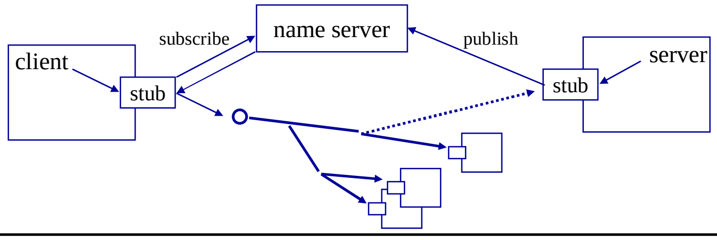
  broadcast call and process incoming replies

- Name servers

  server registers with name server



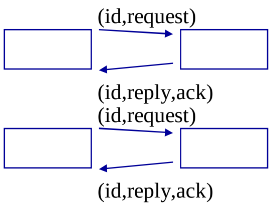
- Combination: publish/subscribe



Communication Protocols for RPC

- Reliable protocols: e.g. TCP
- Unreliable datagram protocols: e.g. UDP
- Specifically designed protocols: Example

Simple Call



Client times out and retransmits request.
Three cases:

- request lost
- server still executing
- ack lost

Complicated Call

- long gaps between requests
  - acknowledge each message transmission separately

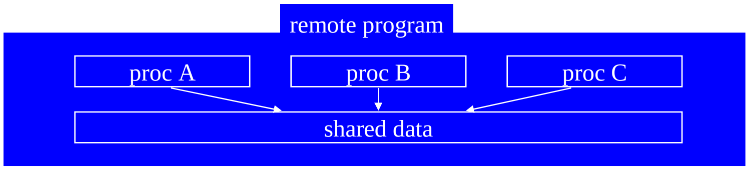
  or
  - periodically send "I-am-alive" message and use simple-call scheme.
- long messages (don't fit into packet)
  - segment message
  - segment-relative seq #'s
  - retransmission scheme for segments

RPC in Heterogeneous Environments

- Compile-time support
- Binding protocol
- Transport protocol
- Control protocol
- Data representation

Case Study: SUN RPC

- Defines format for messages, arguments, and results.
- Uses UDP or TCP.
- Uses XDR (eXternal Data Representation) to represent procedure arguments and header data.
- Compiler system to automatically generate distributed programs.
- Remote execution environment: remote program.



remote program

proc A

proc B

proc C

shared data

Mutually exclusive execution of procedure in remote program.

Identifying Remote Programs and Procedures

- Conceptually, each procedure on a computer is identified by pair :

(prog, proc)

***prog*: 32-bit integer identifying remote program**

***proc*: integer identifying procedure**

- Set of program numbers partitioned into 8 sets.

0x00000000 - 0x1fffffff	**assigned by SUN**
0x20000000 - 0x3fffffff	**assigned by local system manager**
0x40000000 - 0x5fffffff	**temporary**
0x60000000 - 0xffffffff	**reserved**

- Multiple remote program versions can be identified:

(prog, version, proc)

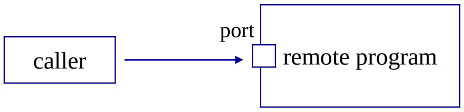
Example RPC Program Numbers

name	assigned no	description
portmap	100000	port mapper
rstatd	100001	rstat, rup, perfmeter
rusersd	100002	remote users
nfs	100003	network file system
ypserv	100004	yp (NIS)
mountd	100005	mount, showmount
dbxd	100006	DBXprog (debug)
ypbind	100007	NIS binder
walld	100008	rwall, shutdown
yppasswdd	100009	yppasswd

Communication Semantics

- TCP or UDP ?
- Sun RPC semantics defined as function of underlying transport protocol.
  - **RPC on UDP: calls can be lost or duplicated.**
- *at-least-once* semantics if caller receives reply.
- *zero-or-more* semantics if caller does not receive reply.
- Programming with zero-or-more semantics: *idempotent* procedure calls.
- Sun RPC retransmission mechanism:
  - **non-adaptive timeouts**
  - **fixed number of retransmissions**

