# DISTRIBUTED COMPUTER SYSTEMS

## Communication Fundamental
## REMOTE PROCEDURE CALL

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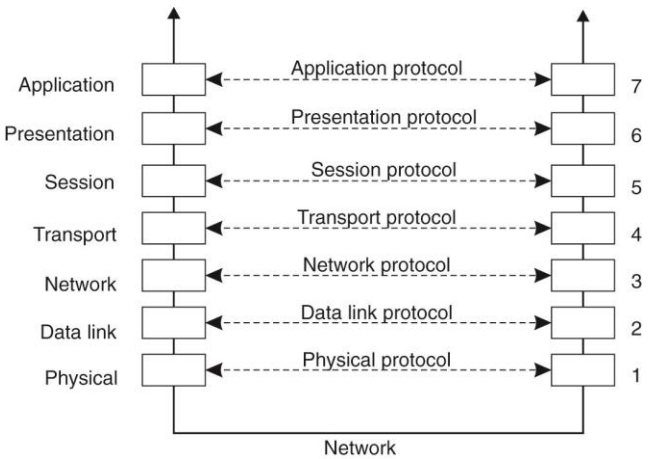
## Outline

- Communication Architecture Fundamentals
- Middleware Layer
- Types of Communications
  - Transient, Asynchronous and Synchronous
- Remote Procedure Call
  - Basic Operation
  - Parameter Passing
  - Parameter Specification and Stub Generation
  - RPC Case Study: DCE
- Conclusion

# Communication Fundamentals

**Layering, Middleware and Communication Types**

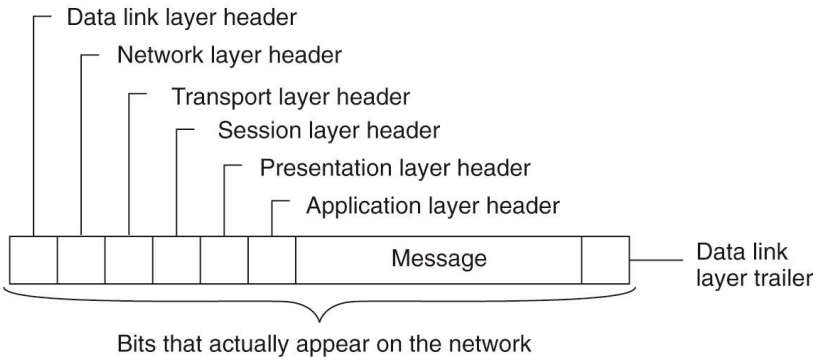
## Protocol Architecture – Layering




- Layers, interfaces, and protocols in the OSI model.

## Layered Protocols – Encapsulation

- A typical message as it appears on the network.

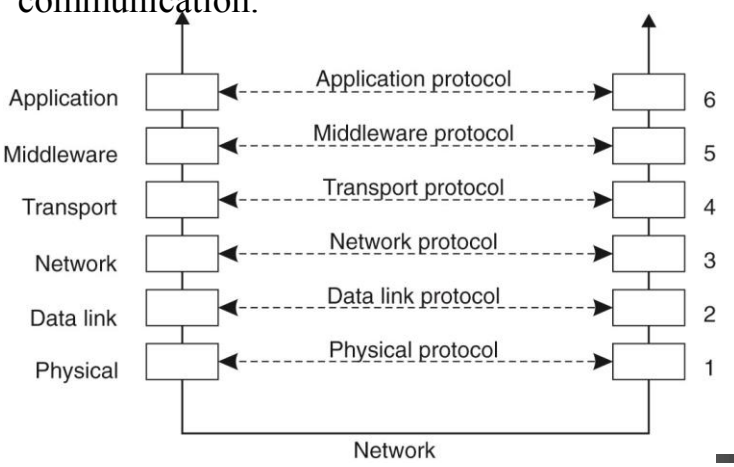



## Middleware Protocols

- A distinction can be made between high-level communication protocols and protocols establishing various middleware services
  - Authentication service to prove a communication channel claimed identity
  - Commit protocols to ensure atomicity
  - Access control protocol through locks, for example
- Above protocols offer specific services, which are highly independent of any specific application
  - Middleware communication protocols support high-level communications

