Remote Procedure Call (RPC)

Web Applications and Services

Spring term

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Contents

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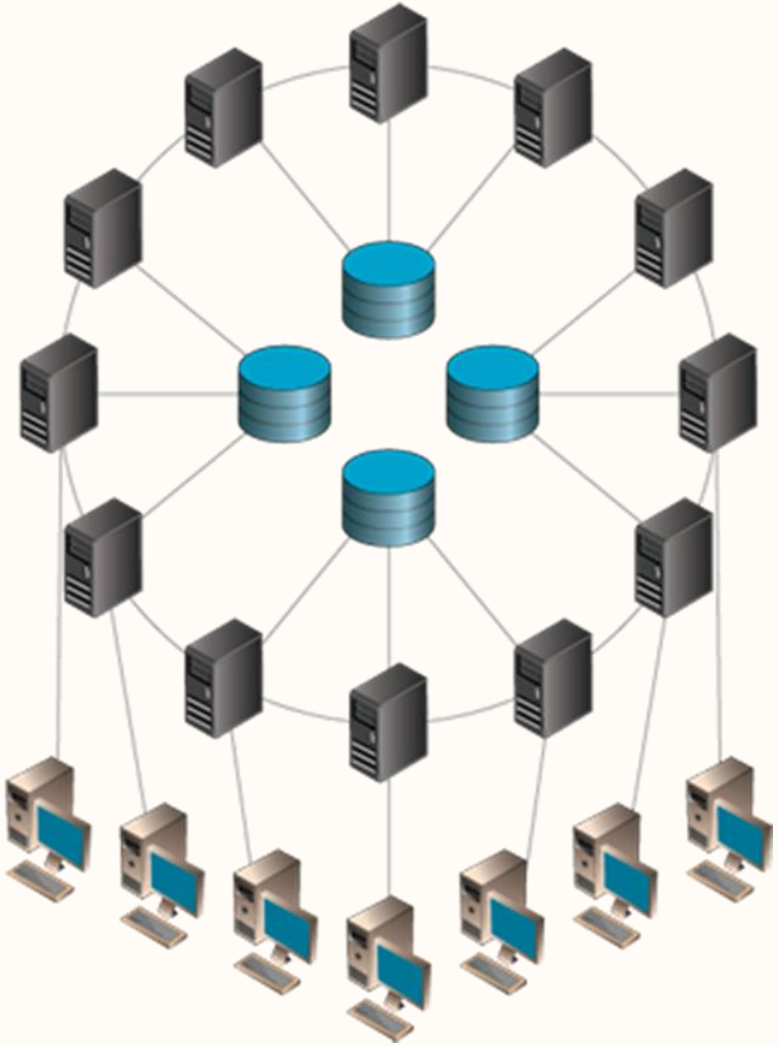
Distributed systems

- It is a group of computers working together as to appear as a single computer to the end-user
- These machines have a shared state, operate concurrently
- They communicate via a network to achieve a task
- Networked computers communicate and coordinate their actions only via messages passing



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Why distributed systems?

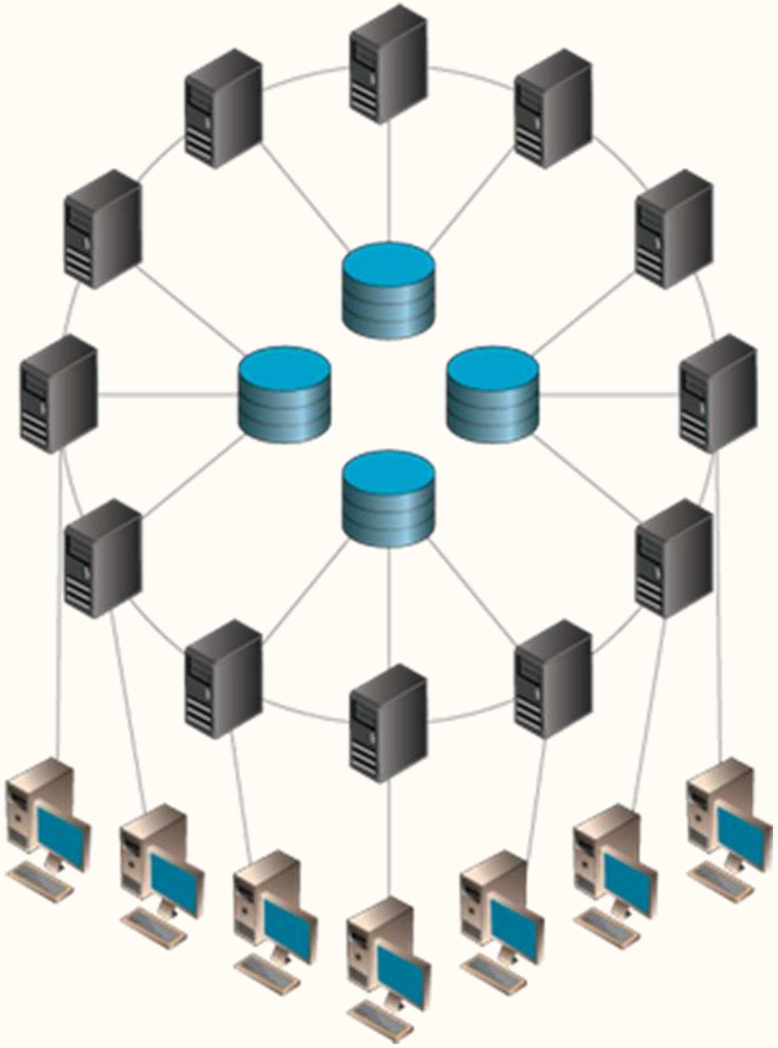
- The desire to share resources
- For scalability, performance and high availability of applications
- Some examples include
  - web search
  - distributed information
  - network file systems
  - real-time process control
  - parallel computation

