EPFL

The Client/Server Design Pattern

Prof. George Candea
School of Computer & Communication Sciences

Outline

same address space

- Local procedure calls (module = procedure)
- Program objects & types (module = memory object)

Memory safety

- Client/server architecture (different address spaces)
- *Example: RPC*

Message-based communication

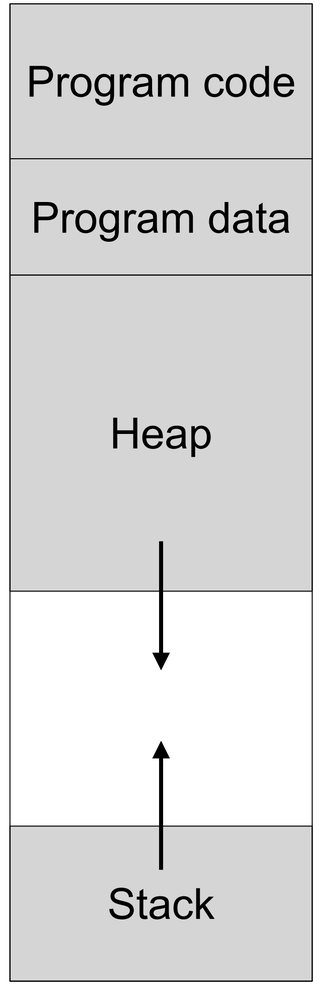
separate address spaces

(Local) Procedure Calls

Basic mechanism for modularizing a program
(Modules = procedures)

Stack-based calling convention

Program memory layout



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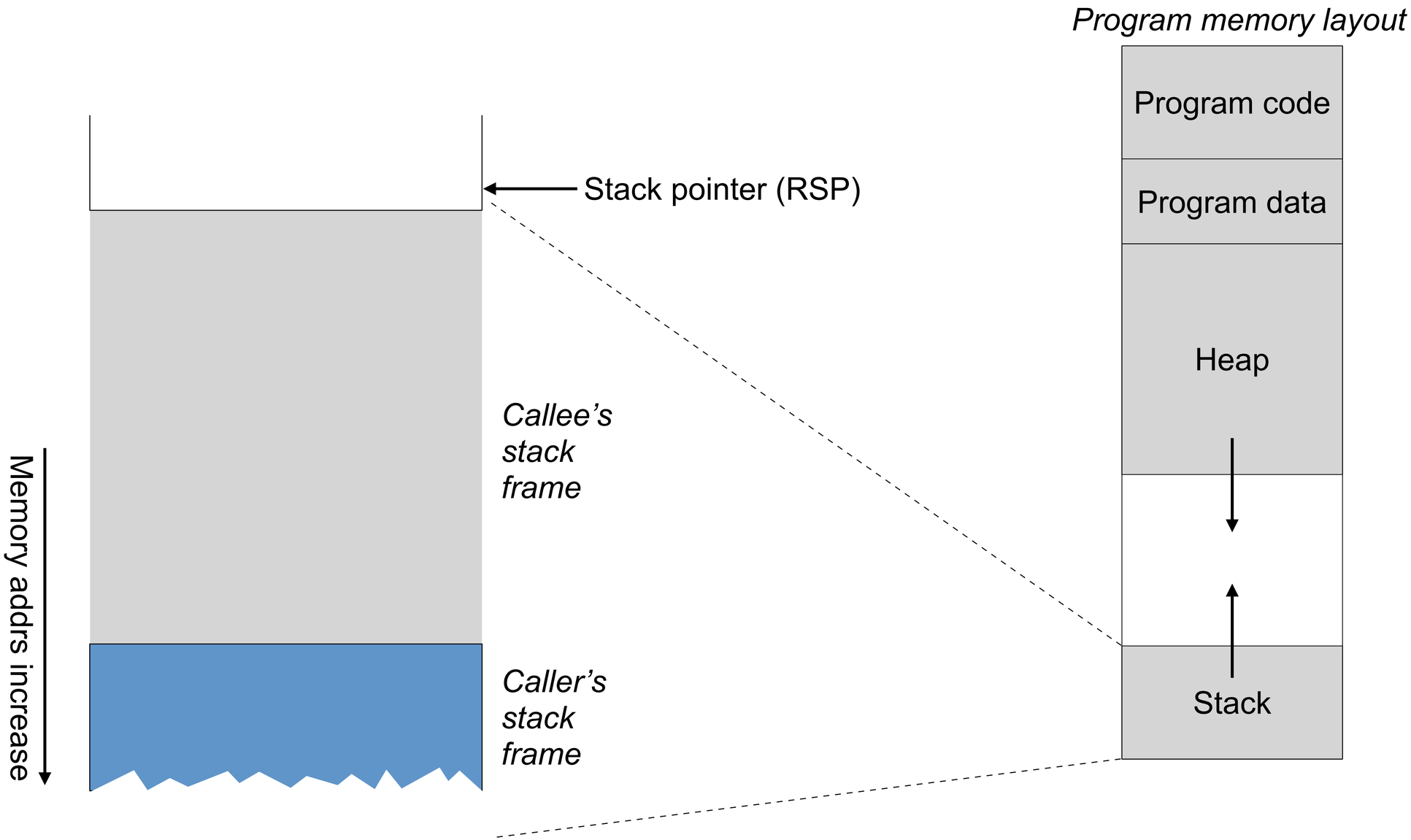

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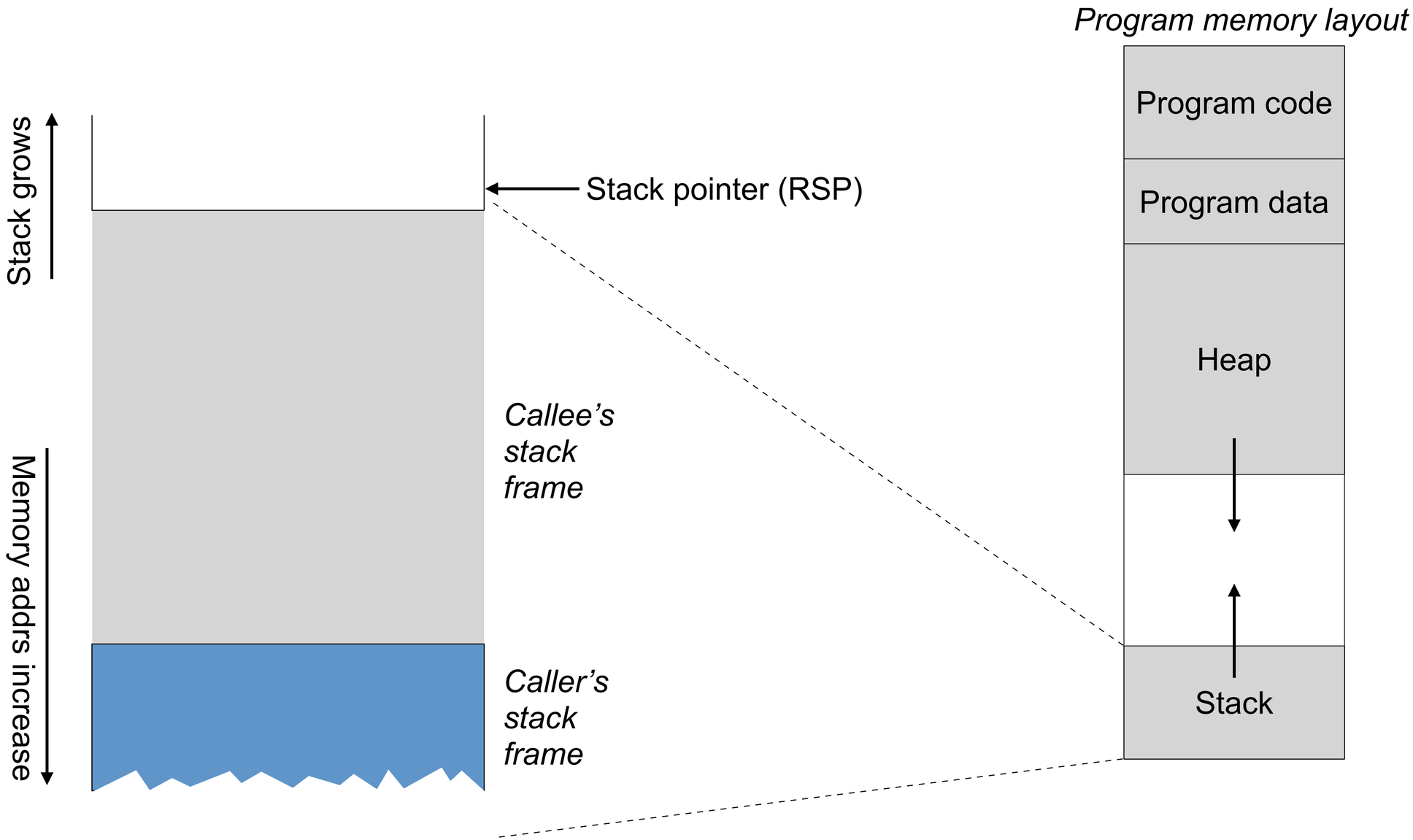

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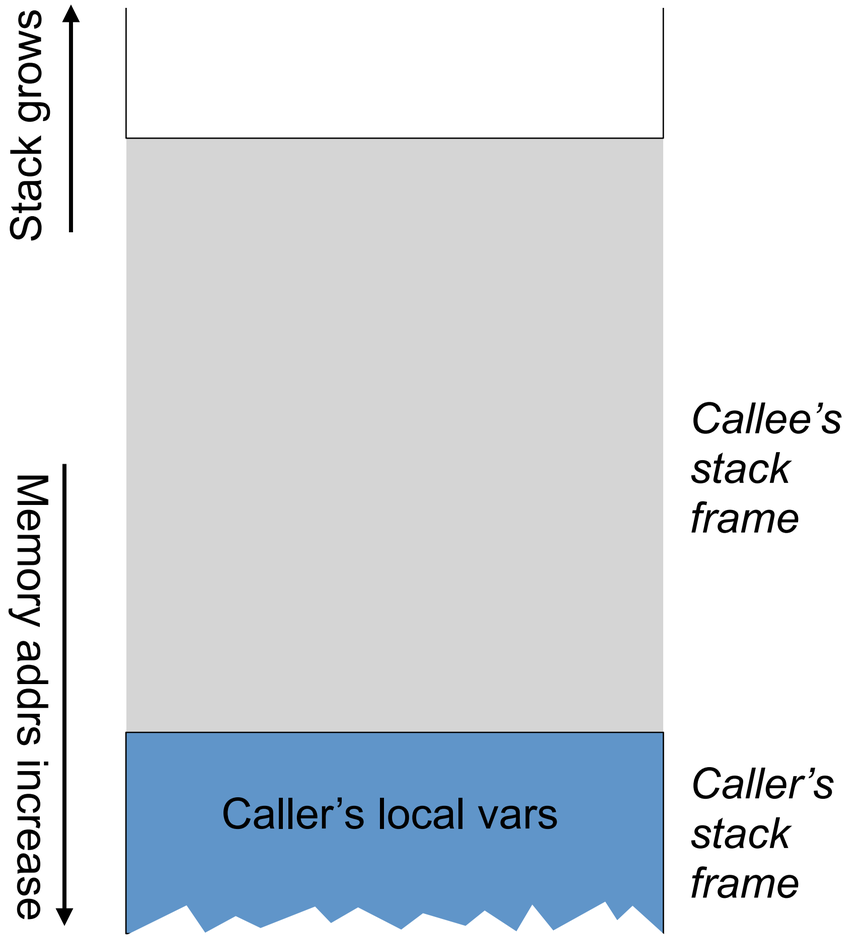

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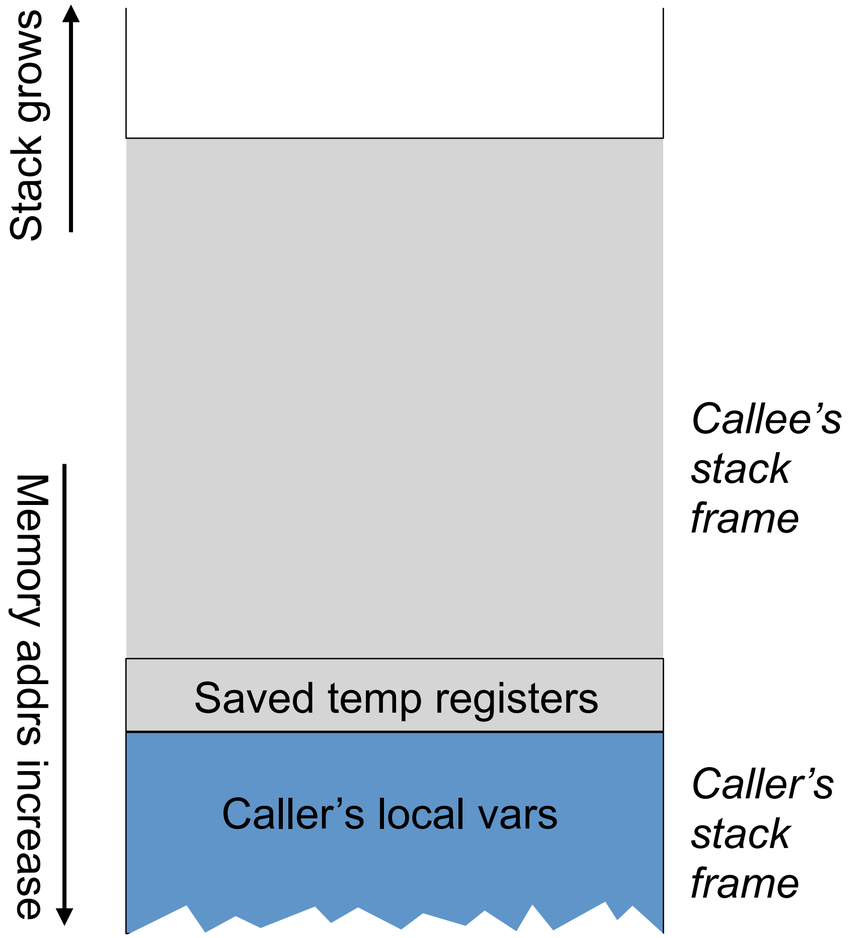

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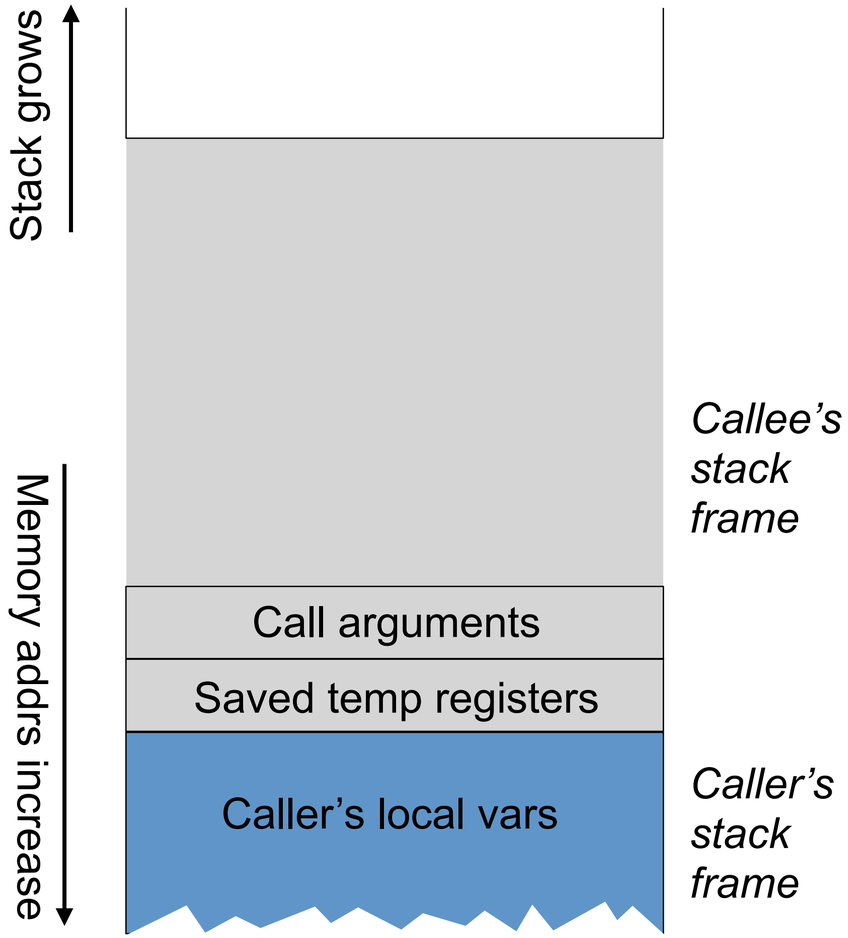

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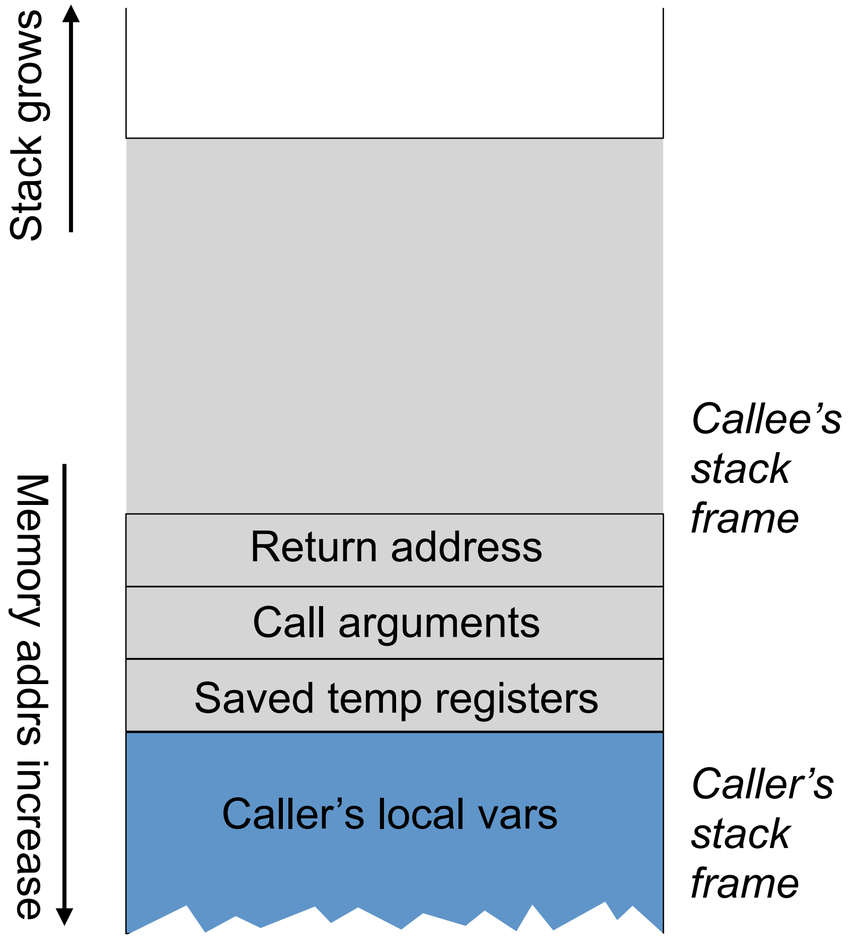