# Middleware Adapted Reference Model

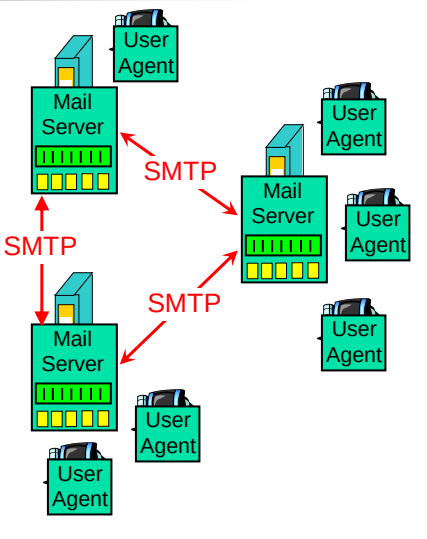
- An adapted reference model for networked communication.




# Middleware Communication Alternatives

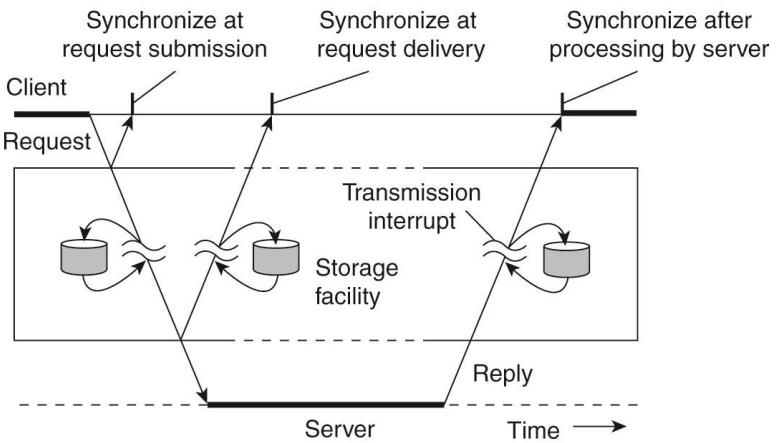
The core of an electronic mail system can be seen as a middleware communication service, involving three major components:

- User agents – Eudora, Outlook, Pine,
- Mail servers for incoming and outgoing messages
- Simple Mail Transfer Protocol: SMTP



## Middleware Communication Alternatives

- Viewing middleware as an intermediate, distributed, service in application-level communication.




## Middleware Communication Types

- **Persistent Communication** – A transmitted message, is stored the communication middleware until deliver is successfully achieved
  - Neither the sender or receiver application need be running after submitting the message
- **Transient Communication** – Message is stored by communication system only as long as sender and receiver are executing
  - Middleware is unable to deliver a message due transmission interrupt
    - Transport-level communication service offer transient communication,
    - Traditional store-and-forward, with possibility of packet dropping

## Middleware Communication Types

- **Synchronous** – Sender is blocked until its request is known to be delivered
  - Synchronization can occur in three different ways
    - Sender is blocked until it received notification from middleware that it took charge of the message
    - Sender may synchronize until its request is received by intended recipient
    - Sender waits until recipient returns response
- **Asynchronous** –Sender continues execution, immediately after submitting message
  - Message is temporarily stored by middleware upon submission

## REMOTE PROCEDURE CALL

**Basic Operation, Stubs, Parameter Passing**

## Remote Procedure Call

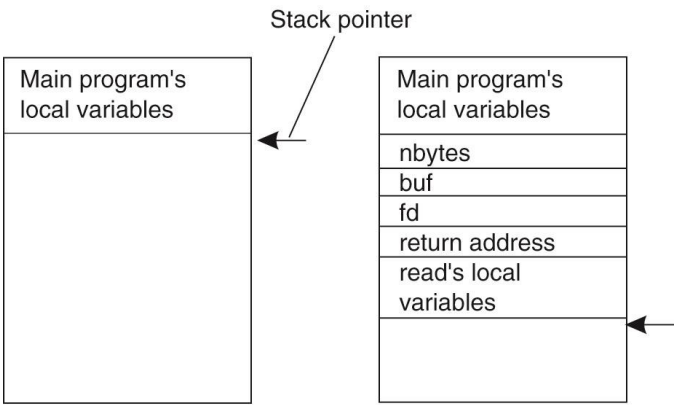
- Explicit message passing has been typically used in early distributed systems
  - The paradigm does not achieve access transparency
    - ***send()*** and ***receive()*** primitives do not conceal communication from the communicating entities
- Alternative method to message passing – Allow programs to call procedures located in other machines
  - Simple and elegant idea, but subtle problems may exist

