Remote Procedure Calls
CS 451 Lecture

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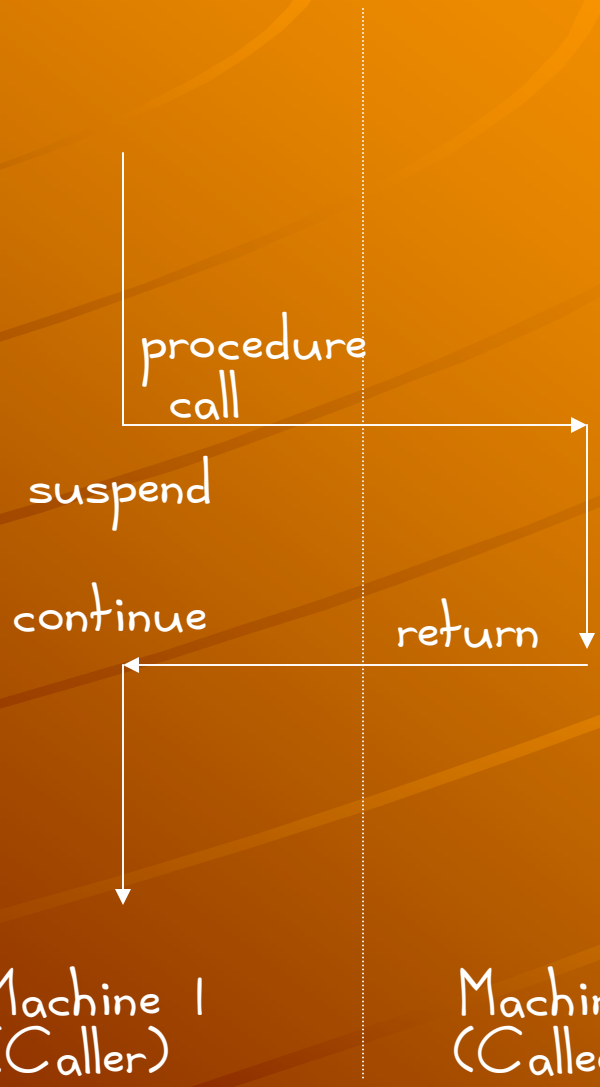
Procedure calls and RPC

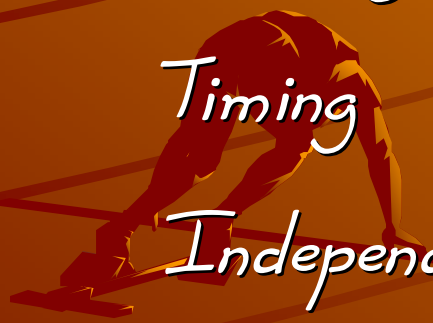
- Procedure call:
  well understood mechanism for *transfer of control and data* within a program on a single computer
- Why not use the same mechanism for *transfer of control and data* across a communication network?
- → Development of Remote Procedure Call

The basic idea



Aims behind RPC

- Make distributed computation easy, by removing unnecessary difficulties,
- Leaving only fundamental difficulties of building distributed systems, i.e.,



Timing

Independent failure of components

Coexistence of independent execution environments

Other performance issues

- Call must be efficient (e.g. they considered that it must be within factor of 5 beyond the necessary transmission times of network)

- Make semantics of RPC as powerful as possible without loosing simplicity or efficiency
  - else the gains of a single unified communication paradigm are lost

Failure semantics

- At least once
- At most once
- Exactly once

Design issues involved

- Precise semantics of a call in presence of a communication failure
- Semantics of address containing arguments in absence of shared address space
- Integration of RPC into an existing programming environment
- Binding procedure (how a caller determines the location and identity if callee)
- Activation
- Data and control transfer protocol
- Data integrity and security in network

Easy to use?

