WebSockets for Java EE

Session AAD-1602

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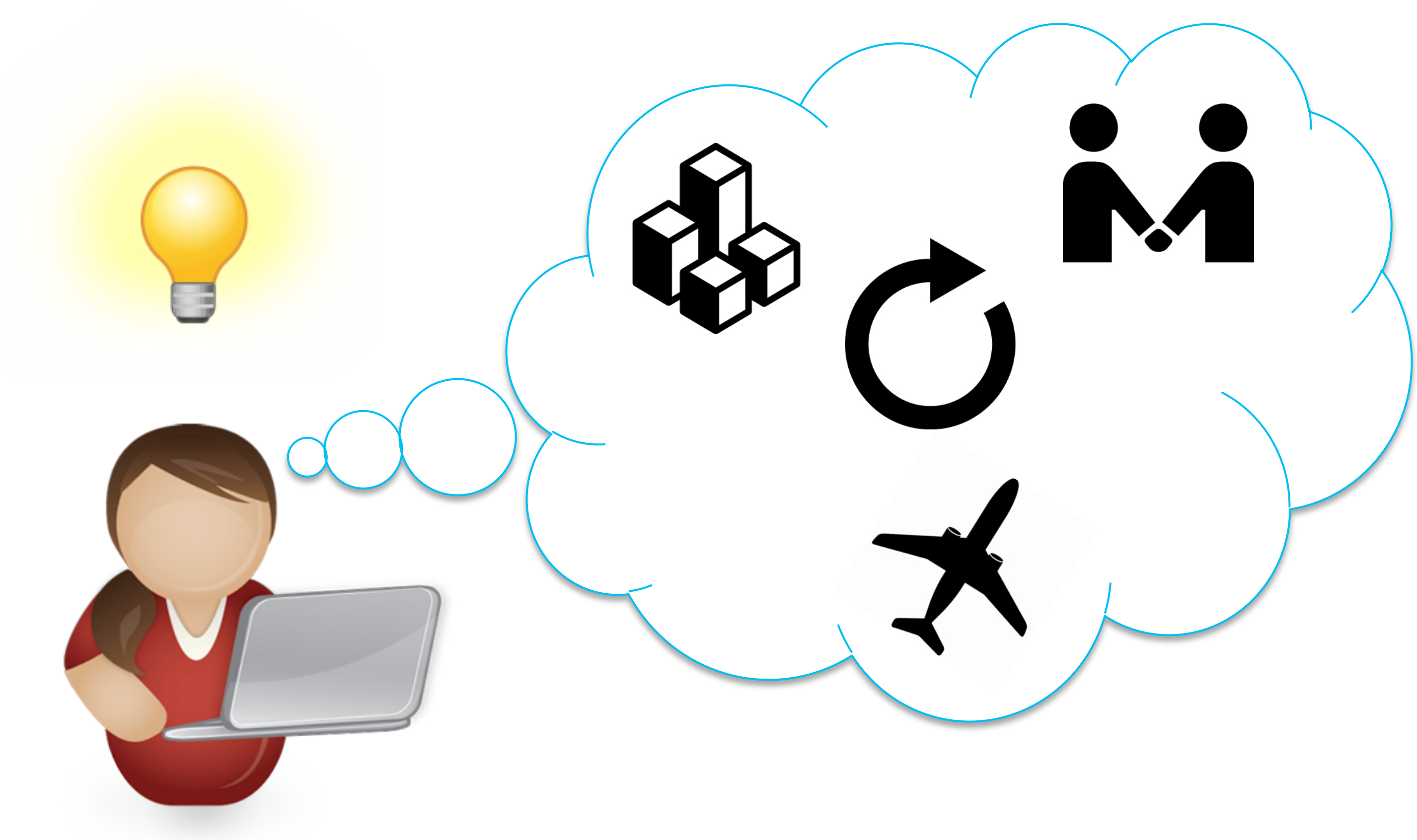
Using WebSockets in a Java EE Environment to Improve Web Application Development

- Programming model for the Java EE environment
- WebSocket API
  - Endpoint configuration
  - Session open/close
  - Message read/write
  - Error handling
  - Annotations
- WebSocket network protocol
  - Data format
- Network architecture
  - Proxies / load balancers / routers…

We're going to start with Judy…



Judy

… and her killer app

The app shares information in real time…

- Real time notifications (server -> client)
  - Flight status
  - Alternate flights
- Location updates (client -> server)
  - GPS data
- Social / conversation (broadcast)
  - Are you there yet?

… so how are they going to build it?

<tripDownMemoryLane>
Before WebSockets...

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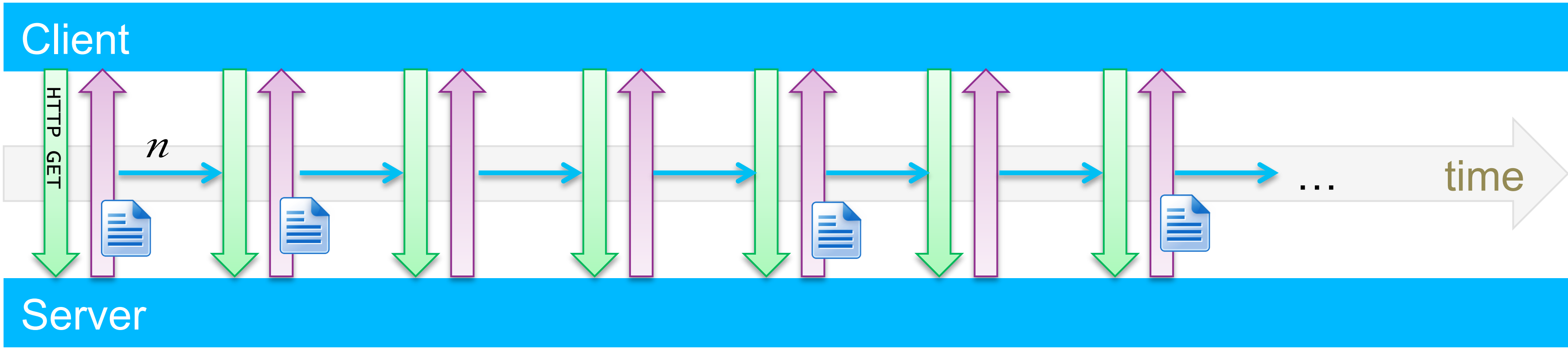
Options for two-way communication

- Polling
- Long polling
- Streaming / forever response
- Multiple connections

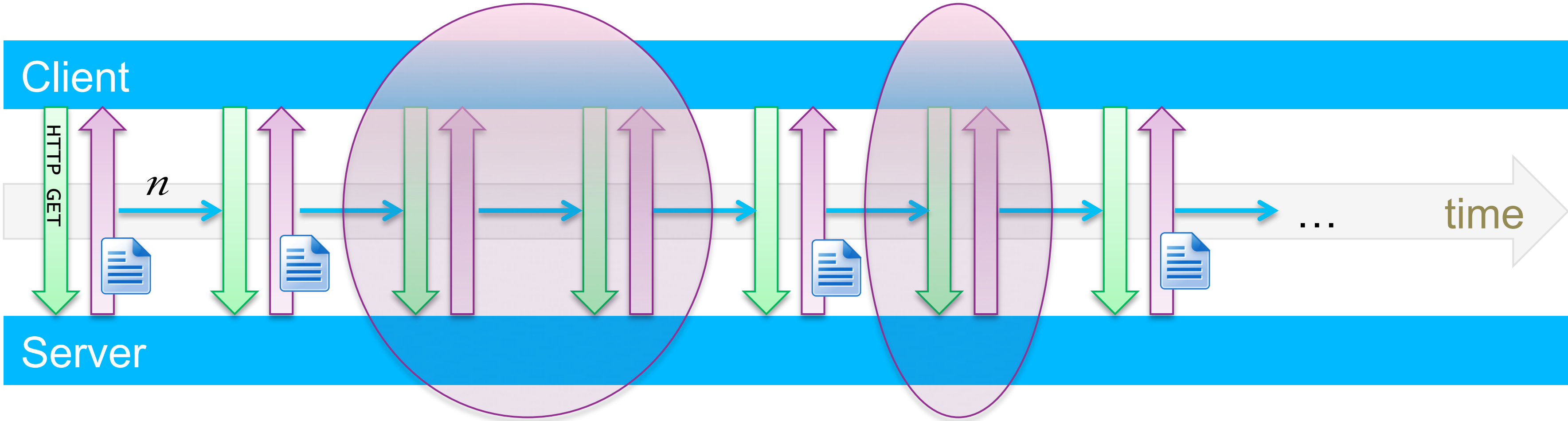
(1): Polling



- Pure JavaScript: client polls the server every n …
- Server always immediately responds (with or without data)
- Might work for periodic data where the period is known/constant