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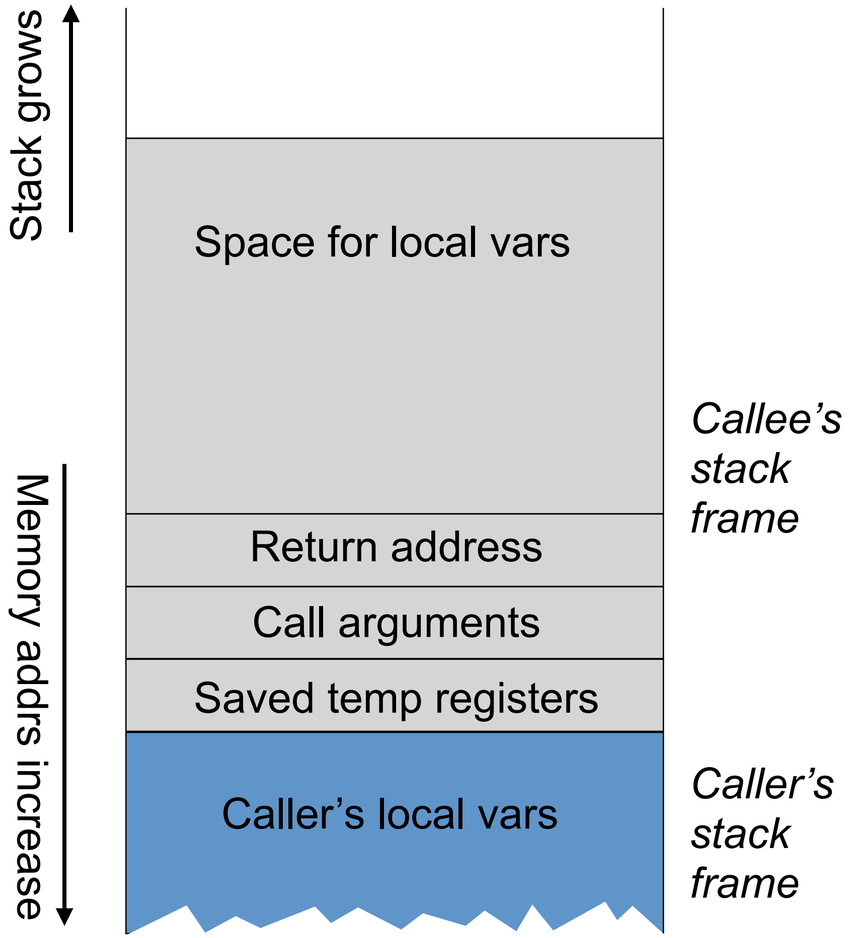

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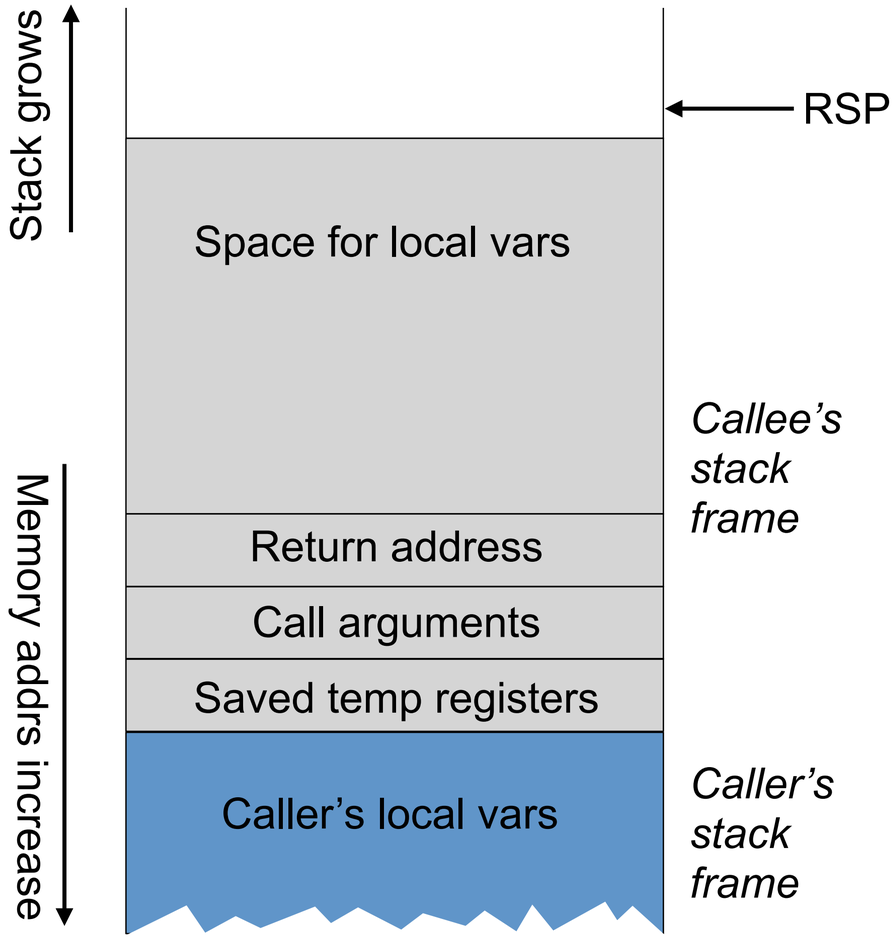

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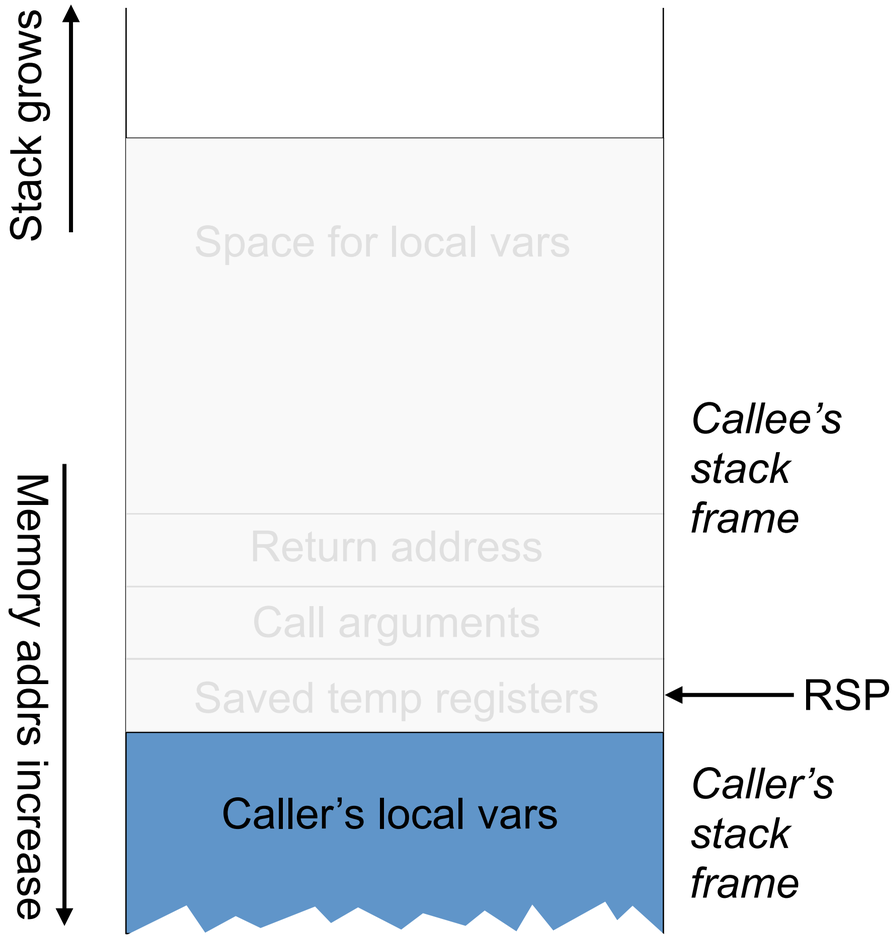
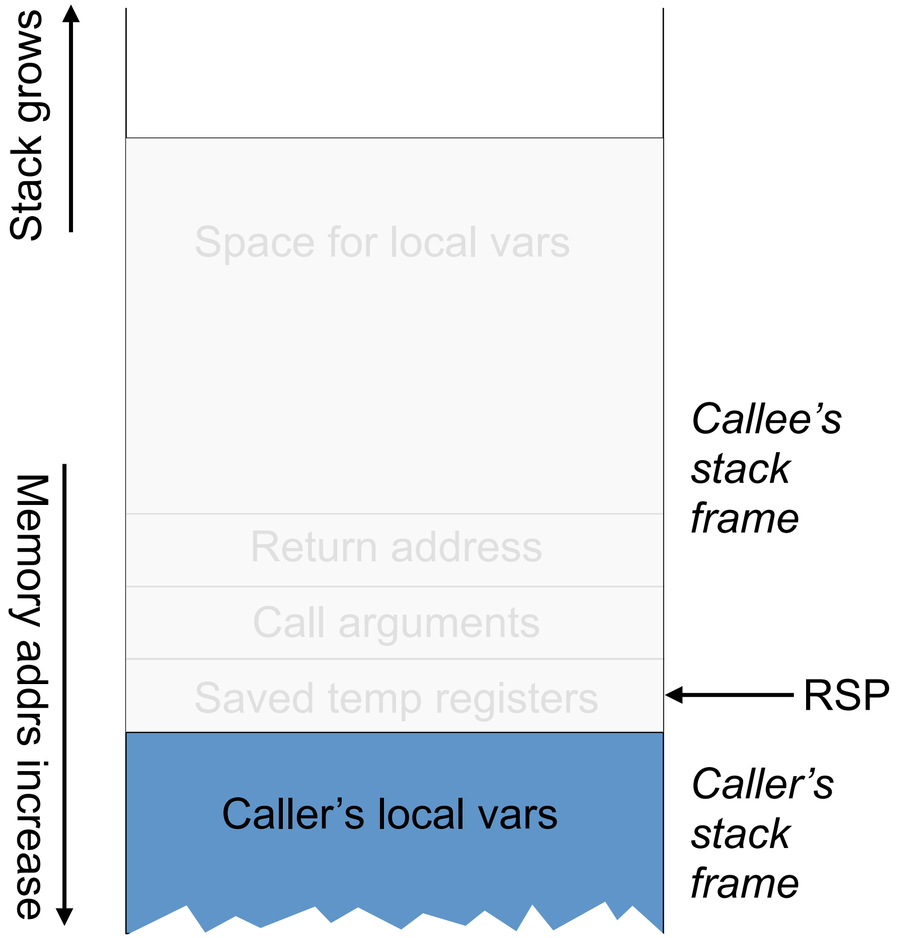


Stack-based calling convention

- ABI = interface between binary modules



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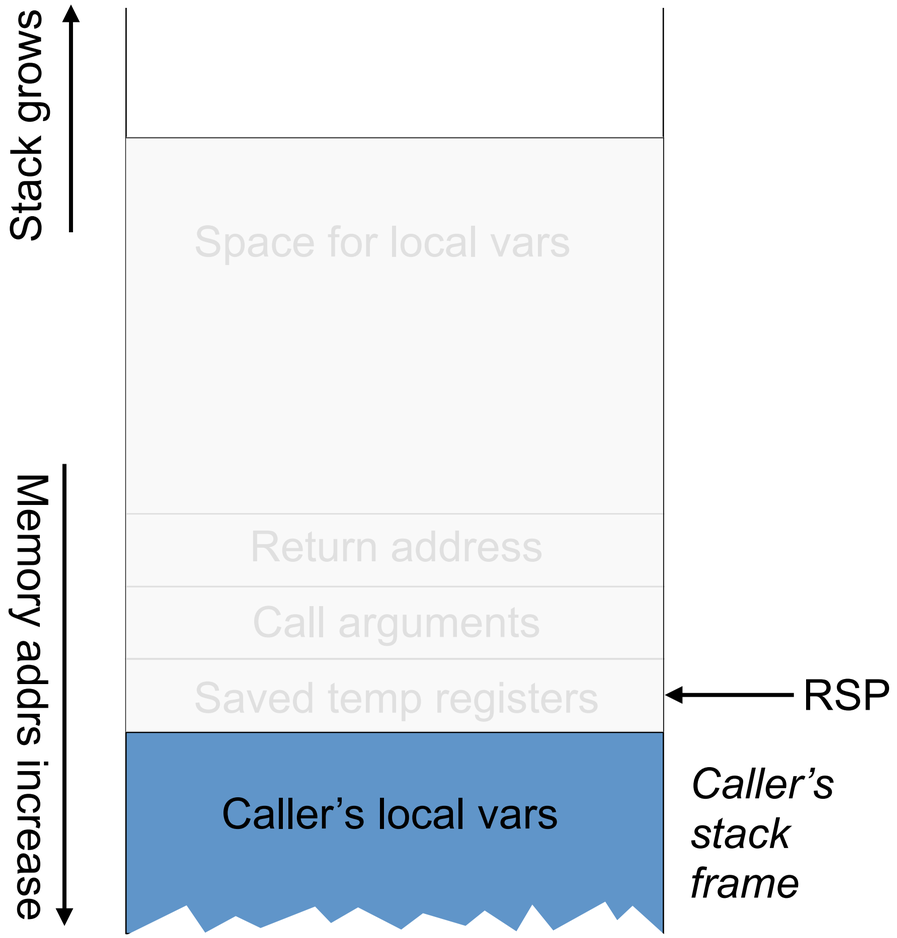

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  - *Depends on programmers doing the right thing (= "soft modularization")*
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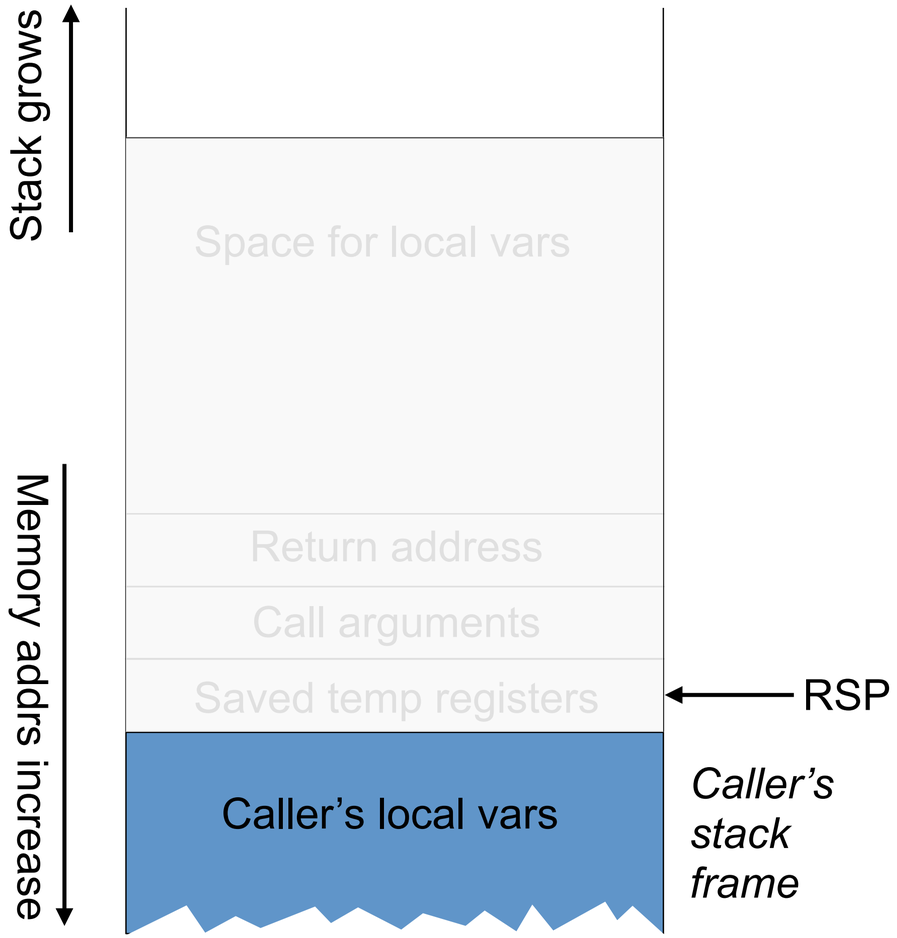

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- Caller and callee trust each other
  - *Callee could corrupt caller's stack (e.g., buffer overflow)*
  - *Callee might return to wrong addr (e.g., stack smashing)*
  - *Callee might fail (e.g., SIGFPE due to div by zero) = "fate sharing"*
  - *Callee might leave return addr in wrong register*
  - *…*

Outline

- Local procedure calls (module = procedure)
- Program objects & types (module = memory objects)
- Client/server architecture (different address spaces)
- Example: Remote procedure calls

Memory safety

Message-based communication

Program Objects & Types

Strong modularization within the same address space
(Modules = objects within the program)

