Data Representation and Remote Procedure Calls

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Topics

- External data representation
  - Motivation
  - Approaches
  - NDR, ASN.1, and XDR
- Remote procedure calls
  - Concepts
  - ONC RPC
    - General operation
    - Code example

Need for Data Representation (1)

- Network applications pass many types of data
  - Characters and character strings
  - Integers (of different lengths)
  - Floats (of different lengths)
  - Arrays and structures (flat types)
  - Complex types (using pointers)
- Different host architectures may use different internal representations
  - Networked environments are often heterogeneous

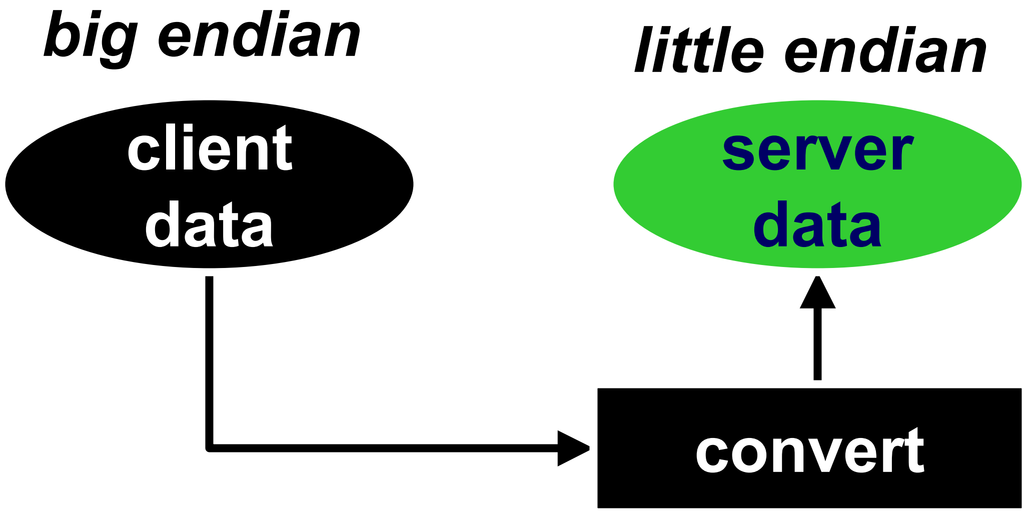
Need for Data Representation (2)

- **Example: $(300)_{10} = (13C)_{16}$**
  - **Stored as a long integer: 00 00 01 3C**
  - **“Big endian” versus “little endian”**

	big endian	***little endian***
byte i:	**00**	**3C**
byte i+1:	**00**	**01**
byte i+2:	**01**	**00**
byte i+3:	**3C**	**00**

Potential Solutions (1)

- **Asymmetric conversion**
  - Convert at one end (client or server)
  - Must know the host type of destination or source
  - With N types of hosts, need N(N-1) converters total.
  - Sometimes known as “receiver-makes-right”
  - Basis for NDR

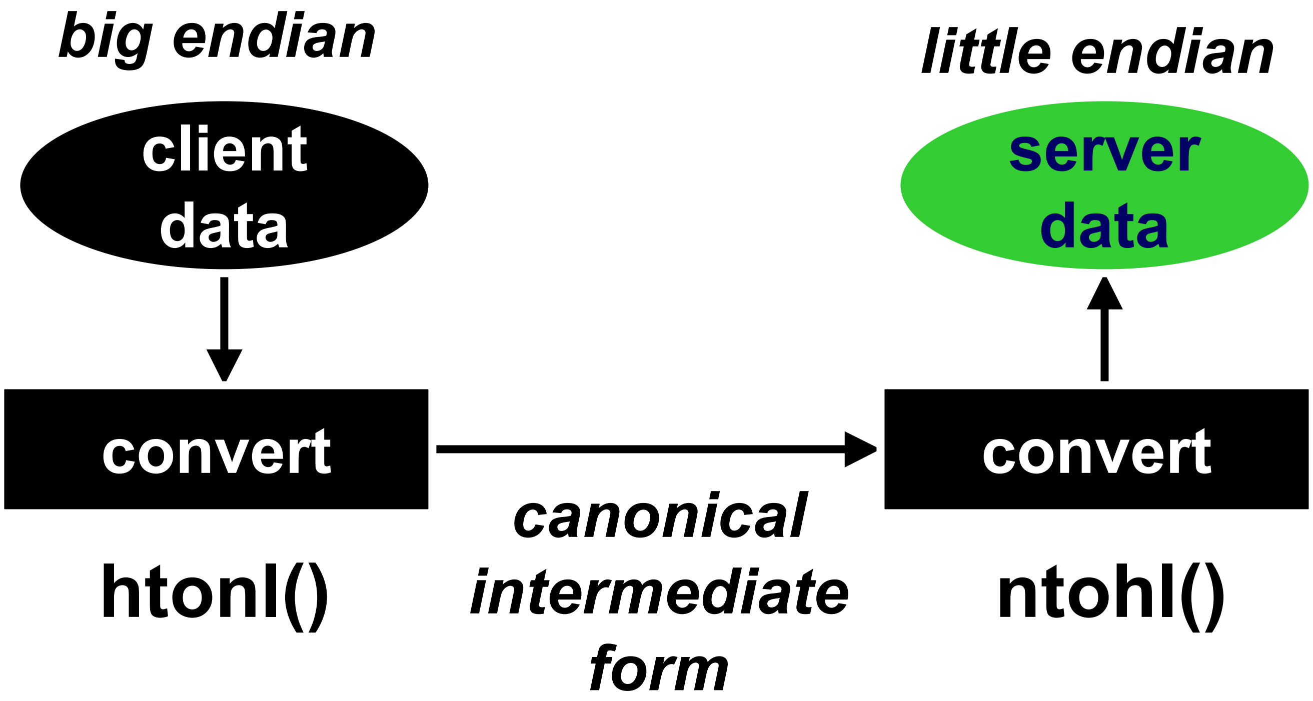


Potential Solutions (2)

- **Symmetric conversion**
  - **Convert to and from a *canonical intermediate form* -- an external data representation**
  - **Flexible and portable, but at a cost in computation**
    - **Conversion required even if client and server use the same internal representation**
  - **With N types of hosts, requires 2N converters**
    - **Fewer converters than for asymmetric conversion**
    - **But, N is usually small**
  - **Basis for XDR and ASN.1**

Potential Solutions (3)

- **Symmetric conversion (continued)**



Network Data Representation (1)

- NDR is used in the Distributed Computing Environment (DCE)
- Uses asymmetric “receiver-makes-right” approach
- Format
  - Architecture tag at the front of each message
    - “Big endian” or “little endian”
    - ASCII or EBCDIC
    - IEEE 754 or other floating point representation

Network Data Representation (2)

- **Architecture tag**

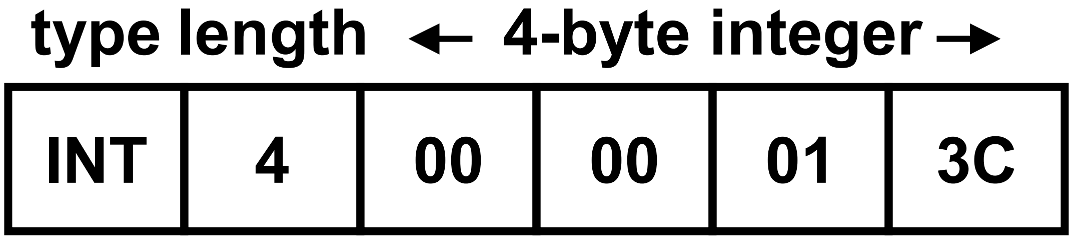
4	4	8	8	8
Integr Rep	Char Rep	Float Rep	Extension 1	Extension 2