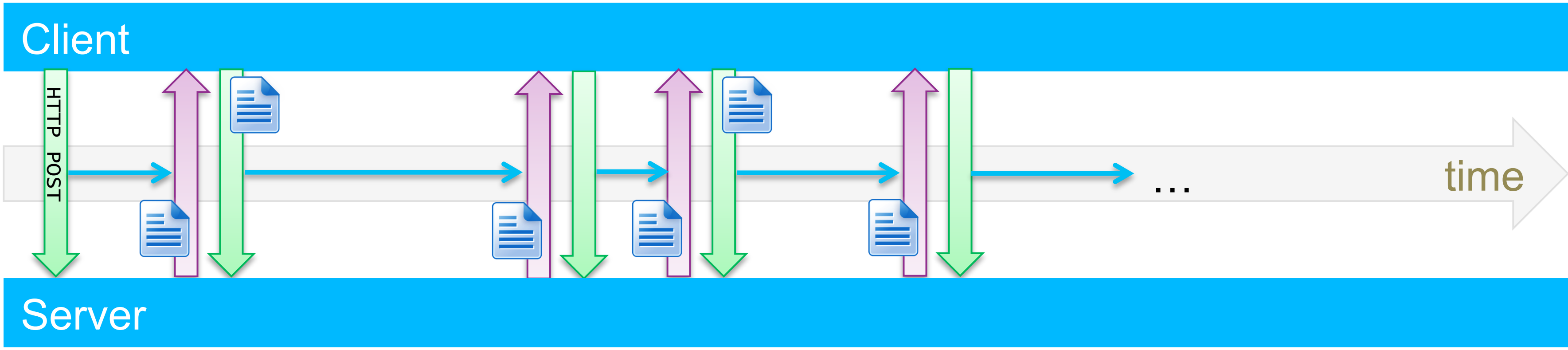
BUT…

(1): Polling



- Pure JavaScript: client polls the server every n …
- Server always immediately responds (with or without data)
- Might work for periodic data where the period is known/constant
- *Obvious waste (CPU and bandwidth) when there is no data*

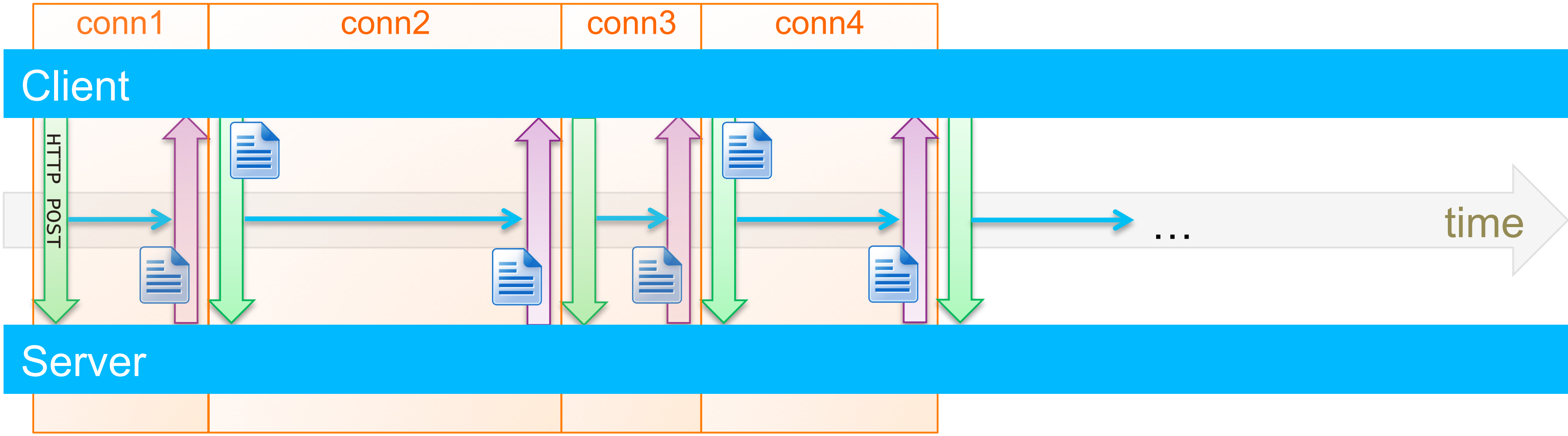
(2): Long Polling



- Client sends initial request
- Server waits until it has data to respond
- Client receives response, and immediately creates new request
- Obvious improvement over plain polling

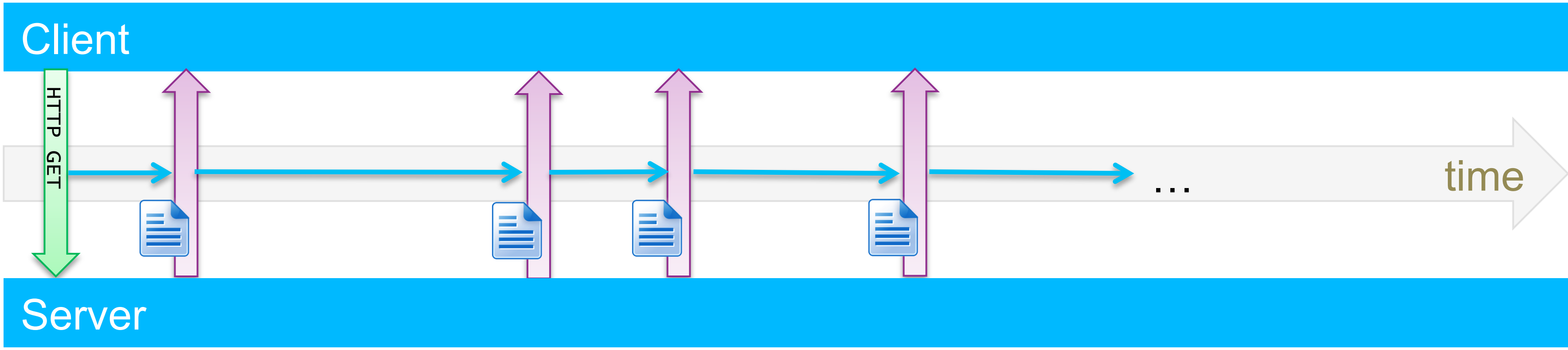
BUT…

(2): Long Polling



- Client sends initial request
- Server waits until it has data to respond
- Client receives response, and immediately creates new request
- Obvious improvement over plain polling
- *Each request/response creates and closes a connection*
- *Client has to wait to send new data until the server responds*

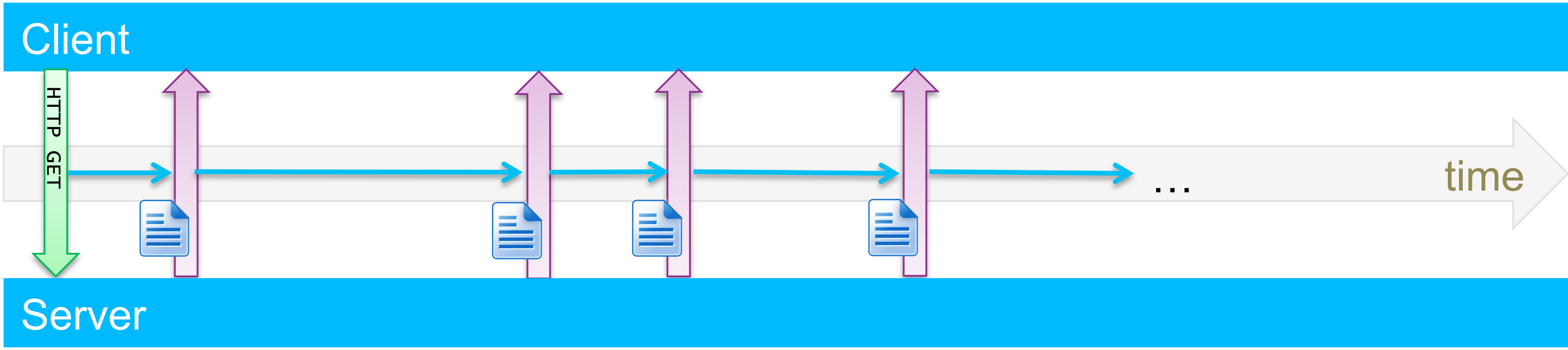
(3): Streaming / forever response



- Client sends initial request
- Server waits until it has data to respond
- Server responds by streaming data
    - Server has an open connection to *push* updates
- Connection is maintained