Program objects

```c
struct Rectangle {
    int length;
    int width;
}

int area(struct Rectangle r)
{
    return r.length * r.width;
}
```

```java
class Rectangle {

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Data + Behavior inseparable

Objects & type safety = stronger intra-program modularity

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Image courtesy of https://cs160debatable.weebly.com

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- Ensuring type safety
  - *Static (Rust, Haskell) vs. dynamic (Python, Ruby)*

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The lower the layer where modularity is enforced, the stronger the modularity

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Memory safety

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- Example: Remote procedure calls

Message-based communication

Clients/Servers Interacting via Messages

Modularization across different address spaces

Splitting into Clients and Servers

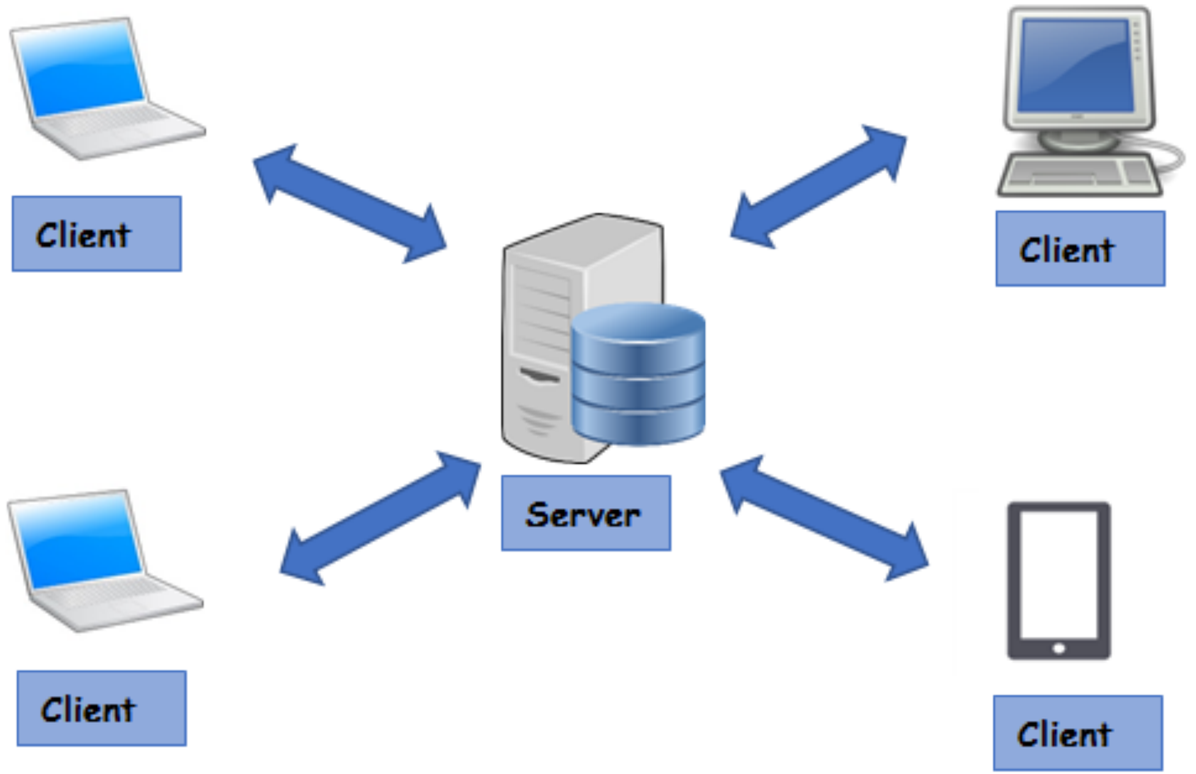
- Is the foundation for many system architecture patterns
  - *event-driven, microservices/SOA, action–domain–responder (e.g., MVVM), multi-tiered, peer-to-peer, publish-subscribe, etc.*

Splitting into Clients and Servers

- Is the foundation for many system architecture patterns
  - *event-driven, microservices/SOA, action–domain–responder (e.g., MVVM), multi-tiered, peer-to-peer, publish-subscribe, etc.*
- Key ideas
  - *place modules in separate, strongly isolated domains, and have them communicate via messages*
