WebServices & WebSockets

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WebService and WebSocket **basics**

http://www.danekja.org (Twitter & LinkedIn links)
http://www.yoso.fi (yep, in Finnish)

Motivation

- **How to connect different applications?**
  - Written in different languages
  - Deployed on different platforms
  - By different people

WebService

- **W3C definition:**

  A **Web service** is a software system designed to support **interoperable machine-to-machine interaction over a network**. It has an interface described in a **machine-processable format** (specifically WSDL).

  Other systems interact with the Web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other Web-related standards.

- Restricted to SOAP, not meant as generic definition (other things can be webservices too...)

WebService

- **Way to connect applications on web**
  - Using standardized open protocols (HTTP, SOAP)
  - Using standardized open data formats (XML, JSON)

  → providers do not need to care about their client's technology stack, platform, etc.

WebService

- **Example**

WebService

- **Black box**
  - Consumers are not aware of implementation of the services they are consuming
- **Stateless**
  - In most cases web service calls are stateless
  - Simpler design
  - Better scalability

WebService – Uses

- **Reusable components**
  - User authentication, weather forecast, currency conversion, navigation
- **Connect existing software**
  - Independent of programming language (web standards)
  - Independent of platform (Unix, Windows, Raspberry PI)

Sources

- **http://www.w3schools.com/xml/xml_services.asp**
- **https://www.w3.org/TR/ws-arch/**

Simple Object Access Protocol (SOAP)

SOAP

- **Messaging protocol**
  - Message format
  - Encoding rules for datatypes
- **XML-based**
  - All messages exchanged in XML format
- **Actions determined by message content**

SOAP - Message

- **Envelope**
  - XML element encapsulating the SOAP message
- **Header**
  - Means for protocol extension, may provide additional information about the message sent, security, etc...
- **Body**
  - The message data
- **Fault**
  - Information generated by a processing node on error

SOAP

```
<env:Envelope xmlns:env="http://www.w3.org/2003/05/soap-envelope">
  <env:Fault>
    ...
  </env:Fault
  <env:Header>
    ...
  </env:Header>
  <env:Body>
    ...
  </env:Body>
</env:Envelope>
```

SOAP

- **Advantages**
  - Flexible
  - Extensible
  - Uses XML – XSD, internationalization, namespaces

SOAP

- **Disdvantages**
  - No standardized API design approach
  - Uses XML
    - Message size and complexity grows quickly

      → Performance issues

SOAP – Example 1 (request)

```
POST /InStock HTTP/1.1
Host: www.example.org
Content-Type: application/soap+xml; charset=utf-8
Content-Length: nnn

<?xml version="1.0"?>

<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope/"
               soap:encodingStyle="http://www.w3.org/2003/05/soap-encoding">

  <soap:Body xmlns:m="http://www.example.org/stock">
    <m:GetStockPrice>
      <m:StockName>IBM</m:StockName>
    </m:GetStockPrice>
  </soap:Body>

</soap:Envelope>
```

SOAP – Example 1 (response)

```
HTTP/1.1 200 OK
Content-Type: application/soap+xml; charset=utf-8
Content-Length: nnn

<?xml version="1.0"?>

<soap:Envelope xmlns:soap="http://www.w3.org/2003/05/soap-envelope/"
               soap:encodingStyle="http://www.w3.org/2003/05/soap-encoding">

  <soap:Body xmlns:m="http://www.example.org/stock">
    <m:GetStockPriceResponse>
      <m:Price>34.5</m:Price>
    </m:GetStockPriceResponse>
  </soap:Body>

</soap:Envelope>
```

SOAP – Example 2

- **Example**

  See the attached file **WebServices_sovohje_en.pdf**

- **Portion of WS API specification of OP Bank (Finland)**

- **Specifically pages 12 and 13**

WebService Description Language (WSDL)

- XML Schema for describing WebServices
- Not restricted to SOAP
  - But commonly used in conjunction
- Allows generating of client code

WSDL - Elements

- <types>
  - defines the (XML Schema) data types used by the web service
- <message>
  - defines the data elements for each operation
- <portType>
  - operations that can be performed and the messages involved as input, output, on error
- <binding>
  - binding of portType to certain protocol (e.g. SOAP)

WSDL Example – OP Bank (www.pohjola.fi) WS API

WSDL - Elements

- **<types>**
  - **defines the (XML Schema) data types used by the web service**
  - **standard XSD**

```
<wsdl:types>
  <xsd:schema targetNamespace="http://mlp.op.fi/OPCertificateService"
              elementFormDefault="qualified" attributeFormDefault="qualified">

    <xsd:complexType name="CertificateRequestHeader">
      ...
    </xsd:complexType>

    <xsd:complexType name="GetCertificateRequest">
      <xsd:sequence>
        <xsd:element name="RequestHeader" type="tns:CertificateRequestHeader" nillable="false"/>
        <xsd:element name="ApplicationRequest" type="xsd:base64Binary" nillable="false"/>
      </xsd:sequence>
    </xsd:complexType>

    <xsd:element name="getCertificatein" type="tns:GetCertificateRequest"/>
  </xsd:schema>
</wsdl:types>
```

WSDL - Elements

- **<message>**
  - **defines the data elements for each operation**

```
<wsdl:message name="getCertificateRequest">
    <wsdl:part element="tns:getCertificatein" name="getCertificatein"/>
</wsdl:message>
```

WSDL - Elements

- **<portType>**
  - **operations that can be performed and the messages involved as input, output, on error**

```
<wsdl:portType name="OPCertificateServicePortType">
    <wsdl:operation name="getCertificate">
      <wsdl:input message="tns:getCertificateRequest" name="getCertificateRequest"/>
      <wsdl:output message="tns:getCertificateResponse" name="getCertificateResponse"/>
      <wsdl:fault message="tns:certificateServiceFault" name="certificateServiceFault"/>
    </wsdl:operation>
</wsdl:portType>
```