Benefits of distributed systems

- Computation speedup, better performance
  - Parallel computation on multiple servers
  - Solve bigger problems
- Redundancy, reliability, fault-tolerant
  - Several machines can provide the same services, so if one is unavailable, the work does not stop.
- Many applications are inherently distributed

Challenges

- The network may fail
- Processes may crash
- Writing a program to run on a single computer is comparatively easy?
- How can we coordinate the processes of these machines?



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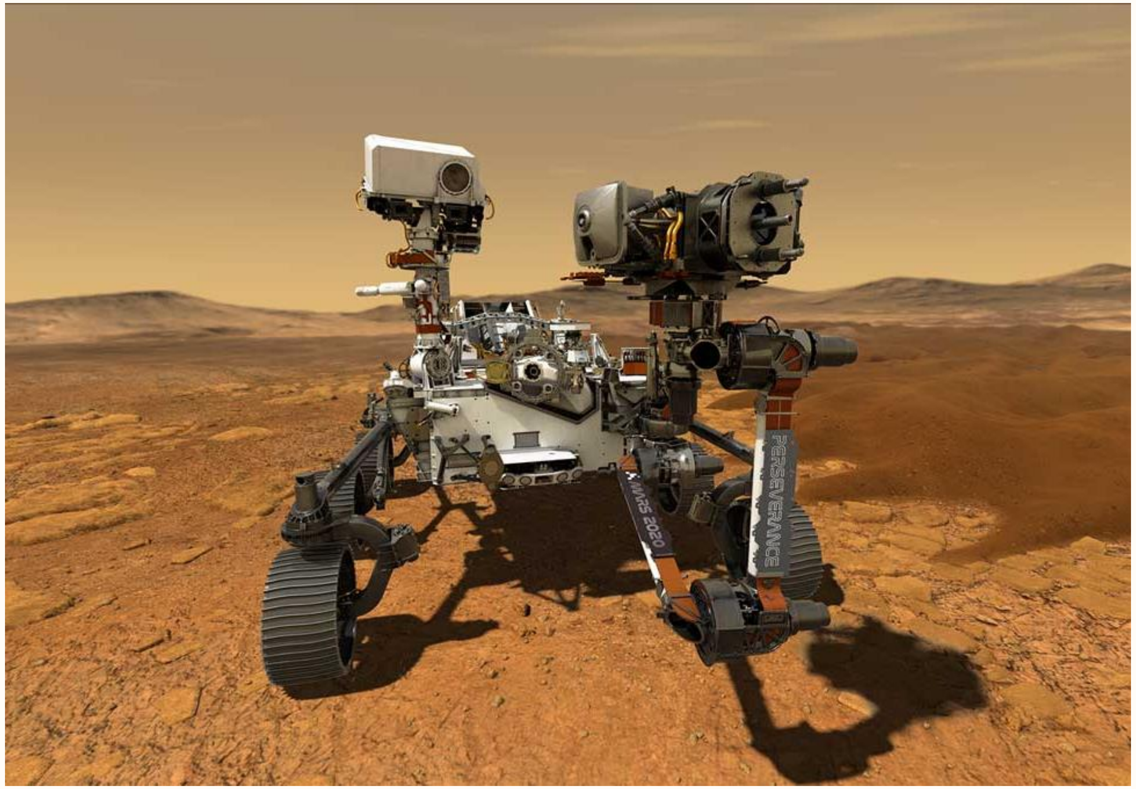
Programming

- The goal of making the programming of distributed systems look similar, if not identical, to conventional programming