  - *messages typically need to be marshalled/unmarshalled for send/receive*

Physical (and virtual) servers

- Rely on physics
- Reduce fate sharing
- Improve encapsulation



https://www.omnisci.com/technical-glossary/client-server

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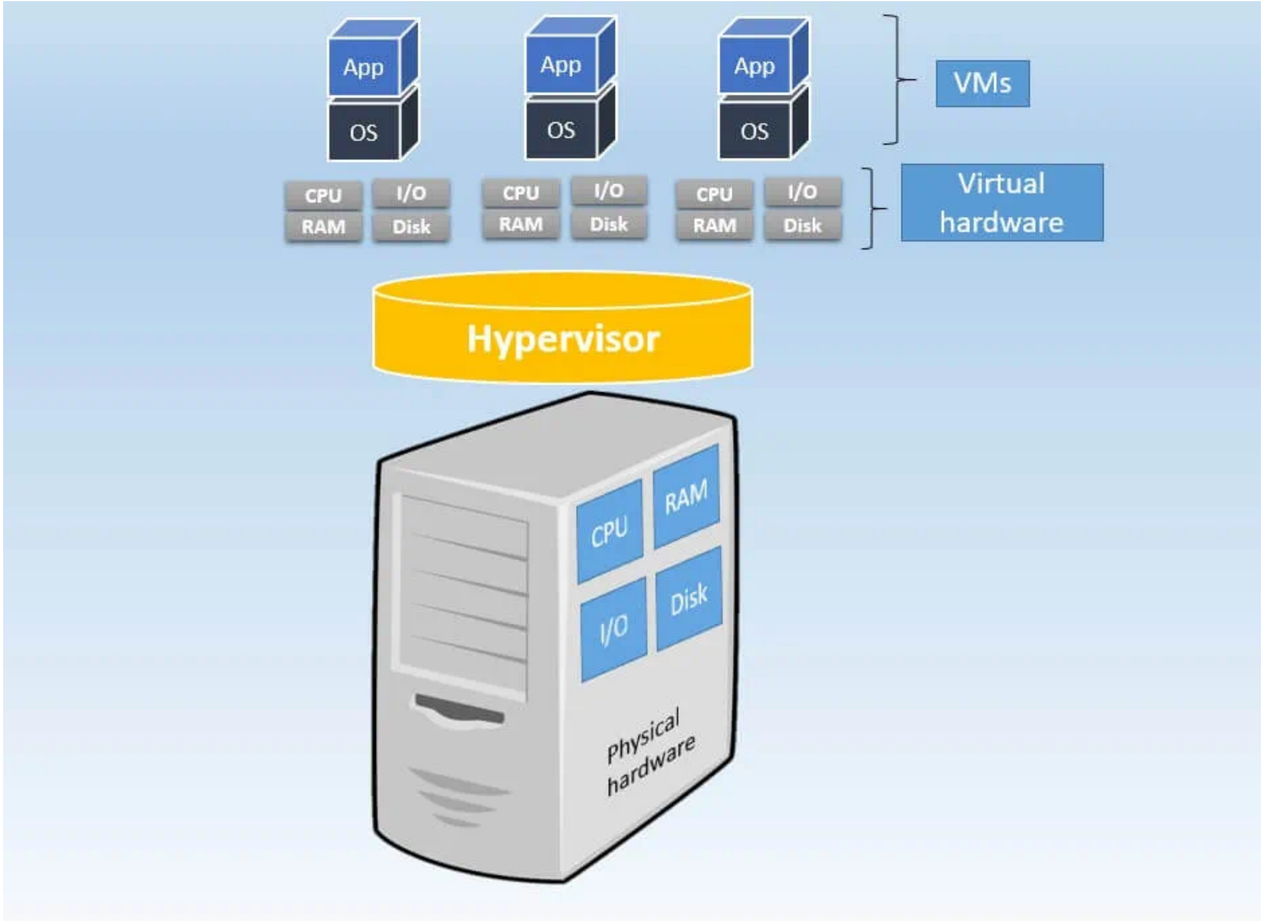

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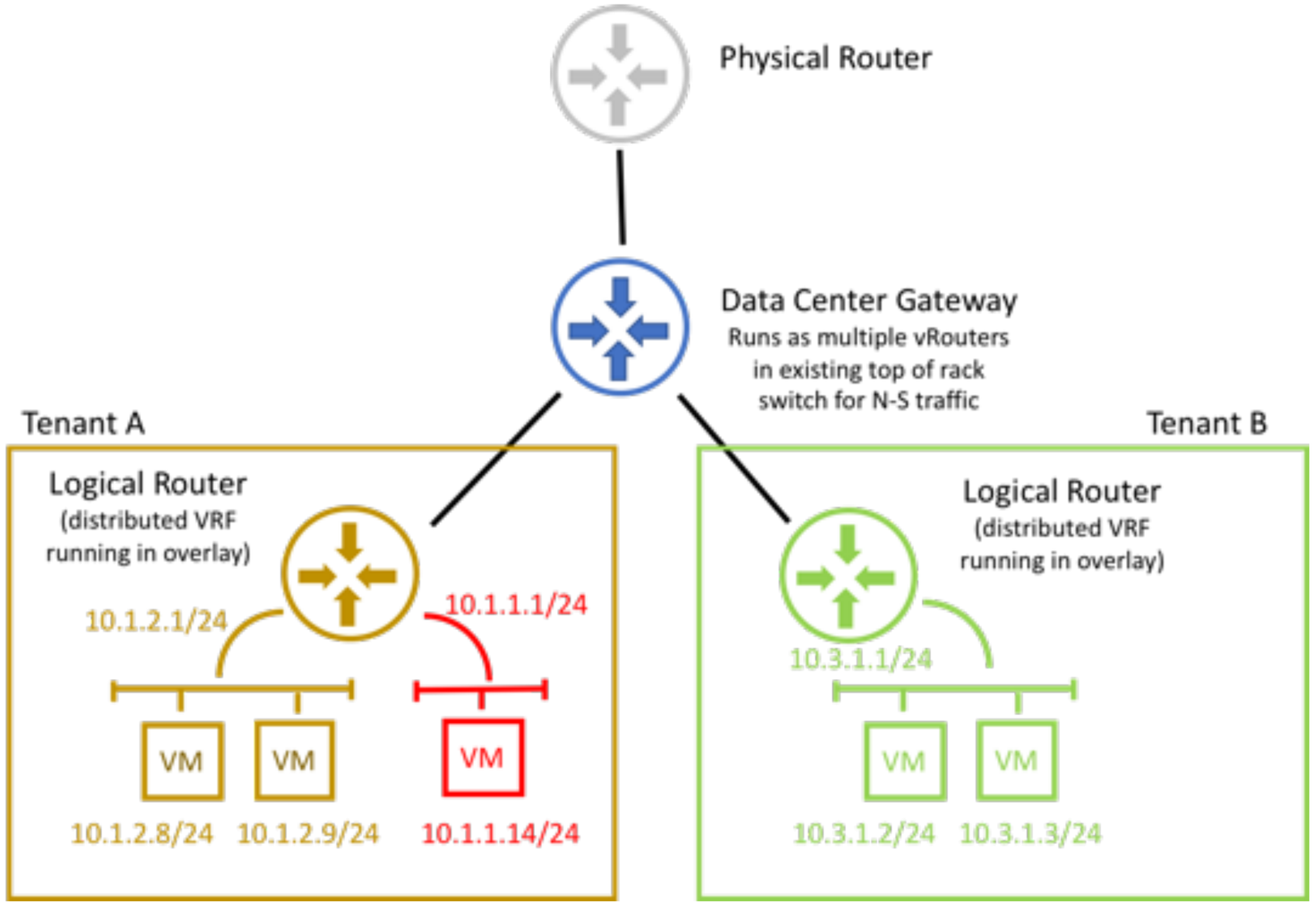

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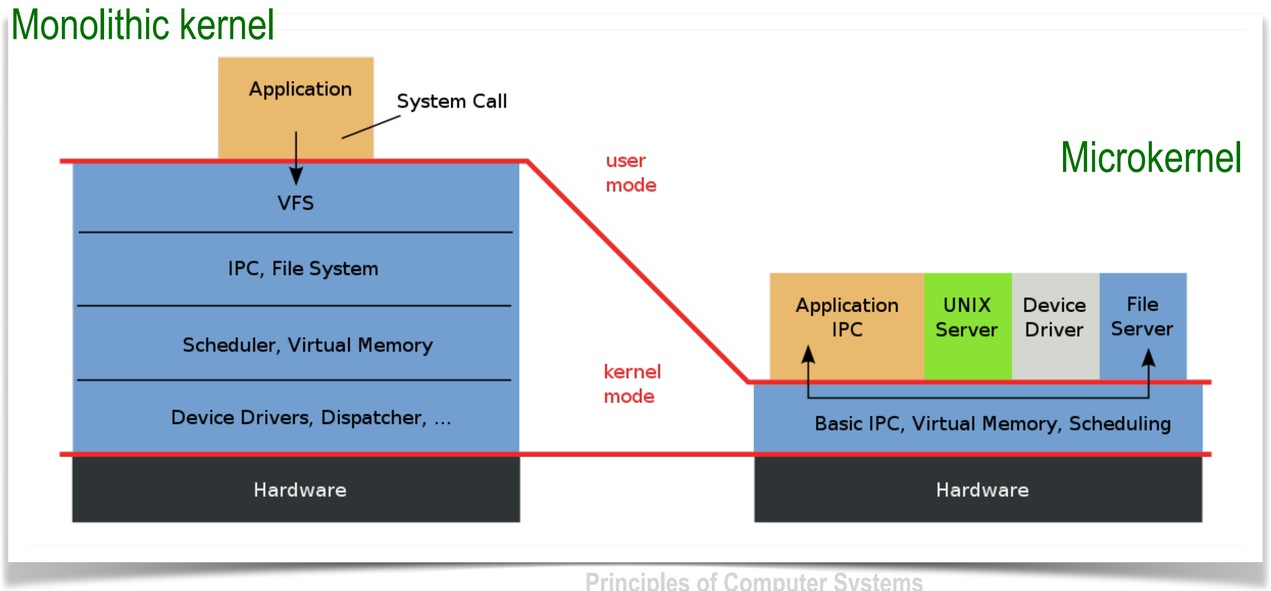

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- How is fate sharing? How is encapsulation?

Benefits of Client/Server

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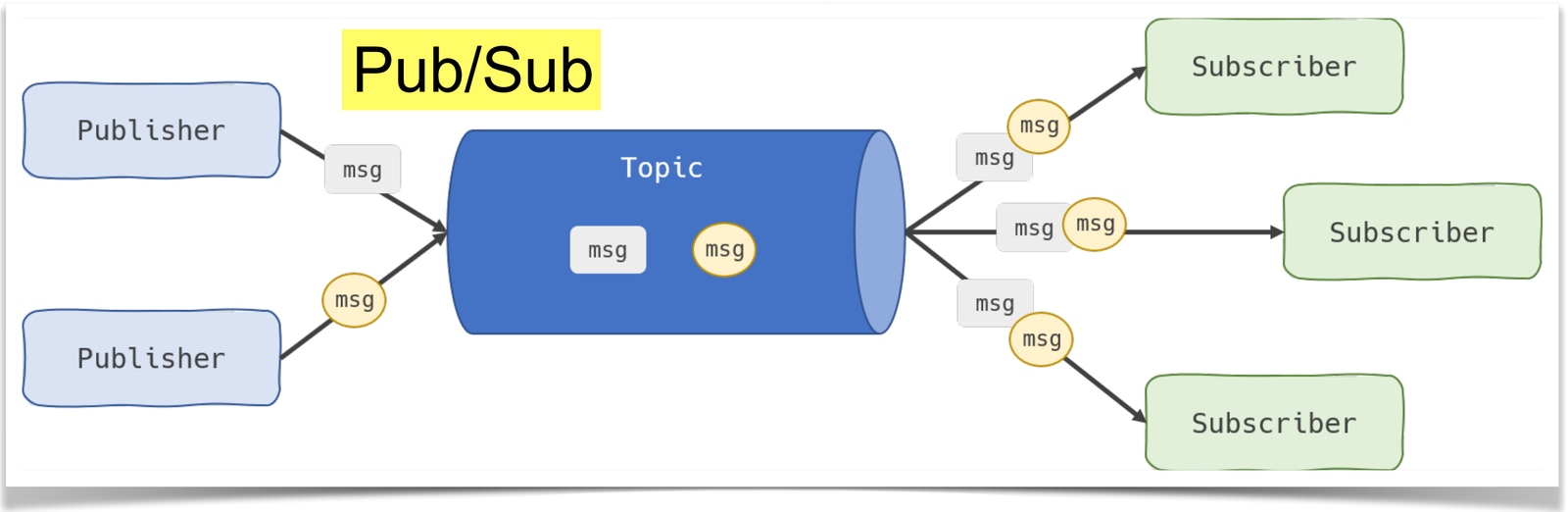
- Unnatural interaction between modules
- Semantic coupling may render functional decoupling moot
  - *E.g., caller cannot make progress without an answer*

A couple of examples of client/server architectures



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https://microservices.io/i/Microservice_Architecture.png

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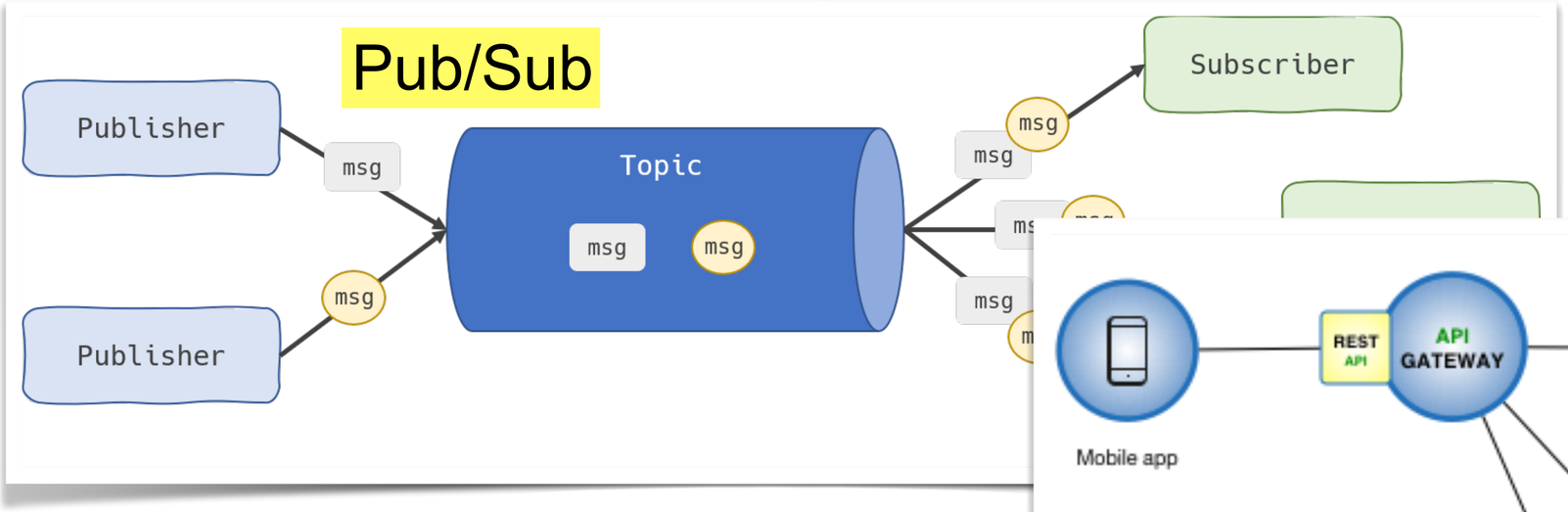

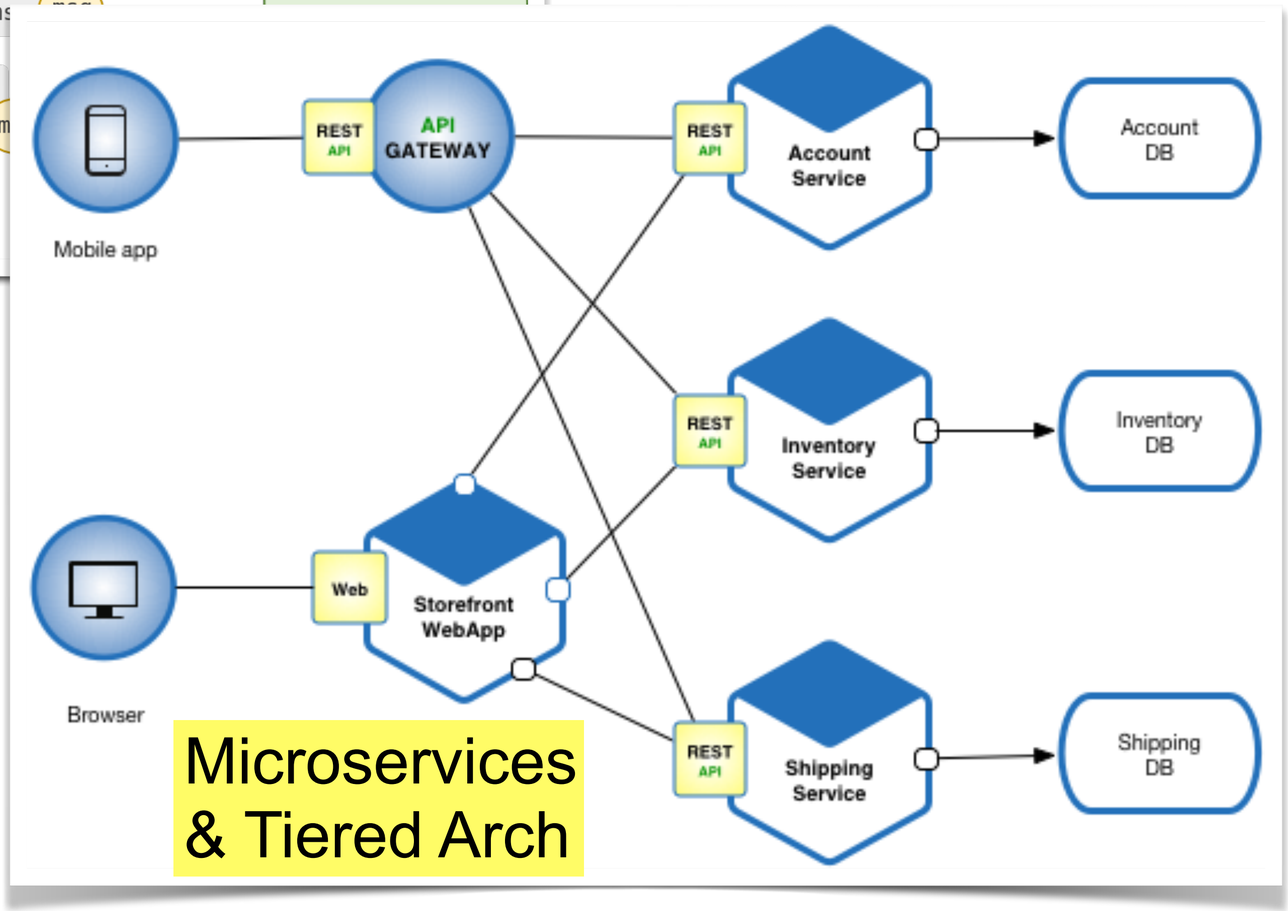

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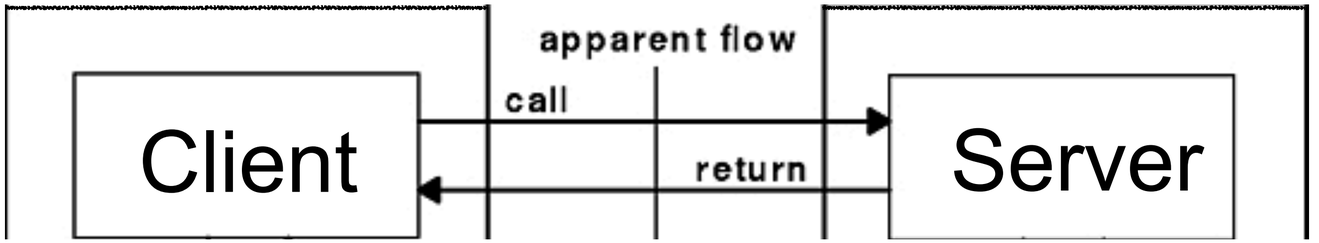
Remote Procedure Calls (RPC)

Get benefits of client/server organization
with the comfort of a procedure call

Mechanics of RPC



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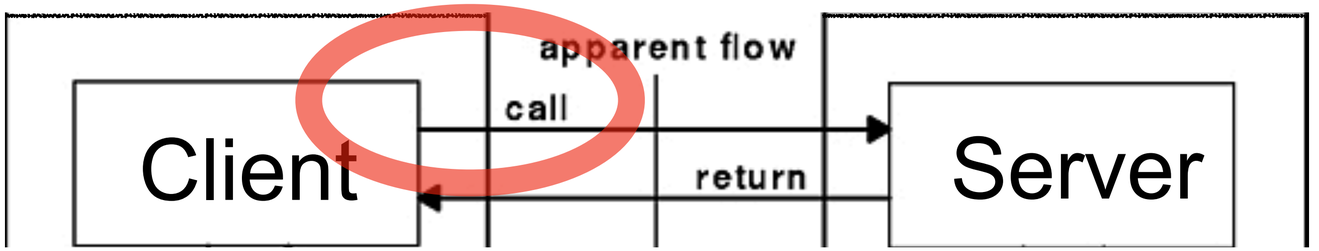