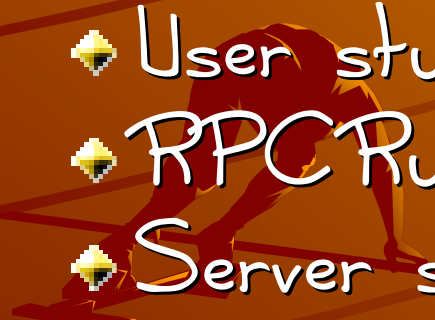
- What's the guiding principle?
- Make the semantics of remote procedure calls as close to local procedure calls as possible
- E.g. no timeout mechanism (in absence of machine or communication Failure)

Structure

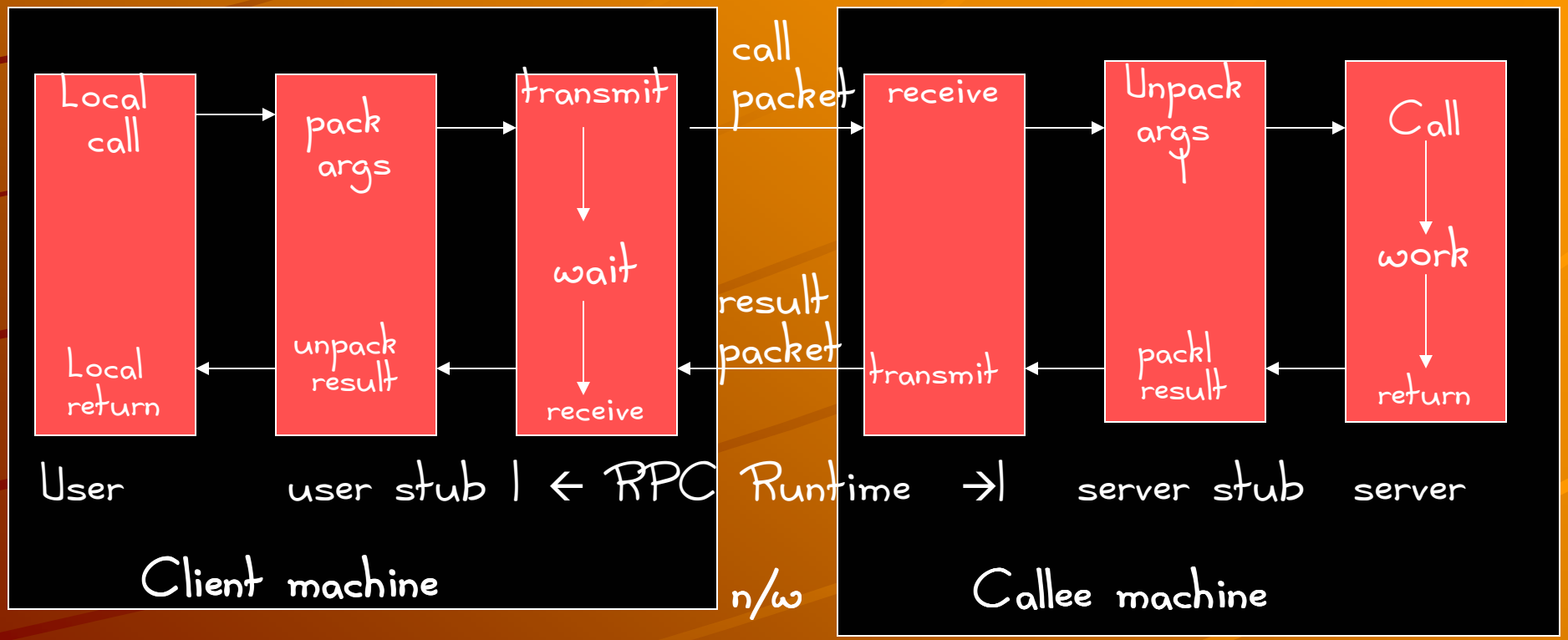
- Five pieces of program involved in one call:
  - User
  - User stub
  - RPCRuntime (communications package)
  - Server stub
  - Server

