

Communication

address array asynchronous base big-endian bytes
calls class client code
communication
declarations defined copy data distributed
implementations interface java language little-
endian machine message method
multicast network object operations
parameters passing pointers procedure
program protocol remote request
result return rmi rmiregistry running send
server service skeleton start **stub**
system xdr

Overview

- ▶ Communication types and role of Middleware
- ▶ Remote Procedure Call (RPC)
- ▶ Message Oriented Communication
- ▶ Multicasting

Communication Types

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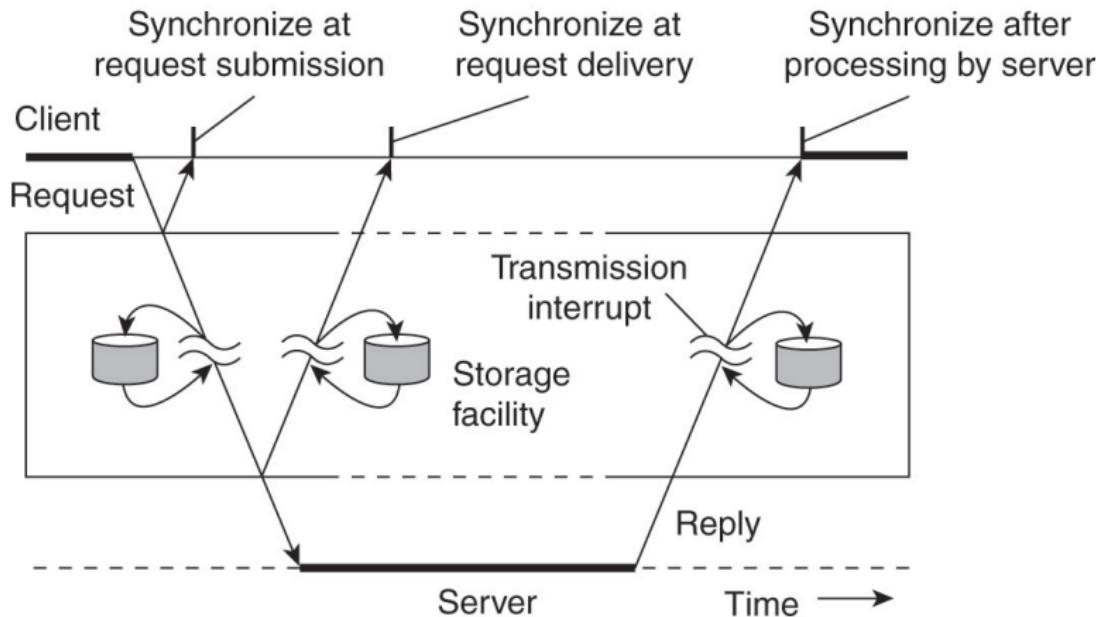
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- ▶ **Asynchronous communication.** The sender continues immediately after it has submitted its message for transmission. This means that the message is (temporarily) stored immediately by the middleware upon transmission.

Role of Middleware



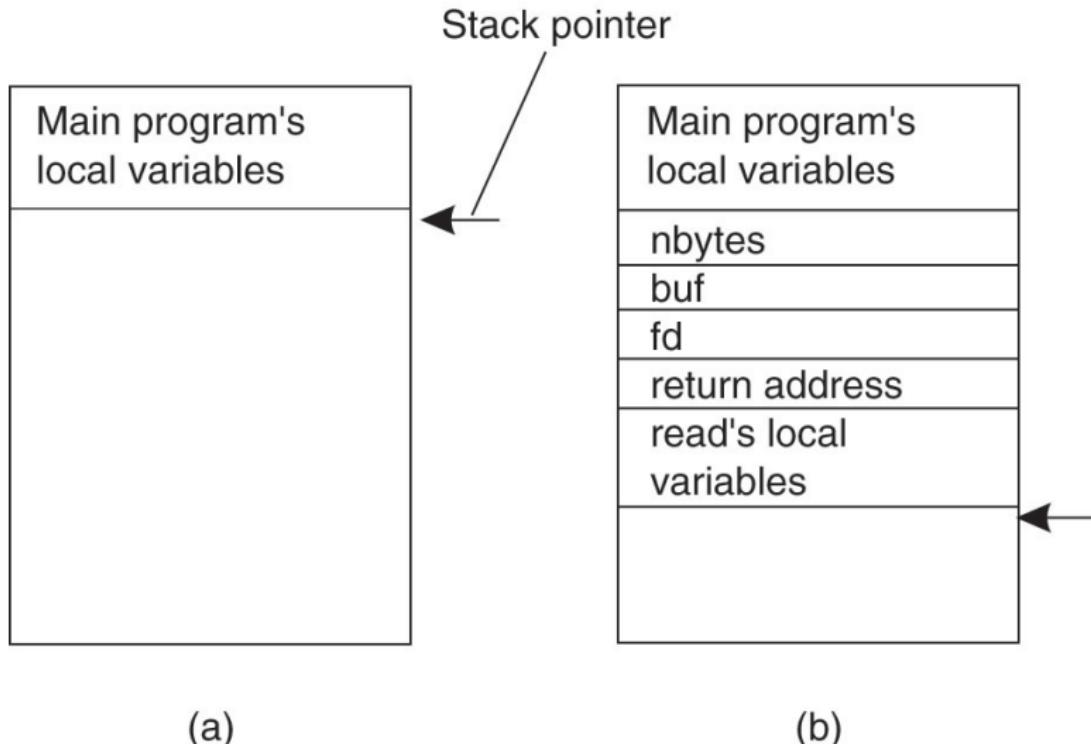
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- ▶ A widely used technique that underlies many distributed systems.