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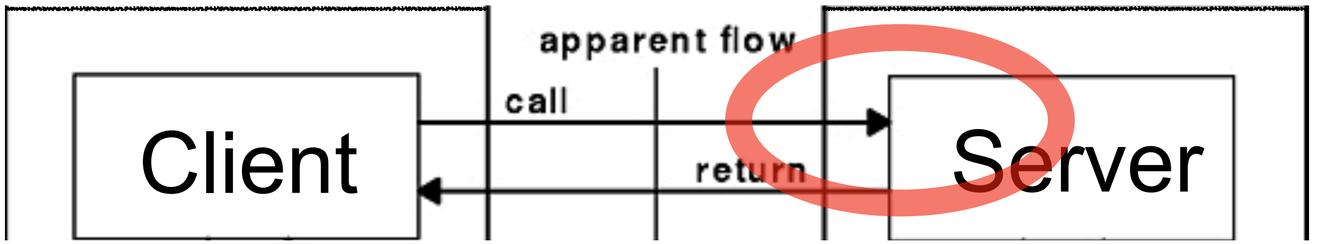

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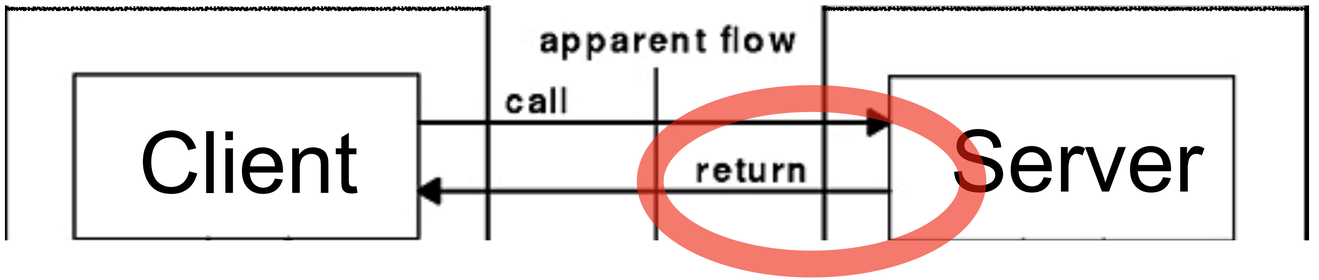

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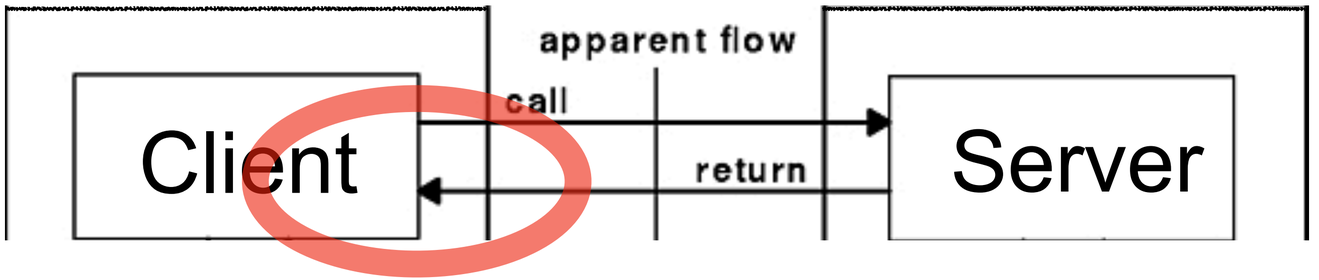

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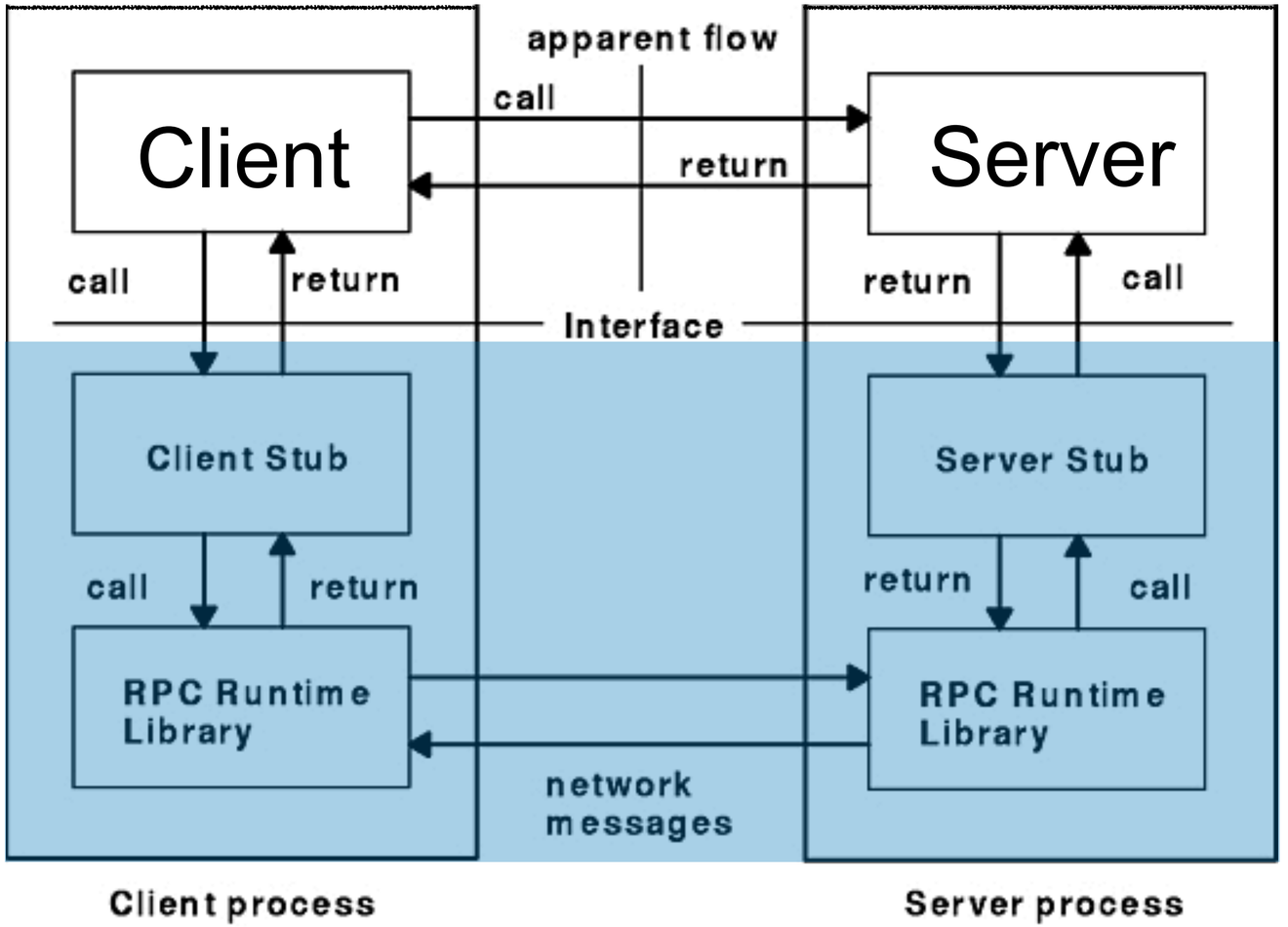

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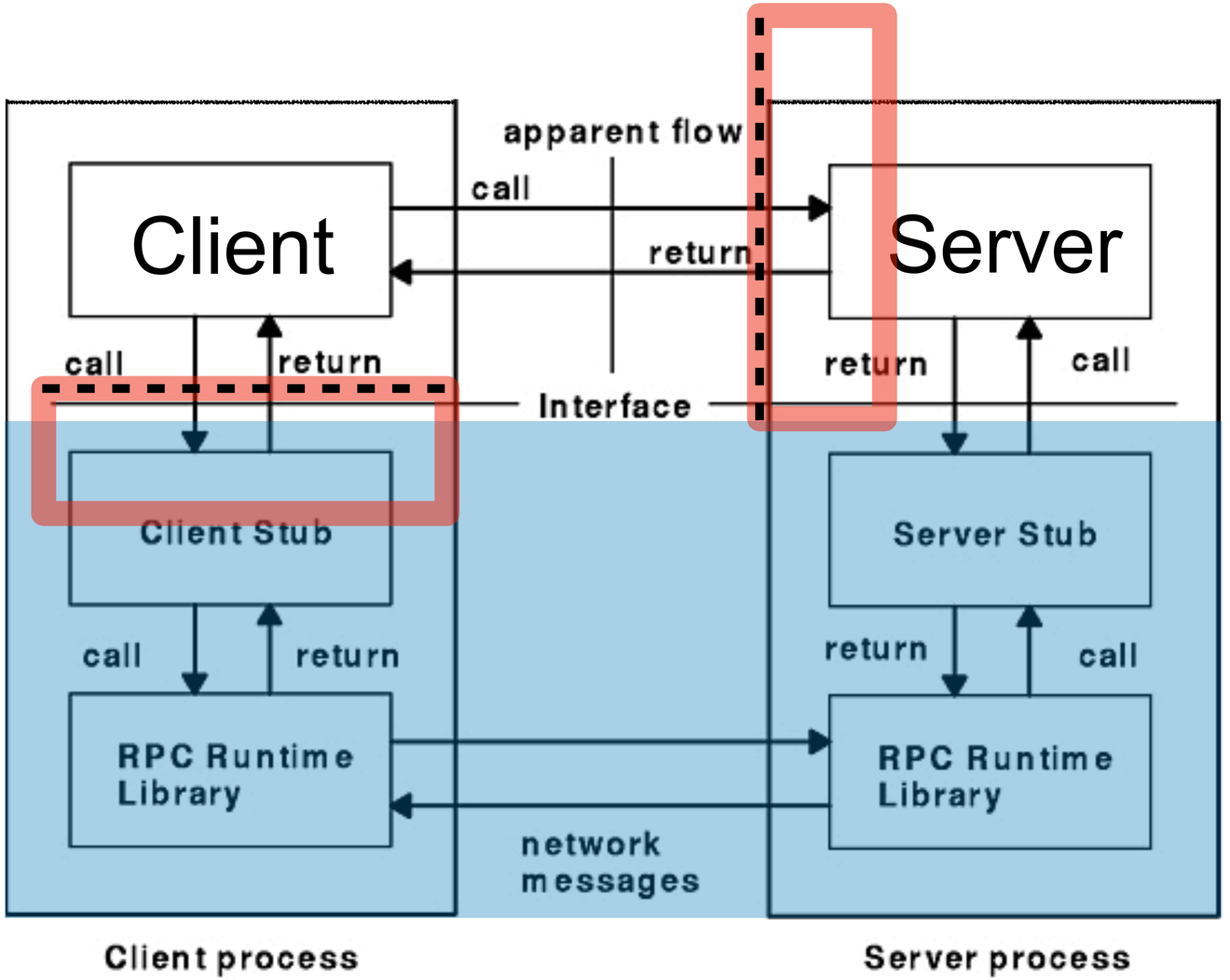

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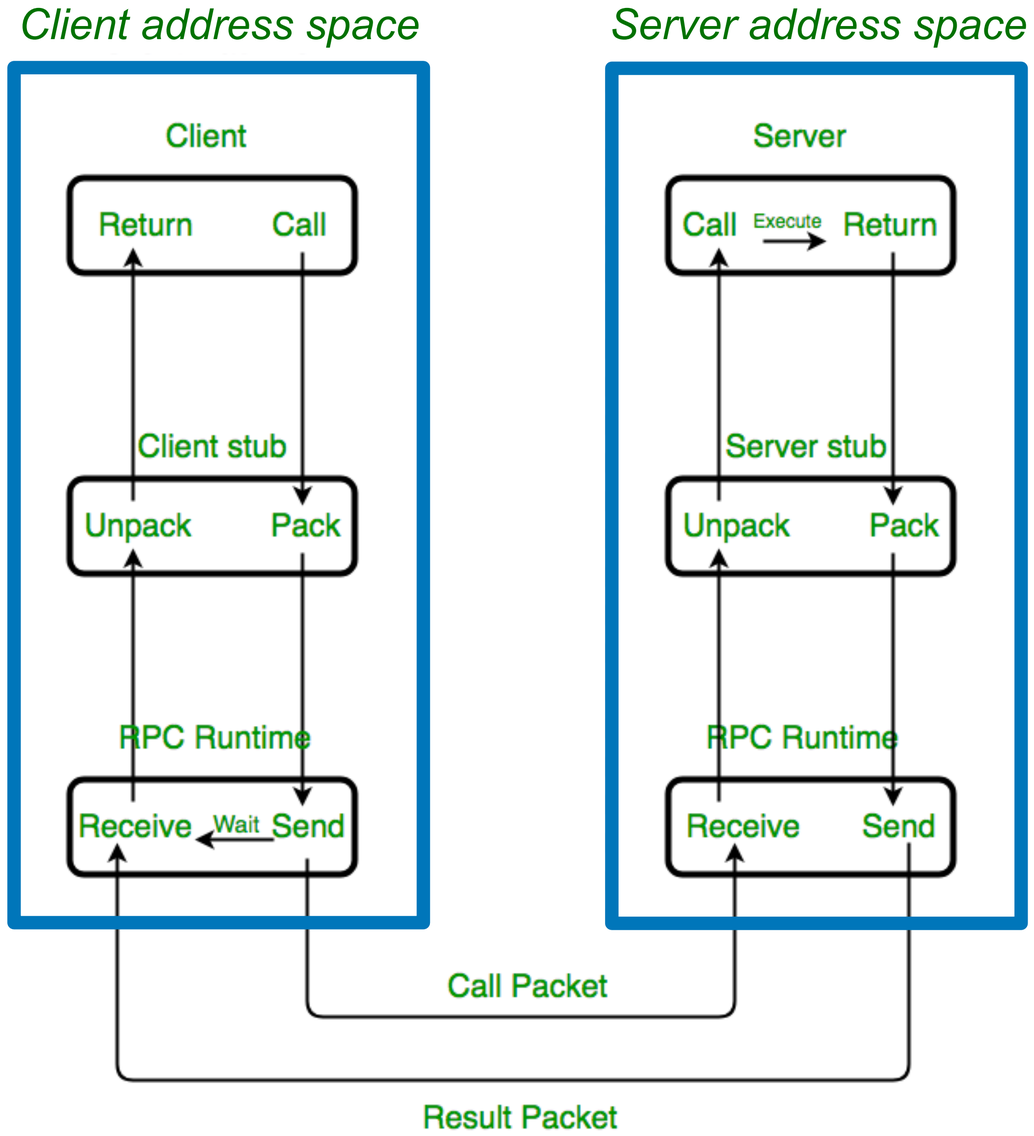

Local procedure call

Parameters -> message

Message -> packet

Local procedure invocation

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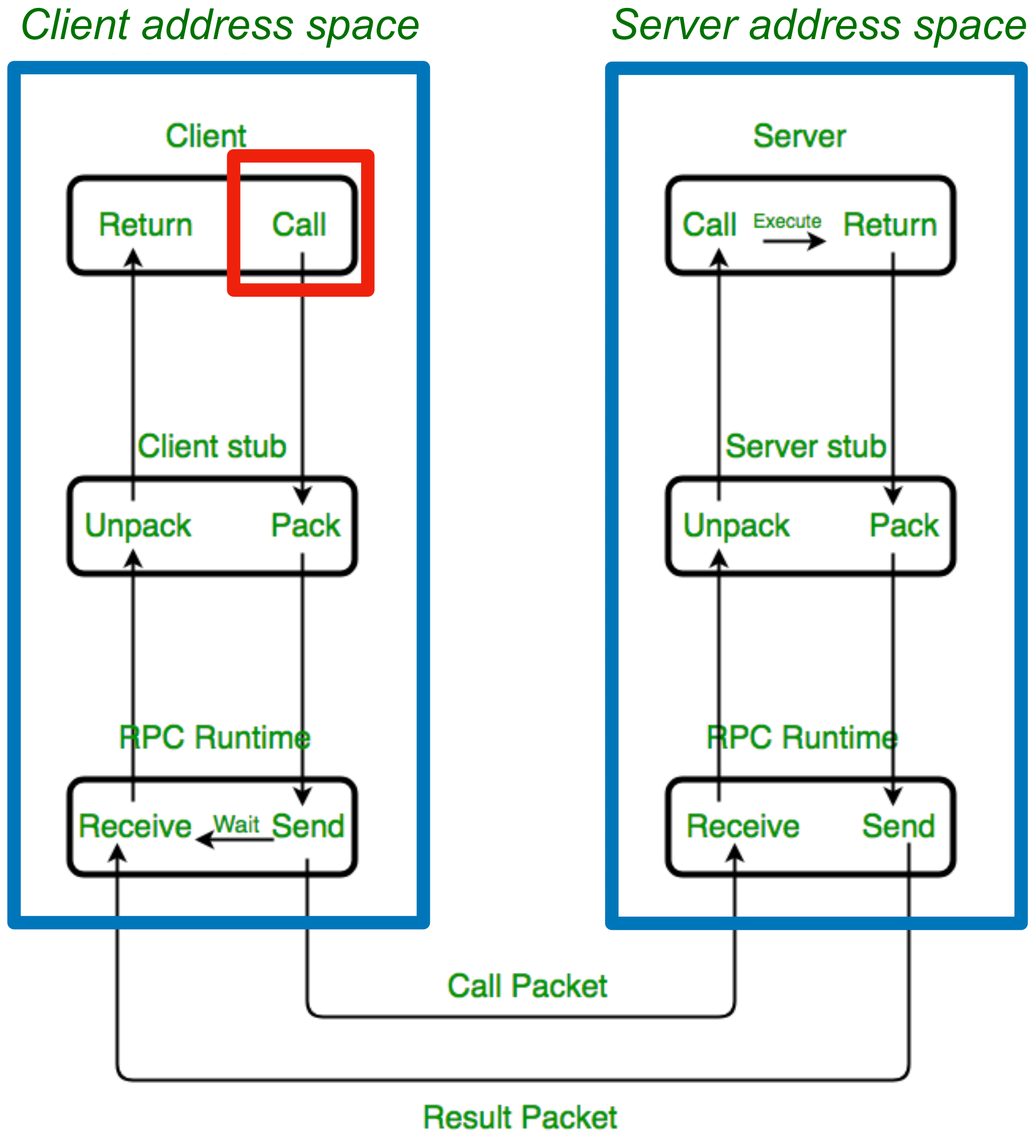

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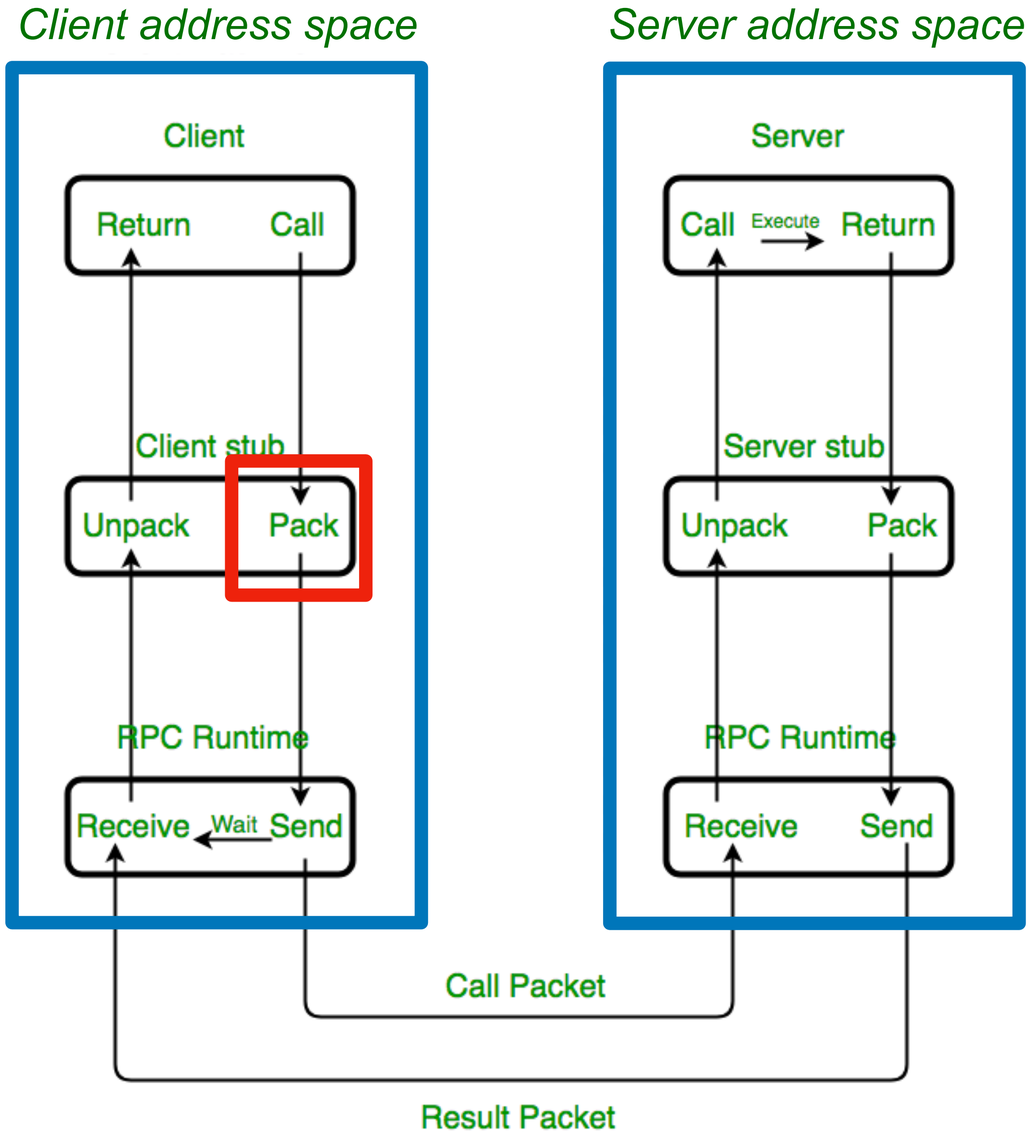

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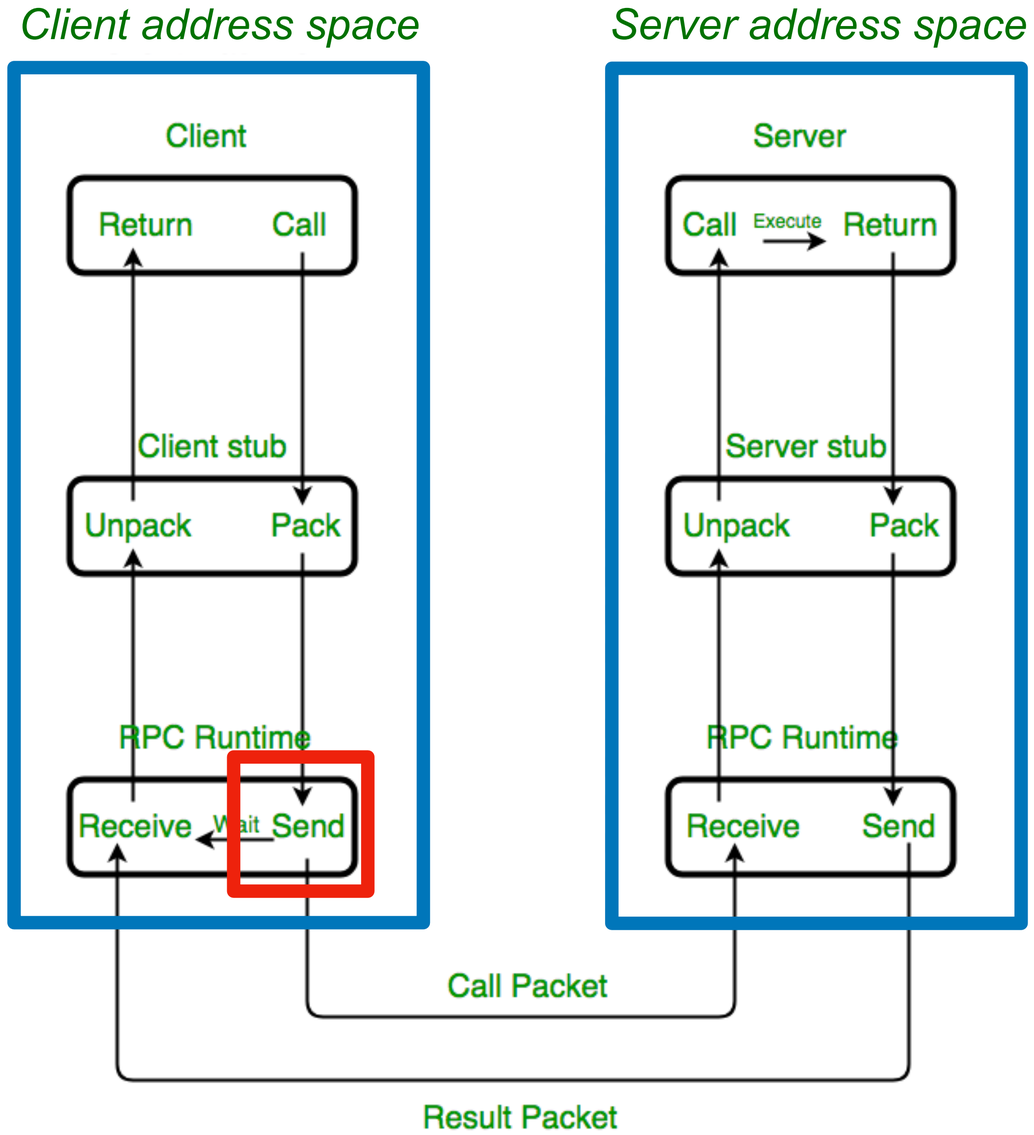

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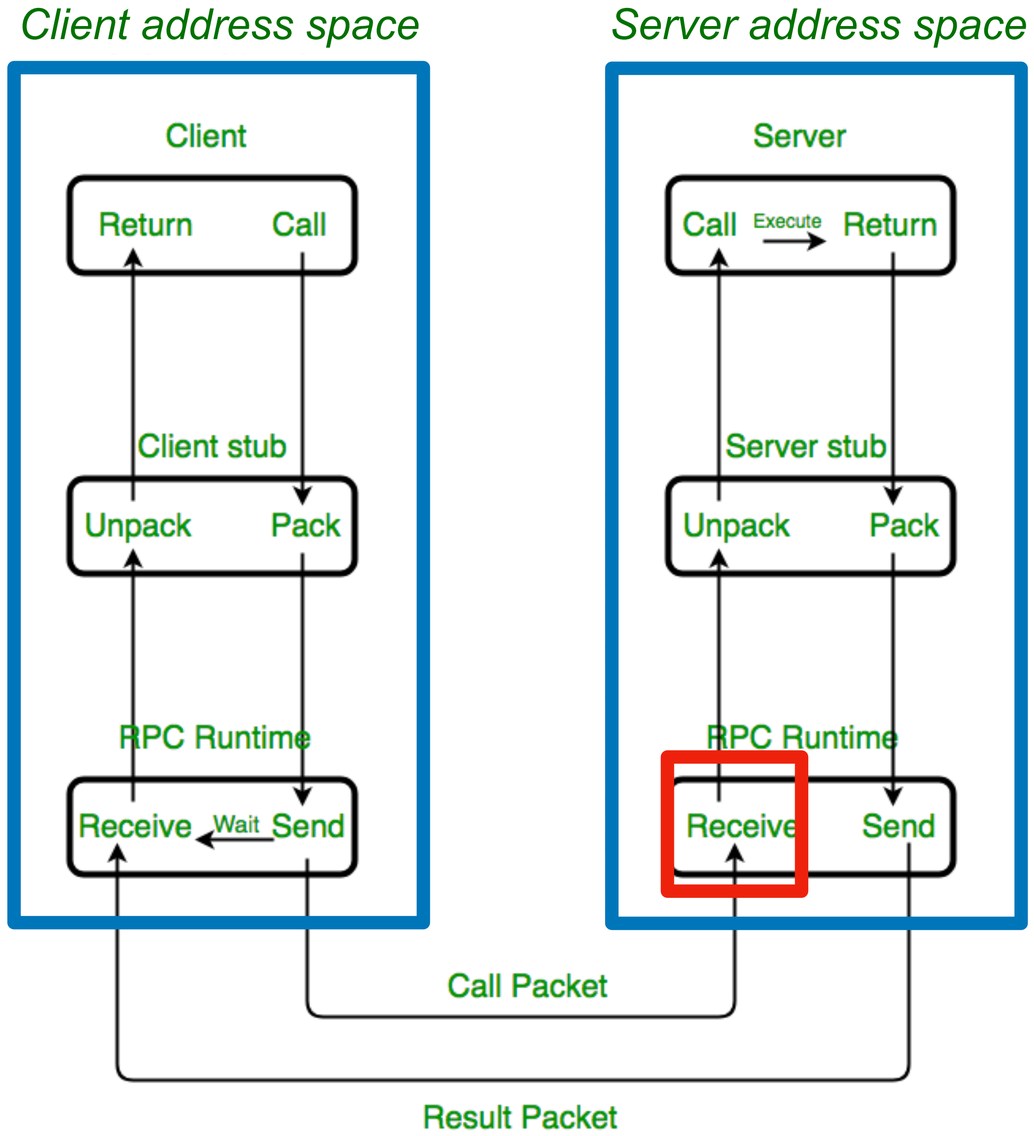

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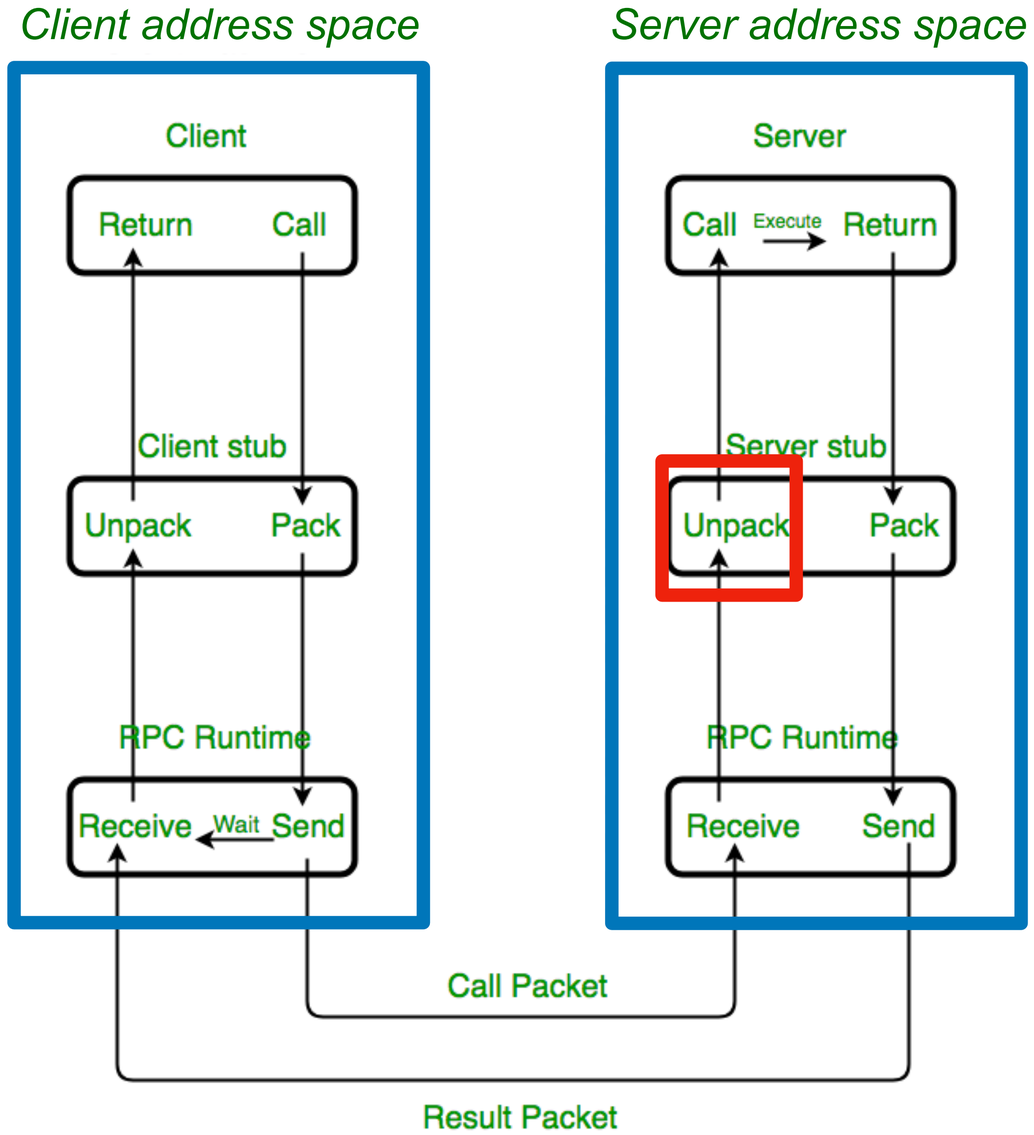

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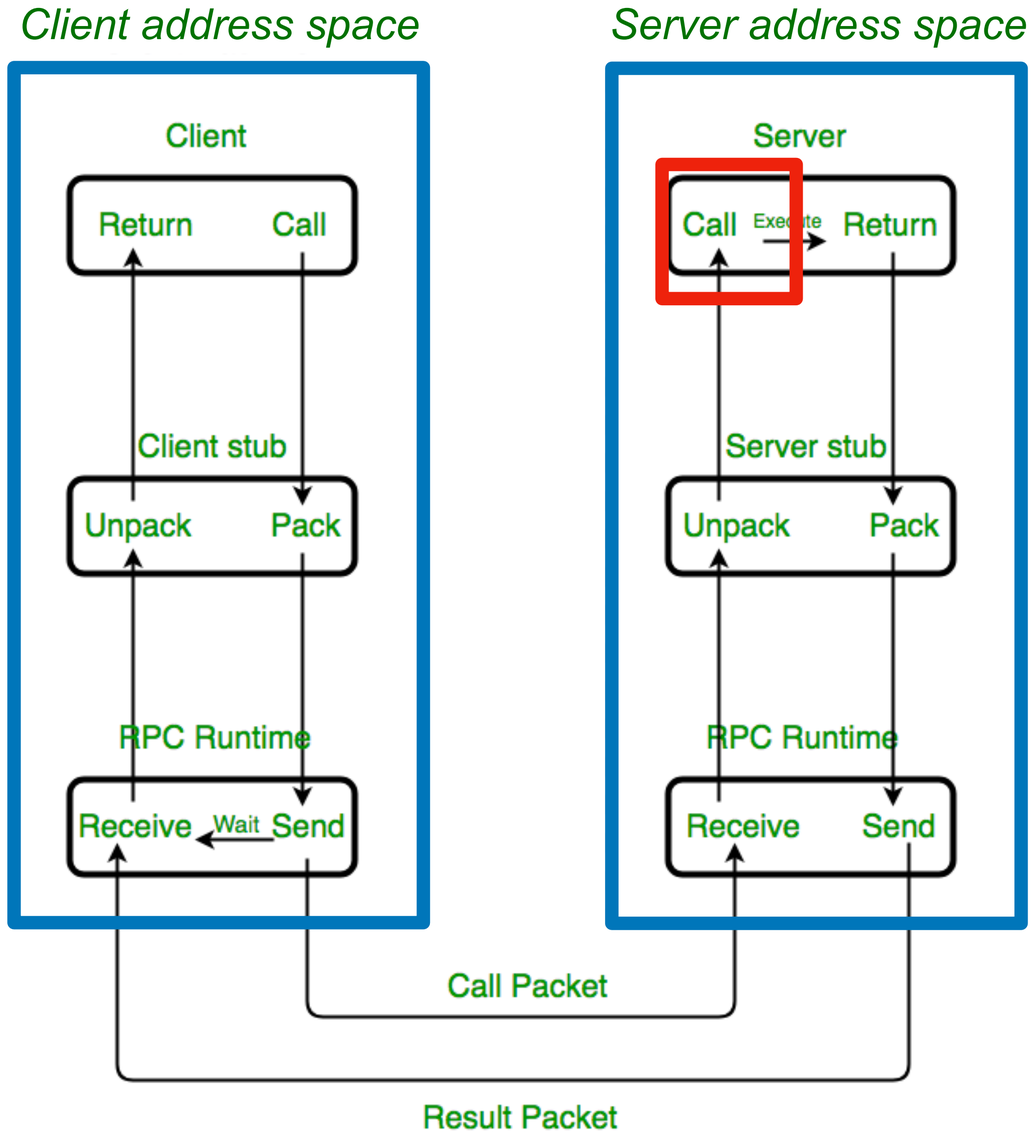

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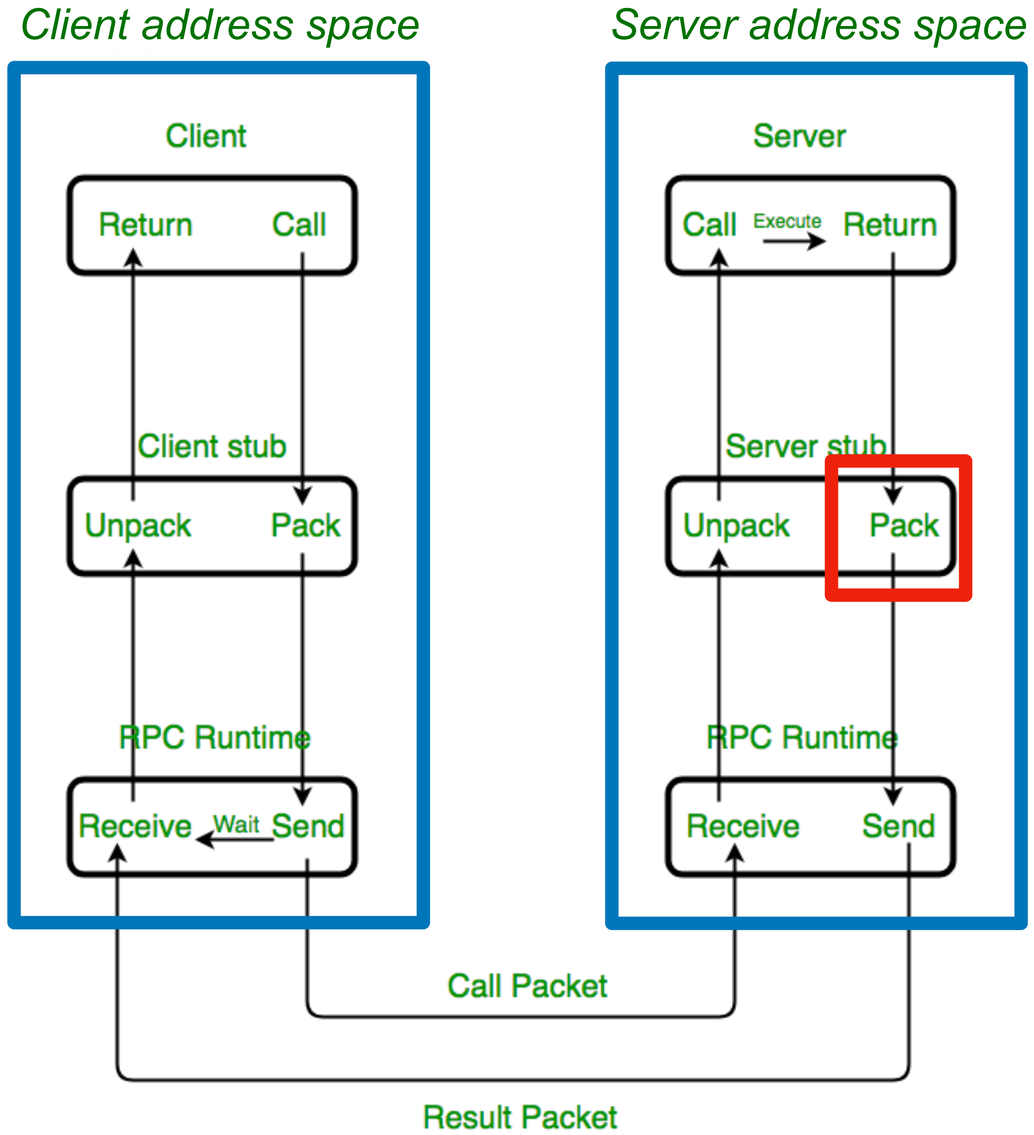

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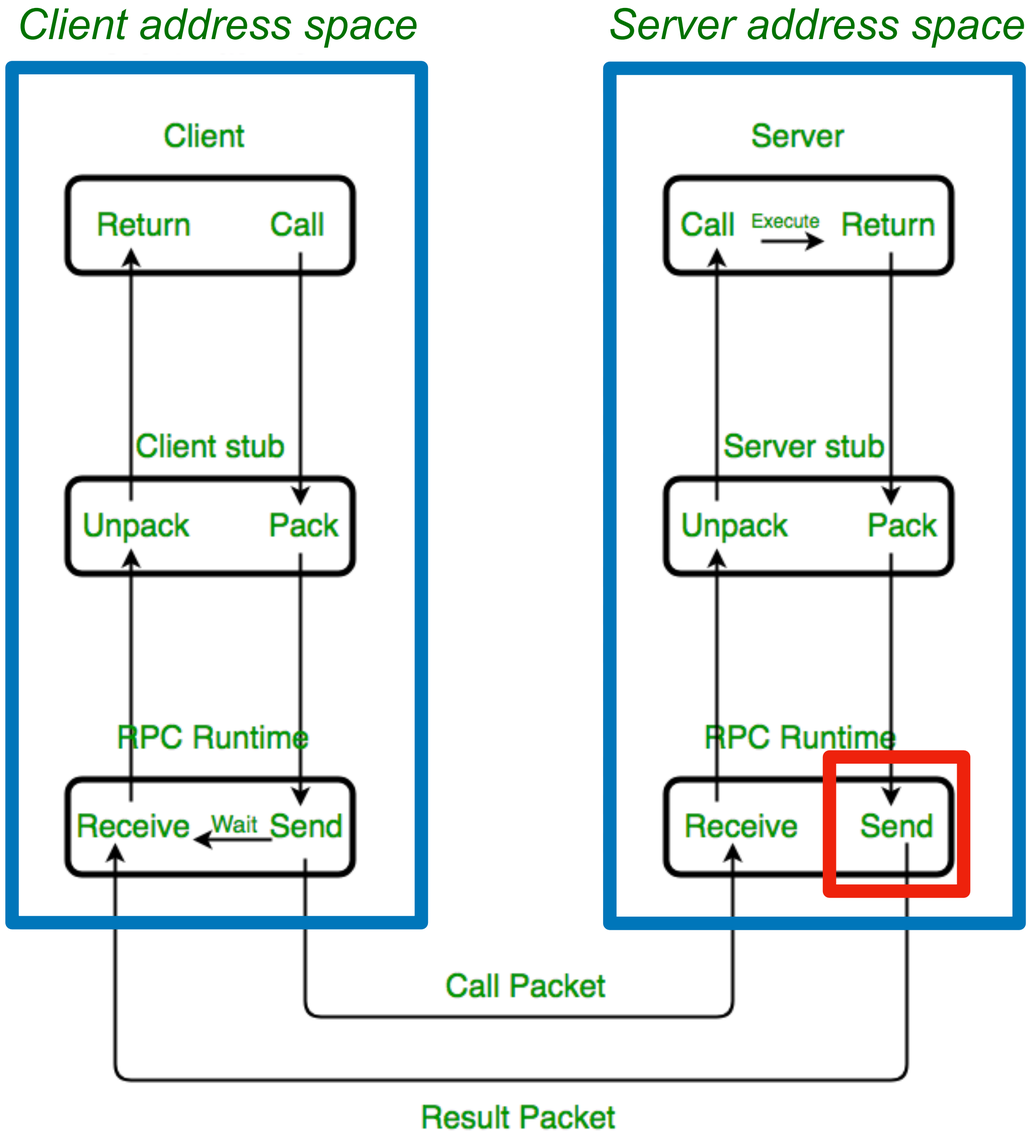

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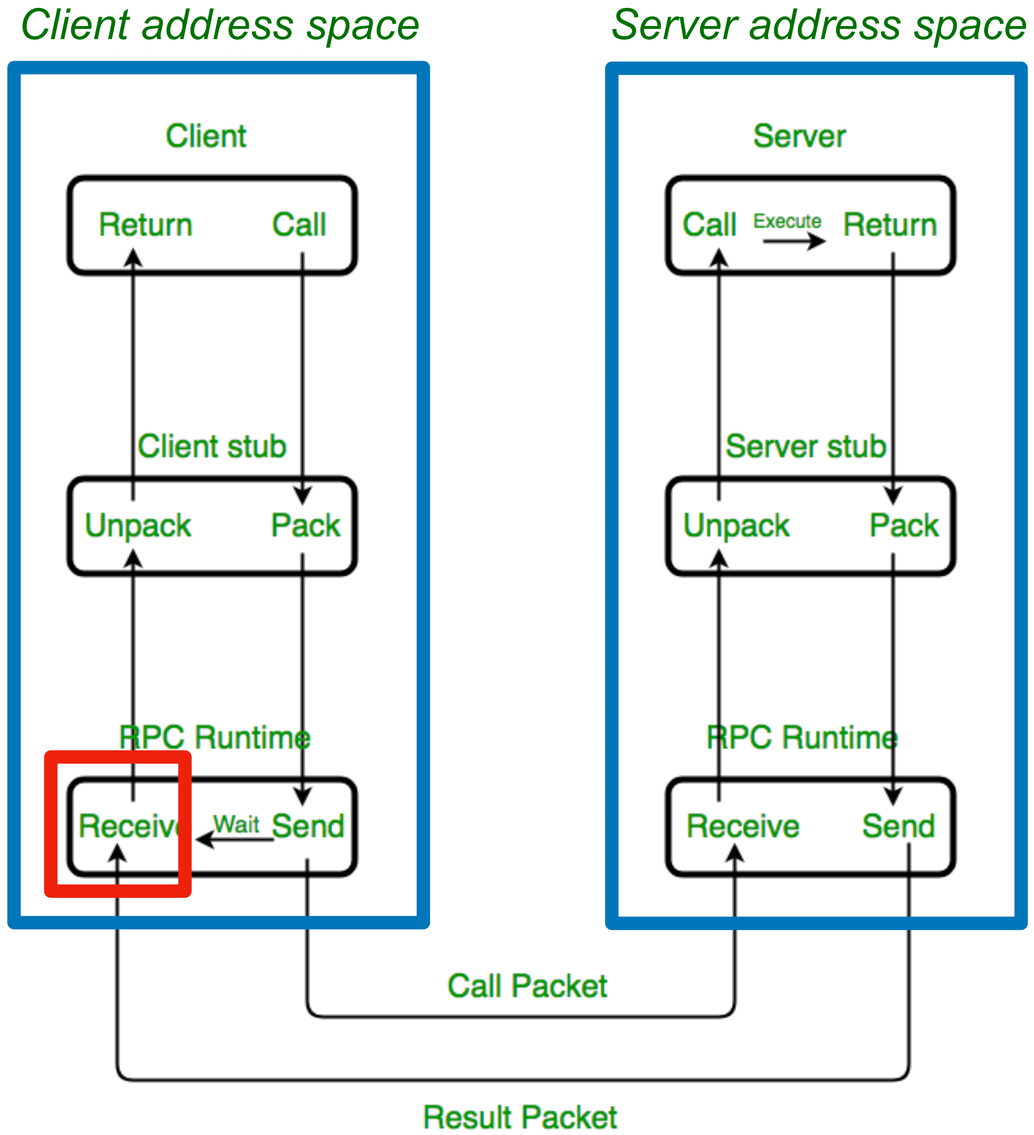

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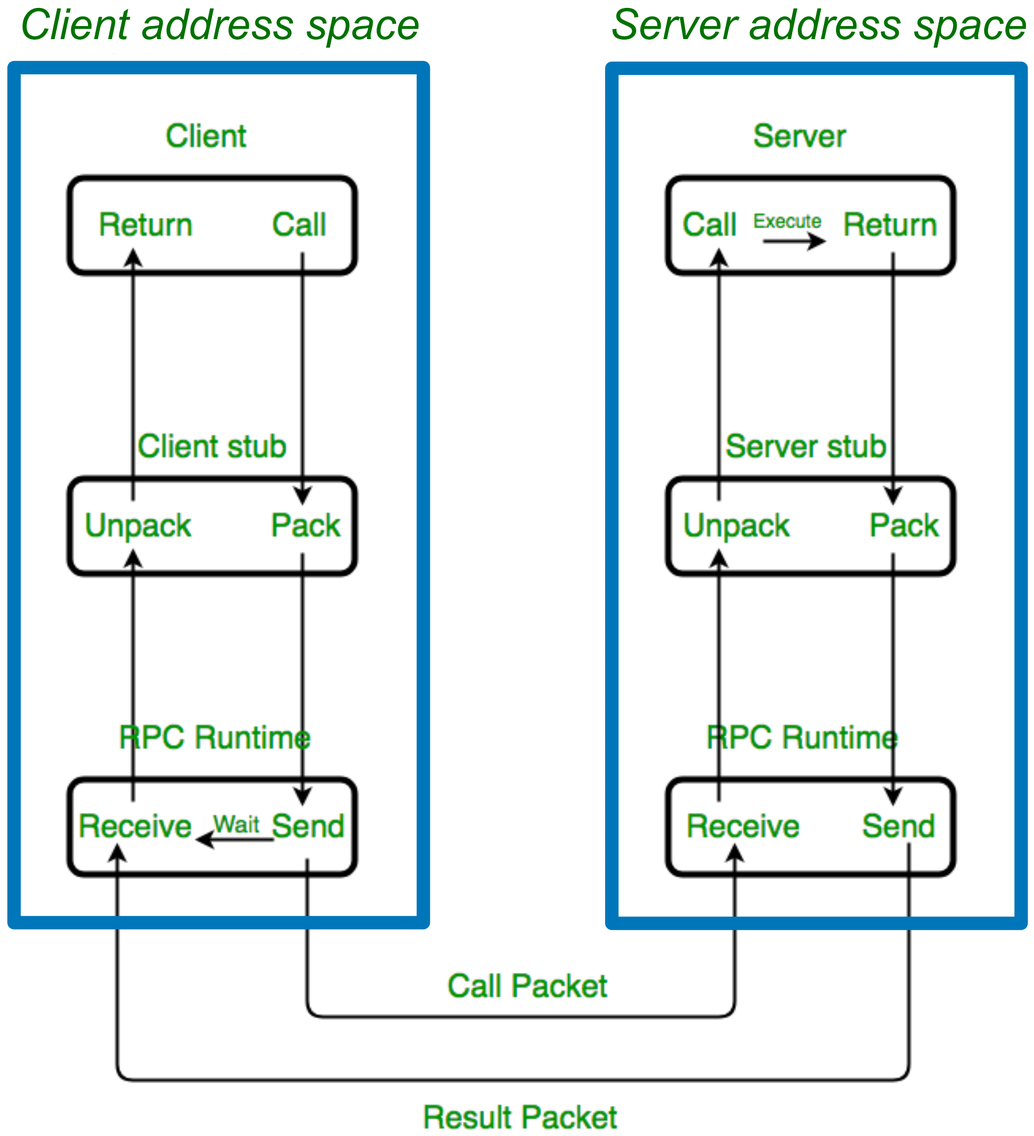