Abstract Syntax Notation One (1)

- ASN.1 is an ISO standard
  - Scope is broader than network data representation
  - Basic Encoding Rules (BER) defines representation
- Uses a canonical intermediate form (symmetrical)
- Uses a triple to represent each data item
  - < tag, length, value >
  - Tag defines type (usually 8 bits)
  - Length is number of bytes in value field
  - Value is in canonical intermediate form

Abstract Syntax Notation One (2)

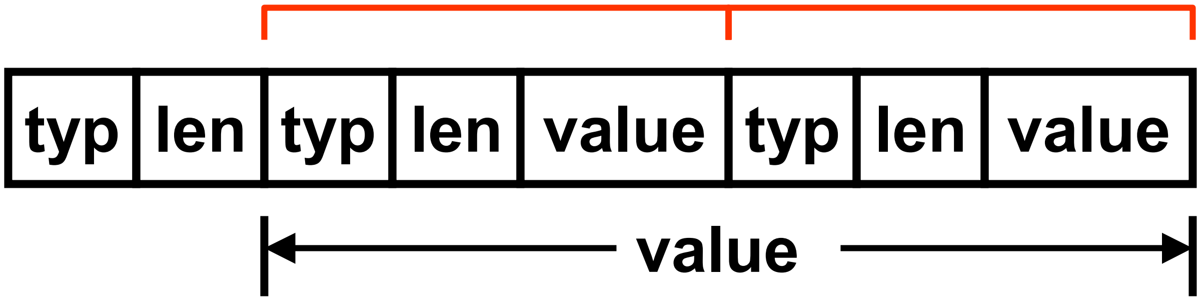
- Example



type length ← 4-byte integer →

INT 4 00 00 01 3C

- Compound data types can be represented by nesting primitive types

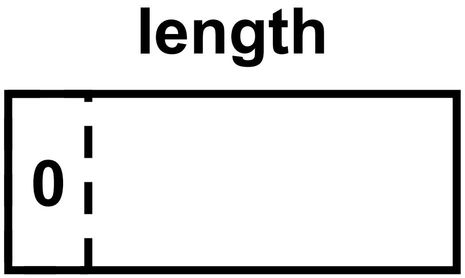


typ len typ len value typ len value

value

Abstract Syntax Notation One (3)

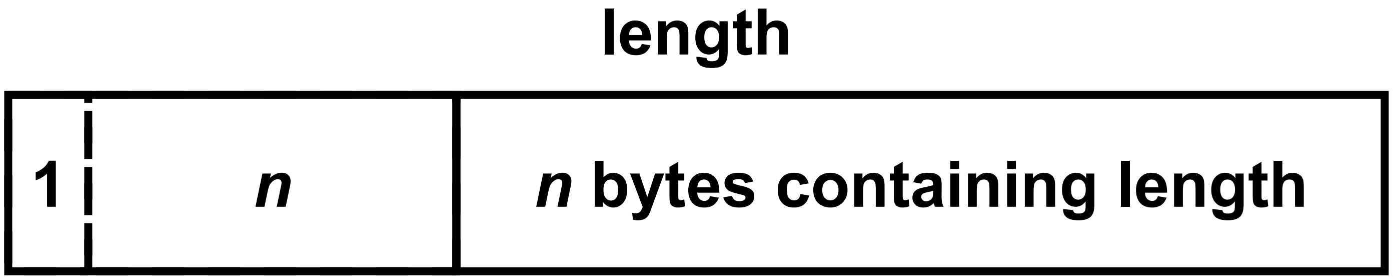
- **Length field can be made arbitrarily large**
  - **1- to 127-byte value**



length

0

Greater than a 127-byte value



length

1 ***n*** ***n* bytes containing length**

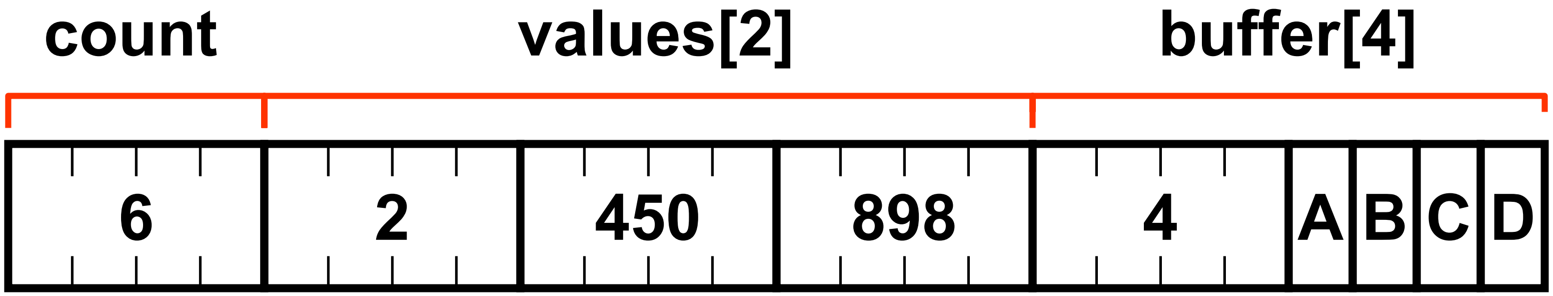
External Data Representation (1)

- XDR is used with SunRPC (Open Network Computing RPC)
  - Defined in RFC 1014
- Uses a canonical intermediate form (symmetrical)
- Types are implicit
  - XDR codes data, but not the type of data
  - Type of data must be determined by application protocol
- Tags are not used except to indicate array lengths

External Data Representation (2)

- **Example XDR encoding of a structure**

```
struct example {
         int  count;
         int  values[2];
         char buffer[4];
}
```



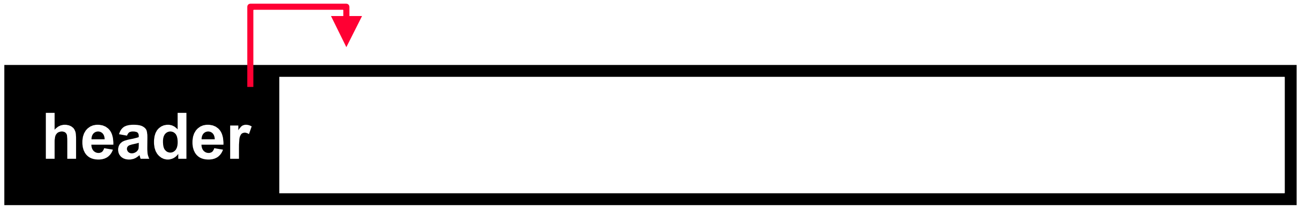
count values[2] buffer[4]

6 | 2 | 450 | 898 | 4 | A | B | C | D

Creating an XDR Data Stream (1)

1) Create buffer

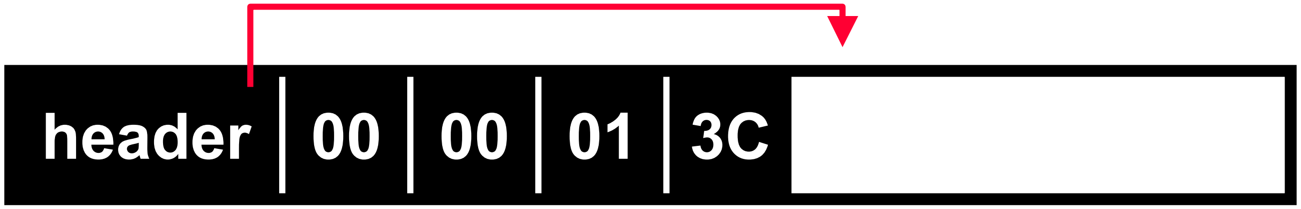
- xdrmem_create(xdrs, buf, BUFSIZE, XDR_ENCODE);



header

2) Make calls to build buffer

- int i = 300;
  xdr_int(xdrs, &i);



header 00 00 01 3C

Creating an XDR Data Stream (2)