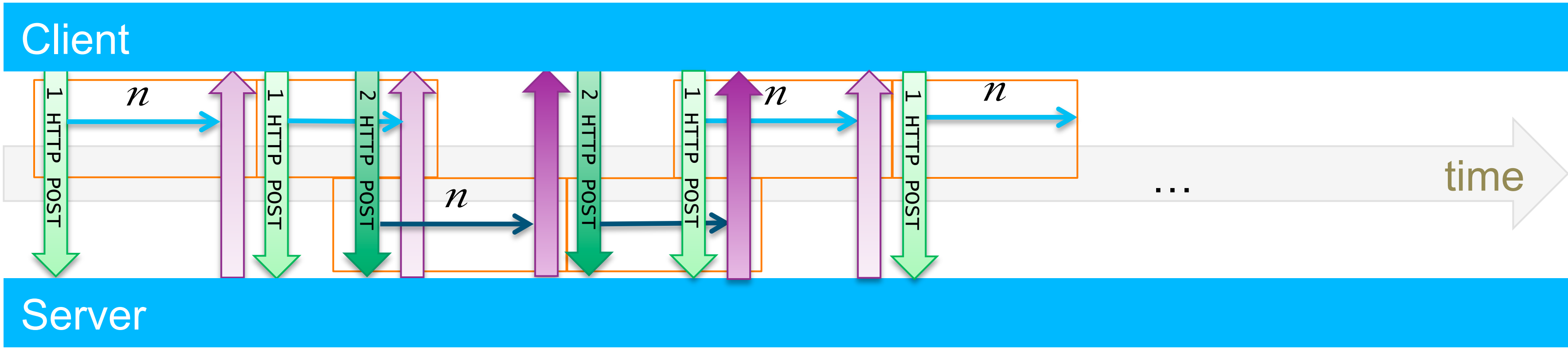
BUT…

(3): Streaming / forever response



- Client sends initial request
- Server waits until it has data to respond
- Server responds by streaming data
  - Server has an open connection to *push* updates
- Connection is maintained
- *It is half-duplex: only server to client*
- *User agents and proxies might not like partial responses*

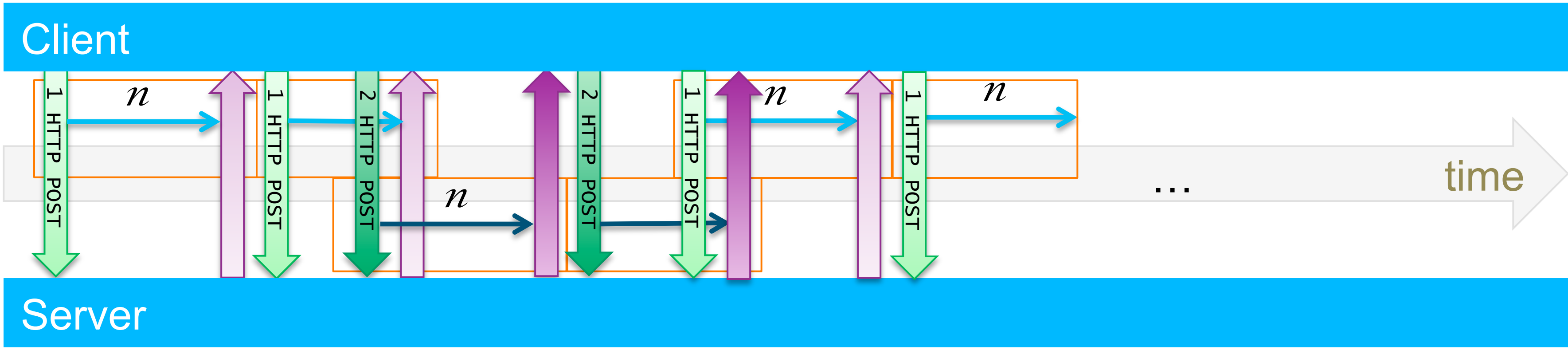
(4): Multiple connections



- Long polling over two separate HTTP connections
  - Approximation of bi-directional connection
  - Two connections are used (HTTP recommended max)
    - long polling
    - second connection allows client to send data to the server

BUT...

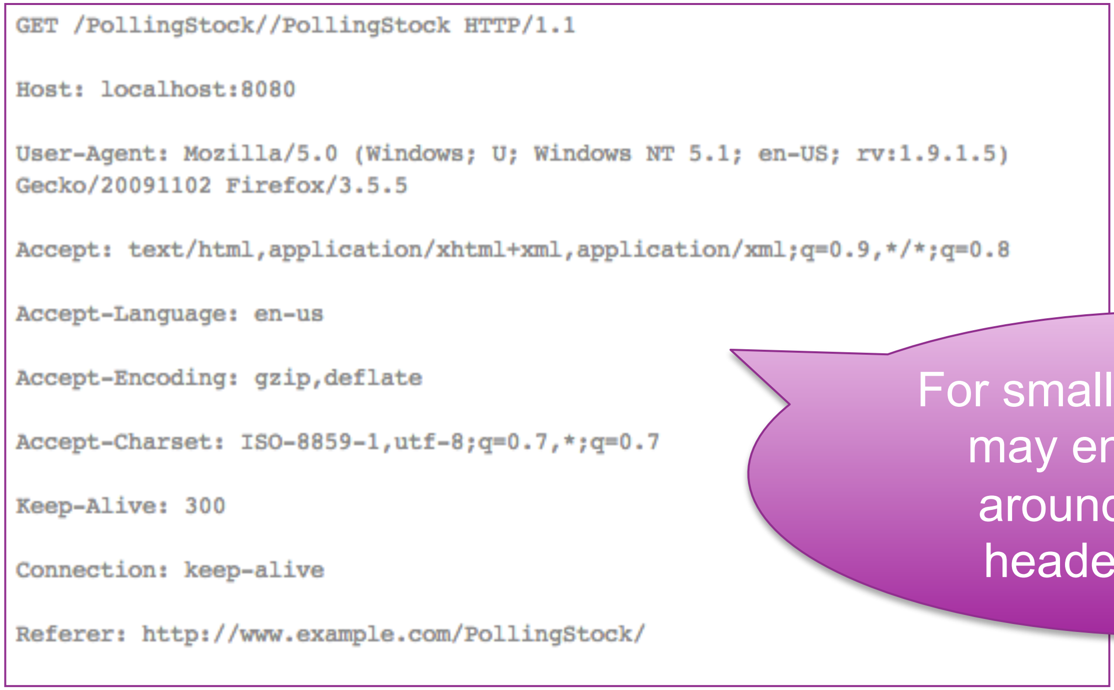
(4): Multiple connections



- Long polling over two separate HTTP connections
  - Approximation of bi-directional connection
  - Two connections are used (HTTP recommended max)
    - long polling
    - second connection allows client to send data to the server
- *Non-trivial connection coordination and management*
- *Two connections for every client*

Hidden cost of HTTP…

- TCP handshake when establishing new connection
  - Even worse for SSL...
- HTTP headers on every message
  - Always present, can vary in size and quantity



```
GET /PollingStock//PollingStock HTTP/1.1

Host: localhost:8080

User-Agent: Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.9.1.5)
Gecko/20091102 Firefox/3.5.5

Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8

Accept-Language: en-us

Accept-Encoding: gzip,deflate

Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7

Keep-Alive: 300

Connection: keep-alive

Referer: http://www.example.com/PollingStock/
```

http://www.websocket.org/quantum.html

For small messages, you may end up pushing around more HTTP headers than data!

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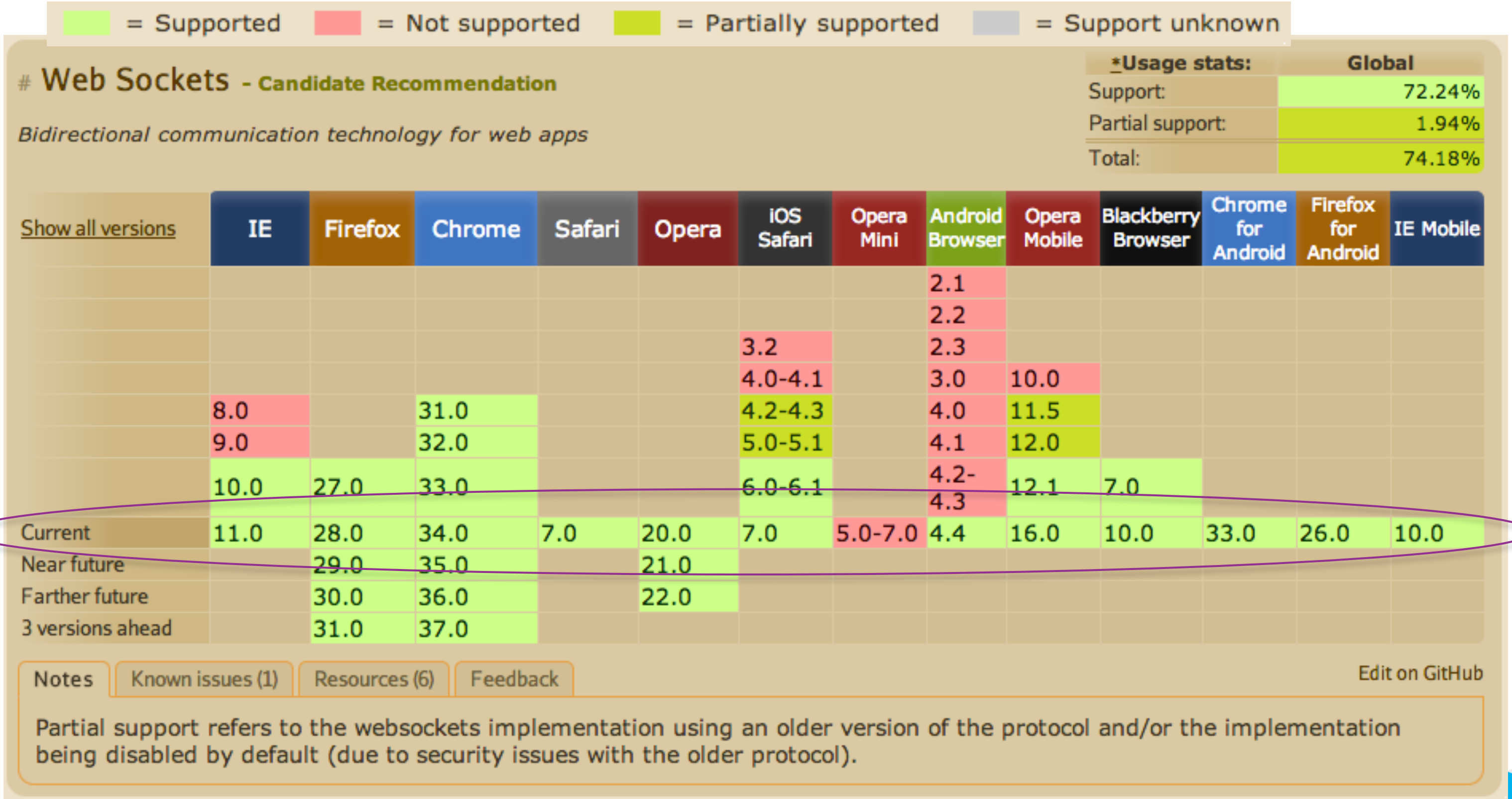
There is a better way: WebSockets