Examples

The black hole image



Perseverance on Mars

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Local Procedure Call

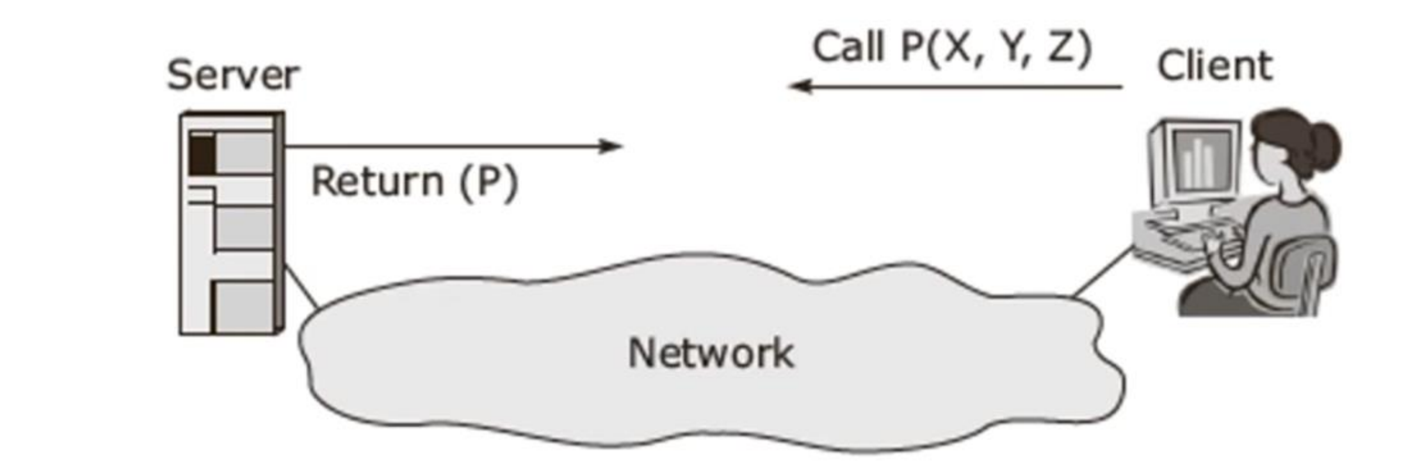
- Everything in the same address space
- Calls cannot fail (i.e., they can but programmers have full control)

```
ret = foo(64, "string", &myStruct);
```

- Push arguments, local variables and return address in the stack
- Call `foo`
- Pop everything out of the stack and put `ret` to a register
- Continue with the next call
- What about parameter passing?

Remote Procedure Call (RPC)

- Makes a call to a remote function look the same as a local function call



- In practice,
  - What if the service crashes during the function call?
  - What if a message is lost?
  - What if a message is delayed?
  - If something goes wrong, is it safe to retry?