## Procedure Call – Basic Operation

- Conventional procedure call
  - count = **read**(fd, buff, nbytes)
  - **fd** = file descriptor, handle
  - **buff** = an array of characters
  - **nbyte** = number of bytes to be read
- The execution of a procedure call made from the main program requires the following steps:
  - Caller pushes the parameters onto the stack in order, last one first, including return address
  - The read() procedure puts **return value** in a register, removes **return address** and **transfers control** back to caller

## Conventional Procedure Call

- Parameter passing in a local procedure call




**Stack before the call to read** **Stack while called procedure is active**

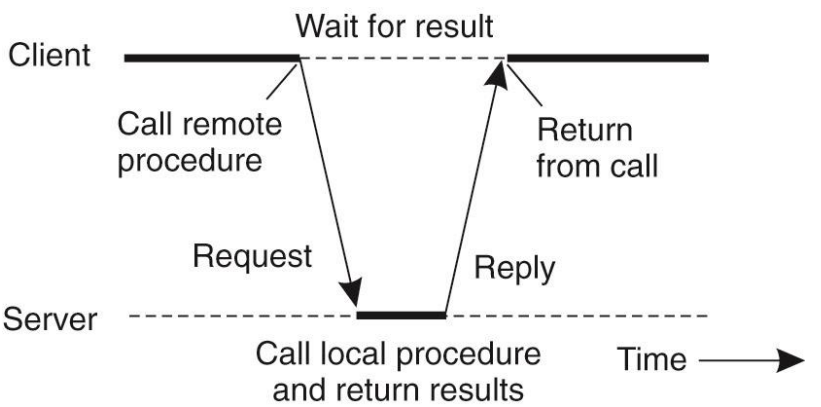
## Parameter Passing

- **Call-by-Value** – To the called procedure a value is just an initialized local variable
- **Call-by-Reference** – The reference parameter is a pointer to a variable, rather than the value of the variable
  - The called procedure modifies the variable in the calling procedure
- **Call-by-Copy/Restore** – The variable is copied onto the stack by the caller and copied back after the call, overwriting the caller's original value
  - Not often used in computer languages

**Which Mechanism to Use in RPC?**

## Remote Procedure Call

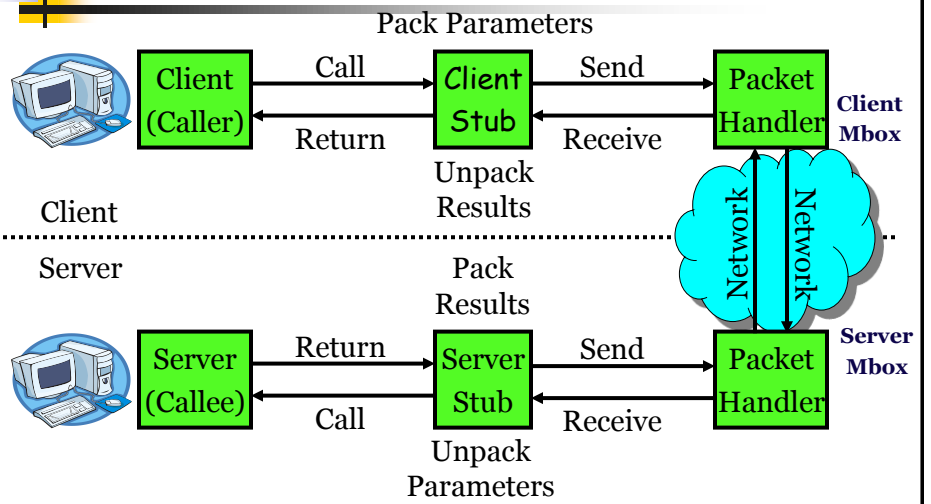
- Principle of RPC between a client and server program.