- Sample routines (see fig 20.4 in text)
  - xdr_bool()
  - xcr_bytes()
  - xdr_enum()
  - xdr_float()
  - xdr_vector()
  - xdr_string()
  - xdr_opaque()
- Same calls are used to encode and decode
- Stream header specifies direction
  - For decode: xdrmem_create(xdrs, buf, BUFSIZE, XDR_DECODE);

Comparing XDR, ASN.1, and NDR

- Symmetric versus asymmetric trade-off for comparing ASN.1 and XDR to NDR
  - Potentially more converters needed for NDR, but number of different host types is small
  - Overhead of type fields
  - Conversion can often be avoided
- Comparing ASN.1 and XDR
  - XDR has less overhead than ASN.1 since it does not use tags
  - XDR adheres to natural byte boundaries
  - Expressiveness of ASN.1 is very rich, more flexible than XDR

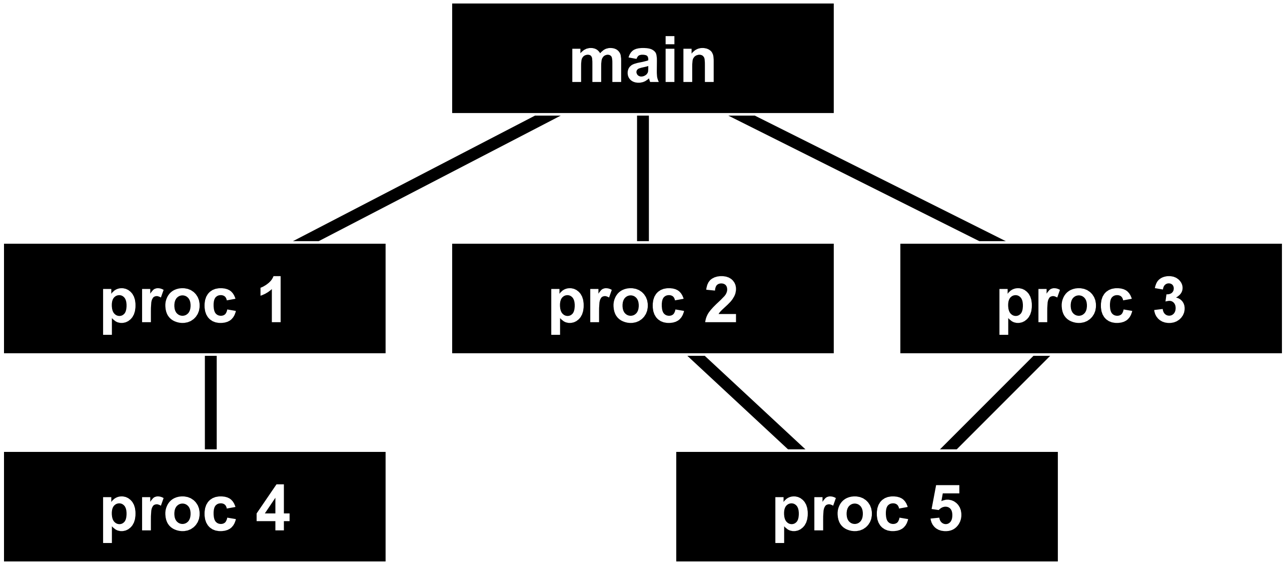
Remote Procedure Calls

- Remote Procedure Call (RPC) is an alternate model for networked applications
- Used for many standard applications
  - NFS
  - NIS, NIS+
  - Microsoft Exchange Server
  - and others …
- Closely associated with data representation
  - Function parameters must pass over the network

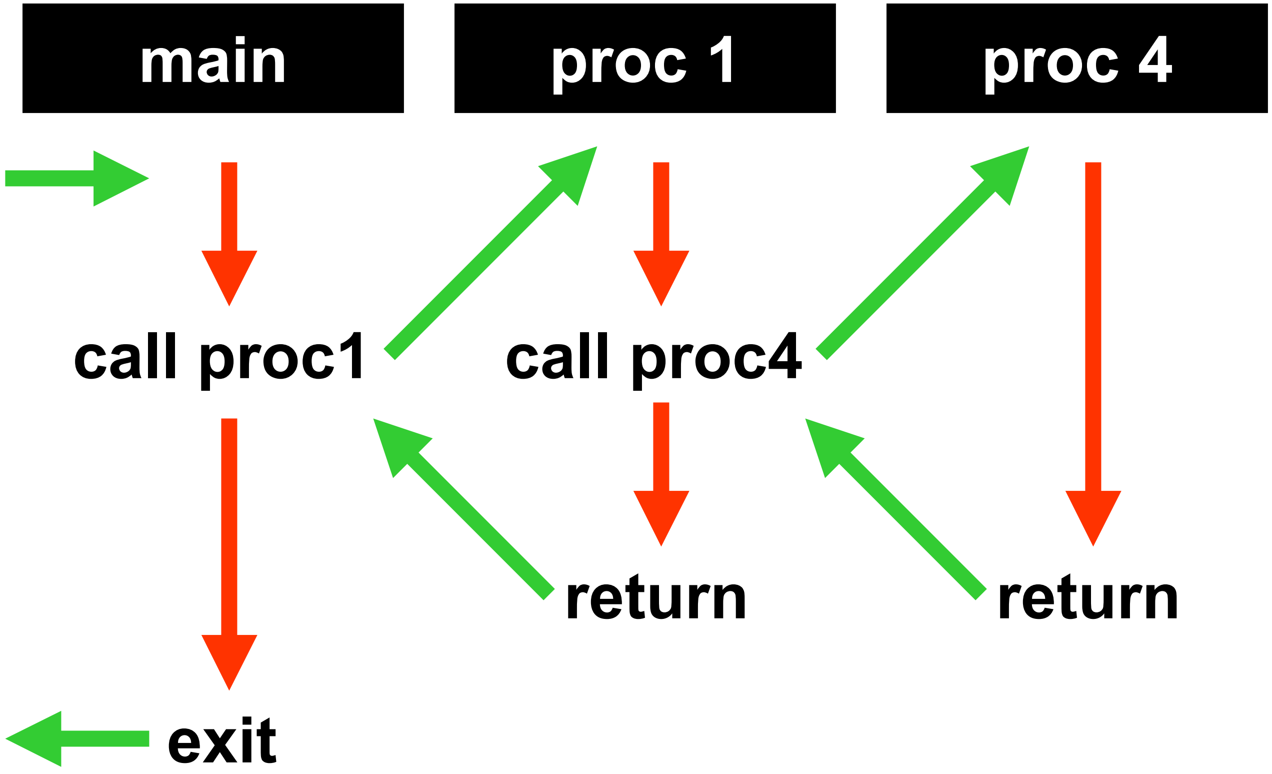
Models for Distributed Applications

- **Communication-oriented design**
  - **Focus on protocol and communications**
  - **Our approach to date**
- **Application-oriented design**
  - **Focus on application program structure and make communications “transparent”**
  - **RPC approach**

A Traditional Program (1)