WSDL - Elements

- **<binding>**
  - **binding of portType to certain protocol (e.g. SOAP)**

```
<wsdl:binding name="OPCertificateServiceHttpBinding" type="tns:OPCertificateServicePortType">
    <soap:binding style="document" transport="http://schemas.xmlsoap.org/soap/http"/>
    <wsdl:operation name="getCertificate">
      <soap:operation soapAction=""/>

      <wsdl:input name="getCertificateRequest">  <soap:body use="literal"/>  </wsdl:input>

      <wsdl:output name="getCertificateResponse">  <soap:body use="literal"/>  </wsdl:output>

      <wsdl:fault name="certificateServiceFault">  <soap:fault use="literal"/>  </wsdl:fault>
    </wsdl:operation>
</wsdl:binding>
```

Sources

- https://www.w3.org/TR/2007/REC-soap12-part0-20070427/
- https://www.w3.org/TR/soap12-part1/
- https://www.pohjola.fi/pohjola/corporate-customers/payment-services-and-cash-management/bank-connection-methods/web-services?id=323430&kielikoodi=en
- http://www.w3schools.com/xml/xml_soap.asp

RESTful Web Services

Representational State Transfer (REST)

- **Architectural pattern for web-service design**
  - **NOT a protocol (such as SOAP)**
- **Set of simple guidelines on designing WS API**
- **Goal: create APIs that are easy to use**

REST

- **Resource-oriented**
  - **Endpoints like: /posts, /users, /categories etc.**
- **Explicit use of HTTP methods**
  - **GET, PUT, DELETE etc.**
- **Stateless**

REST - Resource

- **Identified by URI (commonly a link on the Web)**

  e.g. **http://www.blogysek.com/authors**

  - “authors” resource

- **Directory-like structure**

  http://www.blogysek.com/authors – all authors

  http://www.blogysek.com/authors/{id} – single author

  http://www.blogysek.com/authors/{id}/articles – all articles belonging to the author

REST - Operations

- **Use of HTTP Methods**
- **GET – read data**

```
GET /posts HTTP/1.1

//response
HTTP/1.1 200 OK
{
  "id": 4,
  "content": "Good morning, we've talked the whole night
             through.",
  "createdBy": "Duelling Cavalier"
}
```

REST - Operations

- **Use of HTTP Methods**
- **GET – query data**

```
GET /posts?author=”Duelling Cavalier” HTTP/1.1

//response
HTTP/1.1 200 OK
{
  "id": 4,
  "content": "Good morning, we've talked the whole night
             through.",
  "createdBy": "Duelling Cavalier"
}
```

REST - Operations

- **Use of HTTP Methods**
- **DELETE – remove data**

```
DELETE /posts/12 HTTP/1.1

//response
HTTP/1.1 204 No Content
```

REST - Operations

- **Use of HTTP Methods**
- **POST – create/update data**

```
POST /posts/ HTTP/1.1
{
  "content": "Good morning, we've talked the whole night
             through.",
  "createdBy": "Duelling Cavalier"
}

//response
HTTP/1.1 201 Created
Location: /posts/63636
```

REST - Operations

- **Use of HTTP Methods**
- **PUT – create/update data**

```
PUT /posts/12 HTTP/1.1
{
  "content": "Good morning, we've talked the whole night
              through.",
  "createdBy": "Duelling Cavalier"
}

//response
HTTP/1.1 201 Created
Location: /posts/12
```

REST - Operations

- **Use of HTTP Methods**
- **PUT vs POST**
  - **POST – when we do not know exact resource location**

    POST /posts/ HTTP/1.1

    - e.g. when server generates IDs for new resources
  - **PUT – when we do know the exact resource location**

    PUT /posts/12 HTTP/1.1

REST - Operations

- **Use of HTTP Methods**
- **PUT vs POST**
  - **POST – repeated sending of the same data does not guarantee the same result each time**
    - **e.g. multiple resources are created**
  - **PUT – repeated sending of the same data always has the same result**

    → PUT is IDEMPOTENT operation

REST - Operations

- **Use of HTTP Methods**
- **PUT vs POST**

Both can be used for creating new or updating existing resources

POST create:

```
POST /posts/ HTTP/1.1
{
  "content": "Good morning, we've talked the whole night
              through.",
  "createdBy": "Duelling Cavalier"
}
```

REST - Operations

- **Use of HTTP Methods**
- **PUT vs POST**

Both can be used for creating new or updating existing resources

POST update:

```
POST /posts/ HTTP/1.1
{
  "id": "12",
  "content": "Good morning, we've talked the whole night
             through.",
  "createdBy": "Duelling Cavalier"
}
```

REST - Operations

- **Use of HTTP Methods**
- **PUT vs POST**

Both can be used for creating new or updating existing resources

PUT create (presuming post 12 doesn't exist):

```
PUT /posts/12 HTTP/1.1
{
  "content": "Good morning, we've talked the whole night
              through.",
  "createdBy": "Duelling Cavalier"
}
```

REST - Operations

- **Use of HTTP Methods**
- **PUT vs POST**

Both can be used for creating new or updating existing resources

PUT update (presuming post 12 exists):

```
PUT /posts/12 HTTP/1.1
{
  "content": "Good morning, we've talked the whole night
              through.",
  "createdBy": "Duelling Cavalier"
}
```

