Introduction to Middleware

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Part I

Sockets: The Hard Way
Outline

1. Berkeley Socket Interface
2. Assignment Part I
3. Marshalling Implementation
4. Assignment Part II
Interface Overview

**Socket**
An abstraction representing a (network) communication channel. Both stream oriented and message oriented channels. Spectrum of supported protocols.

**Stream Oriented Channel**
Socket on *client side* initiates outgoing connections. Socket on *server side* waits for incoming connections. Data flows in both directions after connection established.

**Message Oriented Channel**
No connection established. Sender and receiver roles symmetrical.
Stream Oriented Channel

Client Side Pseudocode

socket = CreateSocket (comms_domain, socket_type);
ConnectToServer (socket, server_address);
... Write (socket, data);
... Read (socket, data);
Shutdown (socket);
Close (socket);

Server Side Pseudocode

server_socket = CreateSocket (comms_domain, socket_type);
BindToLocalAddress (socket, address);
PermitListeningOnSocket (socket, backlog);
client_socket, client_address = AcceptIncomingConnection (socket);
... Write (client_socket, data);
... Read (client_socket, data);
Shutdown (client_socket);
Close (client_socket);
Outline

1. Berkeley Socket Interface
2. Assignment Part I
3. Marshalling Implementation
4. Assignment Part II
Assignment

Server
Implement a server that will:
- Listen for incoming connections.
- Provide information on current time to connected clients.

Client
Implement a client that will:
- Connect to the server described above.
- Query information on current time.
- Wrap all this in a local function.
- Print the time.
/**
 * Return server time in standard structure.
 * \param result Caller allocated structure to fill.
 * \return Zero for success, non zero error code otherwise.
 */

int server_time (struct tm *result);

struct tm {
    int tm_sec;       // Seconds (0-60)
    int tm_min;       // Minutes (0-59)
    int tm_hour;      // Hours (0-23)
    int tm_mday;      // Day of the month (1-31)
    int tm_mon;       // Month (0-11)
    int tm_year;      // Year - 1900
    int tm_wday;      // Day of the week (0-6, Sunday = 0)
    int tm_yday;      // Day in the year (0-365, 1 Jan = 0)
    int tm_isdst;     // Daylight saving time
};
/**
 * Access server time in standard structure.
 */

public interface ServerTime {
    int getSecond (); // Gets the second-of-minute field.
    int getMinute (); // Gets the minute-of-hour field.
    int getHour ();   // Gets the hour-of-day field.
    int getDayOfMonth (); // Gets the day-of-month field.
    Month getMonth ();  // Gets the month-of-year field.
    int getYear ();     // Gets the year field.
    DayOfWeek getDayOfWeek (); // Gets the day-of-week field.
    int getDayOfYear (); // Gets the day-of-year field.
}

... javadoc LocalDateTime
Python Local Function

def server_time ():
    """Returns server time in datetime.datetime class."""
    ...

# Instance attributes (read-only):
#
#    datetime.year
#        Between MINYEAR and MAXYEAR inclusive.
#    datetime.month
#        Between 1 and 12 inclusive.
#    datetime.day
#        Between 1 and the number of days in the given month of the given year.
#    datetime.hour
#        In range(24).
#    datetime.minute
#        In range(60).
#    datetime.second
#        In range(60).

    ... help (datetime.datetime)
Examples To Begin With …

```bash

C

> cd teaching-introduction-middleware/src/sockets-basic-server/c
> cat README.md

Java

> cd teaching-introduction-middleware/src/sockets-basic-server/java
> cat README.md

Python

> cd teaching-introduction-middleware/src/sockets-basic-server/python
> cat README.md
Outline

1 Berkeley Socket Interface
2 Assignment Part I
3 Marshalling Implementation
4 Assignment Part II
C Marshalling

Textual Stream?

```c
int sprintf (char *str, const char *format, ...);
int sscanf (const char *str, const char *format, ...);
```

Network Order Binary Stream?

```c
uint32_t htonl (uint32_t hostlong);
uint16_t htons (uint16_t hostshort);
uint32_t ntohl (uint32_t netlong);
uint16_t ntohs (uint16_t netshort);
```

Native Order Binary Stream?

```c
char buffer [1024];
int *address = (int *) &buffer [16];
*address = 1234;
```
# Java Marshalling

## Serialized Stream?

```java
text_stream = socket.getOutputStream ();
object_stream = new ObjectOutputStream (output_stream);
object_stream.writeInt (1234);
object_stream.writeObject (...);
```

## Textual Stream?

```java
PrintWriter writer = new PrintWriter (output_stream, true);
writer.println ("...");
```

## Byte Stream?