- Bi-directional
  - Client and server can send messages at any time
  - ~~Long-polling, one way streaming~~ (hooray!)
- Full duplex
  - Client and server can send updates at the same time
  - No requirement for request/response pair or message ordering
- Single long running connection with established context
  - No connection management/coordination
- Connection upgraded from HTTP
  - No new connection protocol to build infrastructure for
- Efficient use of bandwidth and CPU
  - **Messages can focus on application data**

WebSockets have been standardized

- IETF RFC-6455: WebSocket Protocol Specification, 2011
- JSR 356: WebSocket API Specification, 2013
  - Part of Java EE 7
- Fairly broad adoption for newer browsers and clients



🟩 = Supported 🟥 = Not supported 🟨 = Partially supported ⬜ = Support unknown

Web Sockets - Candidate Recommendation

Bidirectional communication technology for web apps

*Usage stats:	Global
Support:	72.24%
Partial support:	1.94%
Total:	74.18%

Show all versions	IE	Firefox	Chrome	Safari	Opera	iOS Safari	Opera Mini	Android Browser	Opera Mobile	Blackberry Browser	Chrome for Android	Firefox for Android	IE Mobile
								2.1					
								2.2					
						3.2		2.3					
						4.0-4.1		3.0	10.0				
	8.0		31.0			4.2-4.3		4.0	11.5				
	9.0		32.0			5.0-5.1		4.1	12.0				
	10.0	27.0	33.0			6.0-6.1		4.2-4.3	12.1	7.0			
Current	11.0	28.0	34.0	7.0	20.0	7.0	5.0-7.0	4.4	16.0	10.0	33.0	26.0	10.0
Near future		29.0	35.0		21.0								
Farther future		30.0	36.0		22.0								
3 versions ahead		31.0	37.0										

Partial support refers to the websockets implementation using an older version of the protocol and/or the implementation being disabled by default (due to security issues with the older protocol).

http://caniuse.com/#feat=websockets

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How WebSockets work..

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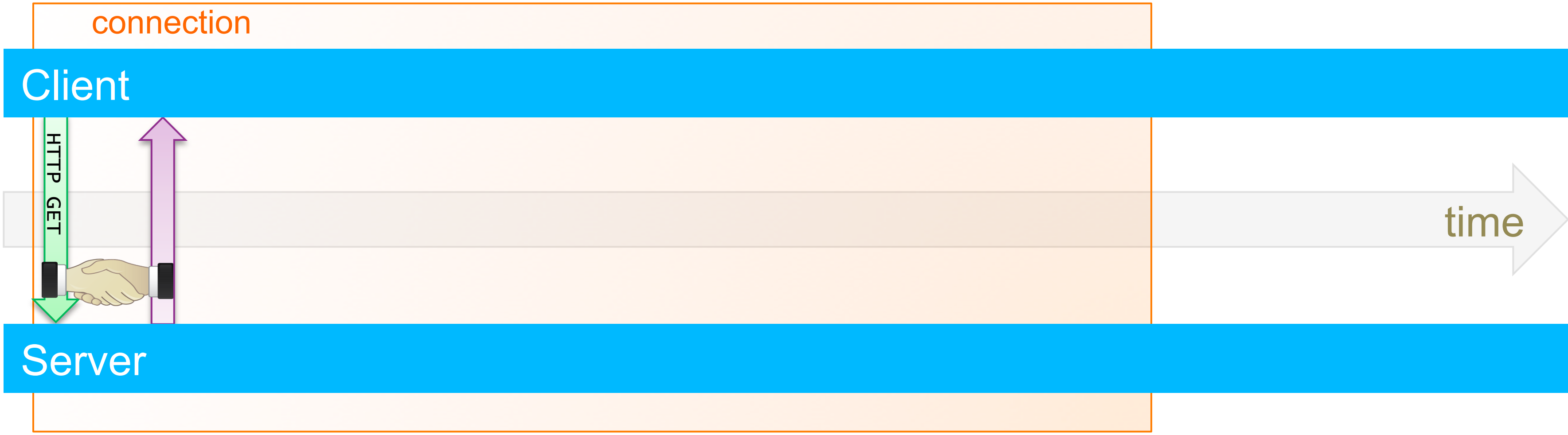
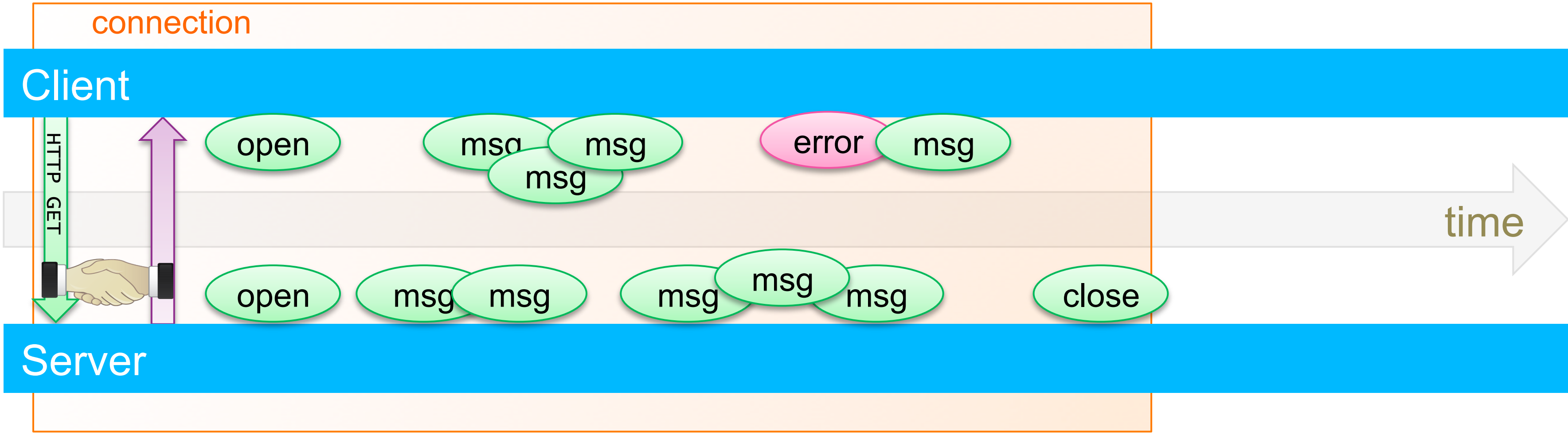
WebSocket connection



- Handshake:
  - Client initiates connection
  - Server responds (accepts the upgrade)

WebSocket connection



- Handshake:
  - Client initiates connection
  - Server responds (accepts the upgrade)
- Once the WebSocket is established
  - both sides notified that socket is open
  - either side can send messages at any time
  - either side can close the socket

WebSocket Protocol: it starts with a handshake...

request

```
GET /myapp HTTP/1.1
Host: server.example.com
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Key: GhlIHNhbXBsZSBub25jZQ==
Sec-WebSocket-Version: 13
Sec-WebSocket-Protocol: custom
Sec-WebSocket-Extensions: compress
Origin: http://example.com
...
```