A Traditional Program (2)



main

proc 1

proc 4

call proc1

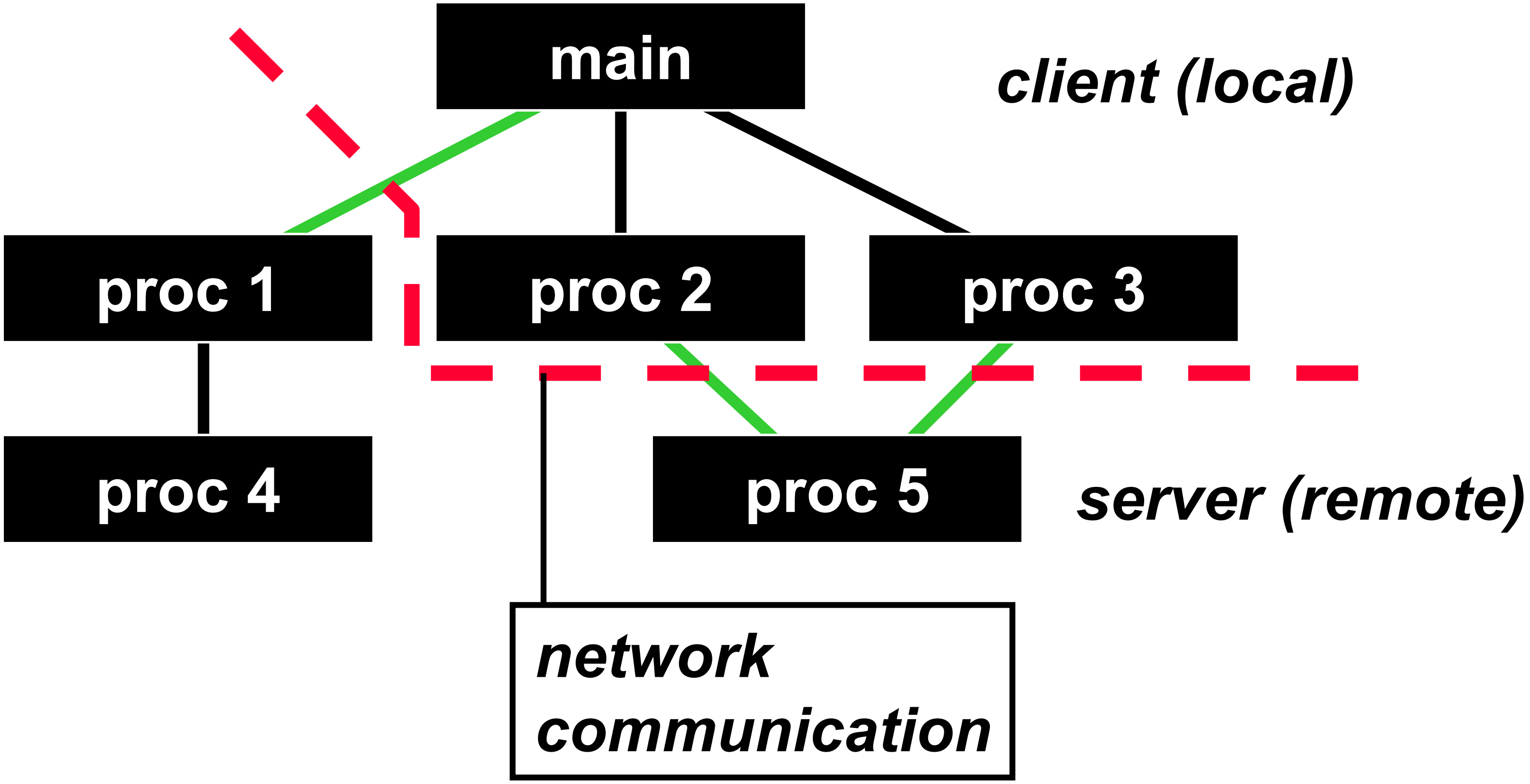
call proc4

return

return

exit

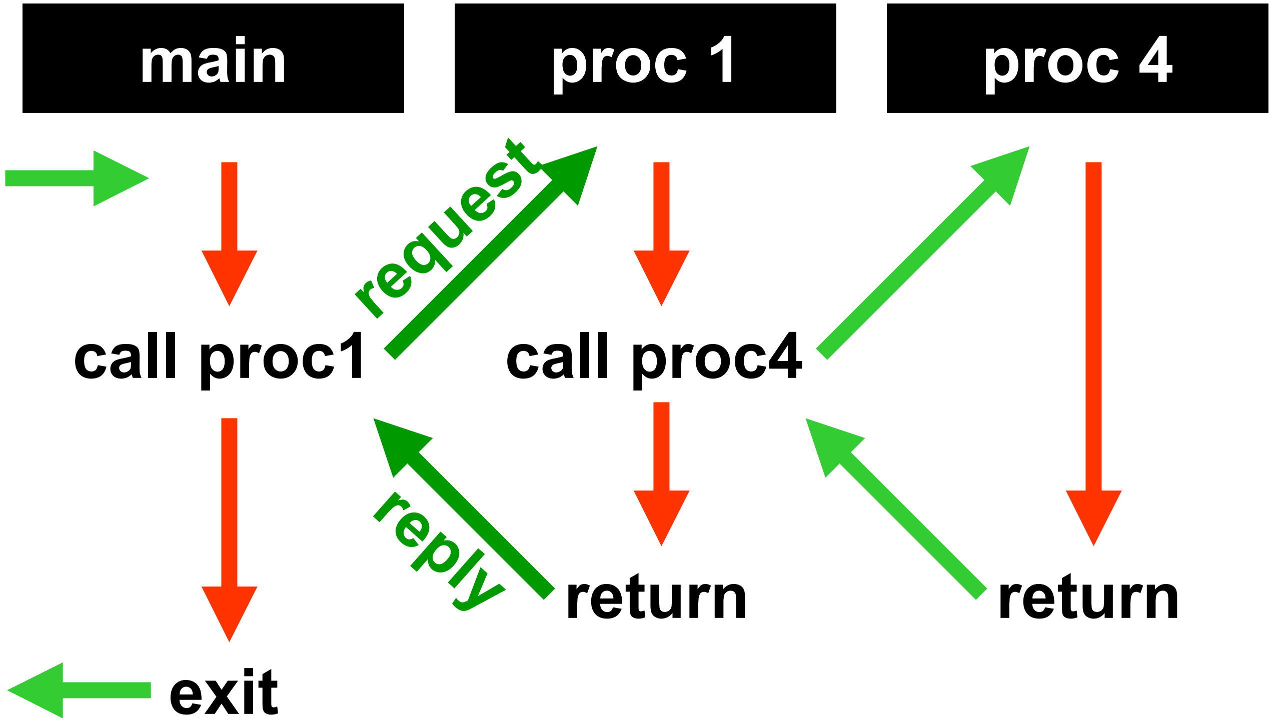
Make the Program Distributed (1)