REST - Operations

- **Use of HTTP Methods**
- **OPTIONS – list of allowed methods**

```
OPTIONS /posts/ HTTP/1.1

//response
HTTP/1.1 200 OK
Allow: HEAD,GET,DELETE,OPTIONS
```

REST - Operations

- **Use of HTTP Methods**
- **PATCH – partial modification of a resource**

```
PATCH /posts/12 HTTP/1.1
{
  "createdBy": "Gene Kelly"
}

//response
HTTP/1.1 200 OK
```

REST - Operations

- **Design notes:**
  - **You do not have to implement all methods for all resources**
  - **Which methods you allow for a resource is up to you**
  - **What if I really need method name in URI?**
    - **e.g. advanced search (too many parameters for URI query parameters)**

REST - Operations

- **Design notes:**
  - **What if I really need method name in URI?**
    - **e.g. advanced search (too many parameters for URI query parameters)**

```
POST /posts/queries HTTP/1.1
```

or

```
POST /posts/forms/search HTTP/1.1
```

REST – Data Format

- **Any standard data serialization format that suits you (or support multiple)**
  - **XML**
  - **JSON**
    - **JSON takes less space than XML :)**
  - **YAML**

REST - HATEOAS

- **Hypertext As The Engine Of Application State**

Use hypertext to allow clients to traverse your API:

```
GET /posts/4 HTTP/1.1

//response
HTTP/1.1 200 OK
<post id=”4”>
  <content>
          Good morning, we've talked the whole night through.
  </content>
  <createdBy>Duelling Cavalier</createdBy>
  <link rel=”author” href=”/authors/22”/>
</post>
```

REST - Summary

- **Directory-like, resource oriented endpoint structure**
- **HTTP methods for operations**

  → all APIs look similar

- **You do not need to follow all the guidelines for your API to be usable**

REST - Sources

- **http://restcookbook.com**
- **http://www.restapitutorial.com**
- **http://docs.oracle.com/javaee/6/tutorial/doc/gijqy.html**
- **https://apiary.io/**

WebSockets

Motivation

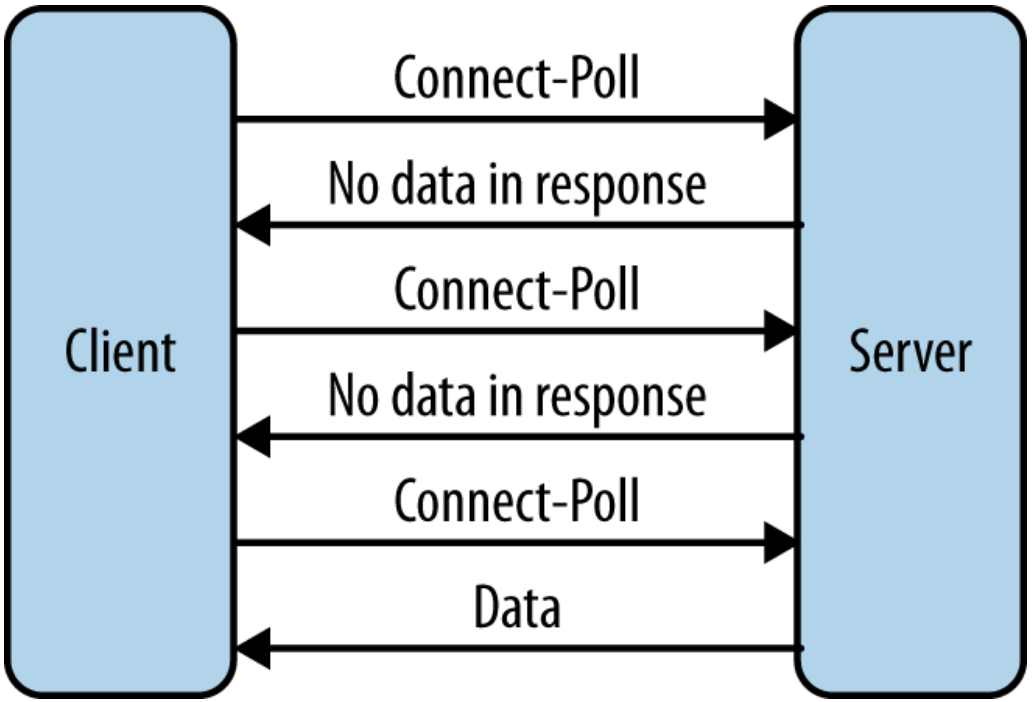
- **Some applications need to notify users of new events “real-time”**
  - e.g. an auction system
- **But standard scenario on the web is that server sends information to clients only “on request”**

Polling

Clients ask server periodically for new information (“Are we there, yet?”)