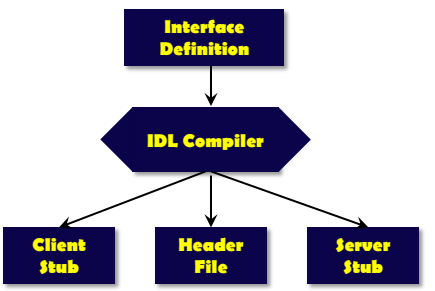

## RPC Design Issue

- Make RPC look like LPC, **as much as possible**
  - **Transparency** – Local procedure should not be aware that the called procedure is executing remotely
- RPC achieves its transparency in a similar way as LPC by invoking a library function call
  - The execution of the RPC uses the concept of a stub
    - A **client stub**, at the calling procedure
    - A **server stub**, at the called procedure
    - Communication between the stubs is achieved through message passing, transparently from the local procedure

# RPC Information Flow




# RPC COMPILATION



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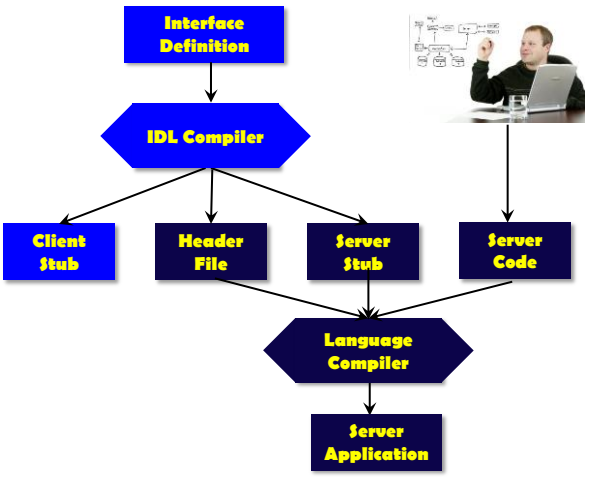


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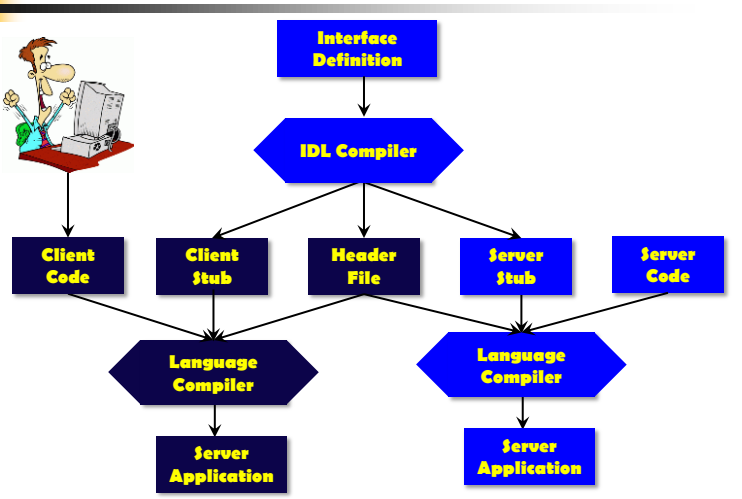
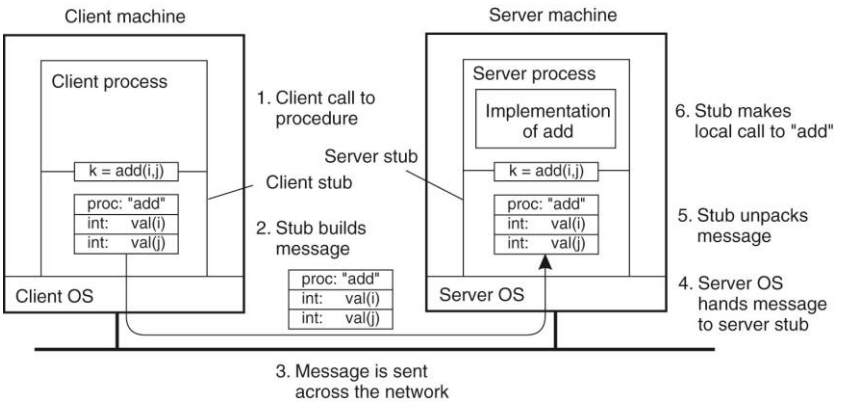


# RPC Steps – Example

- The steps involved in a doing a remote computation through RPC.