Normal local call

Normal local call



Components of an RPC system and interactions



The Binding mechanism

- How does a client of the binding mechanism specify what is wants to be bound to?
- How does the caller determine the machine address and specify to the callee the procedure to be invoked?
- Naming scheme and location

Naming Scheme

- Interface are exported and imported
- 2 components of a name:
  - Type
  - Instance

E.g. type: mail server, instance: a specific mail server

Location: Grapevine Distributed database

- Available from all sites
- Data is Replicated
- Highly reliable
- Supports 2 types of entries:

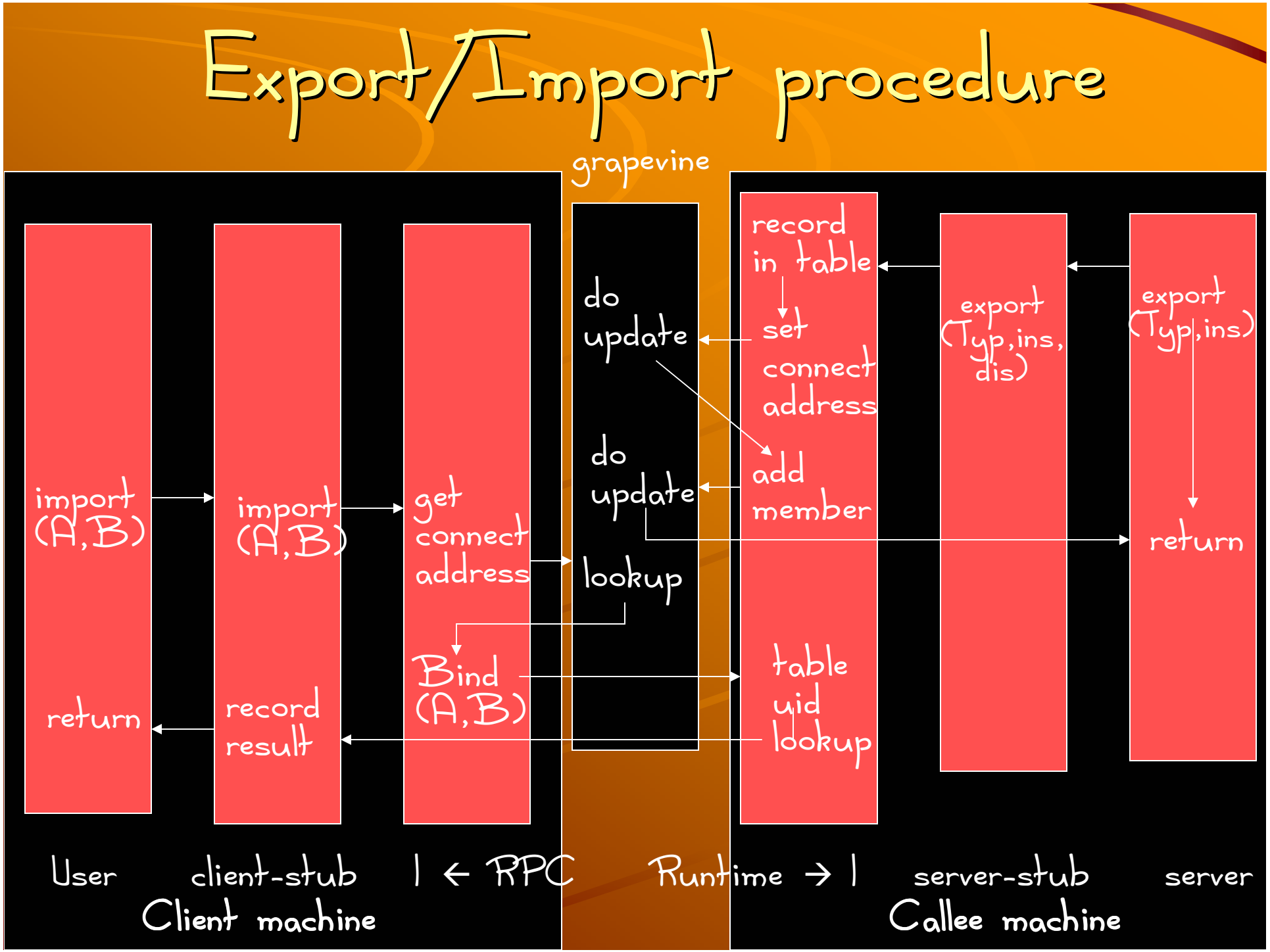
  - Individual entries
  - Group entries