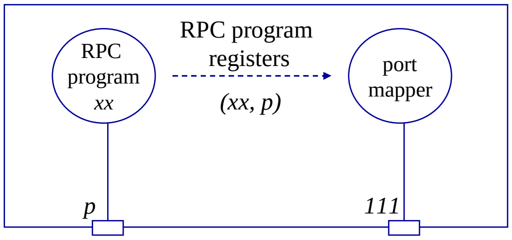
Remote Programs and Protocol Ports



program_id *vs.* port_id

(32 bit) (16 bit)

- Dynamic port mapping: *RPC port mapper*



port currently used
by this RPC program

well-known port
for port manager

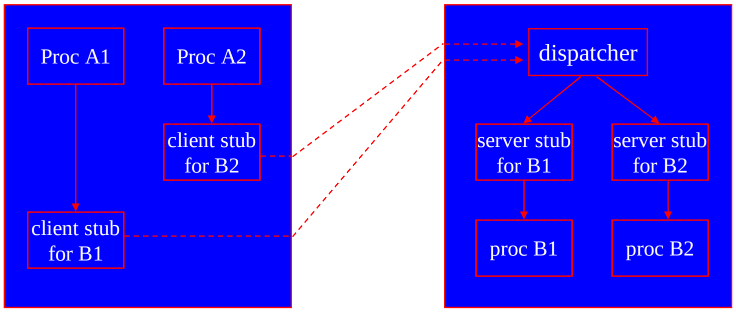
Sun RPC Message Format: XDR Specification

```
enum msg_type {  /* RPC message type constants */
      CALL  = 0;
      REPLY = 1;
};
```

```
struct rpc_msg {        /* format of a RPC message     */
  unsigned int mesgid; /* used to match reply to call */
  union switch (msg_type mesgt) {
      case CALL : call_body  cbody;
      case REPLY: reply_body rbody;
  } body;
};
```

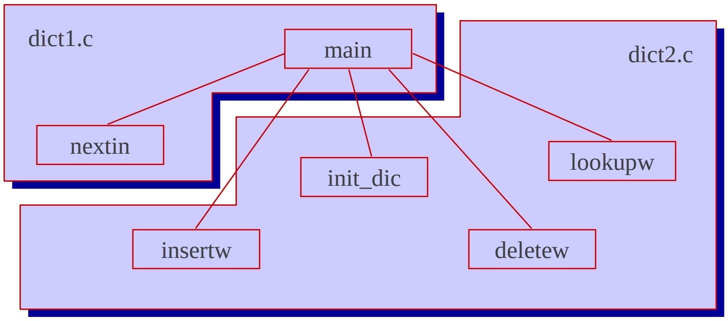
```
struct call_body {  /* format of RPC CALL                */
  u_int rpcvers;    /* which version of RPC?             */
  u_int rprog;      /* remote program number             */
  u_int rprogvers;  /* version number of remote prog */
  u_int rproc;      /* number of remote procedure        */
  opaque_auth cred; /* credentials for called auth.      */
  opaque_auth verf; /* authentication verifier           */
  /* ARGS */
};
```