# RPC FAILURE HANDLING

Failures can be of three types

- Lost message
- Server crash
- Client crash

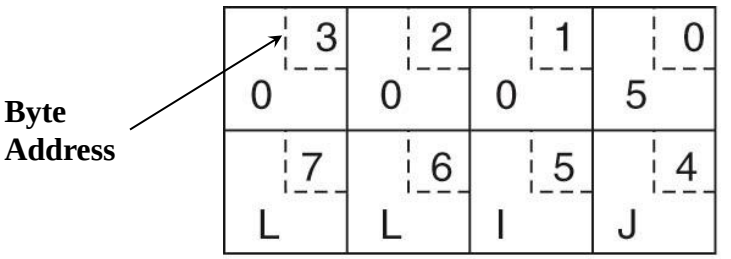
## RPC Details

- Equivalence with regular procedure call
  - Parameters – Request Message
  - Result – Reply message
  - Name of Procedure – Passed in request message
  - Return Address – client return mail box
- Where do stubs come from? – Compiler generates stubs
  - Input: interface definitions in an "interface definition language (IDL)"
    - Contains, among other things, types of arguments/return
  - Output: stub code in the appropriate source language
    - Client code to pack and send message, wait for result, unpack result and return to caller
    - Server Code to unpack message, call procedure, pack and send back results

## RPC Implementation Issues

- Cross-platform issues
  - What if client/server machines are different architectures or in different languages?
- How does client know where to send call request?
  - Biding process – Need to translate name of remote service into network endpoint: Server network address, port number, possibly other information
- How to pass complex structures, pointers, big arrays?
  - Handling these structure could be very costly, and perhaps impractical to pass as arguments
  - Should there be limitation on size and types of RPC arguments?.

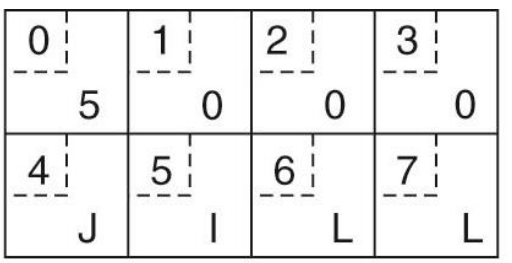
## Passing Parameters – Original Message




- Original message on the sending machine

## Passing Parameters – Upon Arrival

- The original message upon arrival on the receiving machine.



## Passing Parameters – Upon Conversion

- The message after being inverted at receiving machine

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

## Parameter Specification and Stub Generation

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

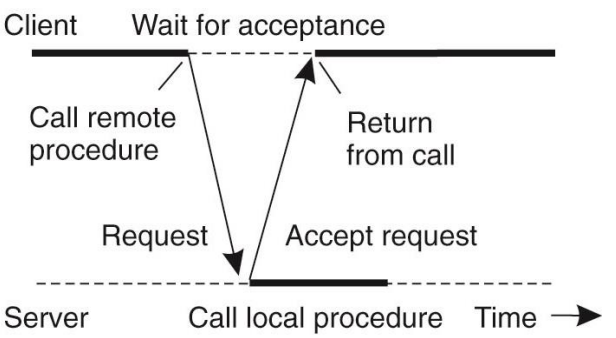
Procedure Description

| foobar's local variables | |
|---|---|
| | x |
| y | |
| 5 | |
| z[0] | |
| z[1] | |
| z[2] | |
| z[3] | |
| z[4] | |

Corresponding Message

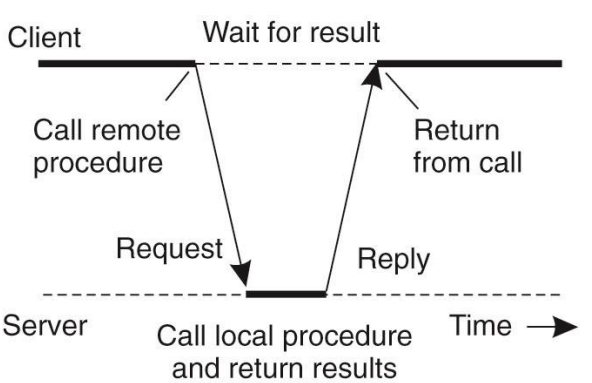
## Asynchronous RPC (2)

- The interaction using asynchronous RPC.