Conventional Procedure Call



```
count = read(fd, buf, nbytes); //in main
```

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- ▶ **In-class Exercise.** How is call-by-copy/restore different from call-by-reference? Give a concrete example.

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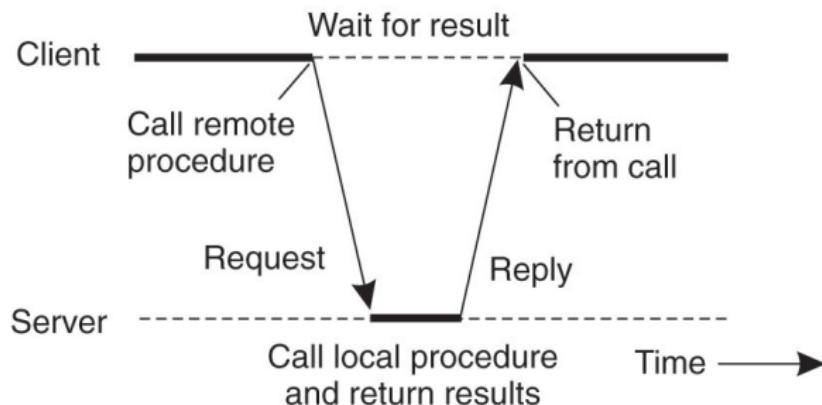
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- ▶ The remote OS gives the message to the server stub.
- ▶ The server stub unpacks the parameters and calls the server.

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- ▶ The stub unpacks the result and returns to the client.

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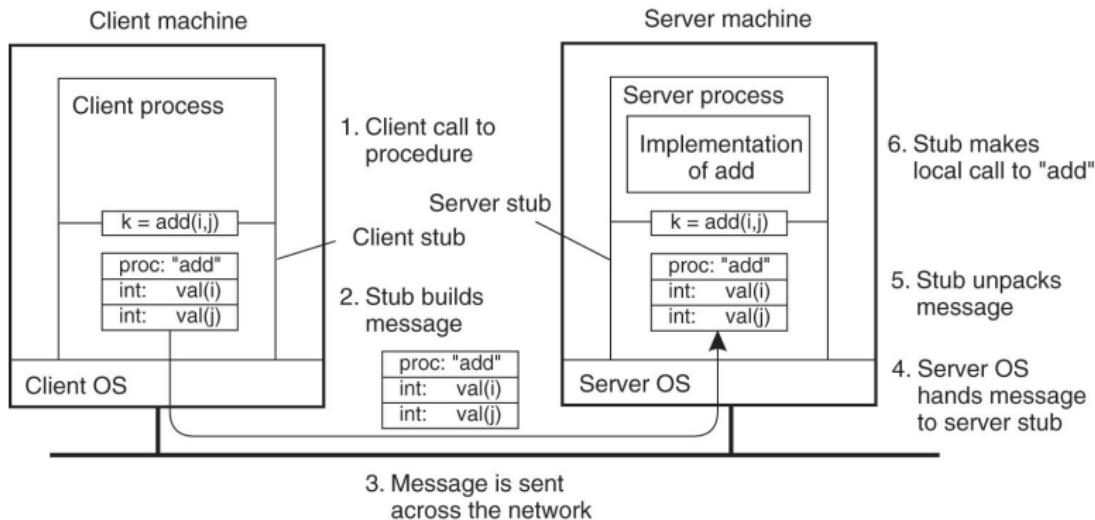
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RPC: Passing Parameters



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- ▶ **Bi-endian machine**: Choose either setting via software or hardware. E.g. ARM processors, SPARC, POWER PC.