```java
ByteBuffer buffer = ByteBuffer.allocate (4);
buffer.putInt (1234);
output_stream.write (buffer.array ());
```
Python Marshalling

**Pickled Stream?**

```python
with socket.makefile () as file_object:
    pickle.dump (... , file_object)
```

**JSON Stream?**

```python
with socket.makefile () as file_object:
    json.dump (... , file_object)
```

**Byte Stream?**

```python
data = 1234;
socket.send (data.to_bytes (4 , 'little'))
```
Can we reuse the code for the module the contractor wrote?
No, it’s not good...

Oh? Why? Is it encrypted?
No
Is it obfuscated?
No

Ah, is it buggy?
Or badly documented?
No, no

Why isn’t it any good then?

I don’t understand it

Good code is code I can read and understand, you know?

http://www.commitstrip.com/en/2016/06/07/good-code
Outline

1. Berkeley Socket Interface
2. Assignment Part I
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Assignment

Languages
Implement Part I in at least two programming languages.

Interoperability
Make sure your clients and servers in both languages are interchangeable:
- Run any client with any server.
- Basic fields are enough (YYYY-MM-DD HH:MM:SS).
- Use sensible defaults for other fields (TZ, DOW, DOY).
Part II

Protocol Buffers: Marshalling
Outline

5 Technology Overview

6 Assignment Part I

7 Message Encoding

8 Message Specification

9 Message Manipulation

10 Assignment Part II
Technology Overview

Goals
Provide platform independent structured data serialization framework.

Features
- Platform independent data description language.
- Serialization code generation for multiple languages (C++, Java, Python, Go, Ruby, JavaScript, Objective C, C# ...).
- Binary transport format with compact data representation.
- Textual transport using JSON.

... http://developers.google.com/protocol-buffers
Installation

Fedora Packages

> dnf install protobuf-devel
> dnf install python3-protobuf

Source Distribution

> git clone -b 3.6.x http://github.com/protocolbuffers/protobuf
> cd protobuf
> ./autogen.sh
> ./configure --prefix=${HOME}/.local
> make -j 8
> make install
> export PATH=${HOME}/.local/bin:${PATH}
> export LD_LIBRARY_PATH=${HOME}/.local/lib:${LD_LIBRARY_PATH}
> export PKG_CONFIG_PATH=${HOME}/.local/lib/pkgconfig:${PKG_CONFIG_PATH}

... use supplied install-protobuf.sh script
syntax = "proto3";

package example;

message AnExampleMessage {
  uint32 some_integer = 1;
  sint32 another_integer = 2;
  string some_string = 8;
  repeated string some_more_strings = 11;
}

message MoreExampleMessages {
  repeated AnExampleMessage messages = 1;
}
Outline

Technology Overview

Assignment Part I

Message Encoding

Message Specification

Message Manipulation

Assignment Part II
Assignment

Server
Implement a server that will provide information on current time.
- The server should accept a spec of what fields to return.
- Fields should be standard YYYY-MM-DD HH:MM:SS.

Client
Implement a client that will query server time:
- Pick a random combination of fields.
- Query information on current time.
- Print the time.

Interoperability
Implement compatible clients and servers in two languages.
Examples To Begin With ...


C

> cd teaching-introduction-middleware/src/protocol-buffers-basic-usage/c
> cat README.md

Java

> cd teaching-introduction-middleware/src/protocol-buffers-basic-usage/java
> cat README.md

Python

> cd teaching-introduction-middleware/src/protocol-buffers-basic-usage/python
> cat README.md
Outline

5 Technology Overview
6 Assignment Part I
7 Message Encoding
8 Message Specification
9 Message Manipulation
10 Assignment Part II
Message Encoding

**Goals**
Compact structure with support for field removal and addition.

**Features**
- Sequence of field key value pairs.
- Key is field index and type indication.
  - One of variable integer, explicit length, fixed length.
  - Not enough to tell the exact field type!
- Primitive repeated fields packed.
- Total length not included!
Variable Length Encoding

Goals
Support integers clustered around zero more efficiently.

Features
- Integer stored as variable number of 7 bit values.
- High bit set to zero for last byte.
- Little endian byte order.
- Signed variant.
Outline

5 Technology Overview
6 Assignment Part I
7 Message Encoding
8 Message Specification
9 Message Manipulation
10 Assignment Part II
## Primitive Field Types

### Integer Types
- **(s)fixed(32|64)**: Integers with fixed length encoding.
- **(u)int(32|64)**: Integers with variable length encoding.
- **sint(32|64)**: Integers with sign optimized variable length encoding.

### Floating Point Types
- **float**: IEEE 754 32 bit float.
- **double**: IEEE 754 64 bit float.

### Additional Primitive Types
- **bool**: Boolean.
- **bytes**: Arbitrary sequence of bytes.
- **string**: Arbitrary sequence of UTF-8 characters.
More Field Types

Oneof Type

message AnExampleMessage {
  oneof some_oneof_field {
    int32 some_integer = 1;
    string some_string = 2;
  }
}

Enum Type

class AnEnum {
  INITIAL = 0;
  RED = 1;
  BLUE = 2;
  GREEN = 3;
  WHATEVER = 8;
}
More Field Types

Any Type

```protobuf
ingo/protobuf/any.proto"
import "google/protobuf/any.proto"
message AnExampleMessage {
  repeated google.protobuf.Any whatever = 8;
}
```

Map Type

```protobuf
message AnExampleMessage {
  map<int32, string> keywords = 8;
}
```
Outline

5 Technology Overview
6 Assignment Part I
7 Message Encoding
8 Message Specification
9 Message Manipulation
10 Assignment Part II
# C++ Message Basics

## Construction