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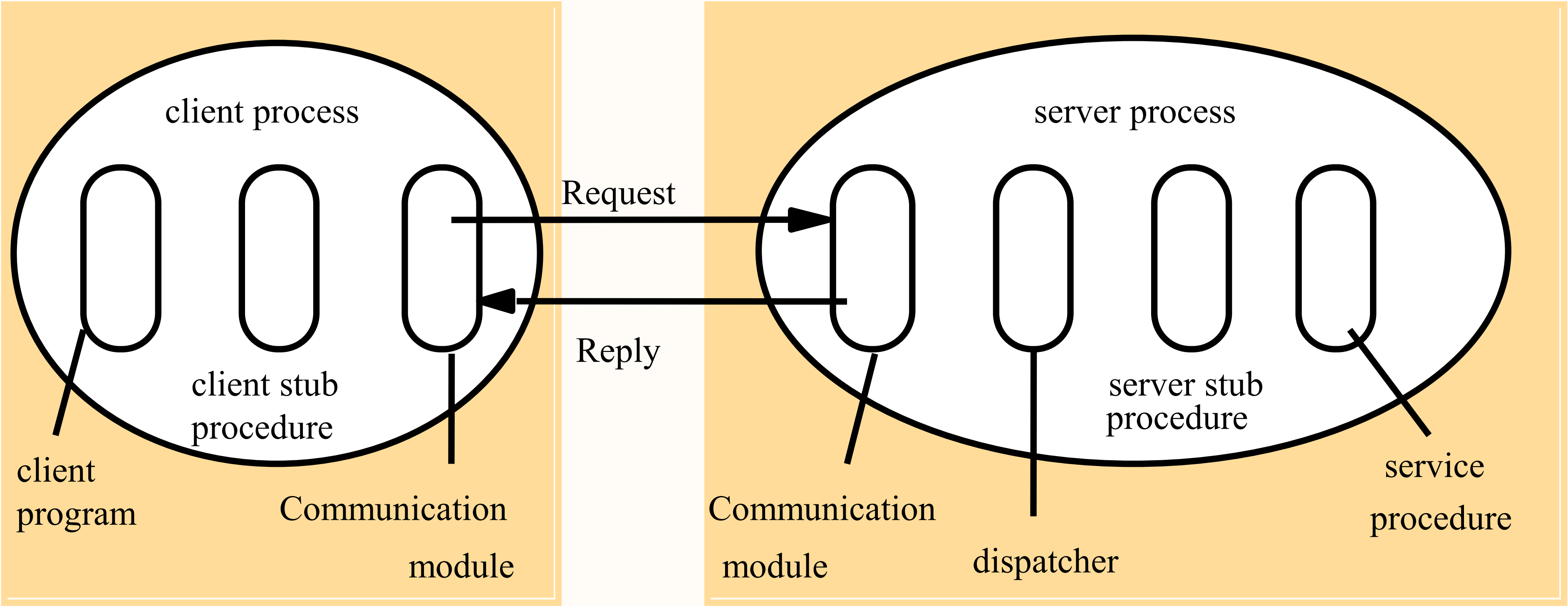
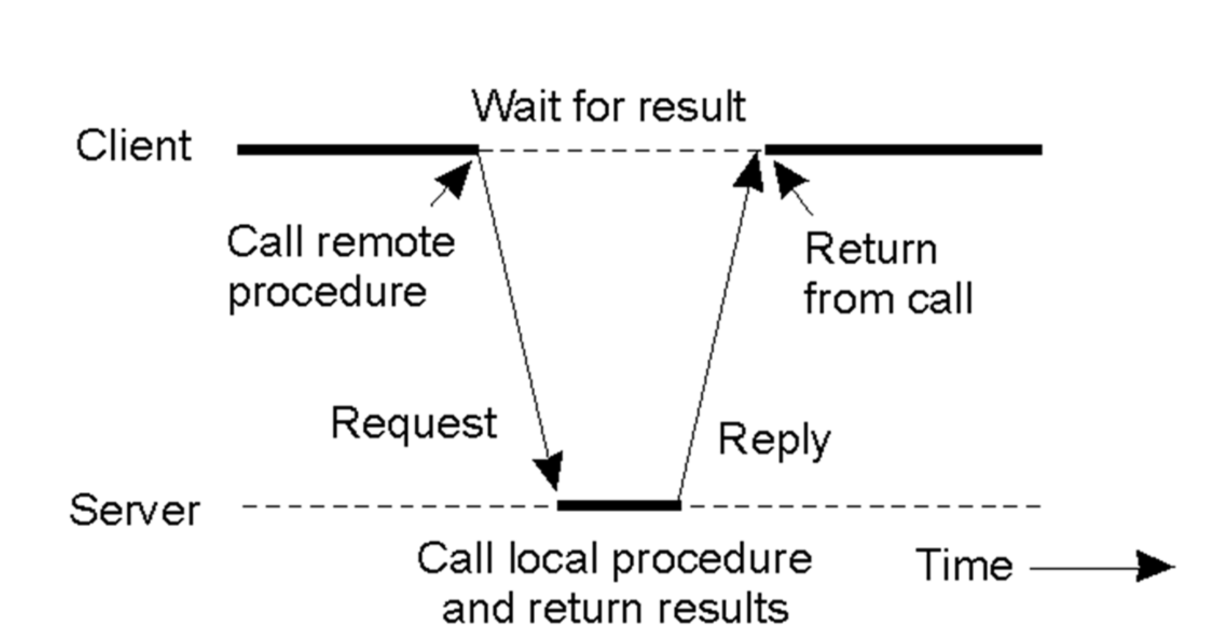
RPC at a Glance



RPC

- A process on machine A can call a procedure on machine B
- The process on A is suspended and execution continues on B
- When B returns, the return value is passed to A, and it continues its execution.