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Examples of RPC systems

- NFS *and*  Google Cloud Filestore
- Java RMI *and* Google Web Toolkit
- Go's `rpc` package
- Cassandra, HBase, Couchbase
- Apache Thrift
- gRPC (uses Google Protocol Buffers IDL)
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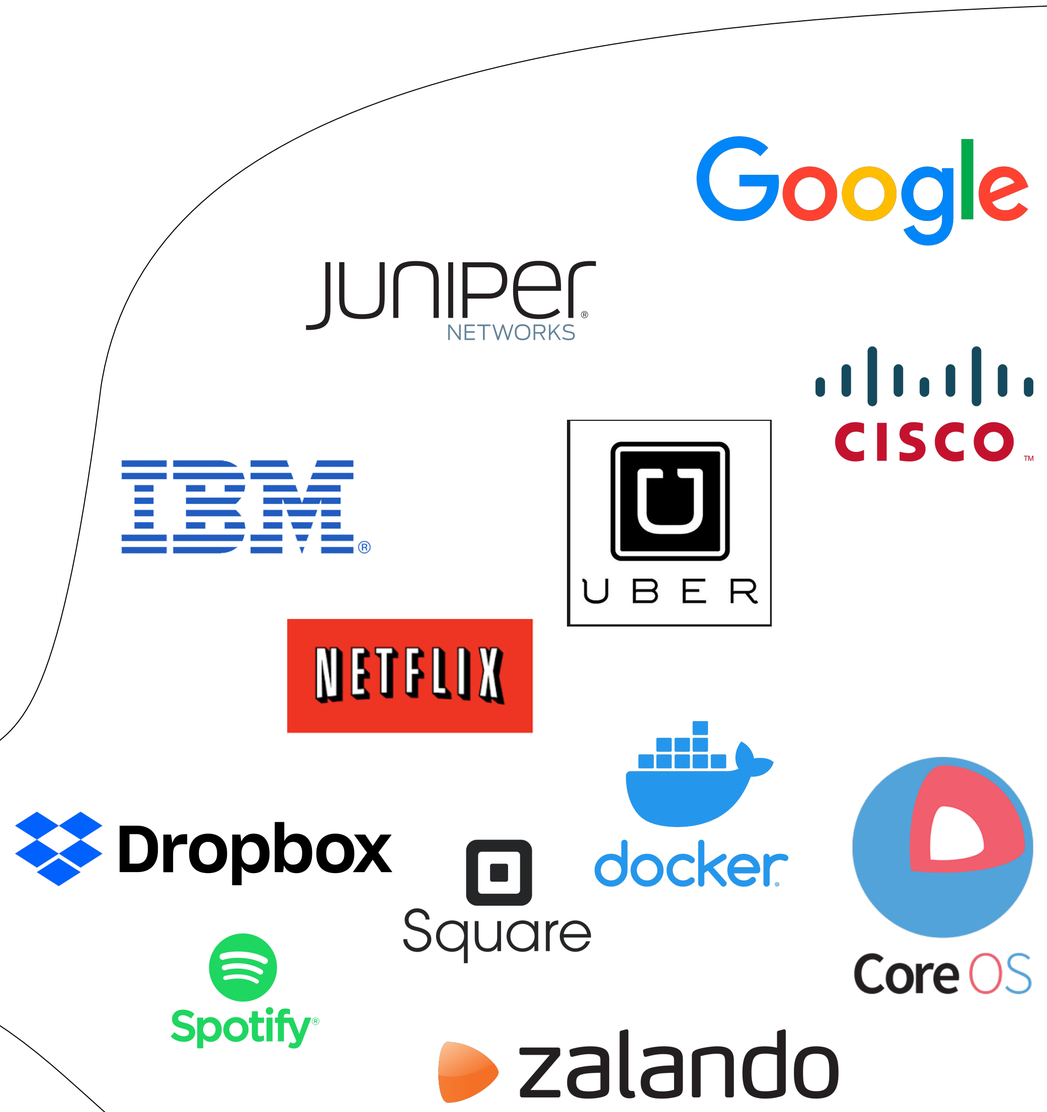
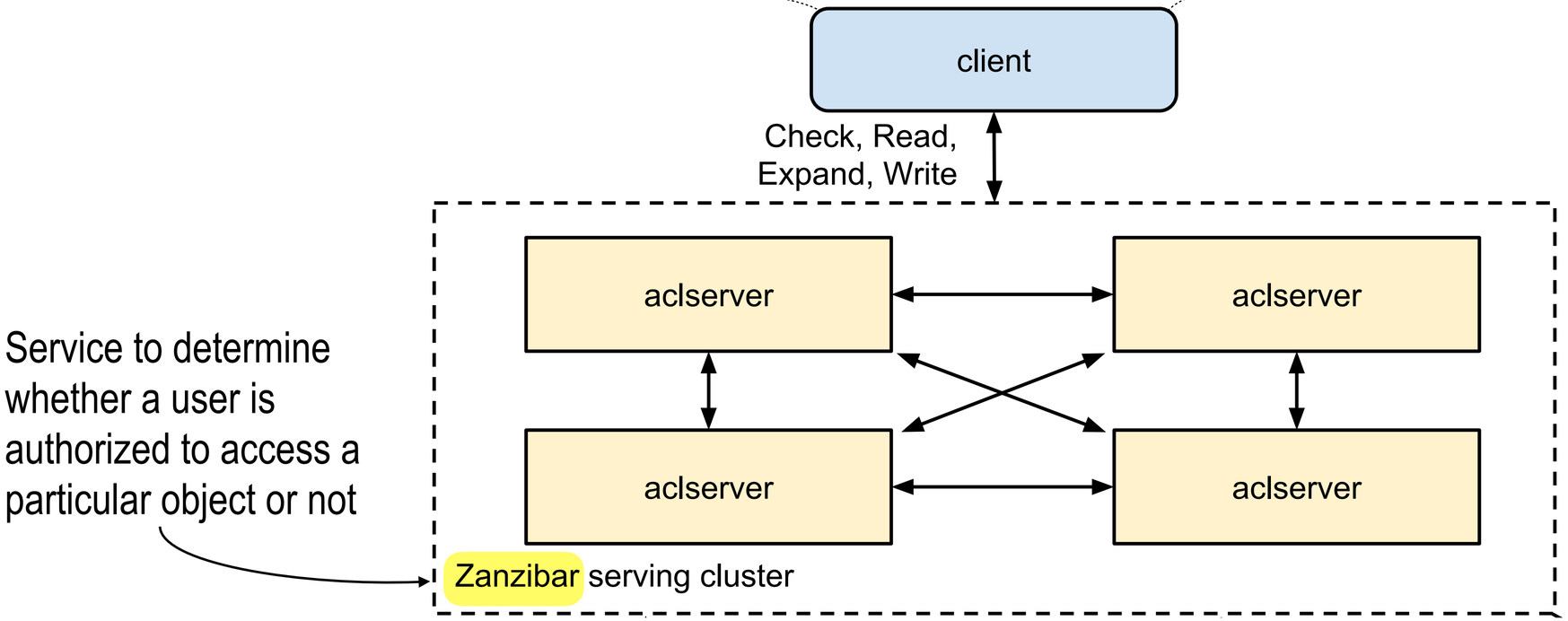
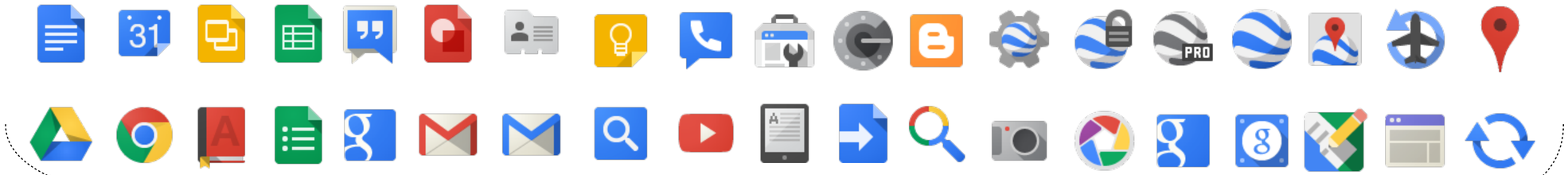
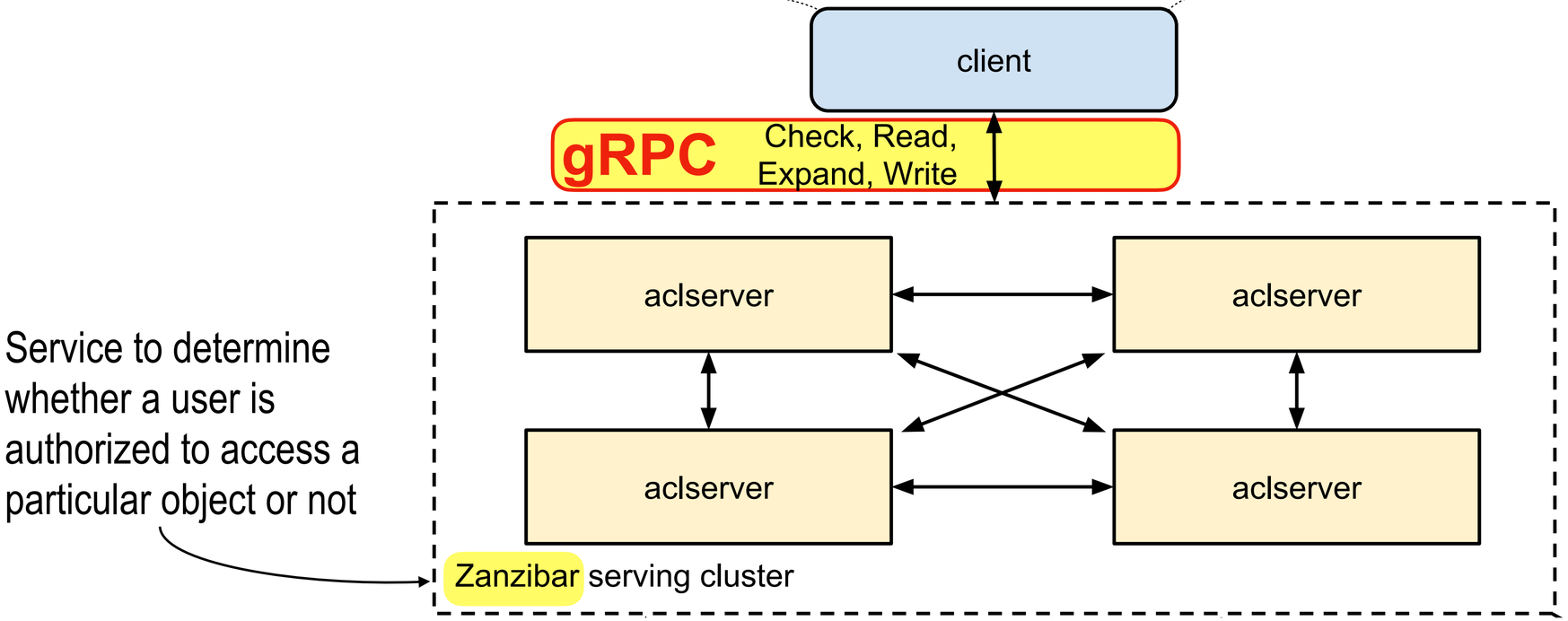




Service to determine whether a user is authorized to access a particular object or not





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client

gRPC Check, Read, Expand, Write

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Zanzibar serving cluster

read/write

read/write

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Externally consistent transactional database

namespace configs

namespace 1 relation tuples

...

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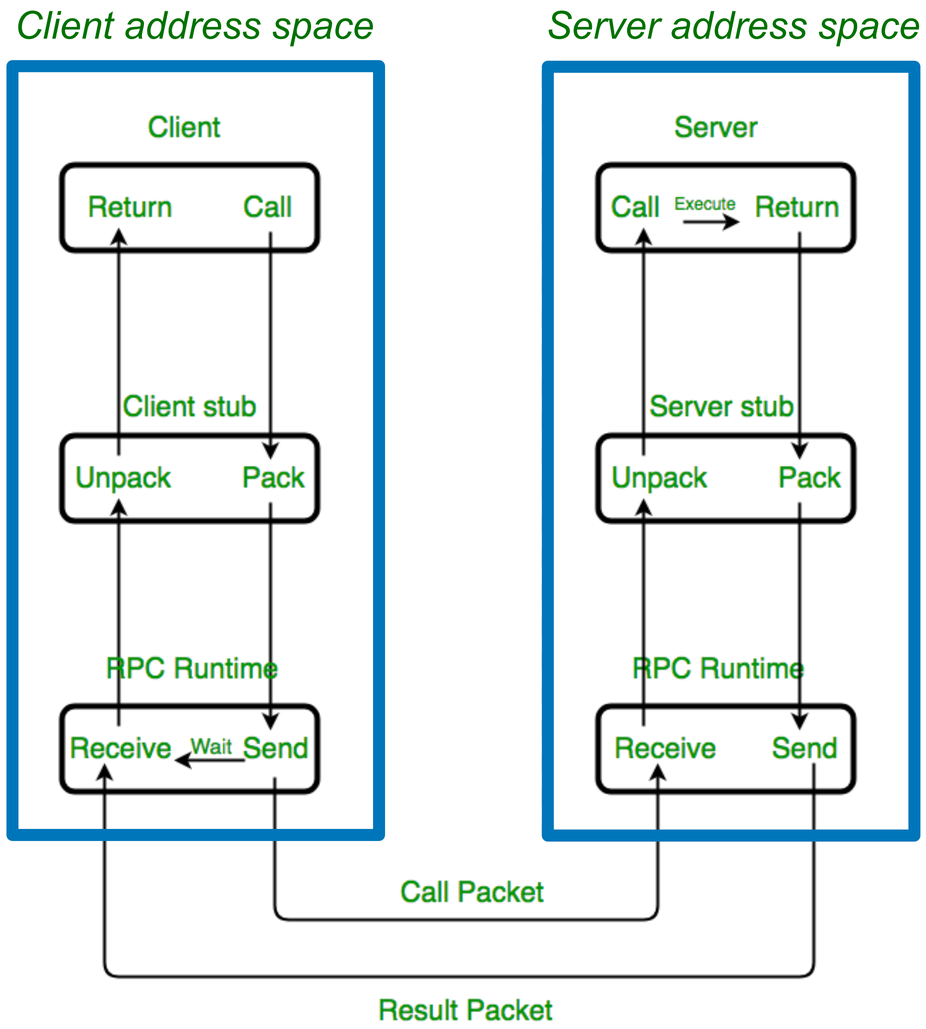
Workflow for writing RPC-based systems



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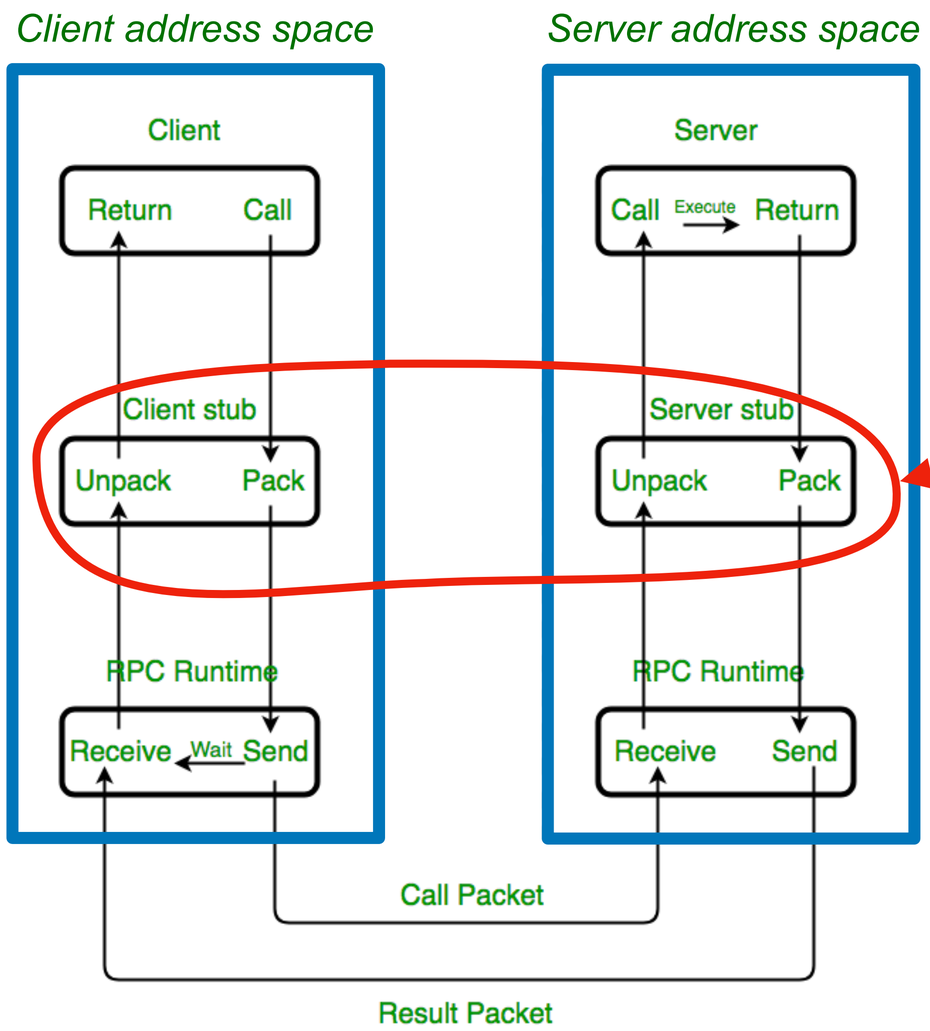

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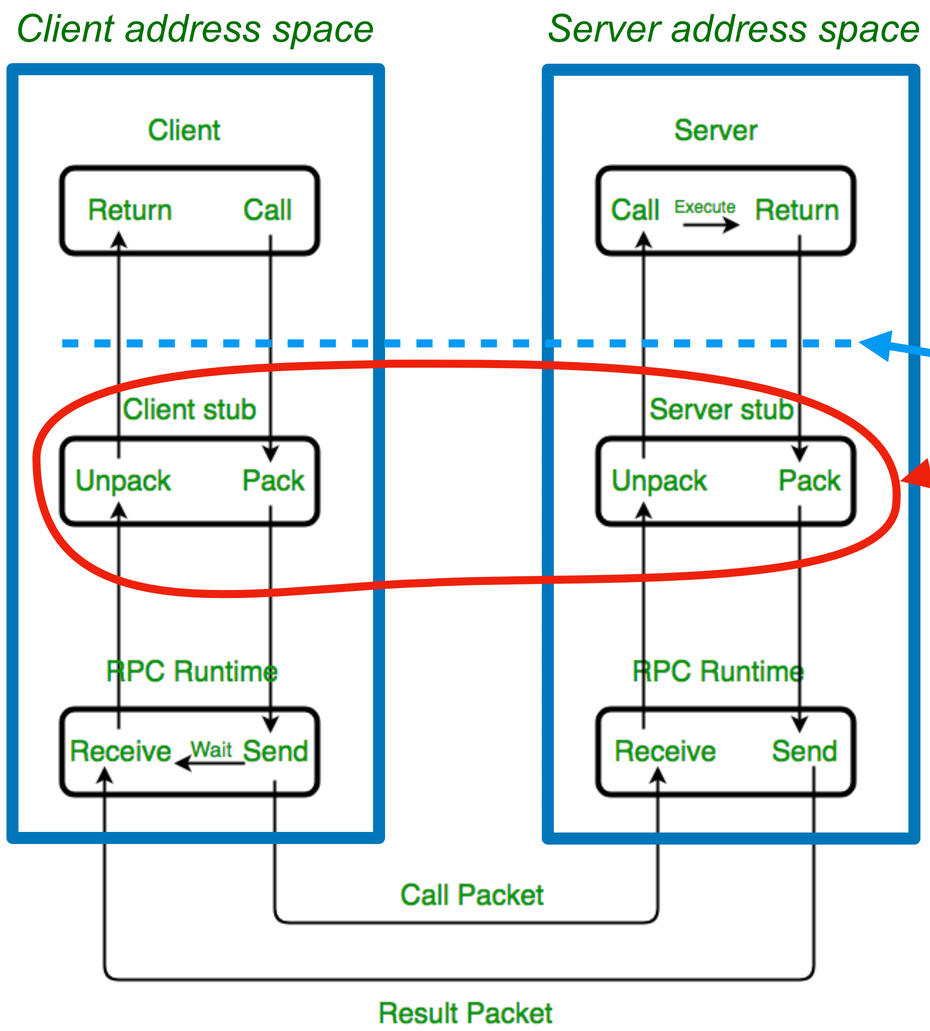

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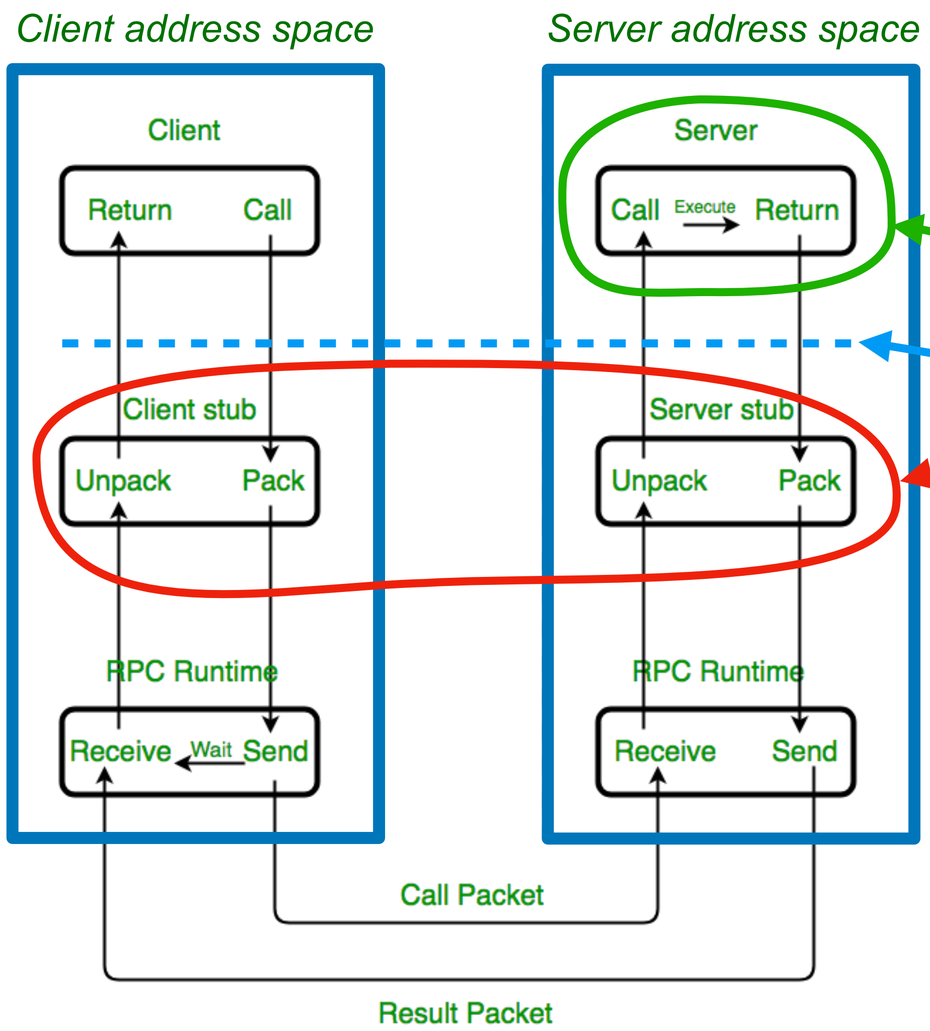

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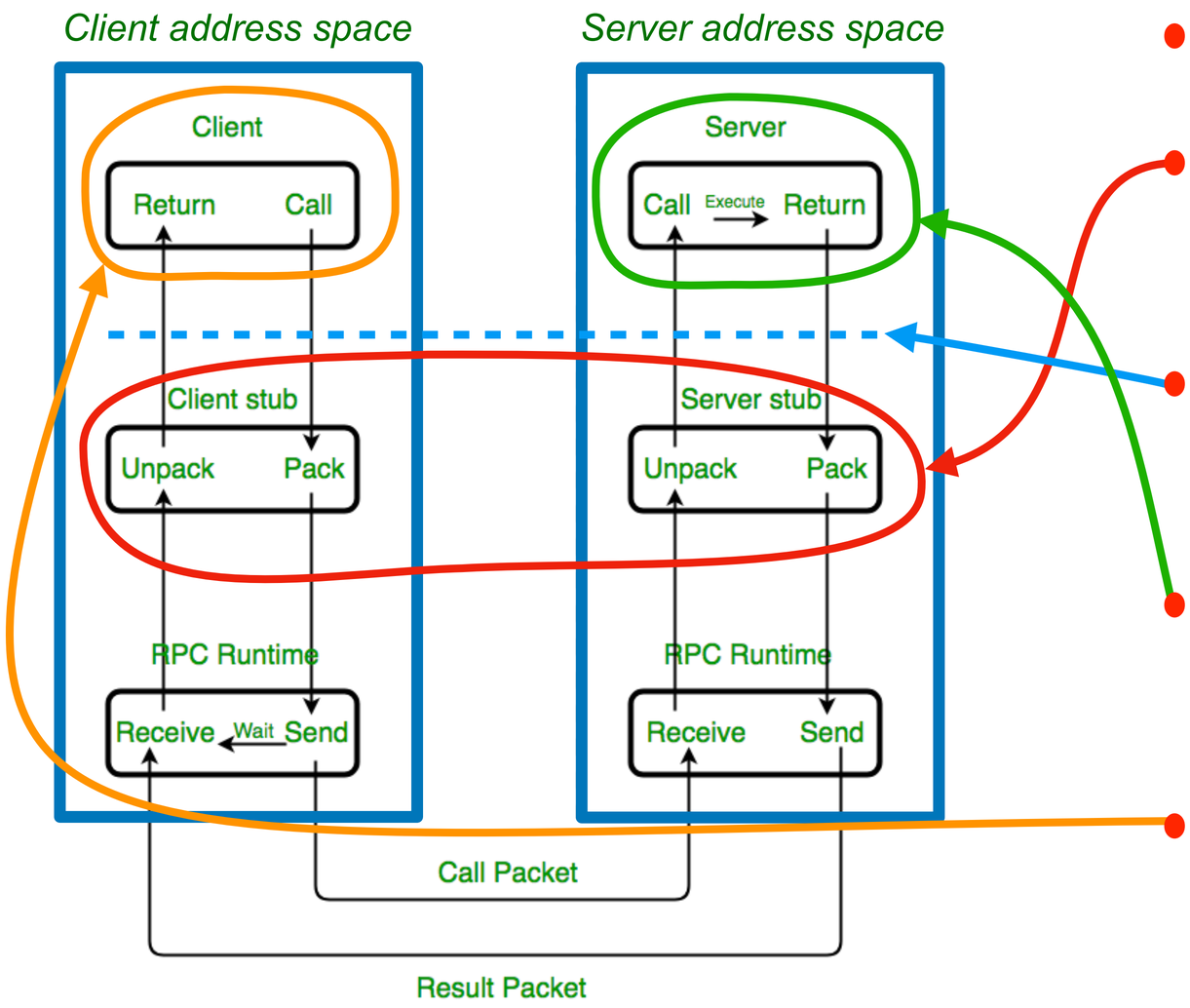

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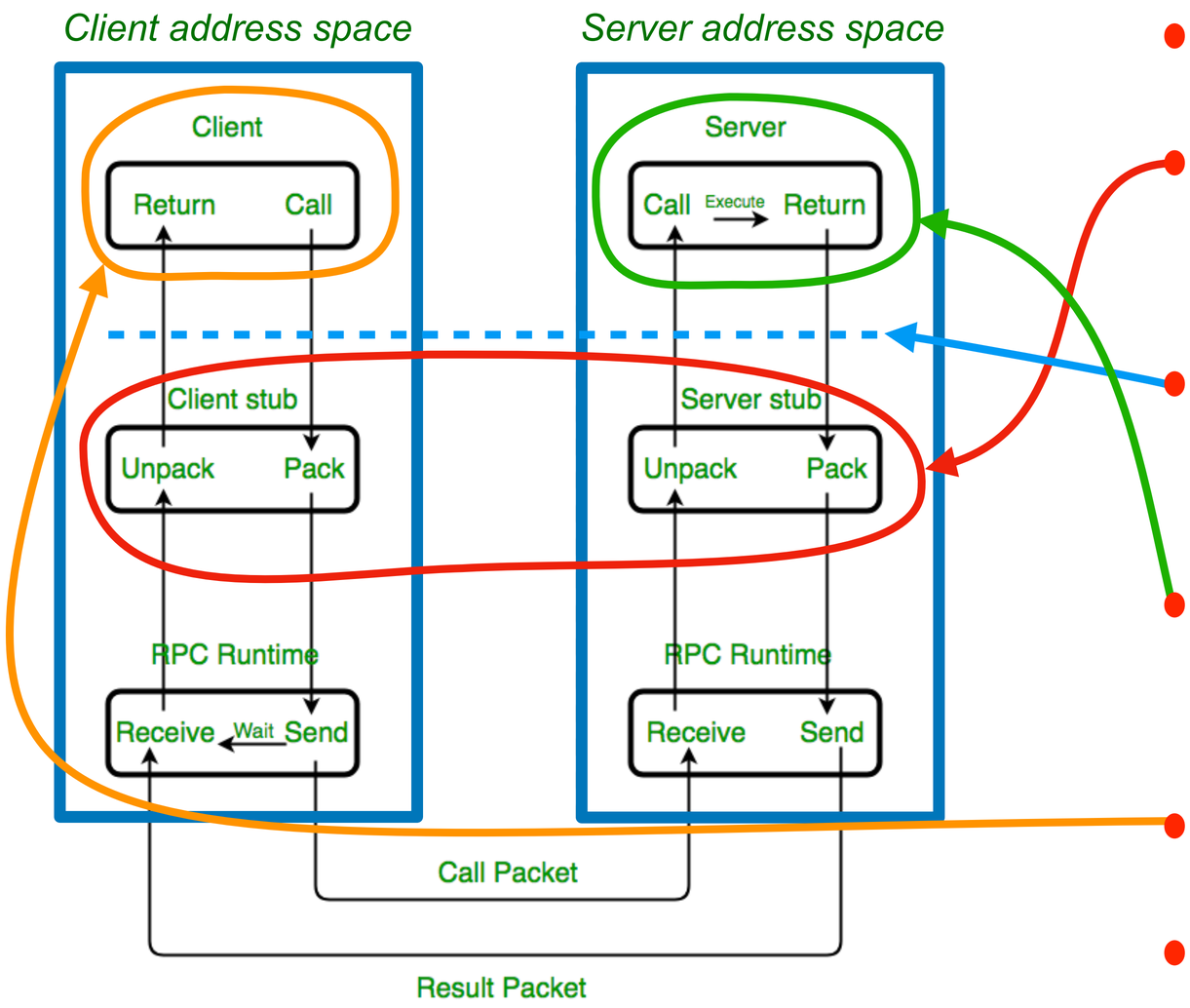