```cpp
AnExampleMessage message;
AnExampleMessage message (another_message);
message.CopyFrom (another_message);
```

## Singular Fields

```cpp
cout << message.some_integer () ;
message.set_some_integer (1234);
```

## Repeated Fields

```cpp
int size = messages.messages_size ();
const AnExampleMessage &message = messages.messages (1234);
AnExampleMessage *message = messages.mutable_messages (1234);
AnExampleMessage *message = messages.add_messages ();
```
C++ Message Serialization

**Byte Array**

```cpp
char buffer [BUFFER_SIZE];
message.SerializeToArray (buffer, sizeof (buffer));
message.ParseFromArray (buffer, sizeof (buffer));
```

**Standard Stream**

```cpp
message.SerializeToOstream (&stream);
message.ParseFromIstream (&stream);
```
Java Message Basics

Construction

```java
AnExampleMessage.Builder messageBuilder;
messageBuilder = AnExampleMessage.newBuilder();
messageBuilder = AnExampleMessage.newBuilder(another_message);
AnExampleMessage message = messageBuilder.build();
```

Singular Fields

```java
System.out.println(message.getSomeInteger());
messageBuilder.setSomeInteger(1234);
```

Repeated Fields

```java
int size = messages.getMessagesCount();
AnExampleMessage message = messages.getMessages(1234);
List<AnExampleMessage> messageList = messages.getMessagesList();
messagesBuilder.addMessages(messageBuilder);
messagesBuilder.addMessages(message);
```
Java Message Serialization

Byte Array

```java
byte [] buffer = message.toByteArray ();
try {
    AnExampleMessage message = AnExampleMessage.parseFrom (buffer);
} catch (InvalidProtocolBufferException e) {
    System.out.println (e);
}
```

Standard Stream

```java
message.writeTo (stream);
AnExampleMessage message = AnExampleMessage.parseFrom (stream);
```
Construction

```python
message = AnExampleMessage()
message.CopyFrom(another_message)
```

Singular Fields

```python
print(message.some_integer)
message.some_integer = 1234
```

Repeated Fields

```python
size = len(messages.messages)
message = messages.messages[1234]
message = messages.messages.add()
```
Byte Array

```python
buffer = message.SerializeToString ()
message.ParseFromString (buffer)
message = AnExampleMessage.FromString (buffer)
```

Standard Stream

```python
file.write (message.SerializeToString ())
message.ParseFromString (file.read ())
AnExampleMessage.FromString (file.read ())
```
Code Now...

I've decided to let the coders do their own thing on this project.

Apparently they'll be more efficient and they'll gain a greater feeling of ownership of the project.

They've been shut away for days, and when they finally come out, we should have a Release Candidate ready.

Ah, here they are now!

So? Are you done?

After a lot of work, a lot of discussion, and a few all-nighters, we finally managed it!

Yeah! It wasn't easy, but we finally agree on the framework we'll use for the project!

Of course!

AMAZING! Well done guys!

We start the real development tomorrow!

Outline

5 Technology Overview

6 Assignment Part I

7 Message Encoding

8 Message Specification

9 Message Manipulation

10 Assignment Part II
Assignment

Performance
Measure the performance of your implementation.

Experiment Design
Stick to the following, or provide arguments for why not:
- Random field mix, each field with probability 1/2.
- Measure at least two minutes long traffic.
- Report average invocation throughput.
- No printing during measurement.
- Compare with past assignments.
Measuring Time

C++

```c
#include <time.h>
#include <stdint.h>
struct timespec time;
clock_gettime (CLOCK_MONOTONIC_RAW, &time);
uint64_t nanoseconds =
    (uint64_t) time.tv_sec * 1000000000 +
    (uint64_t) time.tv_nsec;
```

Java