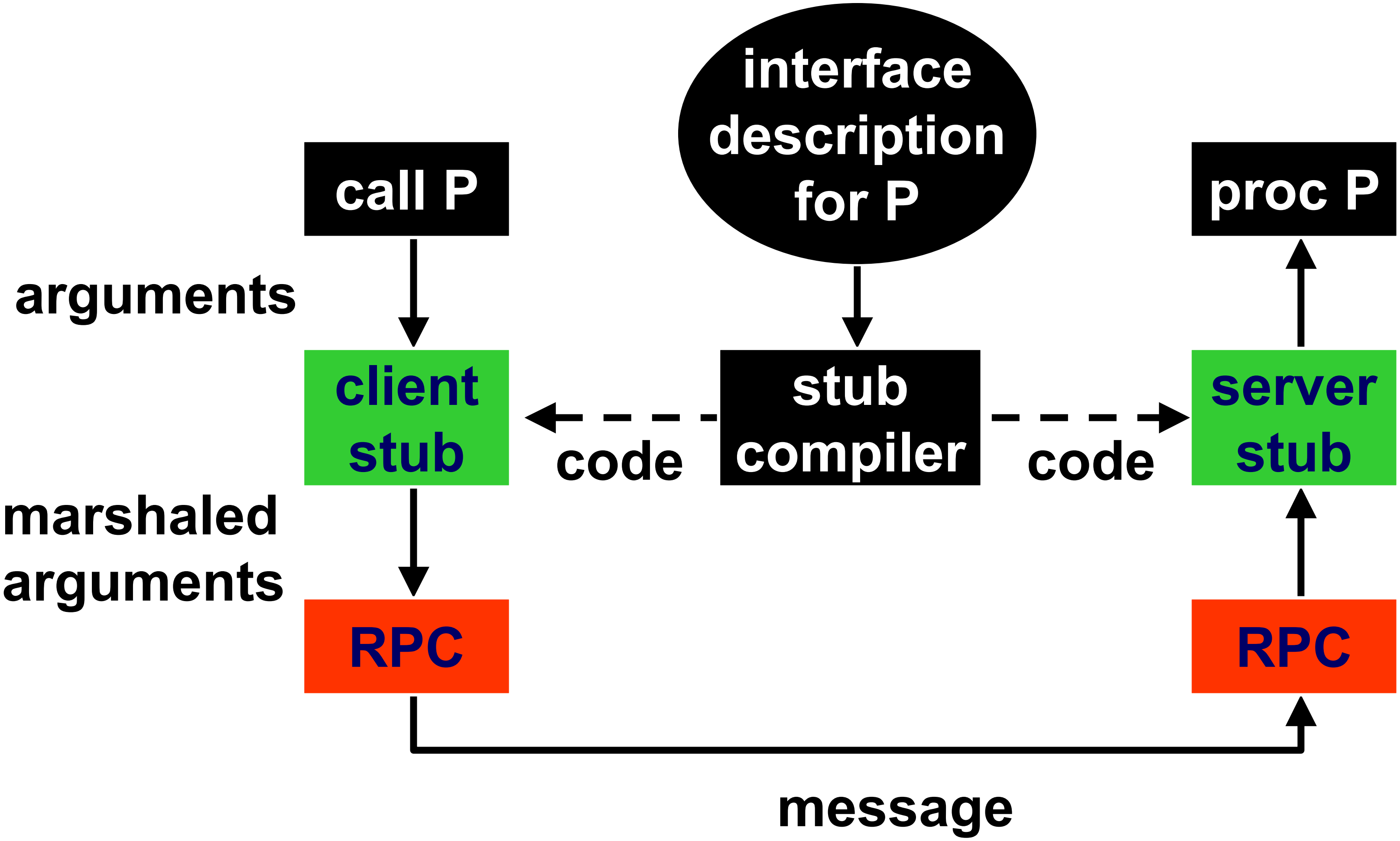
- proc1, proc4, and proc5 are *remote procedures*

Make the Program Distributed (2)

- Call -- send message to invoke remote procedure
- Return -- send reply back to client



RPC Components



call P

arguments

client stub

marshaled arguments

RPC

interface description for P

stub compiler

code

code

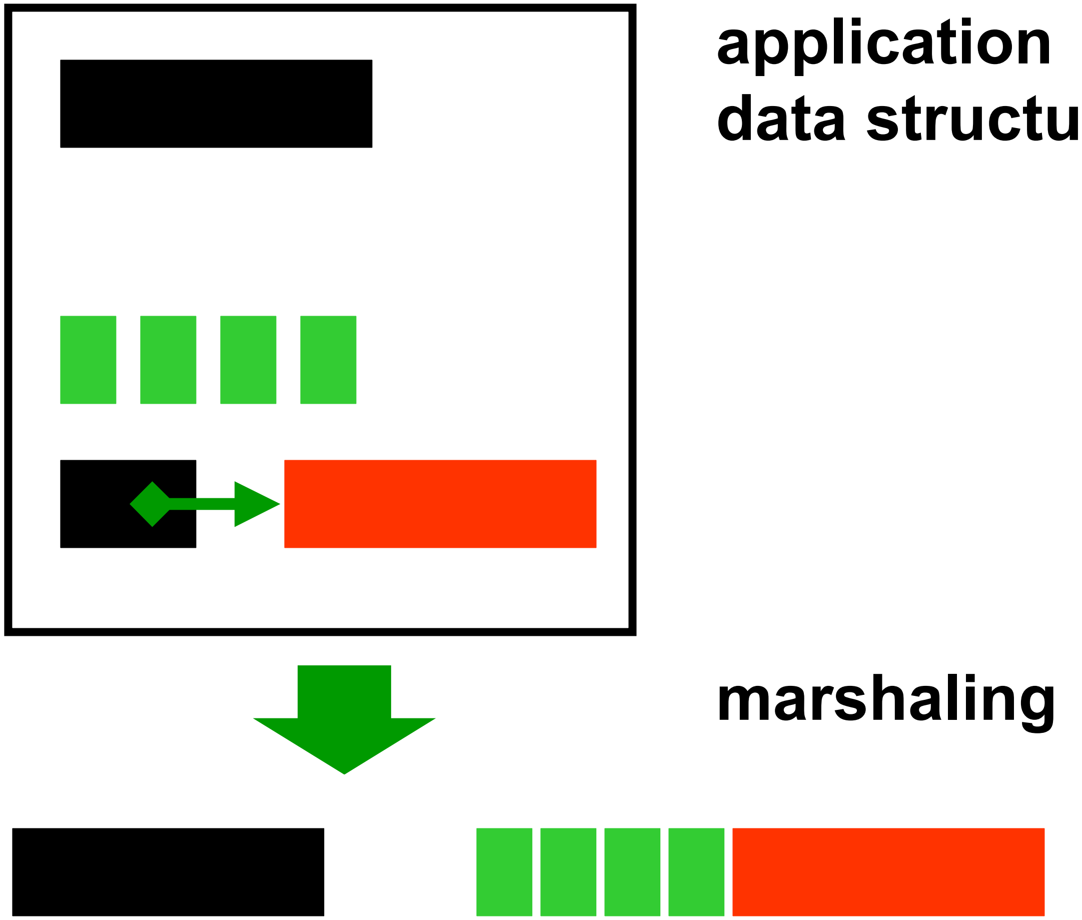
proc P

server stub

RPC

message

Marshaling Arguments



application data structure

marshaling

RPC Design Issues

- Control is multithreaded
  - Procedures executed on different hosts
  - Different threads for each call
- No shared memory
- No shared resources, e.g. files
- More arguments
  - Since no shared memory or other resources
- Server must be active or can be invoked
- Message interface

ONC RPC

- Open Network Computing (ONC) RPC
  - Developed by Sun Microsystems
- “Remote programs”
  - Remote procedures plus shared global data
  - Not just remote procedure
- Functionality
  - Message formats -- carried by TCP or UDP
    - Pass arguments, results, other information
  - Naming scheme for remote programs and procedures
    - Program, version, procedure
  - Authentication scheme