If there is none,
server response is empty

Load issues on the server side



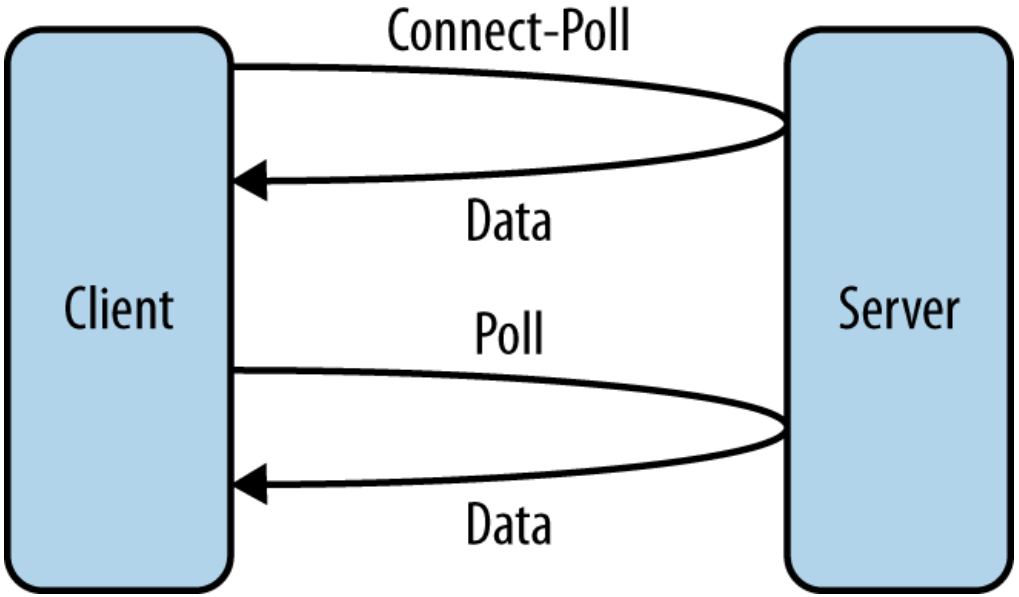
Img src: http://enterprisewebbook.com/ch8_websockets.html

Long-Polling

Clients still ask server periodically for new information

Server doesnt answer until there are some data to return

Or until specified time passes



Img src: http://enterprisewebbook.com/ch8_websockets.html

WebSockets

- **Messaging protocol for two-way communication**
  - Messages can be sent simultaneously in both directions
- **TCP-based**
- **Supported by most modern browsers (HTML 5)**

WebSockets

- **Connection established using HTTP handshake**
- **Use the same ports as HTTP (80 and 443)**
- **ws:// and wss:// URI schemes**
  - ws://www.myserver.com/chat

WebSockets - handshake

- **Connection established using HTTP handshake**

  Client sends:

```
GET /chat HTTP/1.1
Host: www.myserver.com
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Key: x3JJHMbDL1EzLkh9GBhXDw==
Sec-WebSocket-Protocol: chat, superchat
Sec-WebSocket-Version: 13
Origin: http://www.myserver.com
```

WebSockets - handshake

- **Connection established using HTTP handshake**

  If server supports websocket, the response is:

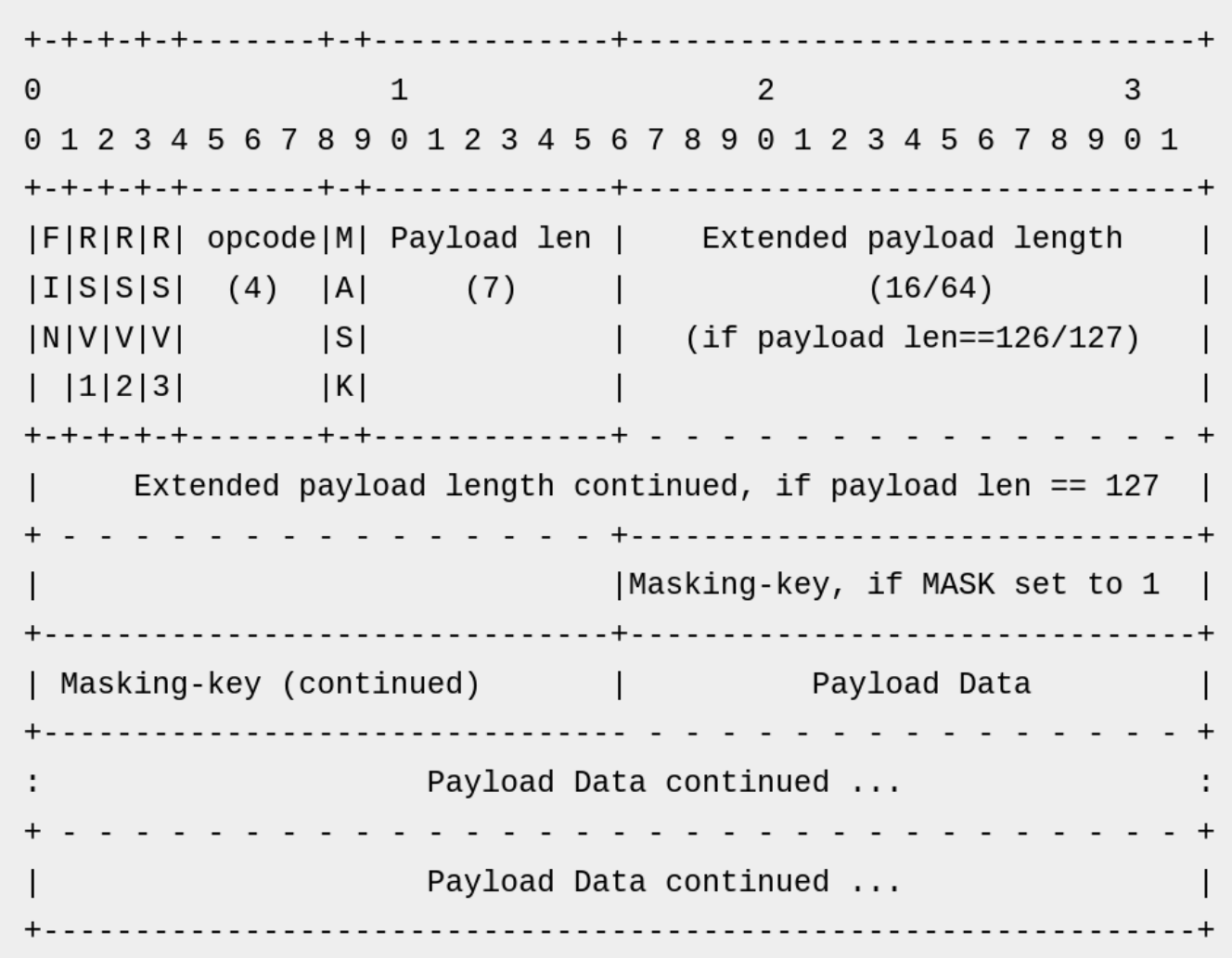
```
HTTP/1.1 101 Switching Protocols
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Accept: HSmrc0sMlYUkAGmm5OPpG2HaGWk=
Sec-WebSocket-Protocol: chat
```