Representation: Little-Endian vs Big-Endian (2)

0	3	2	1	0
7	6	5	4	
L	L	I	J	

(a)

0	1	2	3	0
5	0	0	0	0
4	5	6	7	L

(b)

0	1	2	3	5
0	0	0	0	0
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(c)

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0	5	1	0	2	0	3	0
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Does reversing the bytes fix the problem for all data types?

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- ▶ **In-class Exercise 2.** Do we need to worry about *endianness* for server and clients written in Java? What if they deal with files written on a machine with different endianness?

Passing Reference Parameters

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- ▶ How about arbitrary data structures with pointers? 

RPC Protocol and Stub Generation

- ▶ The RPC protocol would have to define the format of the message, the representation of primitive types and arrays and other data structures. Are integers stored in 2's complement, characters in 16-bit Unicode, floats/doubles in IEEE standard #754 and if everything is big-endian or little-endian?

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- ▶ An example:

```
foobar( char x; float y; int z[5] )  
{  
    ....  
}
```

(a)

foobar's local variables	
	x
y	
5	
z[0]	
z[1]	
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(b)

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- ▶ **Interface Definition Language (IDL)** is used to define interfaces for RPC. IDL is then compiled into client and server stub along with the appropriate compile/run-time interfaces.

Asynchronous RPC (1)

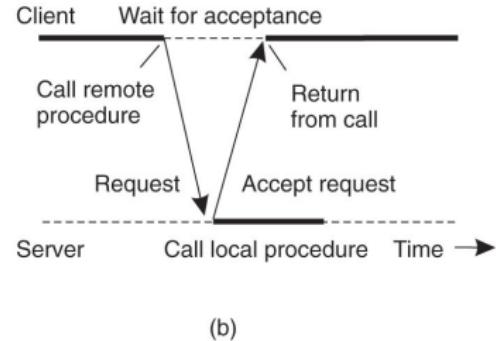
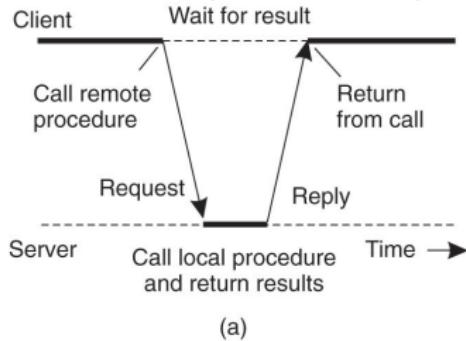
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- ▶ **Deferred asynchronous RPC**: The client calls the server with a RPC request and the server immediately acknowledges it. Later the server does a callback to the client with the result.

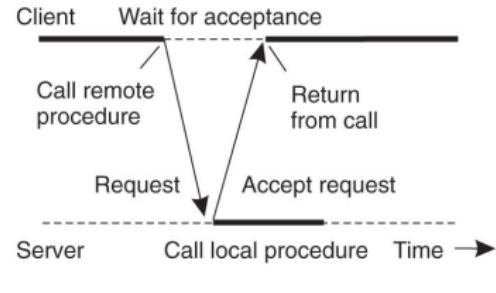
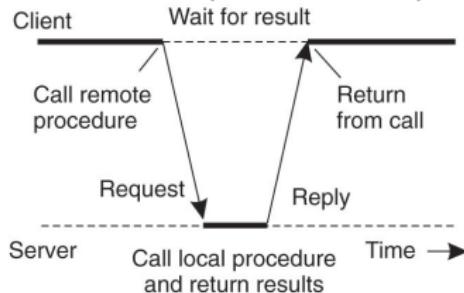
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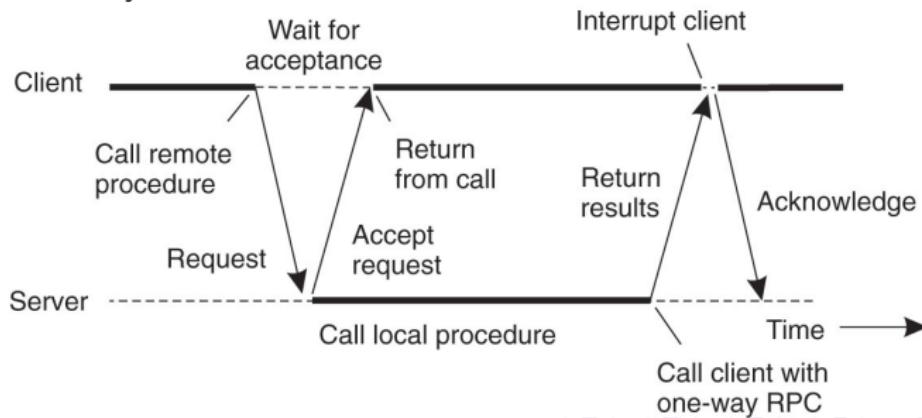
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(a)