Entries in the location database

- RName: connect site network address
- For an individual entry: one RName
- For a group entry: member list (list of Rnames)

- For interface types: Group entries
- For instances: individual entries

Export/Import procedure



Building an RPC infrastructure and the program development process

The following proposal has been iteratively worked out in class through your answers to my questions

Implement an RPC system?

Client:

```
....
X = foo (i);
```

Server:

```
int foo (int
  x) {
  return xxx;
}
```

for this high level view

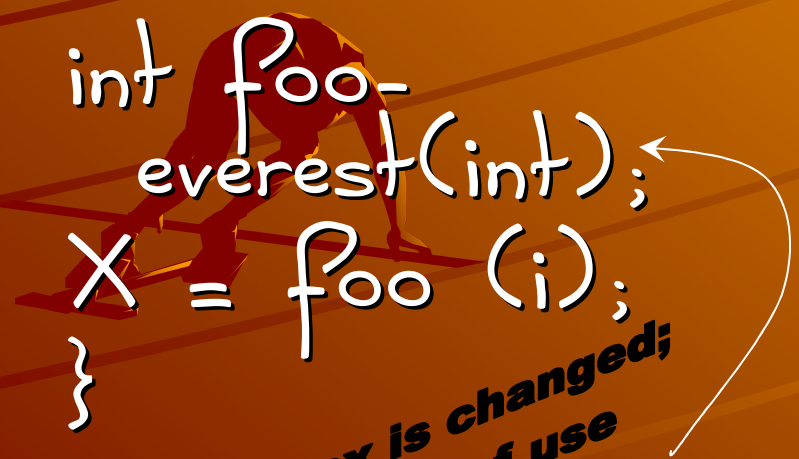
A proposal

Client:

```
main() {
....
int foo-
  everest(int);
X = foo (i);
}
```

Server:

```
int foo (int
  x) {
  return xxx;
}
```

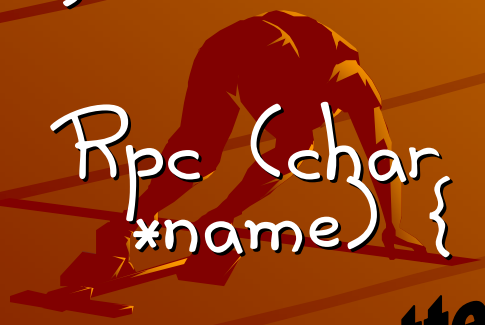


C syntax is changed; also ease of use is in danger!

Another proposal

Client::

```
int foo (int i) {
Rpc("everest");

}

Rpc (char
  *name) {

}
```



looks better,
but is this sufficient?

Server:

```
int foo (int
  x) {
  return xxx;
}
```

A workable proposal: with 1 input argument, 1 return result

```
Client::
int foo (int i) {
Int returnval;
Rpc("everest:int:int"
   , i, &returnval);
return returnval;
}

Rpc (char *name,
   ...) {

}
```

```
Server:


int foo (int
   x) {
   return x*x;
}
```