```java
long nanoseconds = System.nanoTime();
```

Python

```python
import time
nanoseconds = time.clock_gettime (time.CLOCK_MONOTONIC_RAW) * 1000000000
```
Part III

gRPC: Remote Procedure Call
Outline

11 Technology Overview

12 Assignment Part I

13 Server Implementation

14 Client Implementation

15 Assignment Part II
Technology Overview

Goals
Provide platform independent remote procedure call mechanism.

Features
- Protocol buffers as interface description language.
- Stub code generation for multiple languages (C++, Java, Python, Go, Ruby, JavaScript, PHP, C# ...).
- Binary transport format with compact data representation.
- Supports streaming arguments during remote call.
- Synchronous and asynchronous invocation code.
- Compression support at transport level.
- Security support at transport level.

http://www.grpc.io
Installation

Source Distribution

> git clone -b v1.16.x http://github.com/grpc/grpc
> cd grpc
> git submodule update --init
> make -j 8 prefix=${HOME}/.local
> make install
> export PATH=${HOME}/.local/bin:${PATH}
> export LD_LIBRARY_PATH=${HOME}/.local/lib:${LD_LIBRARY_PATH}
> export PKG_CONFIG_PATH=${HOME}/.local/lib/pkgconfig:${PKG_CONFIG_PATH}

... use supplied install-grpc.sh script
Service Specification Example

syntax = "proto3";

message AnExampleRequest { ... }
message AnExampleResponse { ... }

service AnExampleService {
    rpc OneToOneCall (AnExampleRequest) returns (AnExampleResponse) { } 

    rpc OneToStreamCall (AnExampleRequest)
        returns (stream AnExampleResponse) { } 

    rpc StreamToStreamCall (stream AnExampleRequest)
        returns (stream AnExampleResponse) { } 
}
Outline

11 Technology Overview

12 Assignment Part I

13 Server Implementation

14 Client Implementation

15 Assignment Part II
Assignment

Server
Implement a server that will provide information on current time.
- The server should accept a spec of what fields to return.
- Fields should be standard YYYY-MM-DD HH:MM:SS.

Client
Implement a client that will query server time:
- Pick a random combination of fields.
- Query information on current time.
- Print the time.

Interoperability
Implement compatible clients and servers in two languages.
Examples To Begin With ...


**C**

> cd teaching-introduction-middleware/src/grpc-basic-server/c
> cat README.md

**Java**

> cd teaching-introduction-middleware/src/grpc-basic-server/java
> cat README.md

**Python**

> cd teaching-introduction-middleware/src/grpc-basic-server/python
> cat README.md
Outline

11 Technology Overview

12 Assignment Part I

13 Server Implementation

14 Client Implementation

15 Assignment Part II
C++ Service Basics

Implementation

class MyService : public AnExampleService::Service {
  grpc.Status OneToOne (grpc.ServerContext *context,
    const AnExampleRequest *request, AnExampleResponse *response) {
    // Method implementation goes here ...
    return (grpc.Status::OK);
  }

  ...
}

Execution

MyService service;
grpc.ServerBuilder builder;
builder.AddListeningPort ("localhost:8888", grpc.InsecureServerCredentials ());
builder.RegisterService (&service);
std::unique_ptr<grpc.Server> server (builder.BuildAndStart ());
server->Wait ();
Java Service Basics

Implementation

class MyService extends AnExampleServiceGrpc.AnExampleServiceImplBase {
    @Override public void OneToOne (AnExampleRequest request, io.grpc.stub.StreamObserver<AnExampleResponse> responseObserver) {
        // Method implementation goes here ...
        responseObserver.onNext (response);
        responseObserver.onCompleted ();
    }
    ...
}

Execution

io.grpc.Server server = io.grpc.ServerBuilder
    .forPort (8888).addService (new MyService ()).build ().start ();
server.awaitTermination ();
Python Service Basics

Implementation

```python
class MyServicer (AnExampleServiceServicer):
    def OneToOne (self, request, context):
        # Method implementation goes here ...
        return response
```

Execution

```python
server = grpc.server (futures.ThreadPoolExecutor (max_workers = SERVER_THREAD_COUNT))
add_AnExampleServiceServicer_to_server (MyServicer (), server)
server.add_insecure_port ("localhost:8888")
server.start ()
```
Outline

11 Technology Overview

12 Assignment Part I

13 Server Implementation

14 Client Implementation

15 Assignment Part II
# C++ Client Basics

## Connection

```cpp
std::shared_ptr<grpc.Channel> channel = grpc.CreateChannel (  
    "localhost:8888", grpc.InsecureChannelCredentials ());
```

## Invocation

```cpp
grpc.ClientContext context;  
AnExampleResponse response;  
std::shared_ptr<AnExampleService::Stub> stub = AnExampleService::NewStub (channel);  
grpc.Status status = stub->OneToOne (&context, request, &response);  
if (status.ok ()) {  
    // Response available here ...
}
```
Java Client Basics

Connection

```java
io.grpc.ManagedChannel channel = io.grpc.ManagedChannelBuilder
    .forAddress("localhost", 8888)
    .usePlaintext(true)
    .build();
```

Invocation

```java
AnExampleServiceGrpc.AnExampleServiceBlockingStub stub =
    AnExampleServiceGrpc.newBlockingStub(channel);
AnExampleResponse response = stub.oneToOne(request);
// Response available here ...
```
Python Client Basics

Connection

with grpc.insecure_channel("localhost:8888") as channel:

Invocation

stub = AnExampleServiceStub(channel)
response = stub.OneToOne(request)
# Response available here ...
Outline

11 Technology Overview

12 Assignment Part I

13 Server Implementation

14 Client Implementation

15 Assignment Part II
Assignment

Performance
Measure the performance of your implementation.

Experiment Design
Stick to the following, or provide arguments for why not:
- Random field mix, each field with probability 1/2.
- Measure at least two minutes long traffic.
- Report average invocation throughput.
- No printing during measurement.
- Compare with past assignments.
Part IV

JGroups: Multicast Messaging
Outline

16 Technology Overview

17 Assignment Part I

18 Interface Overview

19 Assignment Part II
Technology Overview

Goals
Provide reliable group messaging mechanism.

Features
- Basic group messaging interface.
- Groups identified by names.
- Messages are byte arrays.
- Configurable protocol stack.
  - Multiple underlying transports.
  - Multiple reliability mechanisms.
  - Multiple membership discovery mechanisms.
  - Multiple error recovery mechanisms.
  - ...

... http://www.jgroups.org
Outline

16  Technology Overview

17  Assignment Part I

18  Interface Overview

19  Assignment Part II
Assignment

Peer
Implement a process that will update a shared hash map.
- The shared hash map is available through SharedHashMap channel.
- The updates are transmitted through UpdateEvent class.