(b)

- ▶ Deferred Asynchronous RPC



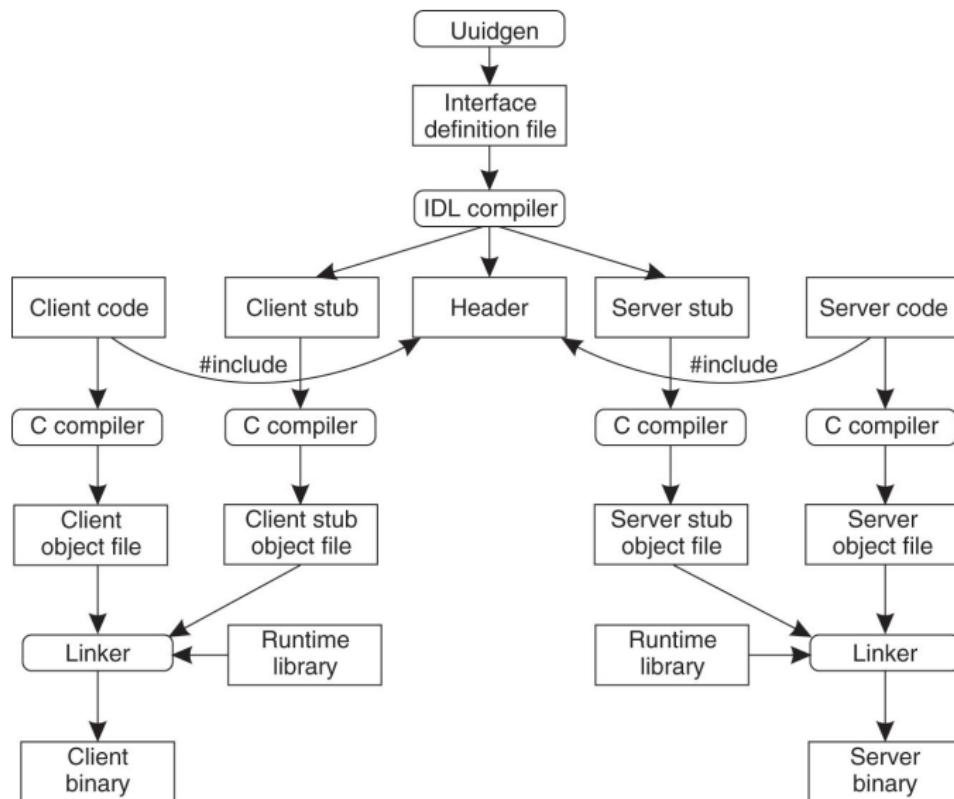
Classic RPC Implementations

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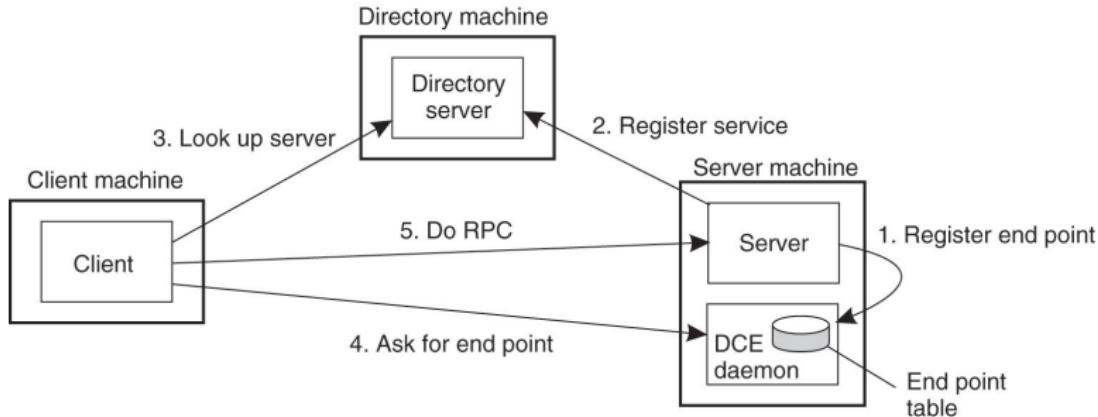
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- ▶ **Open Network Computing Remote Procedure Call** (ONC RPC) is a widely deployed remote procedure call system. ONC was originally developed by Sun Microsystems as part of their Network File System project, and is sometimes referred to as Sun ONC or Sun RPC.

Building a RPC Server and Client



Binding a Client to a RPC Server



Note: ONC RPC uses a [portmapper](#) in place of the DCE daemon.
It doesn't use a directory server.

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 - ▶ This only works for **idempotent** operations: something that can be done multiple times without harm.

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- ▶ Apache Avro is a RPC and data serialization framework developed for the Apcache Hadoop project.

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- ▶ Examples: IBM WebSphere MQ, Oracle AQ, Microsoft Messaging Queue, Amazon Simple Queue Service, JBoss, Apache Active MQ. Part of Erlang/Elixir, most operating systems.
- ▶ Java Messaging Service (**JMS**) is a Java Message Oriented Middleware (MOM) API for sending messages between two or more clients. It is a messaging standard that allows application components based on the Java Enterprise Edition (Java EE) to create, send, receive, and read messages.

Message-Oriented Persistent Communication

- ▶ **Message-Oriented Middleware (MOM)** or **message-queuing systems** support persistent asynchronous communication that is loosely coupled and reliable.
- ▶ These systems provide intermediate-term storage capacity for messages without requiring either the sender or receiver to be active during the message transmission.
- ▶ *Examples:* IBM WebSphere MQ, Oracle AQ, Microsoft Messaging Queue, Amazon Simple Queue Service, JBoss, Apache Active MQ. Part of Erlang/Elixir, most operating systems.
- ▶ **Java Messaging Service (JMS)** is a Java Message Oriented Middleware (MOM) API for sending messages between two or more clients. It is a messaging standard that allows application components based on the Java Enterprise Edition (Java EE) to create, send, receive, and read messages.