Message Dispatch for Remote Programs

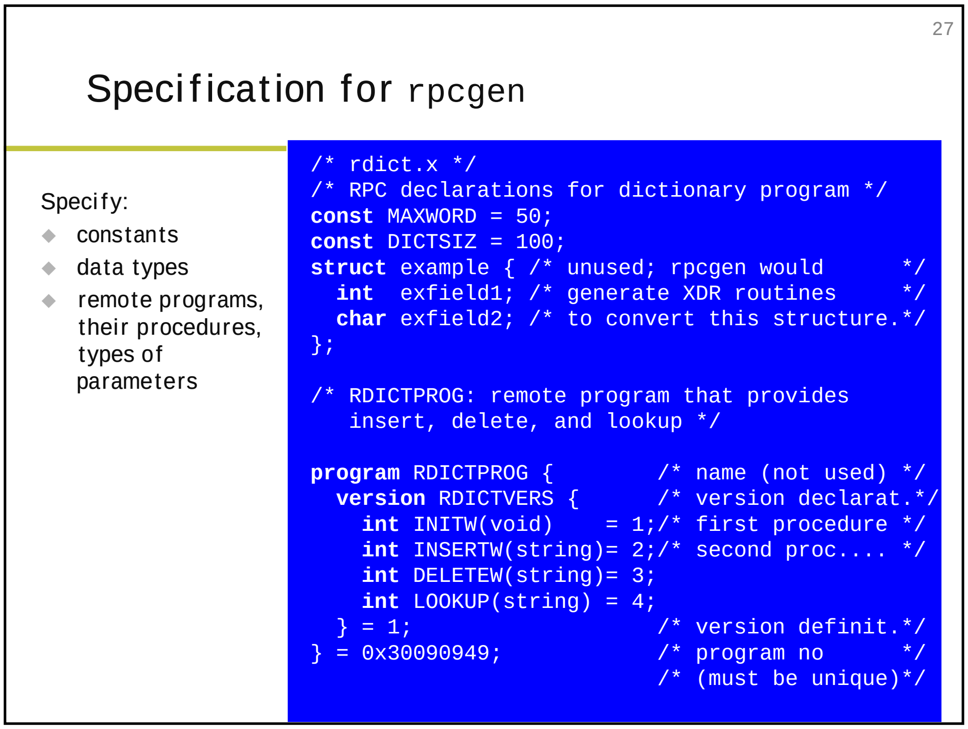


Creating Distributed Applications with Sun RPC Example: Remote Dictionary Using `rpcgen`

- Procedure call structure:



Procedures should execute on the same machines as their resources are located.



Specification for `rpcgen`

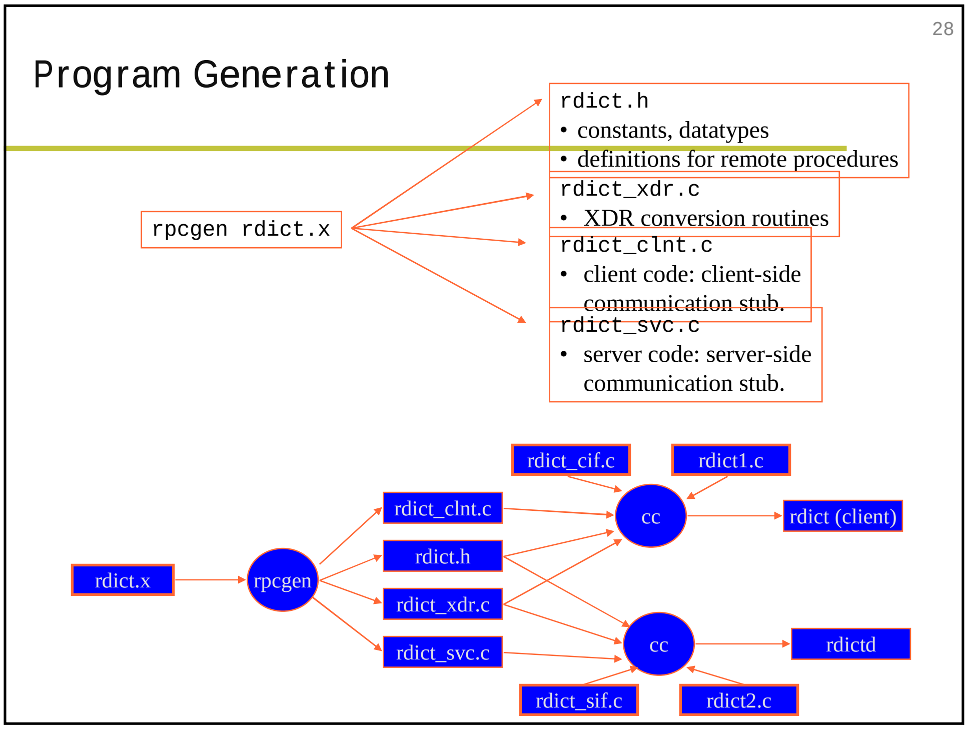
Specify:

- constants
- data types
- remote programs, their procedures, types of parameters

```
/* rdict.x */
/* RPC declarations for dictionary program */
const MAXWORD = 50;
const DICTSIZ = 100;
struct example { /* unused; rpcgen would      */
  int  exfield1; /* generate XDR routines     */
  char exfield2; /* to convert this structure.*/
};

/* RDICTPROG: remote program that provides
   insert, delete, and lookup */

program RDICTPROG {        /* name (not used) */
  version RDICTVERS {      /* version declarat.*/
    int INITW(void)    = 1;/* first procedure */
    int INSERTW(string)= 2;/* second proc.... */
    int DELETEW(string)= 3;
    int LOOKUP(string) = 4;
  } = 1;                   /* version definit.*/
} = 0x30090949;            /* program no      */
                           /* (must be unique)*/
```



Program Generation

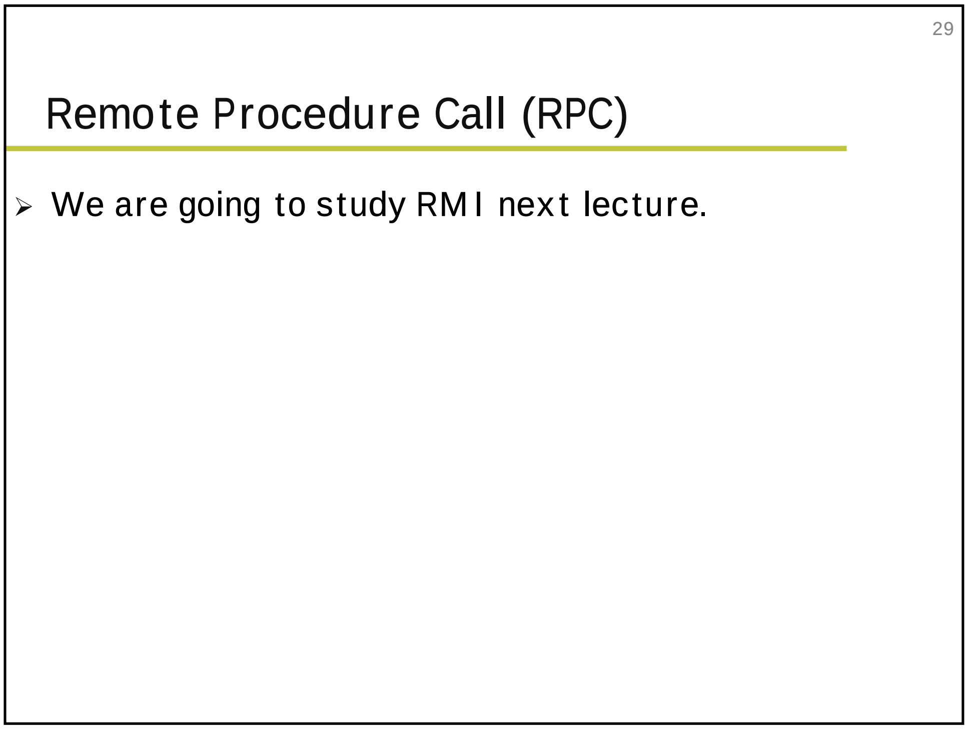
`rpcgen rdict.x`

`rdict.h`
- constants, datatypes
- definitions for remote procedures

`rdict_xdr.c`
- XDR conversion routines

`rdict_clnt.c`
- client code: client-side communication stub.

`rdict_svc.c`
- server code: server-side communication stub.



Remote Procedure Call (RPC)

- We are going to study RMI next lecture.