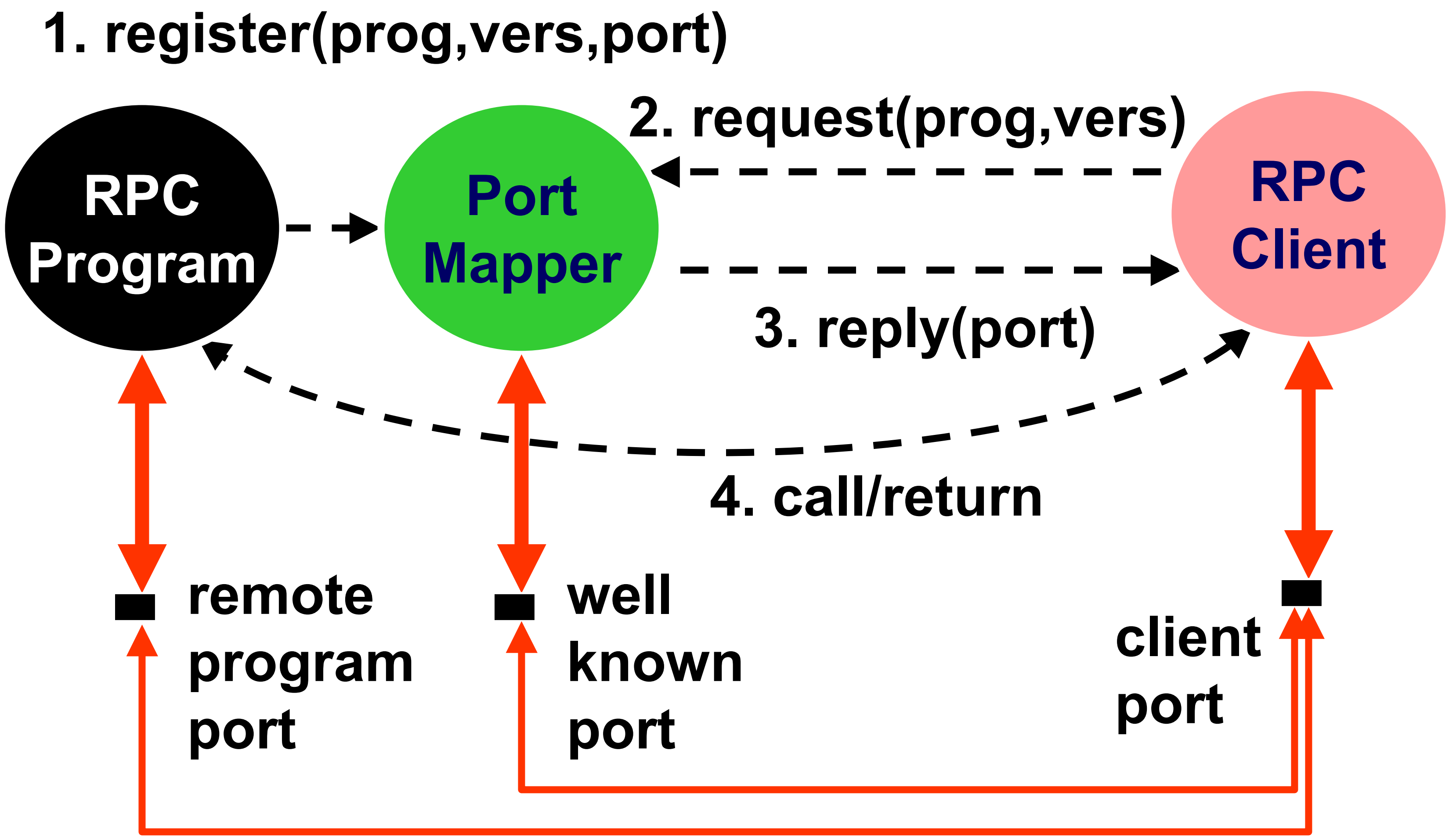
ONC RPC Communications

- Can use TCP or UDP
  - RPC does nothing itself to provide reliability
- With UDP …
  - If client receives a reply, then “at least once” semantics apply
  - If client does not receive a reply, then “zero or more” semantics apply
  - Must be considered in design
    - “read 20 bytes starting at 100”, not
    - “read the next 20 bytes”
- With TCP …
  - Reliable due to use of TCP

Port Mapper (1)

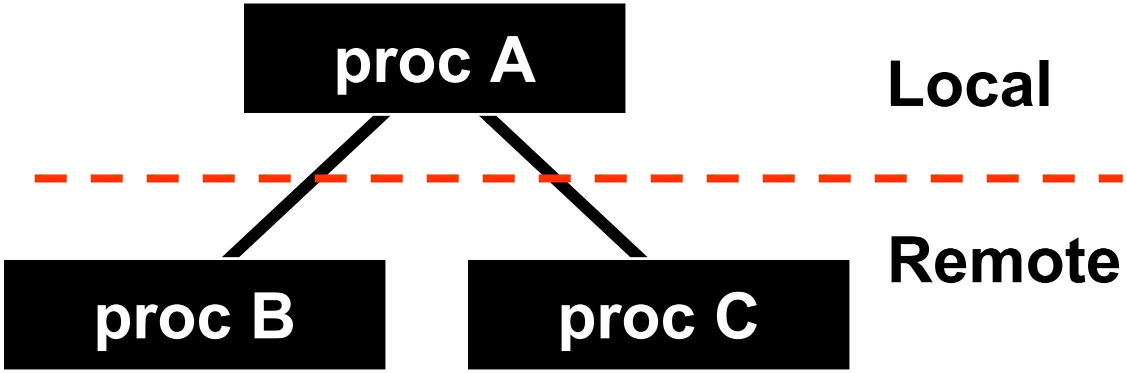
- "Port mapper" allows dynamic maping between protocol port numbers and remote programs
- Remote programs (servers) register with the port mapper on their local host
- Clients query port mapper at well-known port number (111) to get port for remote program

Port Mapper (2)



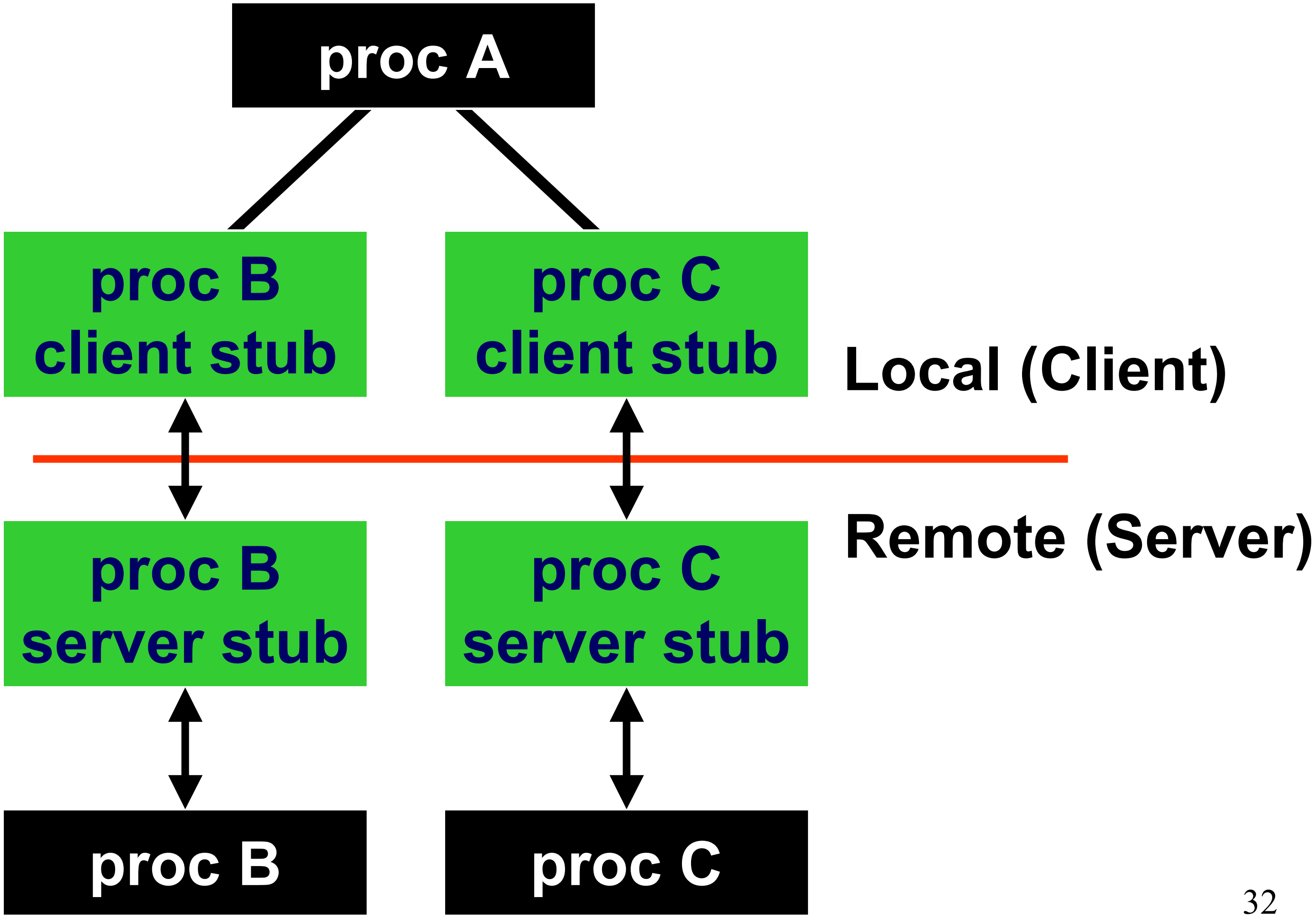
Stub Routines (1)