With 2 input arguments

```
Client::
int foo (int i, int j) {
Int returnval;
Rpc("everest:int:int:int",
   i, j, &returnval);
return returnval;
}

Rpc (char *name, ..) {

}
```

reusable part of client stub

Server:

```
int foo (int
   x) {
   return xxx;
}
```

Making it independent of machine name, and adding fn name

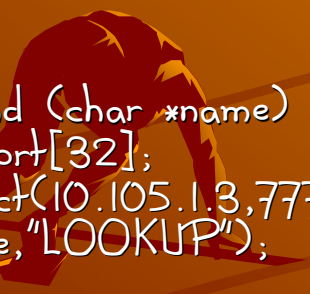
```
Client::
int foo (int i, int j) {
Int returnval;
Rpc("foo:int:int:int", i,
   j, &returnval);
return returnval;
}

Rpc (char *name, ..) {

}
```

```
Server:

int foo (int
   x) {
   return x**x;
}
```

but how do you bind to server?

Making it independent of machine name, and adding fn name

```
Client::
int foo (int i, int j) {
Int returnval;
Rpc("foo:int:int:int", i, j, &returnval);
return returnval;
}

Rpc (char *name, ..) {
Char ip_port[32];
 s=bind(name);
....
}
Char * bind (char *name) {
Char ip_port[32];
s = Connect(10.105.1.3,7777);
s.send(name,"LOOKUP");
s.read(ip);
Return ip_port;
}
```



```
Bind server/name server::

Main () {

Char ip_port[32];

    while (1) {

        socket serv = listen(7777);
        serv.read(char *arg, char
    *request);
        ip_port = tablelookup
    (request);
        serv.send(ip_port);

    }
}
```

Turning bind/name server into an RPC server

```
Client::
int foo (int i, int j) {
Int returnval;
Rpc("foo:int:int:int", i, j, &returnval);
return returnval;
}

Rpc (char *name, ..) {
Char ip_port[32];
If (name=="lookup"
   ip_port=getbindserver_ip_port();
Else ip_port = lookup (name);
}
Char * getbindserver_ip_port() {

}
```

```
Bind server/name server::

Table t;

Char *Lookup (char *fnname) {
   ...
   return (t.fetch (fnname))
}

Int register (char *fnname, char ip,
   int port) {

   return t.add(fnname, ip, port);
}
```

Separating reusable component from client code

Client.c

```
... x = foo (10); ..
}
```

ClientStub.c

```
int foo (int i, int j) {
Int returnval;
Rpc("foo:int:int:int", i, j, &returnval);
return returnval;
}
```

Rpc.c

```
Rpc (char *name, ..) {
Char ip_port[32];
If (name=="lookup"
   ip_port=getbindserver_ip_port();
Else ip_port = lookup (name);
}
Char * getbindserver_ip_port() {
```

Bindserver.c

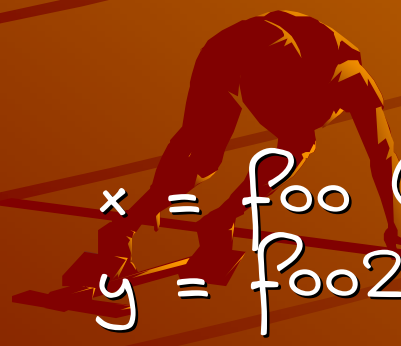
```
Table t;

Char *Lookup (char *fnname) {
   ...
   return (t.fetch (fnname))
}

Int register (char *fnname, char ip,
   int port) {

   return t.add(fnname, ip, port);
}
```

Focusing on Rpc.c

```
Char * GLOBAL_bind_ip_port;

Rpc (char *name, ..) {
Char ip_port[32];
If (name== "bindserv"
  ip_port=getbindserver_ip_port();
Else ip_port = lookup (name);
.....
}

Char * getbindserver_ip_port() {
  return GLOBAL_bind_ip_port;
```