WebSockets - handshake

- **Connection established using HTTP handshake**
- **After a successful handshake**
  - Protocol is switched from HTTP to WebSocket (bi-directional)
    - Uses the same TCP connection

WebSockets - Message

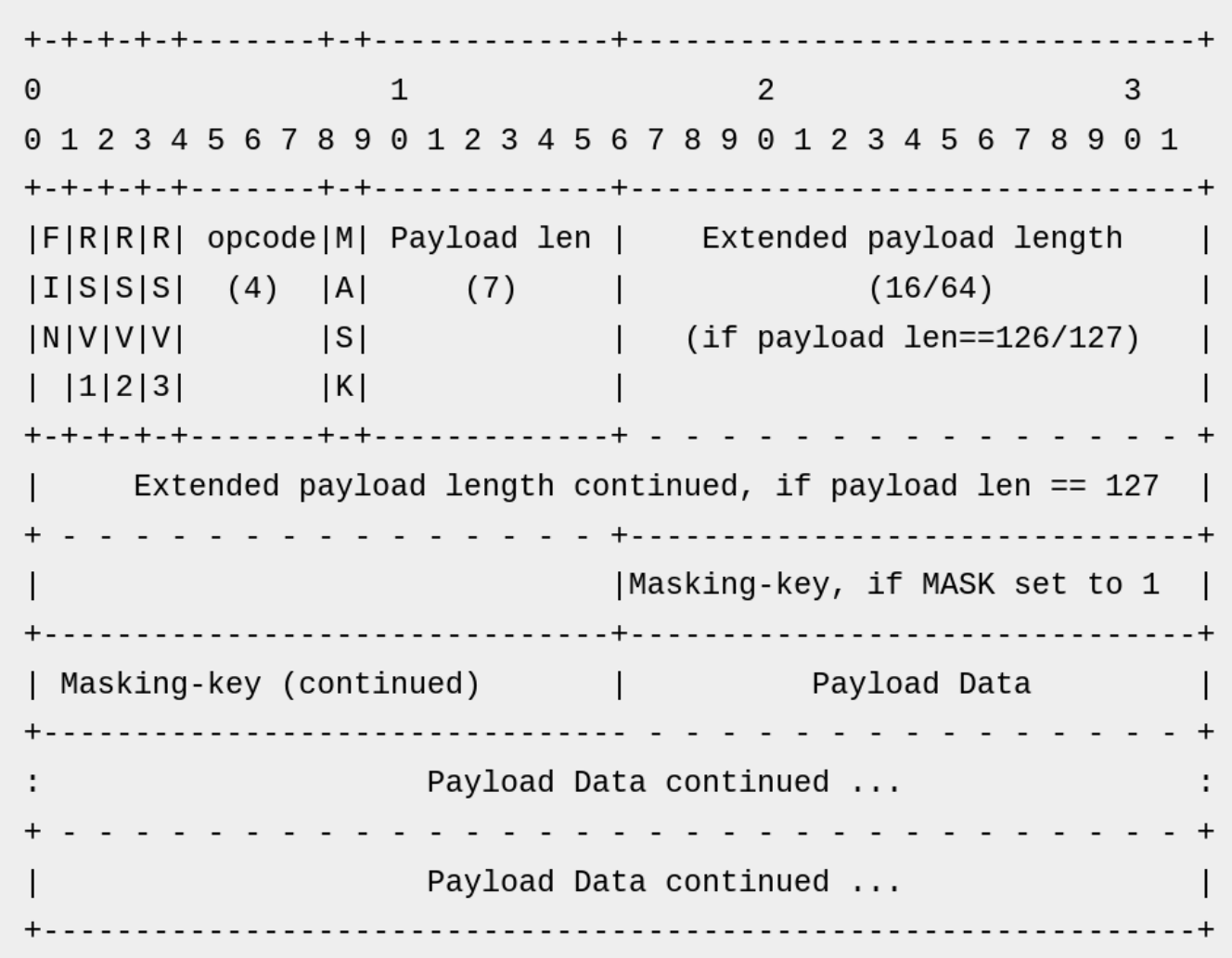
- **Each message is split into either one or multiple data frames**