- Traditional program to be partitioned



Stub Routines (2)

- After partitioning with stub routines



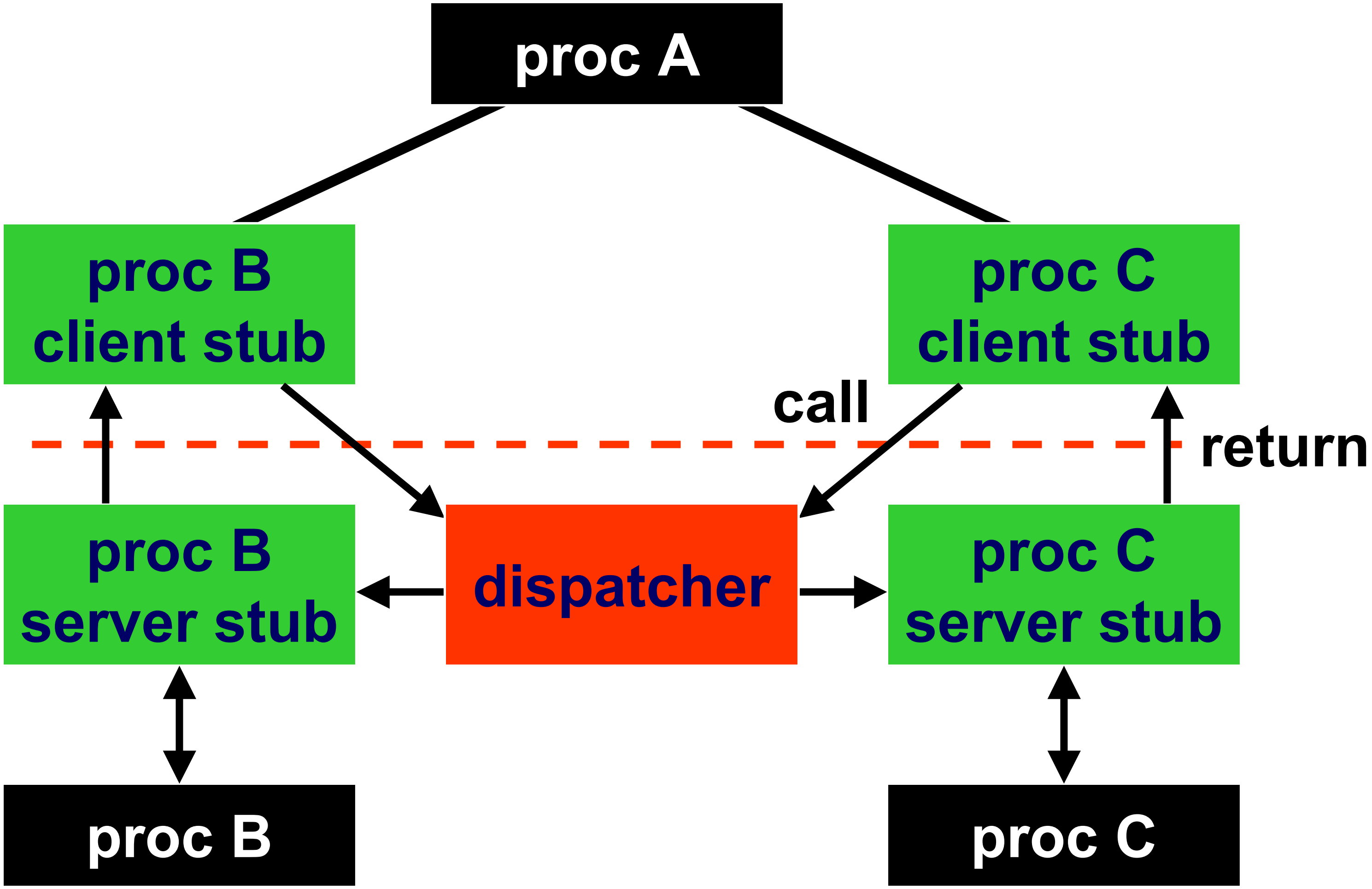
Client Stub

- Is called by client program
- “Marshals” arguments
  - XDR used to encode (with ONC RPC)
- Sends CALL to server
- Waits for reply
- “De-marshals” arguments
  - XDR used to decode
- Returns to client program
  - Client just makes a call that then returns

Server Stub

- **Is dispatched**
- **Accepts arguments, de-marshals and decodes with XDR**
- **Calls server program procedure**
- **Procedure returns to stub**
  - **Server procedure is just called and later returns**
- **Marshals results and encodes with XDR**
- **Sends results back to client**
- **Exits**