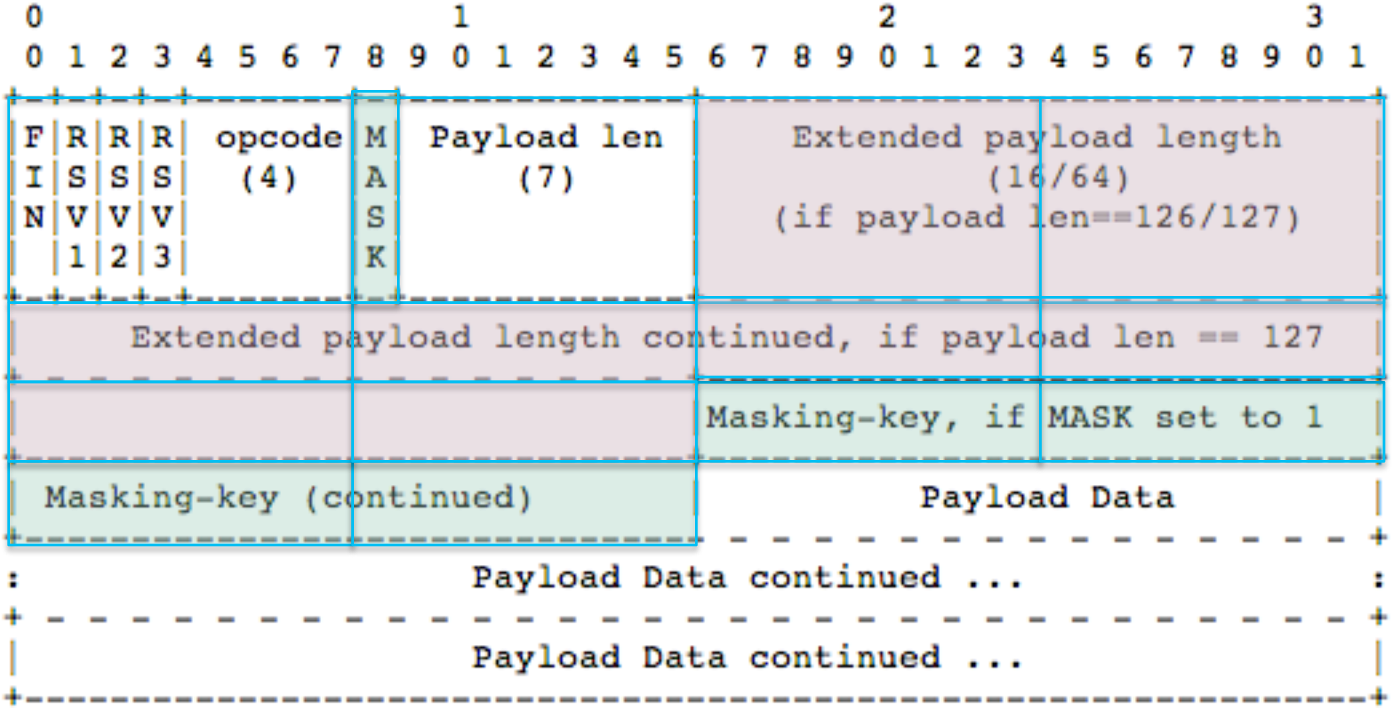
Request upgrade to WebSocket connection

WebSocket handshake headers

response

```
HTTP/1.1 101 Switching Protocols
Host: server.example.com
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Accept: s3pPLMBiTxaQ9kYGzzhZRbK+xOo=
Sec-WebSocket-Protocol: custom
Sec-WebSocket-Extensions: compress
```

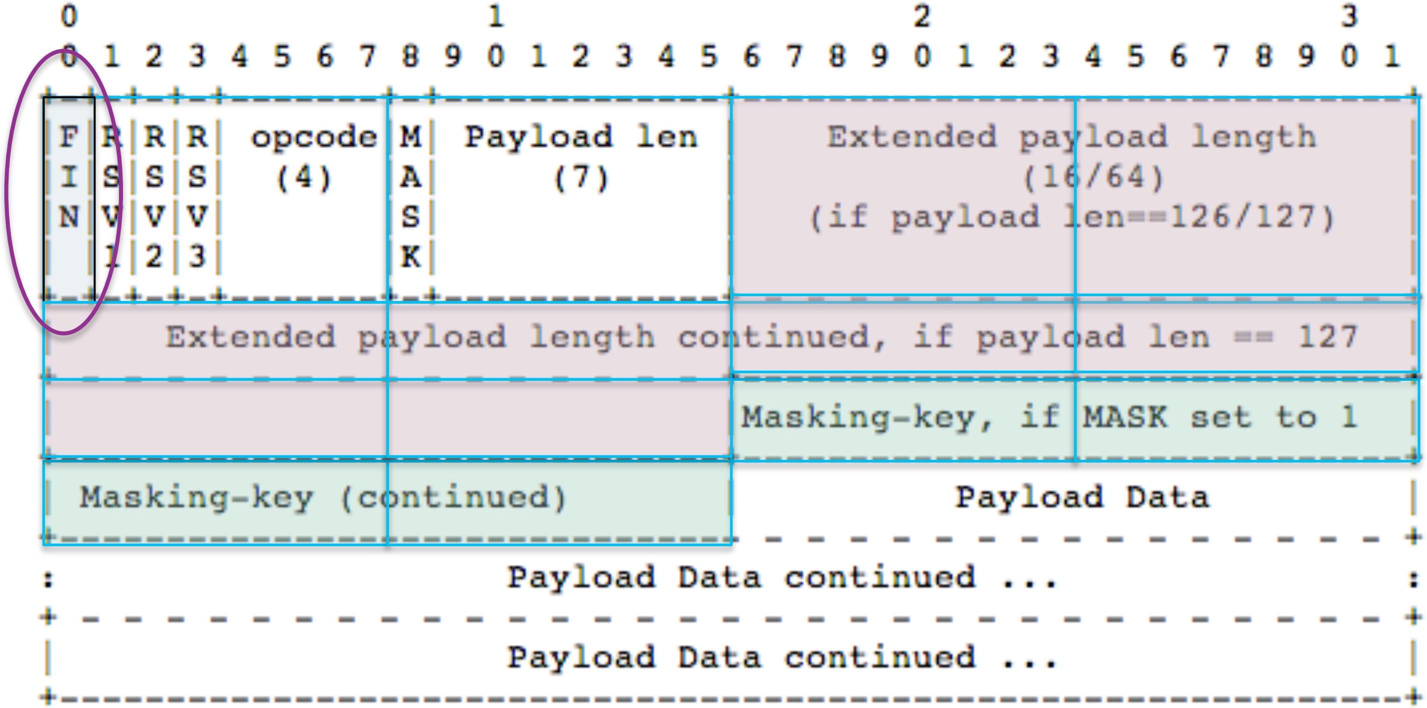
... and then transitions to frames



```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-------+-+-------------+-------------------------------+
|F|R|R|R| opcode|M| Payload len |    Extended payload length    |
|I|S|S|S|  (4)  |A|     (7)     |             (16/64)           |
|N|V|V|V|       |S|             |   (if payload len==126/127)   |
| |1|2|3|       |K|             |                               |
+-+-+-+-+-------+-+-------------+ - - - - - - - - - - - - - - - +
|     Extended payload length continued, if payload len == 127  |
+ - - - - - - - - - - - - - - - +-------------------------------+
|                               |Masking-key, if MASK set to 1  |
+-------------------------------+-------------------------------+
| Masking-key (continued)       |          Payload Data         |
+-------------------------------- - - - - - - - - - - - - - - - +
:                     Payload Data continued ...                :
+ - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - +
|                     Payload Data continued ...                |
+---------------------------------------------------------------+
```

- Data or text is transmitted in frames
  - Minimally framed: small header, then payload

Messages can be fragmented across frames



```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-------+-+-------------+-------------------------------+
|F|R|R|R| opcode|M| Payload len |    Extended payload length    |
|I|S|S|S|  (4)  |A|     (7)     |             (16/64)           |
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| |1|2|3|       |K|             |                               |
+-+-+-+-+-------+-+-------------+ - - - - - - - - - - - - - - - +
|     Extended payload length continued, if payload len == 127  |
+ - - - - - - - - - - - - - - - +-------------------------------+
|                               |Masking-key, if MASK set to 1  |
+-------------------------------+-------------------------------+
| Masking-key (continued)       |          Payload Data         |
+-------------------------------- - - - - - - - - - - - - - - - +
:                     Payload Data continued ...                :
+ - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - +
|                     Payload Data continued ...                |
+---------------------------------------------------------------+
```

- Message can be in one or more frames
  - Continue until FIN
  - A frame contains data for only one message
  - Extensions can be used to multiplex connections

Op Codes: identifying messages

- Control frames
  - Ping – 0xA
  - Pong – 0x9
  - Close – 0x8
- Data frames
  - Text – 0x1
    - UTF-8
  - Binary – 0x2
    - Arbitrary content: up to the application layer to determine
- Additional op codes are defined by negotiated extensions
  - Use reserved flags in the header