 - ▶ Providers of JMS: Amazon SQS, Apache ActiveMQ, Oracle AQ, JBoss, IBM WebSphere MQ and several others.

Message Queuing Model (1)

Sender
running



Receiver
running

Sender
running



Receiver
passive

Sender
passive



Receiver
running

Sender
passive



Receiver
passive

(a)

(b)

(c)

(d)

- ▶ Four combinations of loosely-coupled communications using queues.

Message Queuing Model (2)

Primitive	Meaning
Put	Append a message to a specified queue
Get	Block until the specified queue is nonempty, and remove the first message
Poll	Check a specified queue for messages, and remove the first. Never block
Notify	Install a handler to be called when a message is put into the specified queue

- ▶ Four combinations of loosely-couple communications using queues.

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- ▶ Multicasting requires support from networking hardware such as routers.
- ▶ The most common implementation is **IP Multicast**, used for streaming media. No prior knowledge of who or how many receivers there are is required. Widely used in enterprises, stock exchanges and multimedia content delivery networks.

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- ▶ Some reserved IPv4 multicast addresses:

224.0.0.0	reserved base address
224.0.0.1	all hosts on the same network segment
224.0.0.2	all routers on the same network segment
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- ▶ The most common implementation is using UDP (User DataGram Protocol), which isn't reliable — messages may be lost or delivered out of order.

Java Examples

The main class we will use is `java.net.MulticastSocket`. See examples in `examples/multicasting`

- ▶ `ex0-setup`: Shows how to find out information about network interfaces and if they support multicasting.
- ▶ `ex1-mcast-hello`: Streaming *hello world* using multicasting!
- ▶ `ex2-mcast-time`: Multicast time server
- ▶ `ex3-mcast-group`: Multicast group membership example

References

- ▶ Wikipedia article on Endianness
- ▶ Linus Torvalds on Endianness
- ▶ Multicast Address
- ▶ IP Multicast