Img src: http://enterprisewebbook.com/ch8_websockets.html

WebSockets - Message

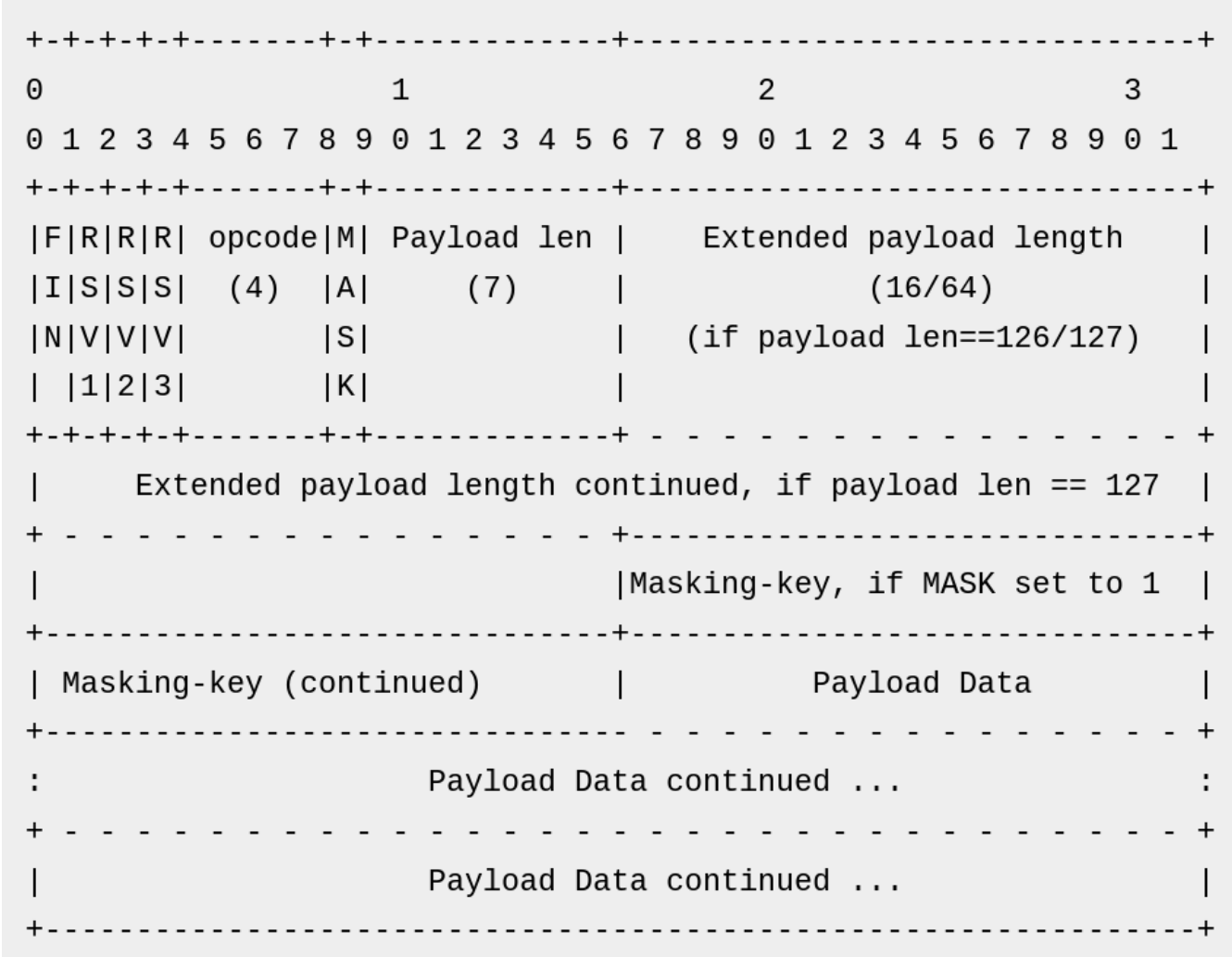
- **FIN (1 bit)**
  - Indicates whether this is the last frame of the message



Img src: http://enterprisewebbook.com/ch8_websockets.html

WebSockets - Message

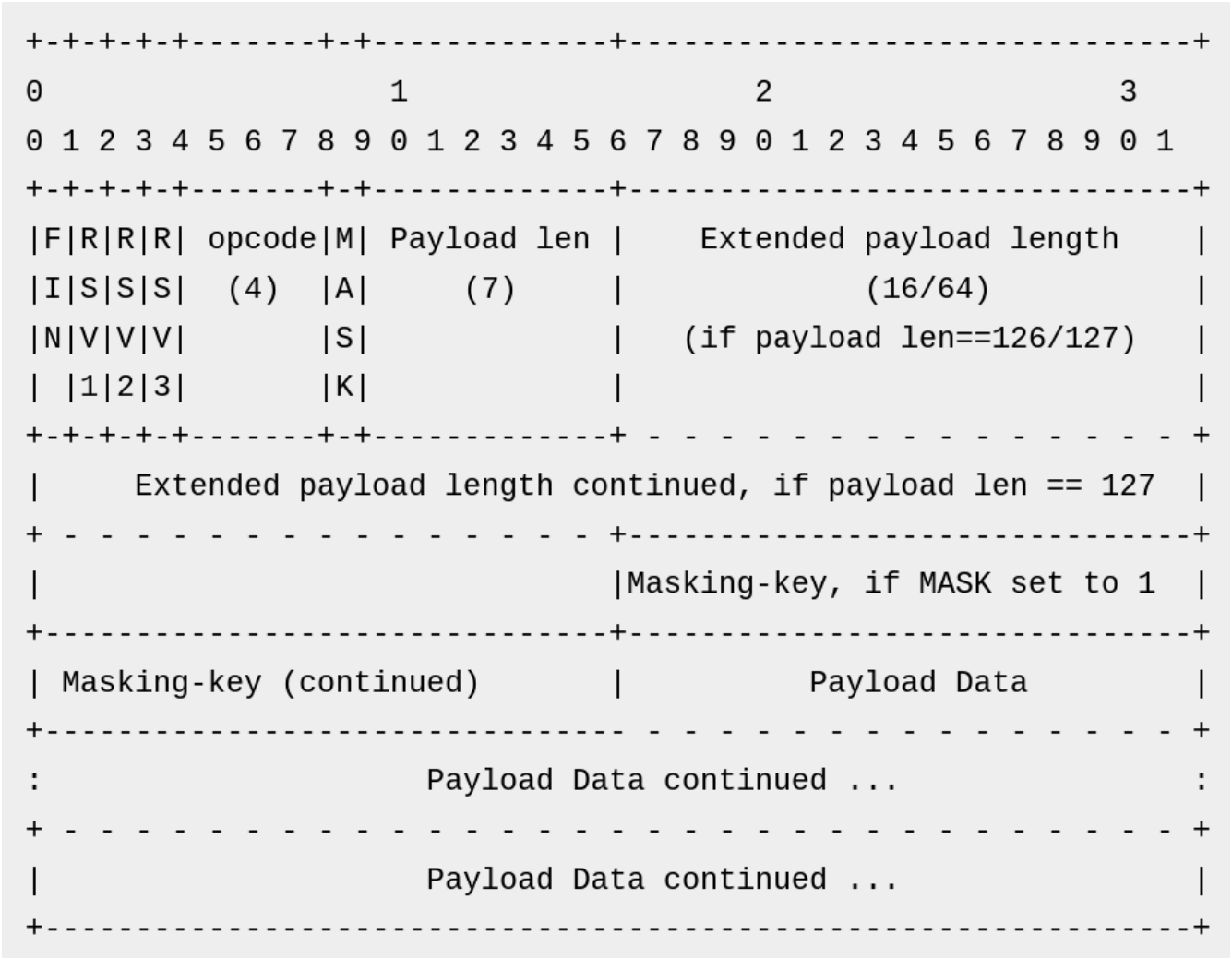
- **RSVx (1 bit)**
  - Reserved bits for future protocol extensions
  - always zero for now