```java
import java.io.Serializable;

public class UpdateEvent implements Serializable {
    private static final long serialVersionUID = 0xBAADBAADBAADL;

    public int key;
    public String value;
}
```
Examples To Begin With ...


Java

> cd teaching-introduction-middleware/src/jgroups-basic-peer/java
> cat README.md
Outline

16 Technology Overview
17 Assignment Part I
18 Interface Overview
19 Assignment Part II
public class JChannel implements Closeable {
    public JChannel ();
    public JChannel (File file);
    public JChannel (URL properties);
    public JChannel (Element properties);

    public void connect (String cluster_name);
    public void disconnect ();

    public void send (Message msg);
    public void send (Address dst, byte [] buf);
    public void send (Address dst, Object obj);

    public void setReceiver (Receiver r);
    public Receiver getReceiver ();

    public View getView ();

    public void addChannelListener (ChannelListener listener);
    public void removeChannelListener (ChannelListener listener);

    ...
public class Message ... {
    public Message (Address dest);
    public Message (Address dest, byte [] buf);
    public Message (Address dest, Object obj);

    public Address getDest ();
    public Message setDest (Address new_dest);
    public Address getSrc ();
    public Message setSrc (Address new_src);

    public int getOffset ();
    public int getLength ();
    public byte [] getBuffer ();
    public Message setBuffer (byte [] b);
    public Message setBuffer (byte [] b, int offset, int length);

    ...
}
public class ReceiverAdapter implements Receiver {
    public void receive (Message msg);
    public void receive (MessageBatch batch);

    public void block ();
    public void unblock ();

    public void getState (OutputStream output);
    public void setState (InputStream input);

    public void suspect (Address mbr);
    public void viewAccepted (View view);
}
public interface ChannelListener {
    public void channelClosed (JChannel channel);
    public void channelConnected (JChannel channel);
    public void channelDisconnected (JChannel channel);
}
Code Now ...

Outline

16 Technology Overview
17 Assignment Part I
18 Interface Overview
19 Assignment Part II
Assignment

Peer

Implement a process that will track and display a shared hash map state.
- The shared hash map is available through `SharedHashMap` channel.
- The updates are transmitted through `UpdateEvent` class.

```java
import java.io.Serializable;