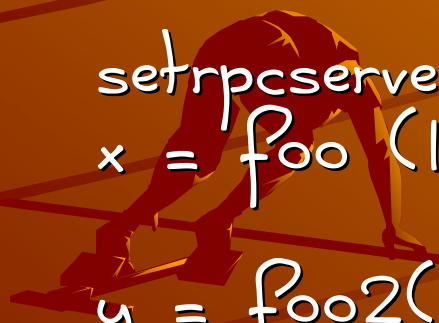
Client.c again: with bind server called automatically from within foo to locate foo

```
#include <rpc.h>
Main () {

  setbindserver(servip, port, AUTO || PERCALL/ONCE);

  x = foo (10);
  y = foo2(...);

}
```



Client.c again: with bind server called explicitly from client to locate foo

```
#include <rpc.h>
Main () {

 setrpcserver(bindserverip, bindserverport);
 <fooserverip,fooserverport> = lokup("foo")1

 setrpcserver(fooserip,fooserverport);
 x = foo (10);

 y = foo2(..);  // local or remote

}
```



Setting server addresses: parameter passing vs. external variables (side effects)

Change rpc.c accordingly

- Pass on server ip and port to low level networking routines, through stub
- The stub sees these values as set by client.c through a side effect
- OO paradigms do better on this aspect

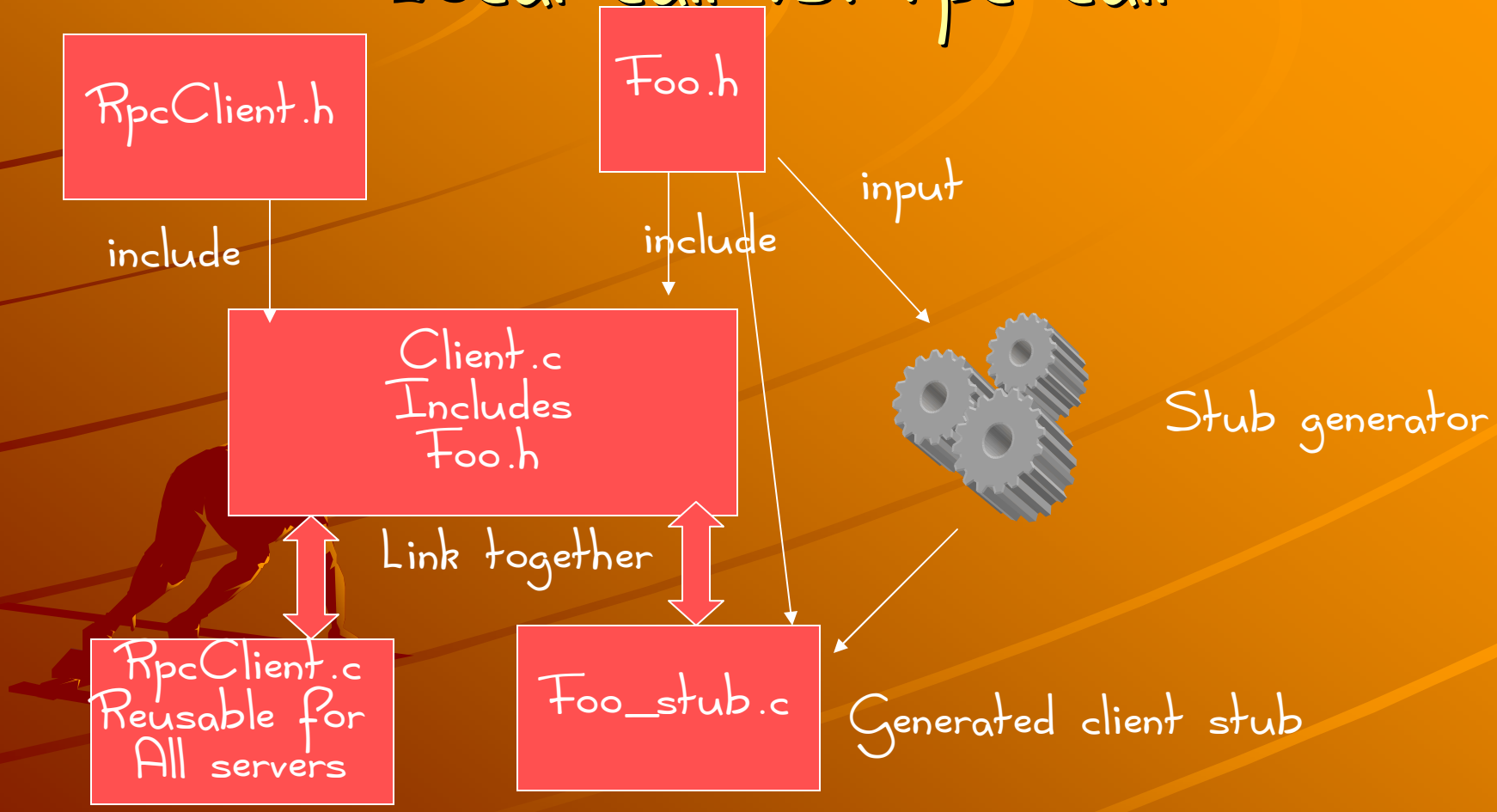
Focusing on Rpc.c

```
Rpc (char *name, server, port..) {
Char ip_port[32];
Pack arguments into one byte(char) * packet
Call low level socket layer
Receive result (through low level networking
  call)
Return;
}
```