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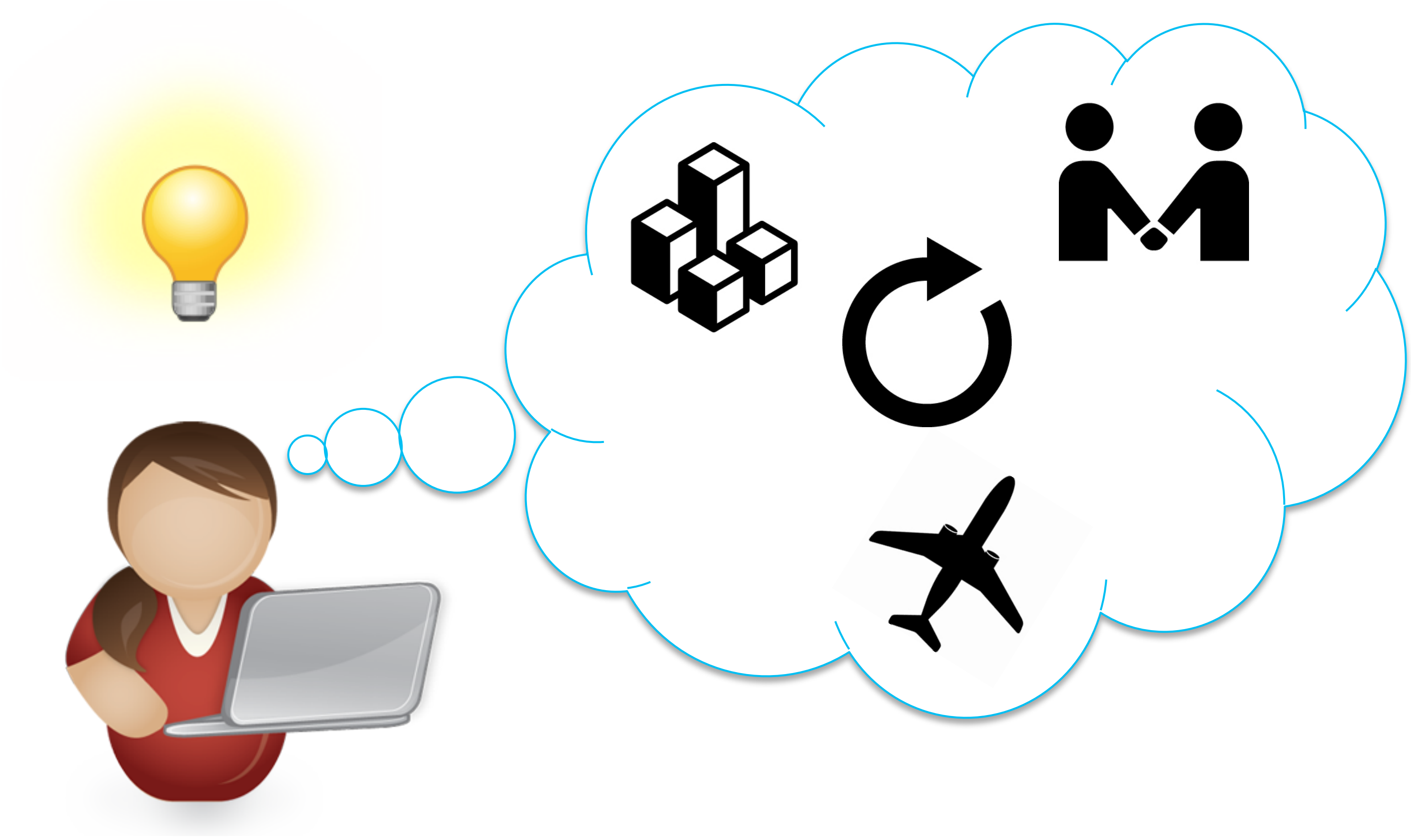
How do we use WebSockets in an application?



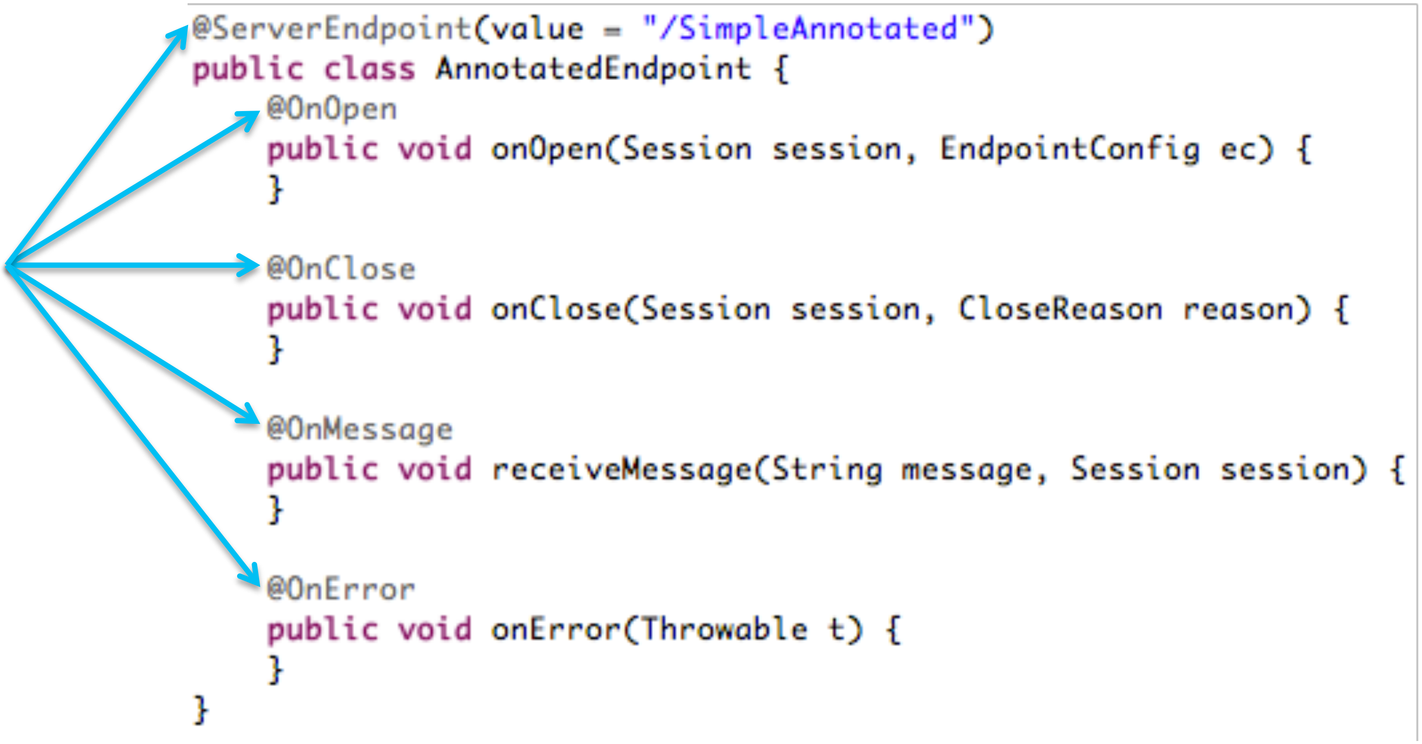
Judy

WebSockets API

- Programmatic or annotation-based approach
- Client and Server Endpoints
  - Have a lifecycle
    - onOpen
    - onClose
    - onError
  - Communicate using Messages
    - onMessage
    - send
  - Use sessions
- Encoders and Decoders deal with data formatting
  - Messages ←→Java Objects
- SPI: extensions and data frames