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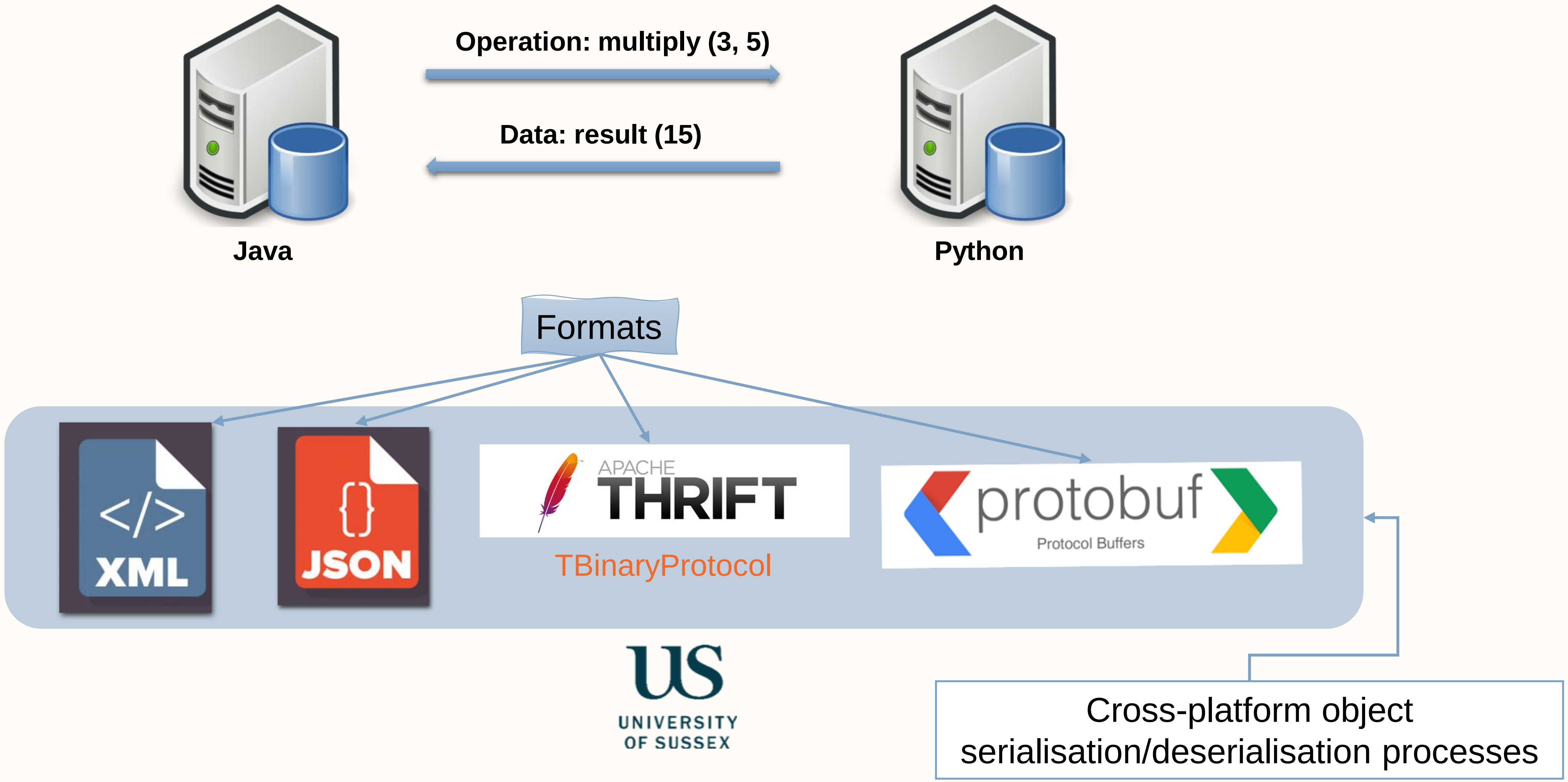
RPC history

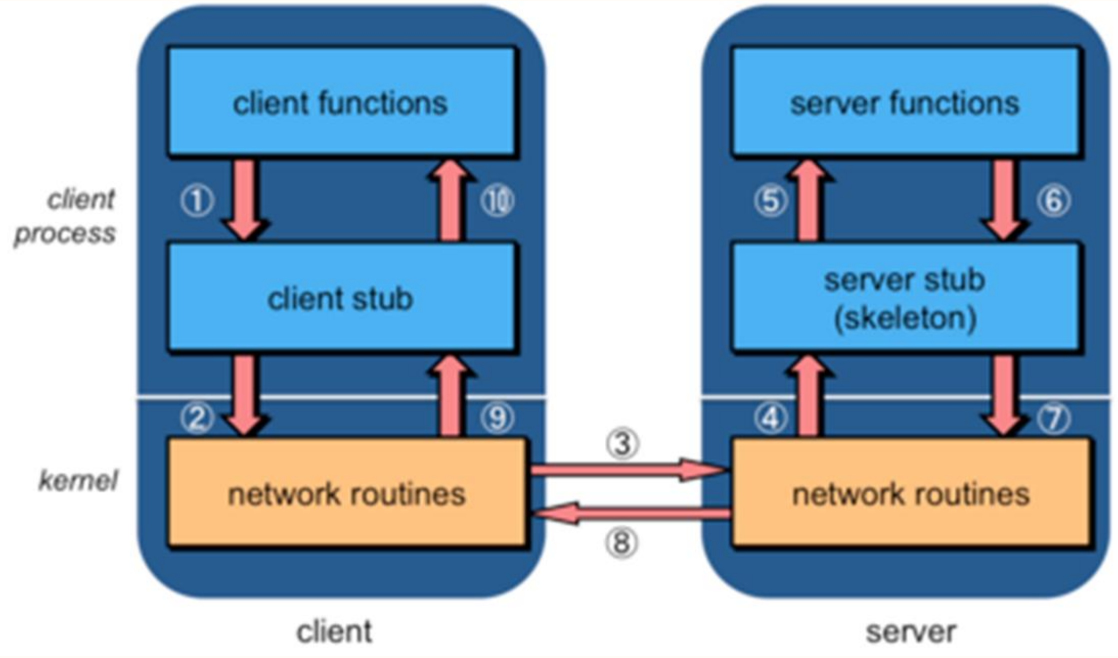
- SunRPC/ONC RPC (1980s, basis for NFS)
- CORBA: object-oriented middleware, hot in the 1990s
- Microsoft’s DCOM and Java RMI (similar to CORBA)
- SOAP/XML-RPC: RPC using XML and HTTP (1998)
- Thrift (Facebook, 2007)
- gRPC (Google, 2015)
- REST (often with JSON)
- …