Client.c again

```
#include <rpc.h>
Main () {

setrpcserver(servip, port);
x = foo (10);

setrpcserver(servip, port);
y = foo2(..);

}
```

Client side RPC infrastructure: Local call vs. rpc call



Server.c

```
Main() {

    initRPC();
    export_foo ();
      serviceloop();
    Program never reaches this point
}
```

Rpcinit and serviceloop

Rpcinit: create serverport

Serviceloop:

conn=Listen on serverport

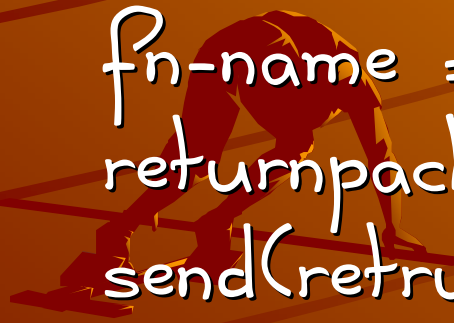
receive request packet on conn

fn-name = packet.extractname;

returnpacket=dispatch(fn-name,packet);

send(retrunpacket) on conn

repeat serviceloop



Fn_name includes signature

Export_foo

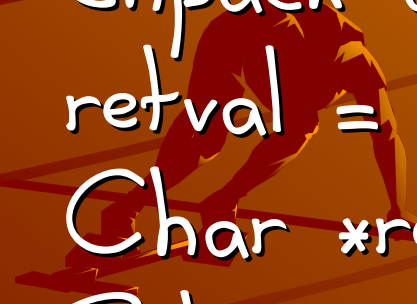
```
addentry("foo",
         (fn_ptr *) stub_foo,
"int:int");
```

Dispatch(char *fnname, byte*packet);