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- Compile, deploy, run

Methods	
`BatchCreateSessions`	Creates multiple new sessions.
`BatchWrite`	Batches the supplied mutation groups in a collection of efficient transactions.
`BeginTransaction`	Begins a new transaction.
`Commit`	Commits a transaction.
`CreateSession`	Creates a new session.
`DeleteSession`	Ends a session, releasing server resources associated with it.
`ExecuteBatchDml`	Executes a batch of SQL DML statements.
`ExecuteSql`	Executes an SQL statement, returning all results in a single reply.
`ExecuteStreamingSql`	Like `ExecuteSql`, except returns the result set as a stream.
`GetSession`	Gets a session.
`ListSessions`	Lists all sessions in a given database.
`PartitionQuery`	Creates a set of partition tokens that can be used to execute a query operation in parallel.
`PartitionRead`	Creates a set of partition tokens that can be used to execute a read operation in parallel.
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rpc ExecuteSql(ExecuteSqlRequest) returns (ResultSet)

Executes an SQL statement, returning all results in a single reply. This method cannot be used to return a result set larger than 10 MiB; if the query yields more data than that, the query fails with a **FAILED_PRECONDITION** error.

Operations inside read-write transactions might return **ABORTED**. If this occurs, the application should restart the transaction from the beginning. See **Transaction** for more details.

Larger result sets can be fetched in streaming fashion by calling **ExecuteStreamingSql** instead.