public class UpdateEvent implements Serializable {
    private static final long serialVersionUID = 0xBAADBAADBAADL;
    public int key;
    public String value;
}
```

Quiz

- How would you go about measuring the cluster throughput?
- Will the entire cluster see the same state?
Part V

Google Cloud: Secure Communication
Outline

20 Technology Overview

21 Assignment Part I

22 Authorization

23 Google Cloud Platform Services

24 Assignment Part II
RSA Refresher

Public Key Cryptography

A key pair where data encrypted with one key (private or public) can be decrypted with the other one (public or private).

- Public key available, private key kept secret
- Encrypting with public key, signing with private key

\[ x^{(p-1)(q-1)} = 1 \pmod{pq} \]  
... for \( p, q \) prime and \( x \) not commensurable with \( pq \)

pick \( p, q \)

have \( n = pq \) and \( \phi = (p - 1)(q - 1) \)

pick \( e, d \) such that \( ed = 1 \pmod{\phi} \)

then \( (m^e)^d = m^{1+k(p-1)(q-1)} = m \cdot m^{k(p-1)(q-1)} = m \pmod{n} \)

... Martin Ouwehand: The (simple) Mathematics of RSA
DH Refresher

Shared Secret Agreement

A process through which parties can agree on a shared secret without actually transmitting the shared secret itself.

have $p$ and $g$ where $g$ is a generator of multiplicative integer group modulo $p$

Alice: pick $a$ and publish $g^a \pmod p$

Bob: pick $b$ and publish $g^b \pmod p$

then $(g^a)^b = (g^b)^a$ is a shared secret
TLS Technology Overview

Goals
Provide privacy and integrity guarantees in network communication.

Features
- Cipher suite negotiation
  - Key exchange (RSA, DHE, PSK ...)
  - Encryption (AES GCM, AES CCM, AES CBC ...)
  - Message authentication (MD5, SHA1, SHA256 ...)
- Secure session key exchange
- Server authentication
- Data encryption
- Data integrity

... TLS 1.2 RFC 5246
TLS RSA Handshake Sketch

[CLT] Hello, I support these cipher suites, 
    and here is my CLIENT RANDOM number

[SRV] Hello, I have picked cipher suite AES256-SHA256, 
    here is my SIGNED SERVER CERTIFICATE 
    and here is my SERVER RANDOM number

[CLT] Here is a random PRE MASTER SECRET encrypted with your RSA key

MASTER SECRET = function (PRE MASTER SECRET, CLIENT RANDOM, SERVER RANDOM)  
various session keys = function (MASTER SECRET)

[CLT] Finished and here is encrypted hash of exchanged messages

[SRV] Finished and here is encrypted hash of exchanged messages
TLS DH Handshake Sketch

[CLT] Hello, I support these cipher suites,
and here is my CLIENT RANDOM number

[SRV] Hello, I have picked cipher suite AES256-SHA256,
here is my SIGNED SERVER CERTIFICATE
and here is my SERVER RANDOM number

[SRV] Here is my signed SERVER DH PUBLIC KEY

[CLT] Here is my CLIENT DH PUBLIC KEY

PRE MASTER SECRET = function (CLIENT DH PUBLIC KEY, SERVER DH PUBLIC KEY)
MASTER SECRET = function (PRE MASTER SECRET, CLIENT RANDOM, SERVER RANDOM)
various session keys = function (MASTER SECRET)

[CLT] Finished and here is encrypted hash of exchanged messages

[SRV] Finished and here is encrypted hash of exchanged messages
Outline

20 Technology Overview
21 Assignment Part I
22 Authorization
23 Google Cloud Platform Services
24 Assignment Part II
Assignment

Server
Implement a server that will provide information on current time.
- The server should accept a spec of what fields to return.
- Fields should be standard YYYY-MM-DD HH:MM:SS.

Client
Implement a client that will query server time:
- Pick a random combination of fields.
- Query information on current time.
- Print the time.

Security
The connection between the client and the server should be encrypted.
Python Secure Connection Basics

Server

key_data = open ('server.key', 'rb').read ()
crt_data = open ('server.crt', 'rb').read ()
credentials = grpc.ssl_server_credentials ([( key_data, crt_data )])

server = grpc.server (...) 
server.add_secure_port (SERVER_ADDR, credentials)

Client

crt_data = open ('server.crt', 'rb').read ()
credentials = grpc.ssl_channel_credentials (root_certificates = crt_data)
channel = grpc.secure_channel (SERVER_ADDR, credentials)

stub = AnExampleServiceStub (channel)
Outline

20 Technology Overview

21 Assignment Part I

22 Authorization

23 Google Cloud Platform Services

24 Assignment Part II
OAuth Technology Overview

Goals
Standard protocol for granting third party applications limited access to HTTP accessible resources.

Features
- Considers multiple client types
  - Applications running in browser
  - Server hosted applications acting on own behalf
  - Server hosted applications acting on user behalf
- Heavily uses browser request redirection
- Requires (mostly) encrypted communication
- Authentication represented by (secret) access token

... OAuth 2.0 RFC 6749
## Authorization Process Participants

<table>
<thead>
<tr>
<th><strong>Resource Owner</strong></th>
<th>This is the end user who authorizes third party clients to access resources. The resource owner accesses the third party client through a browser.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resource Server</strong></td>
<td>This is the server that provides access to resources when shown authorization in the form of access token.</td>
</tr>
<tr>
<td><strong>Third Party Client</strong></td>
<td>This is the application that needs to access resources on behalf of resource owner.</td>
</tr>
<tr>
<td><strong>Authorization Server</strong></td>
<td>This is the server that can authenticate the resource owner and issues access tokens as directed by the resource owner.</td>
</tr>
</tbody>
</table>
Authorization Process Sketch

[OWN] Accesses an application link that needs authorization.

[APP] Responds with REDIRECT sending the browser to authorization server. The link includes CLIENT ID and SCOPE and arbitrary STATE.

[OWN] The browser follows the link to the authorization server.

[AUT] The server authenticates the user behind the browser. The user is then asked to grant authorization for SCOPE. The server concludes with REDIRECT back to the application. The link includes AUTHORIZATION CODE and associated application STATE.

[OWN] The browser follows the link to the application.

[APP] The application gets the AUTHORIZATION CODE from the link. The application asks the authorization server to convert the AUTHORIZATION CODE into an ACCESS TOKEN.

[AUT] The server generates the ACCESS TOKEN as requested.

[APP] The application accesses the resource server with the ACCESS TOKEN included in request header.
Outline

20 Technology Overview

21 Assignment Part I

22 Authorization

23 Google Cloud Platform Services

24 Assignment Part II
Google Cloud Platform Technology Overview

Goals
Computing platform build on Google infrastructure resources and services.

Features
- Tons of services
  - Compute services (IaaS and PaaS and FaaS)
  - Storage services (SQL, tables, documents, raw block storage)
  - Networking (private networks, load balancing, content delivery)
  - Big data processing
  - Machine learning
  - Management
- Accessible through public interfaces
- Libraries for multiple languages

... http://cloud.google.com
Installation

Browser

- Register for free trial at http://cloud.google.com
- Log in to console at http://console.cloud.google.com
- Create a new project
- Enable required libraries
- Create and download a service account key

Shell

```bash
> export GOOGLE_APPLICATION_CREDENTIALS=/path/to/service-account-key.json
```
Cloud Speech API