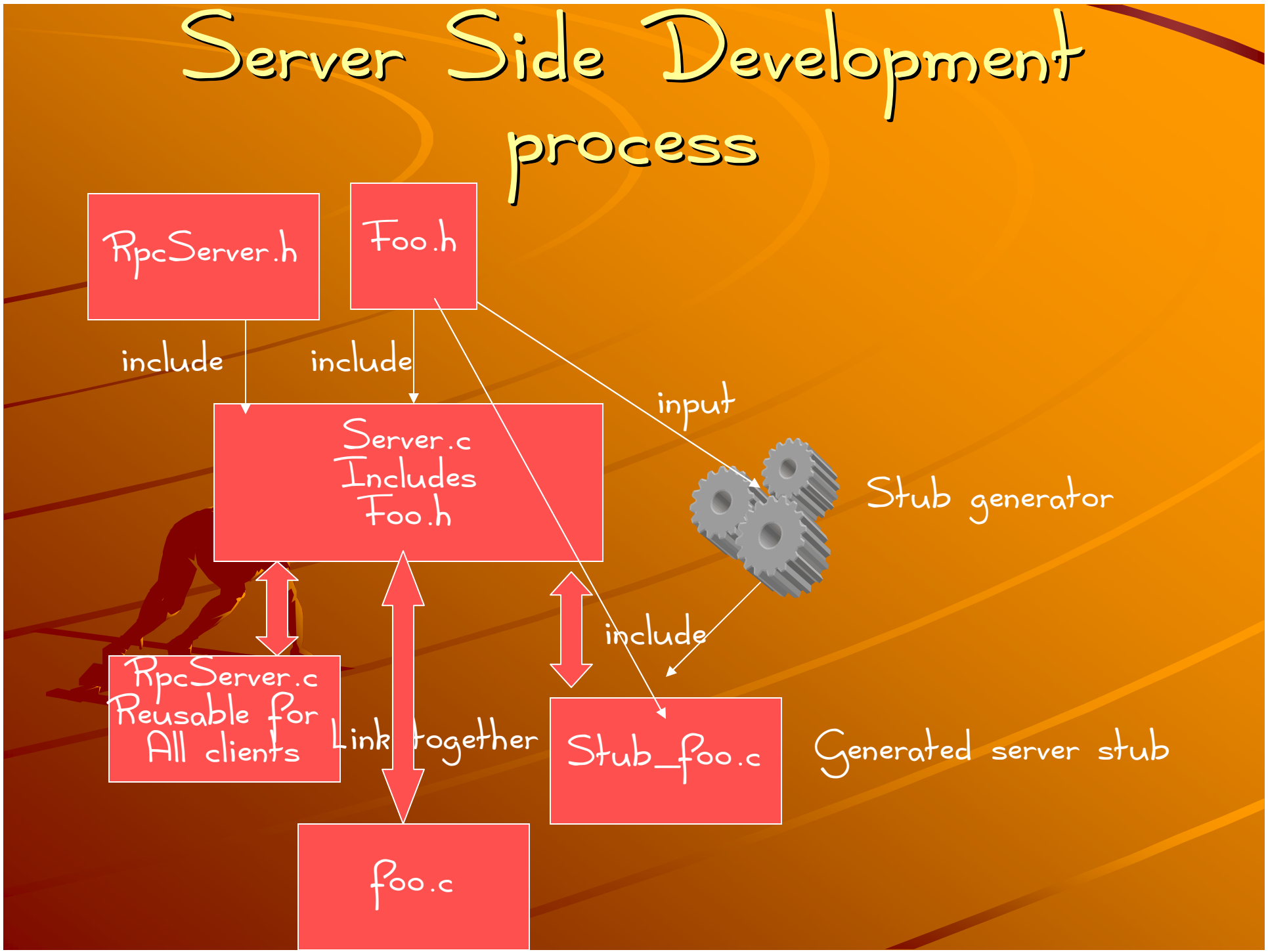
```
(fnptr *) stub = lookup(fnname);
Char *returnpacket=
  ((fn *)(char *))(stub)(packet);
Return returnpacket;
```

Stub_foo(byte *packet)

```
Local arg1, ...argn
Local retval
Unpack arg1..argn from packet
retval = Foo (arg1...argn)
Char *ret=Pack (retval)
Return ret;
```



Server Side Development process



Using name service at server side

- Use a name server as an RPC server to register the server ip and port for a given function
- This is similar to its counterpart in client: where we used the name server as an RPC server to perform a lookup operation to obtain server ip, port for a given name of a function

Class proposal ends

Readings

- Andrew Birrell and BJ Nelson: Implementing Remote Procedure Calls, ACM TCOS Feb 1984