Img src: http://enterprisewebbook.com/ch8_websockets.html

WebSockets - Message

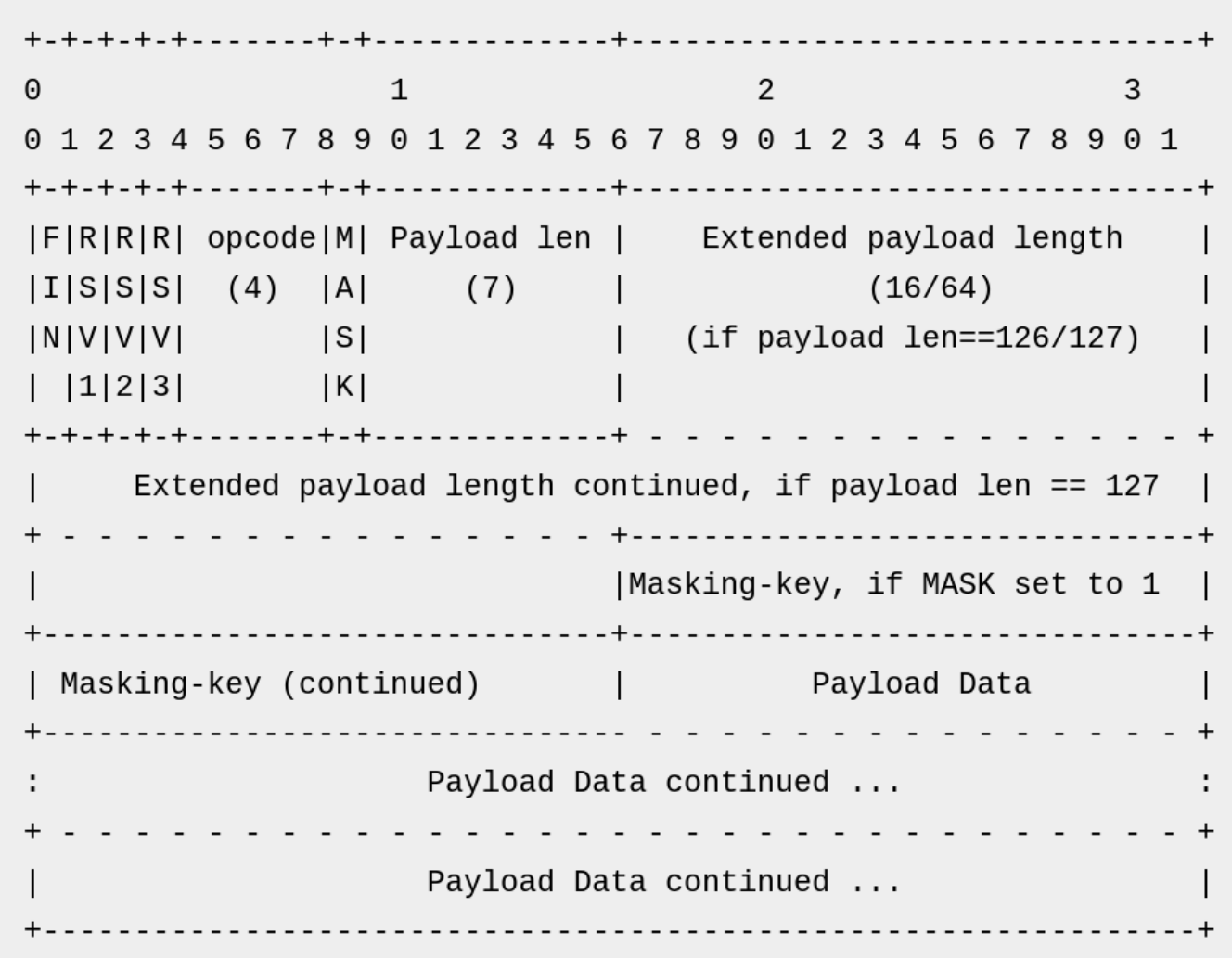
- **opcode (4 bits)**
  - Frame type
  - 0x01 – UTF-8 data
  - 0x02 – binary data
  - 0x00 – continued payload
  - …