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```
void QueryDataWithStruct(google::cloud::spanner::Client client) {
  namespace spanner = ::google::cloud::spanner;
  using NameType = std::tuple<std::string, std::string>;
  auto singer_info = NameType{"Elena", "Campbell"};
  auto rows = client.ExecuteQuery(spanner::SqlStatement(
      "SELECT SingerId FROM Singers WHERE (FirstName, LastName) = @name",
      {{"name", spanner::Value(singer_info)}}));

  for (auto& row : spanner::StreamOf<std::tuple<std::int64_t>>(rows)) {
    if (!row) throw std::move(row).status();
    std::cout << "SingerId: " << std::get<0>(*row) << "\n";
  }
}
```

Benefits of RPC

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- Reduce fate sharing by exposing callee failures in a controlled manner
  - *This means the caller can now recover easily (esp. if asynchronous RPC)*

Drawbacks of RPC

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  - *… ?*
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RPC Tax in Data Centers

- Network latency and transmission overhead
- Context switching on both client and server
- Memory and serialization overheads
- Network load
- Security and authentication
- Error handling and retries
- ...

Recap

same address space

- Local procedure calls (module = procedure)
- Program objects & types (module = memory objects)

Memory safety

- Client/server architecture (different address spaces)
- *Example: RPC*

Message-based communication

separate address spaces