RPC


Operation: multiply (3, 5)
Data: result (15)
Java
Python
Formats
XML
JSON
APACHE THRIFT
TBinaryProtocol
protobuf
Protocol Buffers
Cross-platform object serialisation/deserialisation processes

RPC : Client side

- Emulate the behaviour of local calls (transparently)
- Stub function
  - the same signature as if it was called locally
  - marshals parameters
  - sends request message
  - waits for a response from the server
  - un-marshals the response & returns the appropriate data



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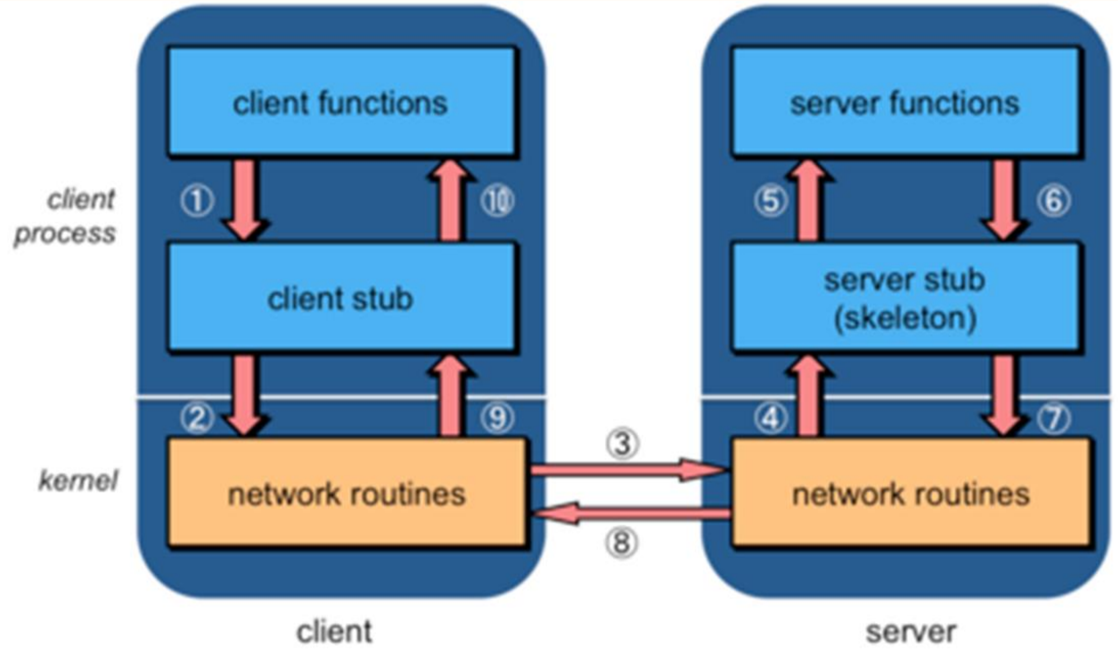
RPC : Server side

- Dispatcher
  - Receives client requests
  - Identifies appropriate function to call
- Skeleton
  - Un-marshals parameters
  - Calls the local function
  - Marshals the response & sends it back to the dispatcher



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Parameter passing

- Passing by value (is simple)
  - Just copy the value into the network message
- Passing by reference (is hard)
  - It makes no sense to pass an address to a remote machine
  - A memory location in a process on one machine is meaningless to another process on another machine

Parameter passing

1. Copy items referenced to message buffer
2. Ship them over
3. Un-marshal data at server
4. Pass local pointer to server stub function
5. Send new values back

Representing data

- Local Calls
  - Primitive types have the same exact representation
- But, for Remote Calls
  - Different byte ordering
    - Big Endian – most significant byte is stored in the smallest address
    - Little Endian - least significant byte is stored in the smallest address
  - Different sizes of integers and other types
  - Different floating-point representations
  - Different Languages!!

Representing data

- We need standards!
  - SunRPC uses eXternal Data Representation (XDR)
  - Abstract Syntax Notation (ASN.1)
  - WSDL for Web Service
  - Google Protocol Buffers
  - JSON
- Implicit typing
  - only values are transmitted, not data types or parameter info
- Explicit typing
  - Type is transmitted with value

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Interface Definition Language

- Allow programmer to specify remote procedure interfaces (i.e., names, parameters, return values)
- Pre-compiler can use this to generate
  - client and server stubs
  - Marshalling code
  - Un-marshalling code
  - Network transport routines

RPC Semantics

- Local Calls
  - exactly Once!
- But RPC involves networking and a remote host
  - delays, server failures
- A remote procedure call may be called
  - never: server crashed, or server process died before executing server code
  - once: everything worked well, as expected
  - more than once: Why?