Img src: http://enterprisewebbook.com/ch8_websockets.html

WebSockets - Message

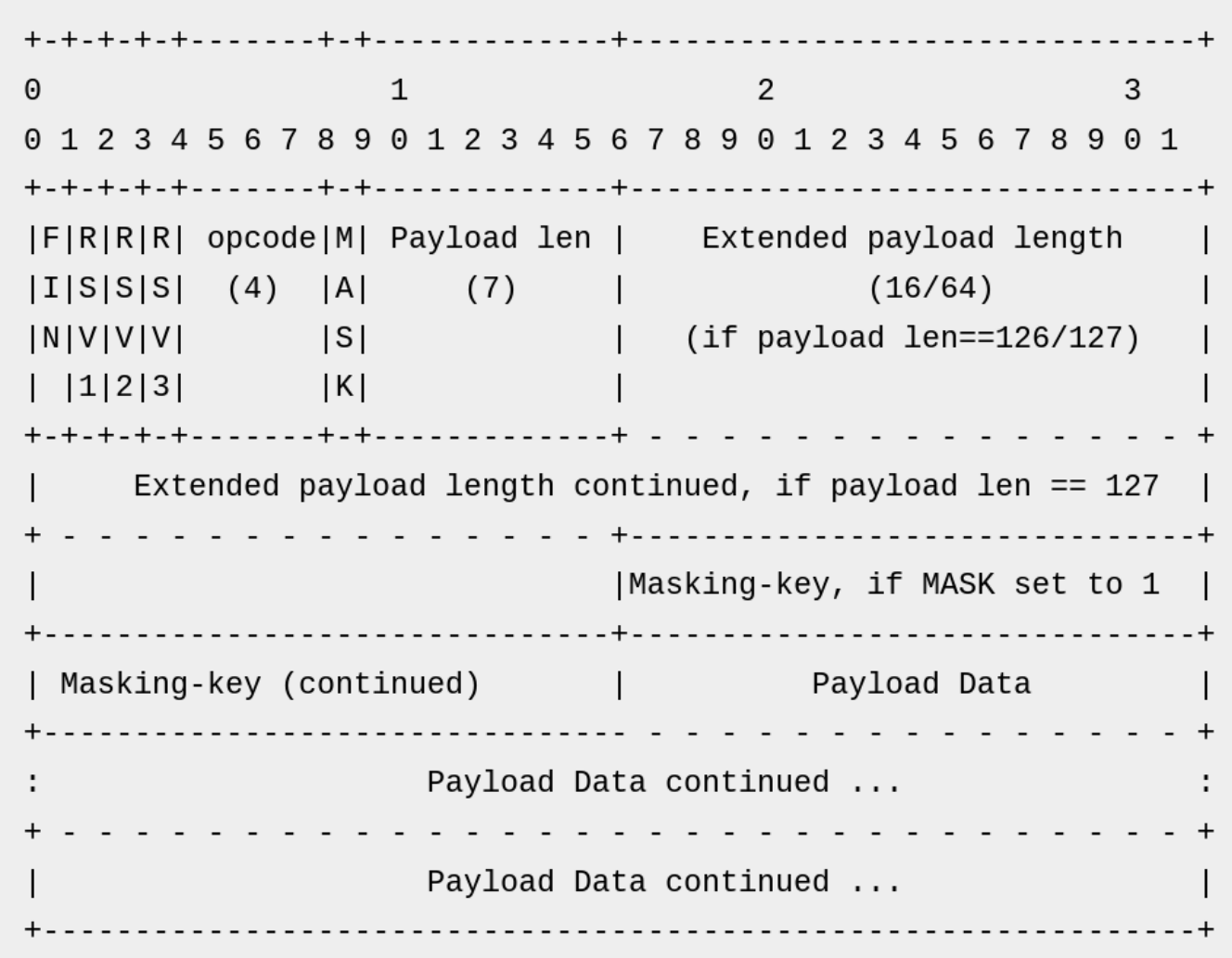
- **mask (1 bit)**
  - True if frame is masked
- **Masking-key**
  - If mask == 1
  - Used to XOR the payload



Img src: http://enterprisewebbook.com/ch8_websockets.html

WebSockets - Message

- **Payload length**
  - 0–125 indicate the length of the payload.
  - 126 means that the following 2 bytes indicate the length.
  - 127 means the next 8 bytes indicate the length.
- **Payload data**
  - The actual sent data



Img src: http://enterprisewebbook.com/ch8_websockets.html

WebSockets - Message

- First frame states message data type using opcode 0x01 or 0x02
- The following frames have opcode 0x00
- Last frame has FIN == 1

WebSockets - Heartbeat

- **Both sides need to be aware if the counterpart is still there**
  - Ideally before the next “send” attempt
  - When asking, “ping” message is sent – opcode 0x9
    - May contain application data (up to 125 bytes)
  - As an answer, “pong” message is sent – opcode 0xA
    - Must contain the same application data as the “ping” message

WebSockets – Closing Connection

- **Both sides may close the connection**
- **Opcode 0x08**
- **Additional data such as exit code, reason (arbitrary string) or whether the closing was “clean” can be sent**

WebSockets - HTML 5 API

```
//attempt connection
var socket = new WebSocket("ws://myserver.com/chat");

//handler called on successful connection
socket.onopen = function() {
  console.log("Connection successful");
}

//handler called when a message is received
socket.onmessage = function(msg) {console.log(msg.data);}

//sending a message
socket.send("Ahoj svete!");
```

Sources

- https://tools.ietf.org/html/rfc6455#page-27
- http://enterprisewebbook.com/ch8_websockets.html
- https://www.websocket.org/aboutwebsocket.html
- http://lucumr.pocoo.org/2012/9/24/websockets-101/
- http://docs.spring.io/spring/docs/current/spring-framework-reference/html/websocket.html

Thank You!