```python
from google.cloud import speech as google_cloud_speech
from google.cloud.speech import enums as google_cloud_speech_enums
from google.cloud.speech import types as google_cloud_speech_types

client = google_cloud_speech.SpeechClient()

content = read_data_from_file(...)  
audio = google_cloud_speech_types.RecognitionAudio(content=content)
config = google_cloud_speech_types.RecognitionConfig(language_code='en-US')

result = client.recognize(config, audio)

... http://cloud.google.com/speech/docs
```
from google.cloud import translate as google_cloud_translate

client = google_cloud_translate.Client()

# Get a list of all supported languages.
languages = client.get_languages()

# Translate a sentence.
result = client.translate('some_text', target_language='en')

... http://cloud.google.com/translate/docs
Outline

20 Technology Overview

21 Assignment Part I

22 Authorization

23 Google Cloud Platform Services

24 Assignment Part II
Assignment

Goal
Create a client that translates input speech.
- An audio file with speech in English on input
- A text with speech translated into Czech on output

Implementation
Use the client libraries rather than generated stub code.
Part VI

Swagger: REST API Generation
Outline

25 Technology Overview

26 Assignment Details
REST: Representational State Transfer

Features

REST compliant web services allow requesting systems to access and manipulate textual representations of web resources using a uniform and predefined set of stateless operations.

Wikipedia

Practically: each object (for example each database record) has its own URL and each action on the object a specific method or a specific child URL.

- Add new person with POST at http://example.com/person/add
- Get person info with GET at http://example.com/person/42
- Update person info with POST at http://example.com/person/42
- Delete person info with DELETE at http://example.com/person/42
REST: Motivation

Motivation

Strike balance between need for *explicit interfaces* and need for *loose coupling*.

- Standard communication protocol (HTTP)
  - Already defines CRUD operations
  - Provides security and reliability
  - Is easy to deploy across internet
- Encourages separating model from view
- Supports independent implementation technology between client and server
REST and CRUD

CRUD

Create  to create an object
Read    to query object attributes
Update  to update object attributes
Delete  to delete an object

- The recommended minimum set of operations
- Corresponds reasonably well to HTTP methods
- Anything beyond CRUD is not considered pure REST
REST: Data Transfer

Data exchange format is application specific but there are obvious choices

- JSON because of JavaScript in the browser
- XML because of existing library support

```json
{
    "name": "Jane Doe",
    "email": "jane.doe@example.com",
    "url": [
        "http://example.com/~jane.doe",
        "http://example.com/people/jane.doe"
    ],
    "address": {
        "street1": "Our Street One",
        "street2": "Street Line Two",
        "city": "The City",
        "postal": "12345"
    },
    "room": 123
}
```
### Interface Description

- **URLs** to identify data model classes
- **Actions** to operate on class instances
- **Attributes** with types to describe class instances
- **Security** defines access rules
- **Comments** provide human readable description

#### Code generation
- Stubs wrap communication in language or framework specific constructs
- RPC style with futures for client
- Callback style for server
- Over 80 targets supported

#### Editor at [http://editor.swagger.io](http://editor.swagger.io)
Assignment

Inventory Application

Keeps track of users and assets.
Basic user related operations are already defined.
Define similar operations for assets and implement everything.

- **Interface**
  - Elementary CRUD operations for assets
  - One to many relationship between users and assets

- **Server**
  - Python implementation using Flask, or
  - Java implementation using Spring

- **Client**
  - TypeScript implementation using Angular, or
  - R and bash helper scripts
Assignment Interface: Prologue

swagger: 2.0

info:
  description: Inventory database service
  version: 1.0.0
  title: Inventory
  termsOfService: ""
  license:
    name: Apache 2.0
    url: "http://www.apache.org/licenses/LICENSE-2.0.html"

host: localhost:8080  # Simplifies usage of generated code

basePath: /v1  # Version your API from the beginning

schemes:
  - http  # For testing only, hide behind SSL proxy in production (and do
           # not forget about CORS (Access-Control-Allow-Origin) etc.)
paths:
  /users:
    get:
      operationId: readUsers  # Callback/stub name in your code
      produces: [ "application/json" ]
      responses:  # HTTP status codes
        200:
          schema:
            type: array
            items:
              $ref: "#/definitions/UserBase"

definitions:
  UserBase:  # Class in the generated code
    type: object
    properties:
      id: { type: integer }
      firstname: { type: string }
      lastname: { type: string }
/user/{id}:
  get:
    summary: Query user information.
    operationId: readUser
    parameters:
      - in: path
        name: id
        description: ID of the user.
        required: true
        type: integer
    produces:
      - "application/json"
    responses:
      200:
        description: Successful operation
        schema:
          type: object
          $ref: "#/definitions/User"
Assignment Interface: Updating User Data

post:
  summary: Update user information.
  operationId: updateUser
  consumes: [ "application/json" ]
  produces: [ "application/json" ]
  parameters:
    - in: path
      name: id
      description: ID of the user.
      required: true
      type: integer
    - in: body
      name: body
      description: Updated data.
      required: true
      schema:
        $ref: "#/definitions/User"
  responses:
    405:
      description: Invalid input
Assignment Interface: Inheritance

definitions:
  UserBase:  # Used in listings
type: object
properties:
id:
  type: integer
firstname:
  type: string
lastname:
  type: string
email:
  type: string
User:  # Detailed information
allOf:
- $ref: "#/definitions/UserBase"
- type: object
  properties:
    homepage:
      type: string
department:
      type: string
Code Generation