RPC Semantics

- RPC systems may offer either
  - *maybe* semantics
  - *at least once* semantics
  - *at most once* semantics
- How can these be implemented?
- What are the ramifications with respect to
  - idempotent functions?
  - non-idempotent functions?

Protocol Buffers (Protobuf)

- Protobuf is Google’s language-neutral, platform-neutral, extensible mechanism for serializing structured data for
  - communications protocols
  - data storage
  - specification of services
- Think XML, but smaller, faster, and simpler
- It currently support generated code in Java, Python, Objective-C, and C++
  - With the new proto3 language version, it is possible to also work with Kotlin, Dart, Go, Ruby, PHP, and C#

protobuf
Protocol Buffers

Protocol Buffers

- Why not XML?
  - Protobuf is simpler, i.e., 3 to 10 times smaller and 20 to 100 times faster
  - It generate data access classes that are easier to use programmatically (should we write source code and auto-produce description/IDL or vice versa?)

```
<person>
    <name>John Doe</name>
    <email>jdoes@example.com</email>
</person>
```

```
# Textual representation of a protocol buffer
# This is *not* the binary format used on thr wire
person {
    name: "John Doe"
    email: "jdoes@example.com"
}
```

- Many projects use protocol buffers, including the following: [gRPC](), [Google Could](), [Envoy Proxy]()

Protocol Buffers : RPC

- The protocol compiler will read .proto files and generate
  - an abstract interface called `SearchService` (must be implemented!)
  - a corresponding “stub” implementation
- The stub forwards all calls to an RpcChannel
- an abstract interface that must be defined for RPC system

```
message SearchRequest {
    required string query = 1;
    optional int32 page_number = 2;
    optional int32 result_per_page = 3;
}

message SearchResponse {
    ...
}
```

```
service SearchService {
    rpc Search(SearchRequest) returns (SearchResponse);
}
```

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Apache Thrift

- A software framework for scalable cross-language services development
- Combines a software stack with a code generation engine
- Builds services that work efficiently and seamlessly between C++, Java, Python, PHP, Ruby, Erlang, Perl, Haskell, C#, Cocoa, JavaScript, Node.js, Smalltalk, OCaml and Delphi and other languages
- Type system consists of pre-defined base types, user-defined structs, container types, exceptions and service definitions

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APACHE THRIFT

Thrift Types

- Base Types
  - bool: A boolean value (true or false)
  - byte: An 8-bit signed integer
  - i16: A 16-bit signed integer
  - i32: A 32-bit signed integer
  - i64: A 64-bit signed integer
  - double: A 64-bit floating point number
  - string: A text string encoded using UTF-8 encoding
- Special Types
  - binary: a sequence of unencoded bytes
- Containers
  - list: An ordered list of elements
  - set: An unordered set of unique elements
  - map<type1,type2>: A map of strictly unique keys to values
- Container elements may be of any valid Thrift Type.

Thrift Types

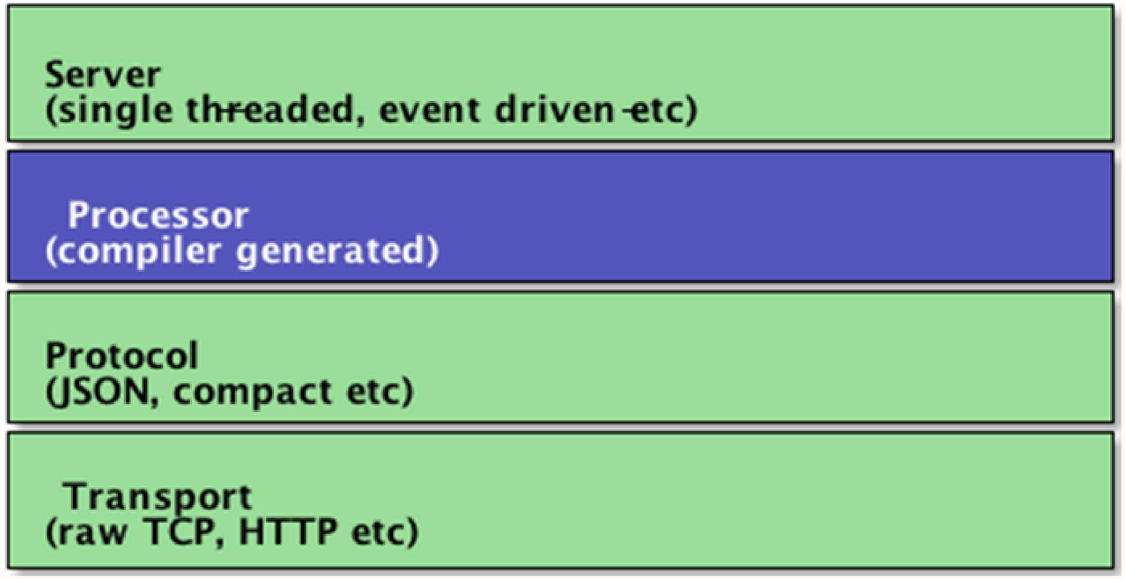
- Structs
  - define a common object – they are essentially equivalent to classes in object-oriented programming (OOP) languages, but without inheritance
  - A struct has a set of strongly typed fields, each with a unique name identifier
  - Fields may have various annotations (numeric field IDs, optional default values, etc.) that are described in the Thrift IDL
- Exceptions
  - are functionally equivalent to structs, except that they inherit from the native exception base class