Server Endpoint: Annotated

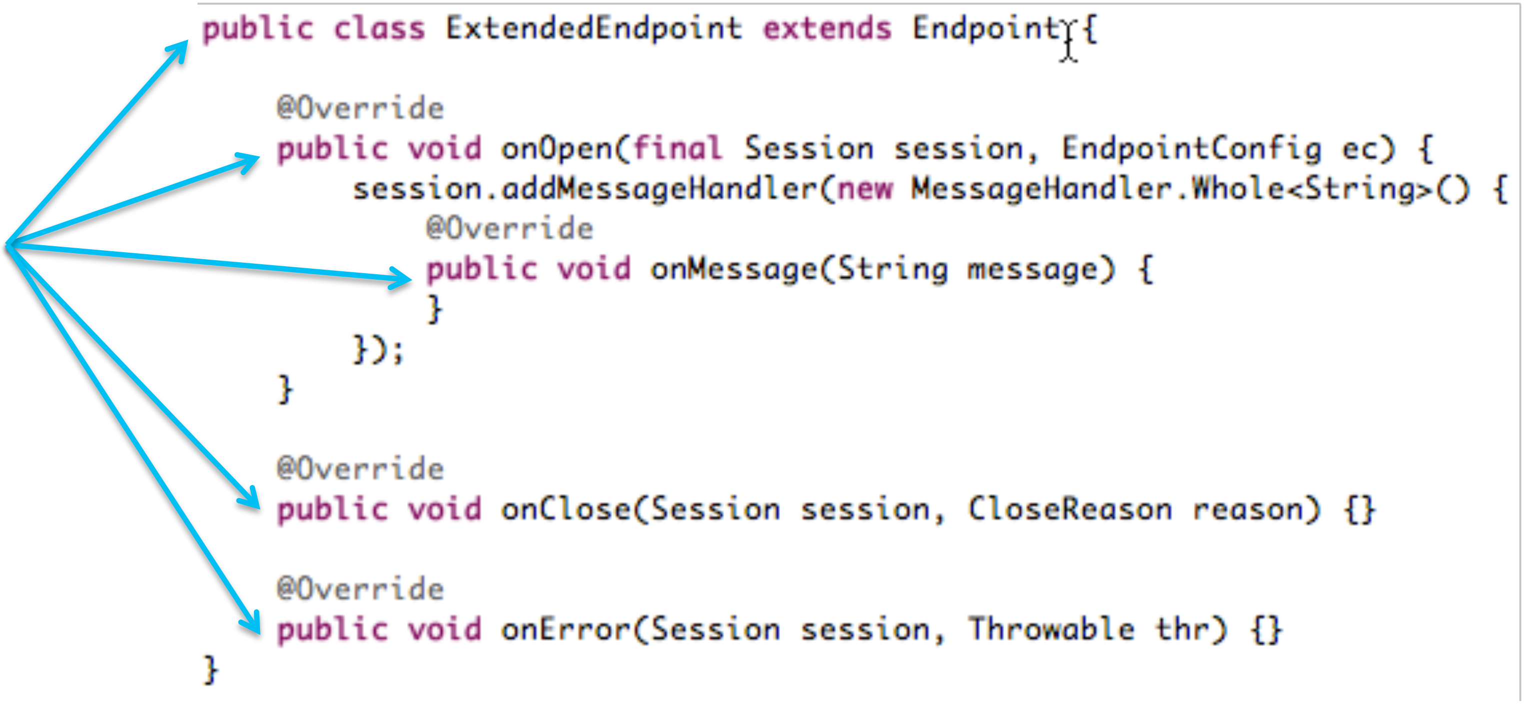
- Simple POJO with `@ServerEndpoint` annotation
  - value is the URI relative to your app's context root, e.g. ws://localhost/myapp/SimpleAnnotated
- Annotations for notifications: lifecycle and messages



```
@ServerEndpoint(value = "/SimpleAnnotated")
public class AnnotatedEndpoint {
    @OnOpen
    public void onOpen(Session session, EndpointConfig ec) {
    }

    @OnClose
    public void onClose(Session session, CloseReason reason) {
    }

    @OnMessage
    public void receiveMessage(String message, Session session) {
    }

    @OnError
    public void onError(Throwable t) {
    }
}
```

Server Endpoint: Programmatic

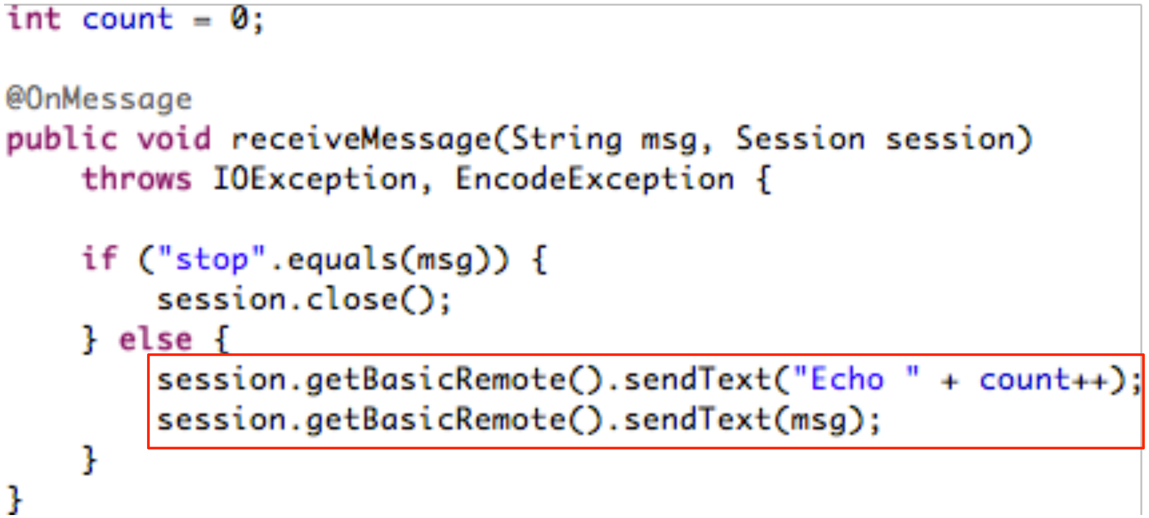
- Class extends `Endpoint`
- Callback methods for lifecycle event notifications
- Message notifications require a `MessageHandler`



```
public class ExtendedEndpoint extends Endpoint {

    @Override
    public void onOpen(final Session session, EndpointConfig ec) {
        session.addMessageHandler(new MessageHandler.Whole<String>() {
            @Override
            public void onMessage(String message) {
            }
        });
    }

    @Override
    public void onClose(Session session, CloseReason reason) {}

    @Override
    public void onError(Session session, Throwable thr) {}
}
```

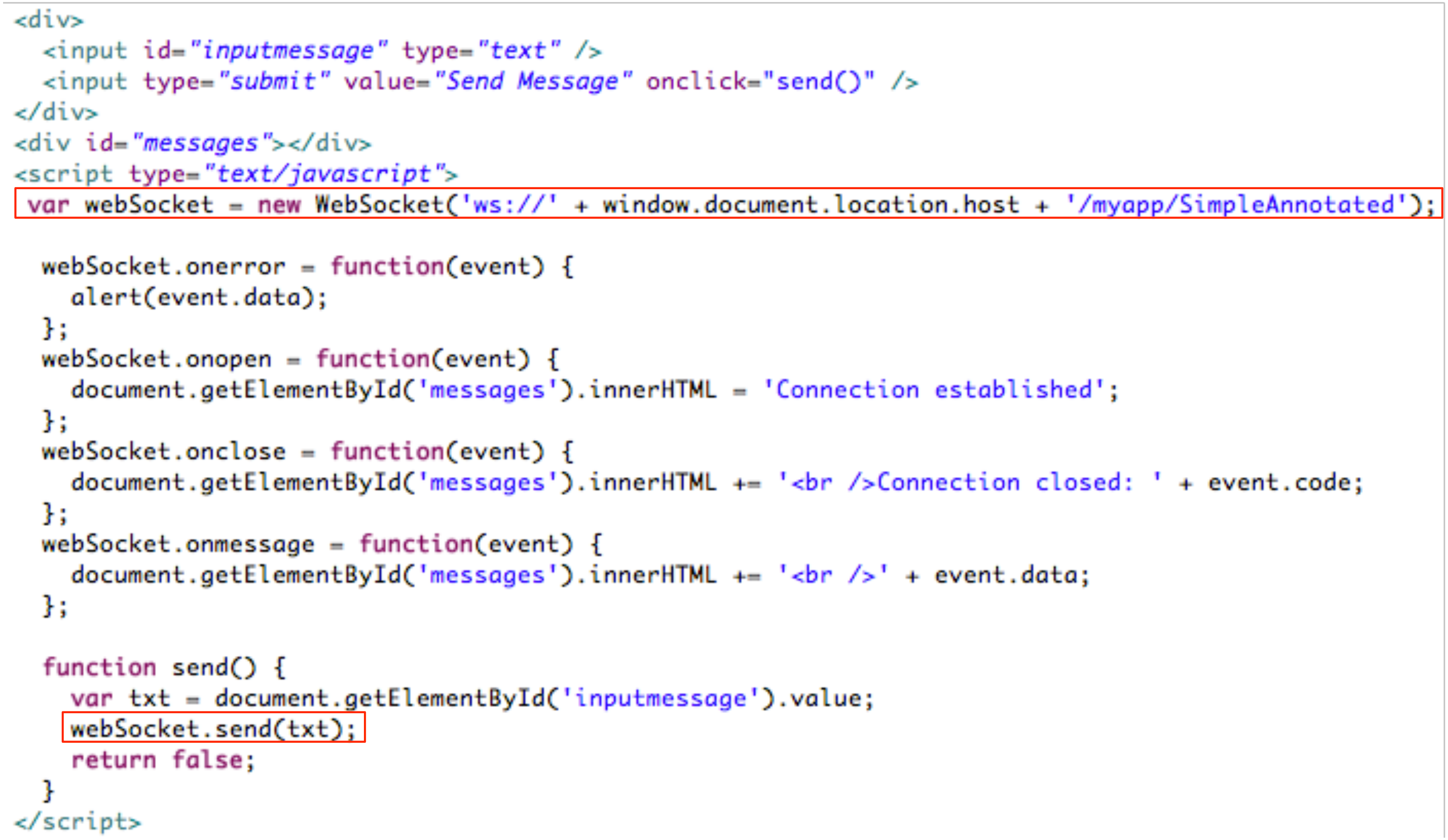
Simple echo + server provided data (using annotations)

- `@OnMessage` method is called when a message is received
  - If message is ‘stop’: close the session
  - Otherwise, echo the message along with a hit count



```
int count = 0;

@OnMessage
public void receiveMessage(String msg, Session session)
    throws IOException, EncodeException {

    if ("stop".equals(msg)) {
        session.close();
    } else {
        session.getBasicRemote().sendText("Echo " + count++);
        session.getBasicRemote().sendText(msg);
    }
}
```