```bash
swagger-codegen generate -i api.yaml -o <path> -l <framework>
```

**Assignment**

The `fetch.sh` fetches the code generator JAR.

Use `on-api-update.sh` scripts after updating `api.yaml` to invoke the code generator.
### Flask (Python)

- microframework
- routing, sessions, templates ...
- but no databases, form validation ...

### Spring (Java)

- application framework for everything :-)
- example uses Boot to simplify configuration

### General

- No real database (data kept in memory)
- Data dump to JSON at termination for debugging
- See README for instructions how to run
Flask-based Server

```
def create_user(body):  # noqa: E501
    """Creates a new user.

    :param body: User to be added.
    :type body: dict | bytes

    :rtype: None
    """
    if connexion.request.is_json:
        body = User.from_dict(connexion.request.get_json())
    return 'do_something'
```

```
Actual implementation with data kept in memory.
```
Spring-based Server

```java
public ResponseEntity<Void> createUser(
    @ApiParam (value = "User to be added." , required=true)
    @Valid
    @RequestBody
    User body)
{
    String accept = request.getHeader("Accept");
    return new ResponseEntity<Void> (HttpStatus.NOT_IMPLEMENTED);
}
```

Actual implementation with data kept in memory.
Clients

**General**
- Wraps the HTTP communication
- Provides classes for individual definitions (model)
- Often future-based communication
- Generated code is used as a library

**Assignment**
- Angular – web UI front-end to the server
- Bash – scriptable command-line access to the server
- R – data processing communication directly with the server
## Angular-based Client

### Assignment

Add interface components for listing complete inventory. Extend user detail page with asset list.

### General

- Sources are under src/app
- *.component.html contains web page snippets of the component
- *.component.ts contains TypeScript implementation of the component
Angular-based Client

**app-routing.module.ts**
- Import all your components
- Add new routes to routes

**app.component.html**
- Items in the topbar
Angular-based Client: Reading Server Data

users/users.component.ts

```ts
export class UsersComponent implements OnInit {
  users: User[];

  constructor (private api: DefaultService) {}  

  ngOnInit () {
    this.api.readUsers ().subscribe (u => this.users = u);
  }
}
```

users/users.component.html

```html
<ul>
  <li *ngFor="let user of users">
    <a routerLink="/user/{{user.id}}">{{user.lastname}}, {{user.firstname}}</a>
  </li>
</ul>
```
Angular-based Application: Writing Server Data

**users/user.component.html**

```html
<form (ngSubmit)="save();">
  <label for="user-first-name">First name:</label>
  <input [(ngModel)]="user.firstname" id="user-first-name" />
  ...
  <button type="submit">Save</button>
</form>
```

**users/user.component.ts**

```typescript
export class UserComponent {
  save (): void {
    const id = +this.route.snapshot.paramMap.get ('id');
    this.api.updateUser (id, this.user).subscribe ();
  }
}
```
Bash client: Overview

**Generated**

The generated script `client.sh` is a thin wrapper on top of `curl` doing the actual requests. Useful to check that the server works as expected.

**make-check-lists and add-employees.sh**

Downloads list of employees, creates printable version of the inventory. Reads employee list from a CSV, adds them to the database.

**Assignment**

Extend the `make-check-lists` to include assets listing and create a similar script for adding assets.

```
asset,price,acquired,owner
Magic Wand,42,2017,harry.potter@example.com
... 
```
Bash client: Usage

> ./client.sh --silent readUsers | json_reformat

> ./client.sh --silent readUser id=1

> ./client.sh createUser \
   firstname==Horatio lastname==Hornblower \
   email==horatio.hornblower@royalnavy.mod.uk \
   department==Navy \
   homepage==https://www.royalnavy.mod.uk/hornblower
R client: Overview

department-plot.r
Draws a barplot showing number of employees in each department.

Assignment
Create a similar script that will show total price of assets across departments and for each employee.
source ("init.r")

api <- DefaultApi$new()

all.users.id <- api$read_users()$content$id

department.people.count <- list()

for (i in all.users.id) {
  u <- api$read_user(i)$content
  dept <- u$department
  if (!(dept %in% names(department.people.count))) {
    department.people.count[[dept]] <- 0
  }

  department.people.count[[dept]] <- department.people.count[[dept]] + 1
}

barplot(unlist(department.people.count), main="Employee count per department")
Assignment Summary

- Extend `api.yaml` with assets-related operations and data definitions
- Extend one of the servers (Flask or Spring)
  - Implement all CRUD operations and listing (all and per-user)
- Extend one of the clients (Angular or R and bash)
  - Angular: allow all of CRUD operations on assets and per-user listing
  - R and bash: asset adding script, printable version of asset listing and two plotting scripts