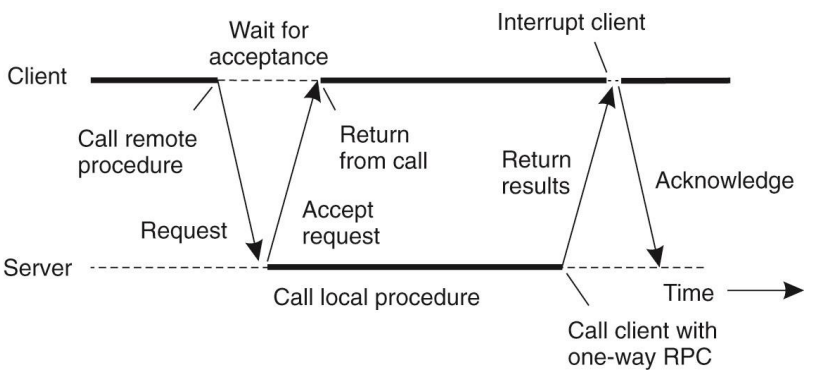

## Asynchronous RPC

- Interaction between client and server in a traditional RPC

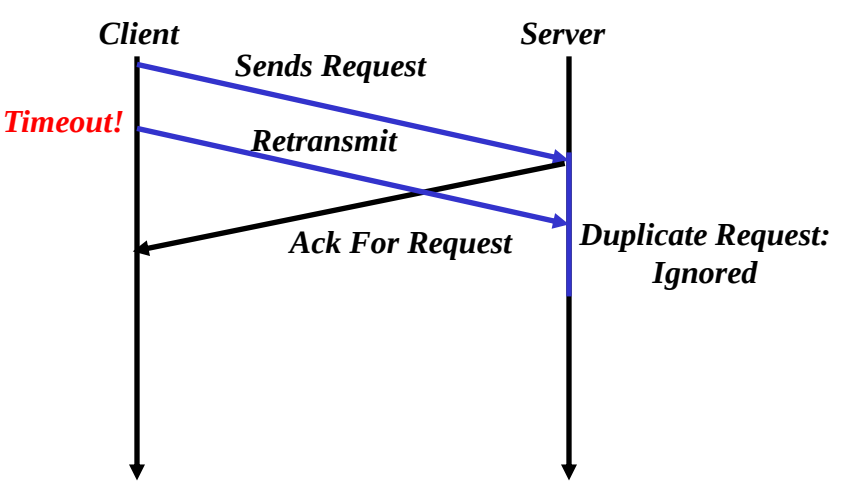


## Asynchronous RPC – Two RPCs

- A client and server interacting through two asynchronous RPCs.




## Overcoming Lost Packets



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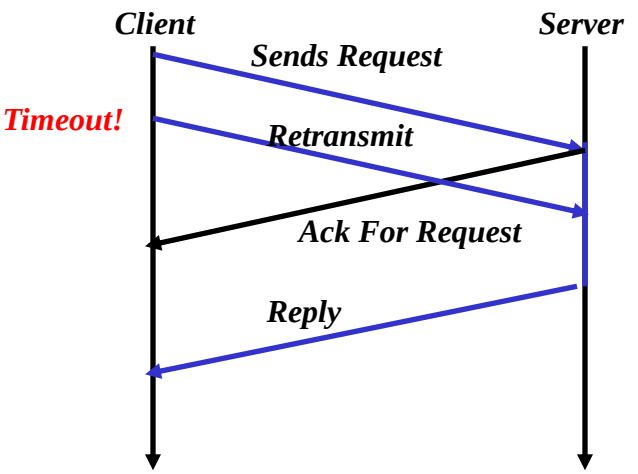


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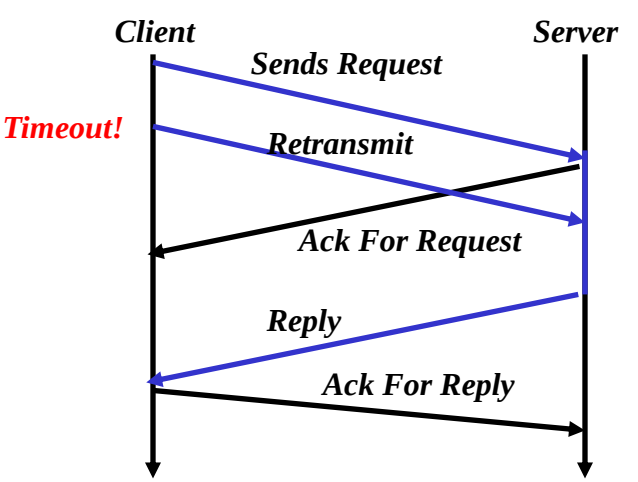
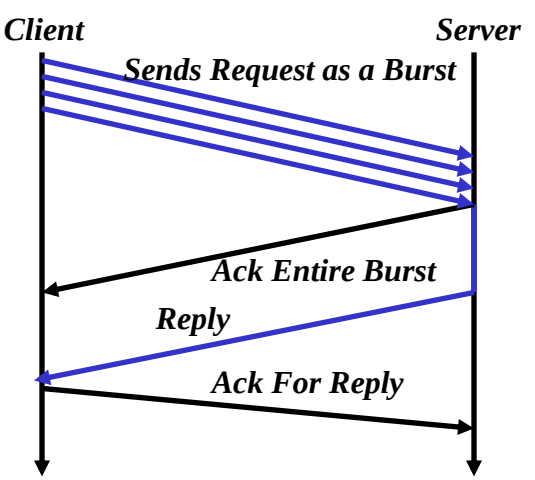