Thrift Types

- Services
  - Are defined using Thrift types
  - Definition of a service is semantically equivalent to defining an interface (or a pure virtual abstract class) in OOP
  - The Thrift compiler generates fully functional client and server stubs that implement the interface
  - A service consists of a set of named functions, each with a list of parameters and a return type

Thrift network stack

- Transport
  - Provides a simple abstraction for reading/writing from/to the network
  - Enables Thrift to decouple the underlying transport from the rest of the system (serialization/deserialization, for instance)
- Protocol
  - Defines a mechanism to map in-memory data structures to a wire-format
    - specifies how datatypes use the underlying Transport to encode/decode themselves
  - Some examples of protocols in this sense include JSON, XML, plain text, compact binary, etc.



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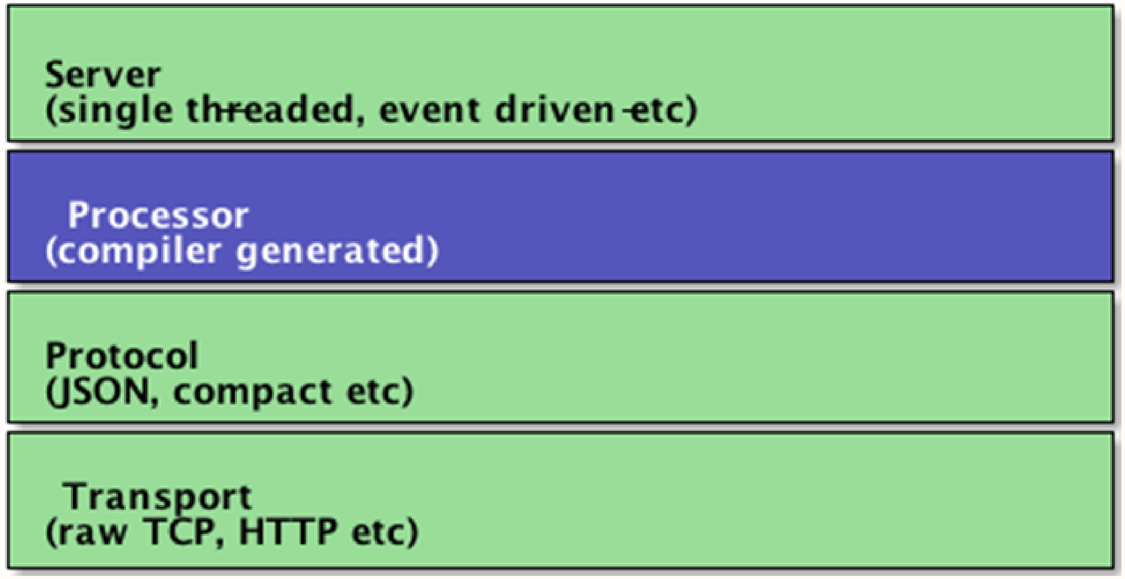
Network Stack

- Processor
  - Encapsulates the ability to read data from input streams and write to output streams
  - The input and output streams are represented by Protocol objects
- Server
  - Create a transport
  - Create input/output protocols for the transport
  - Create a processor based on the input/output protocols
  - Wait for incoming connections and hand them off to the processor



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Thrift definition file

```
service Calculator extends shared.SharedService {

  /**
   * A method definition looks like C code. It has a return type, arguments,
   * and optionally a list of exceptions that it may throw. Note that argument
   * lists and exception lists are specified using the exact same syntax as
   * field lists in struct or exception definitions.
   */

   void ping(),

   i32 add(1:i32 num1, 2:i32 num2),

   i32 calculate(1:i32 logid, 2:Work w) throws (1:InvalidOperation ouch),

   /**
    * This method has a oneway modifier. That means the client only makes
    * a request and does not listen for any response at all. Oneway methods
    * must be void.
    */
   oneway void zip()

}
```

Method definitions can be terminated using comma or semi-colon

void is a valid return type for functions

Arguments can be primitive types or structs, likewise for return types

Next Lecture ...

- ✓ Introduction
- ✓ HTTP, Caching, and CDNs
- ✓ Views
- ✓ Templates
- ✓ Forms
- ✓ Models
- ✓ Security
- ✓ Transactions
- ✓ Remote Procedure Call
- ➢ **Web Services**
- RESTful Services
- Time
- Elections/Group Communication
- Zookeeper

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