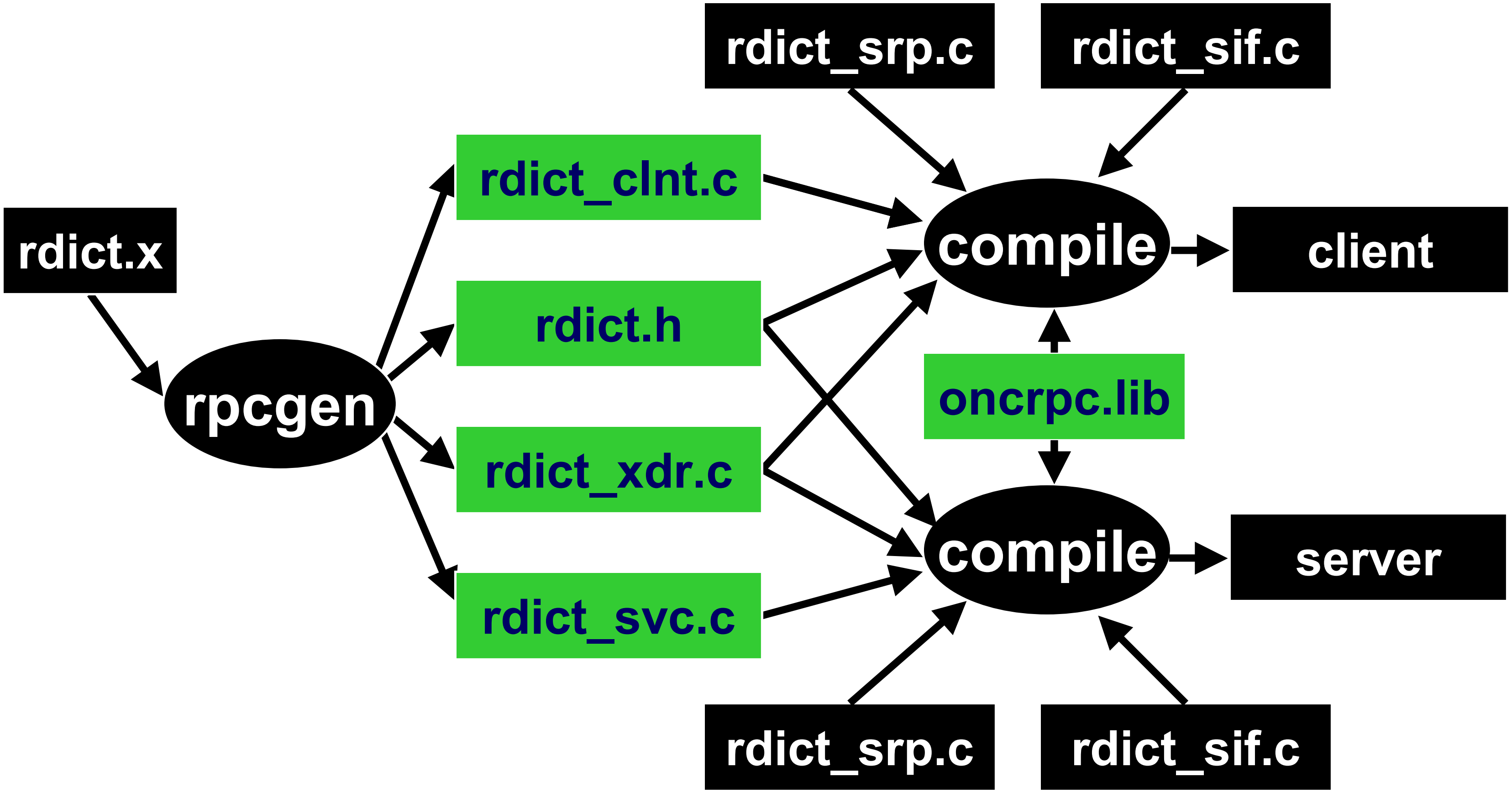
Dispatcher


proc A
proc B
client stub
proc C
client stub
call
return
proc B
server stub
dispatcher
proc C
server stub
proc B
proc C

RPCGEN

- RPCGEN is the RPC program “generator”
- Simplifies the creation of a distributed application using RPC
- Input descriptions of …
  - Remote procedures and interfaces
  - User-defined data types, e.g. structures
- Output files …
  - Client and server stub files
  - Conversion routines for user-defined data types
  - Common header file

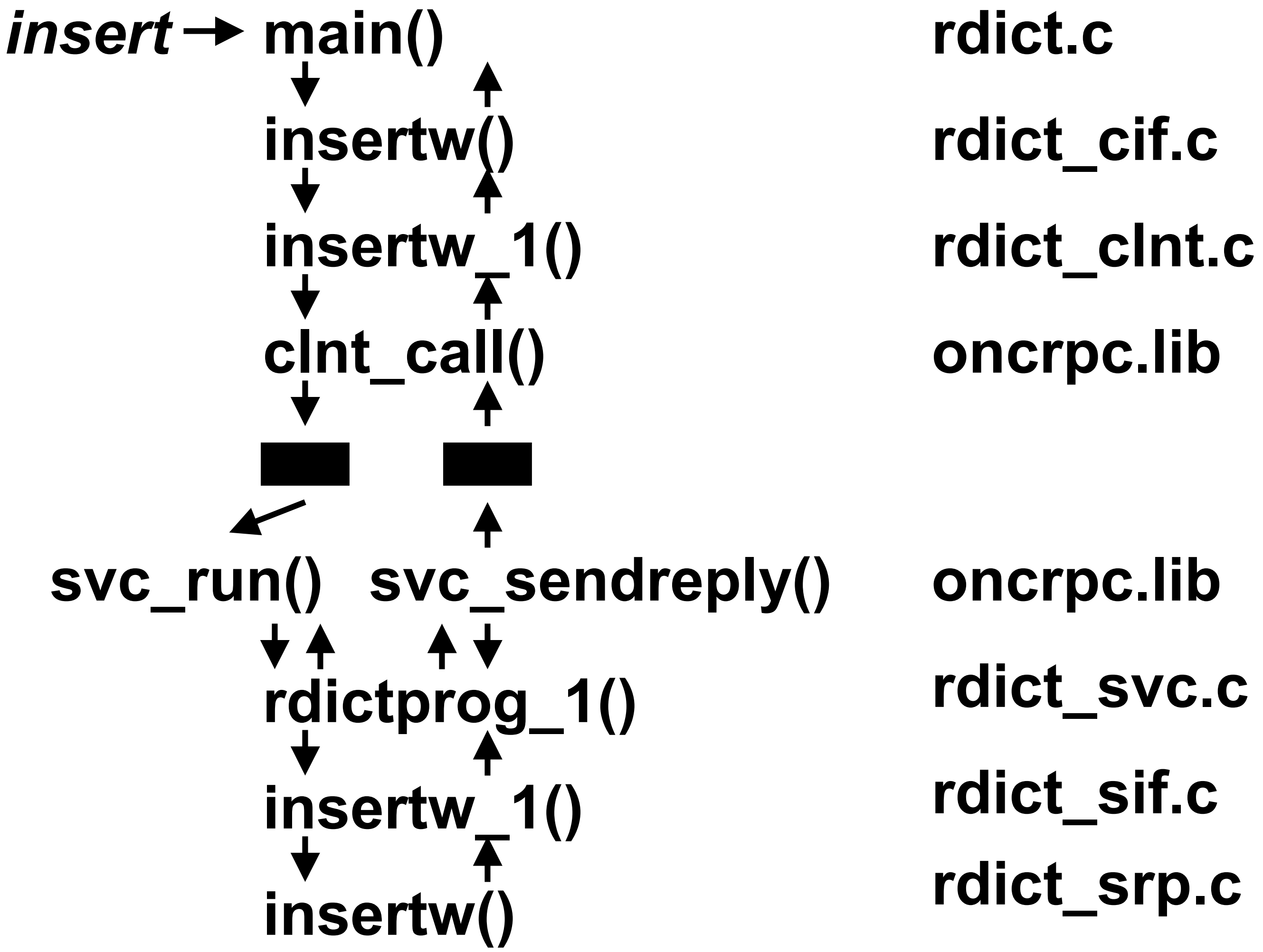
Code Generation using RPCGEN



ONC RPC Code Example Files

- rdict.x: interfaces, common values, data structures
- rdict.h: common header file
- rdict_xdr.c: XDR translations
- rdict_clnt.c: sends calls from client to server
- rdict_svc.c: dispatcher, sends calls from server to client
- rdict.c: main client
- rdict_cli.c: client stub procedures
- rdict_srp: main server routines
- rdict_sif.c: server stub procedures

ONC RPC Code Example Call Sequence



insert → main() rdict.c

insertw() rdict_cif.c

insertw_1() rdict_clnt.c

clnt_call() oncrpc.lib

svc_run() svc_sendreply() oncrpc.lib

rdictprog_1() rdict_svc.c

insertw_1() rdict_sif.c

insertw() rdict_srp.c

You should now be able to … (1)

- Describe different schemes for data representation and identify strengths and weaknesses
  - Generic models
  - Specific schemes (NDR, ASN.1, XDR)
- Show how simple data types would be represented using NDR, ASN.1, and XDR
- Describe the structure of an RPC application including role of stub procedures
- Describe the need for marshaling and wher marshaling is implemented

You should now be able to … (2)

- Describe the structure and operation of …
  - ONC RPC
- Define the role of …
  - RPCGEN
- Design and analyze simple applications using ONC RPC