## Costs in fault-tolerant version?

- Acknowledgments are expensive – Must be avoided, when possible
  - For example, if the reply can be sent quickly suppress the initial acknowledgement
- Retransmission is costly – Try and tune the delay to be "optimal"
- For big messages, send packets in bursts and acknowledge a burst at a time, not burst by burst

## Big Packets



## RPC "Semantics"

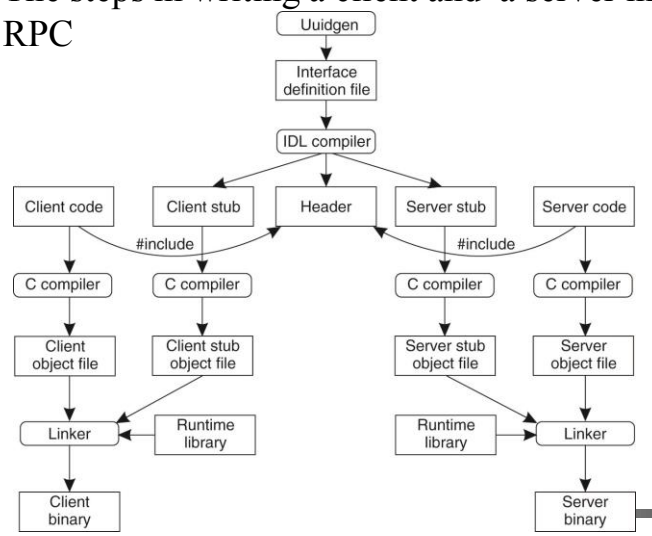
- **At most once:** Request is processed 0 or 1 times
- **Exactly once:** Request is always processed 1 time
- **At least once:** Request is processed 1 or more times
- ... but exactly once is **impossible** because we can't distinguish packet loss from true failures!
  - In both cases, RPC protocol simply times out.

## REMOTE PROCEDURE CALL

**DCE – Case Study**

## Writing a Client and a Server

- The steps in writing a client and a server in DCE RPC




## Writing a Client and a Server

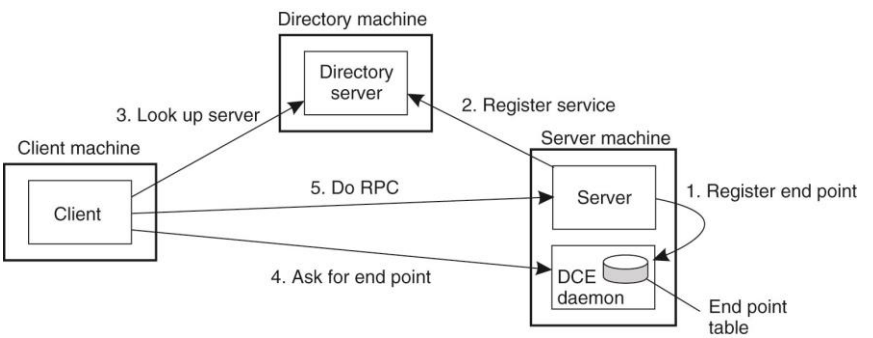
- Three files output by the IDL compiler:
  - A header file (e.g., interface.h, in C terms).
  - The client stub.
  - The server stub.

## Binding a Client to a Server

- Registration of a server makes it possible for a client to locate the server and bind to it.
- Server location is done in two steps:
  1. Locate the server's machine.
  2. Locate the server on that machine.

## Binding a Client to a Server

- Client-to-server binding in DCE



## Conclusion

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