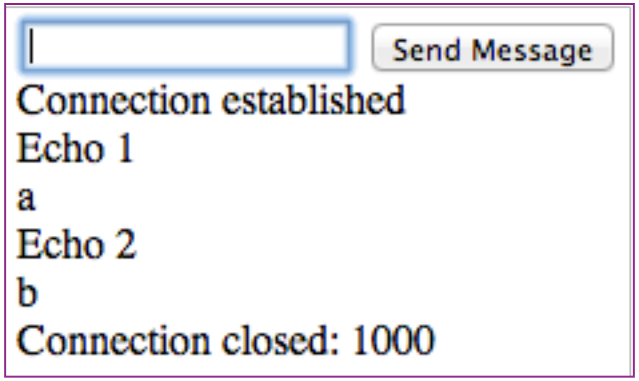
JavaScript client invocation...



```
<div>
  <input id="inputmessage" type="text" />
  <input type="submit" value="Send Message" onclick="send()" />
</div>
<div id="messages"></div>
<script type="text/javascript">
 var webSocket = new WebSocket('ws://' + window.document.location.host + '/myapp/SimpleAnnotated');

  webSocket.onerror = function(event) {
    alert(event.data);
  };
  webSocket.onopen = function(event) {
    document.getElementById('messages').innerHTML = 'Connection established';
  };
  webSocket.onclose = function(event) {
    document.getElementById('messages').innerHTML += '<br />Connection closed: ' + event.code;
  };
  webSocket.onmessage = function(event) {
    document.getElementById('messages').innerHTML += '<br />' + event.data;
  };

  function send() {
    var txt = document.getElementById('inputmessage').value;
    webSocket.send(txt);
    return false;
  }
</script>
```

Invocation.. what happens?

- Connection established with page load
  - Browser starts the handshake
  - Server completes
  - “onopen” invoked on client/server
    - Client prints “Connection established”

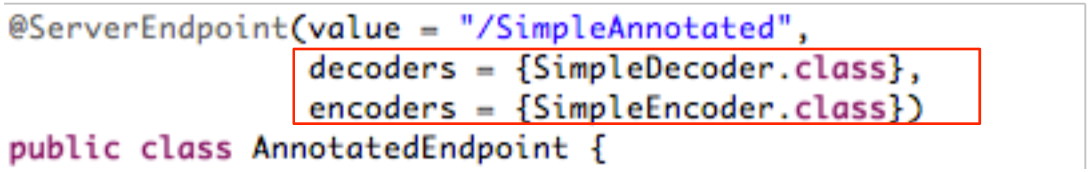


```
Connection established
Echo 1
a
Echo 2
b
Connection closed: 1000
```

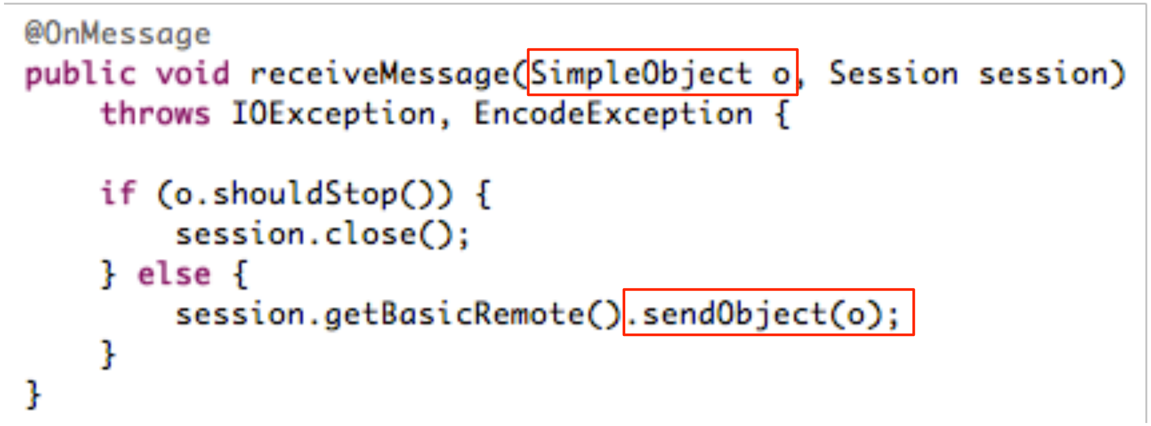
- Client sends ‘a’, receiveMessage method called on the server
  - Server returns “Echo 1” and “a” (two messages)
- Client sends ‘b’,
  - Server returns “Echo 2” and “b”
- Client sends ‘stop’
  - Server closes the session
  - Client’s onclose invoked, prints “Connection closed: 1000”

Encoder/Decoder: dealing with data

- Messages can be in text or binary format
- Encoders and Decoders translate between data on the socket and Java Objects

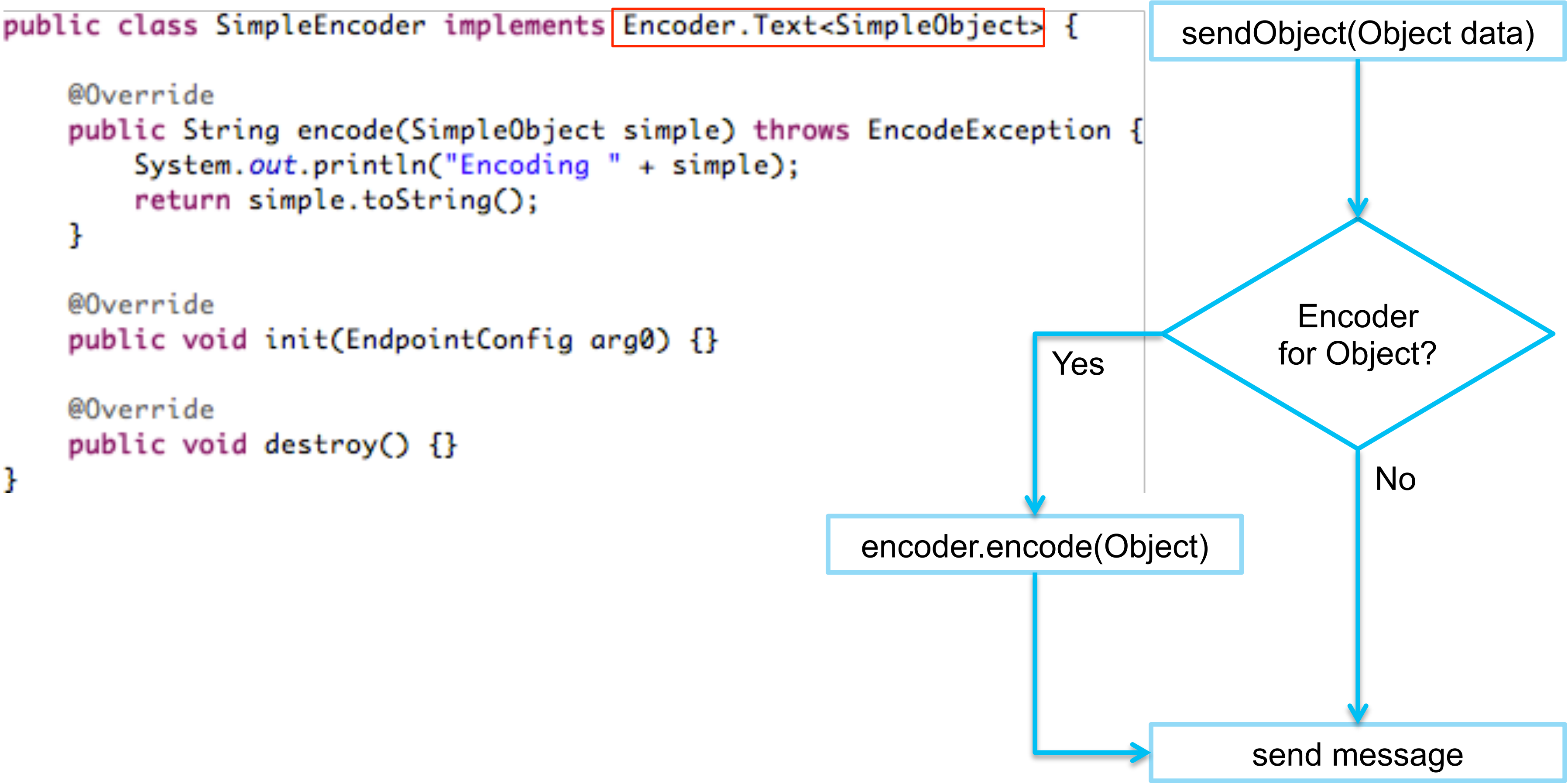


```
@ServerEndpoint(value = "/SimpleAnnotated",
                decoders = {SimpleDecoder.class},
                encoders = {SimpleEncoder.class})
public class AnnotatedEndpoint {
```



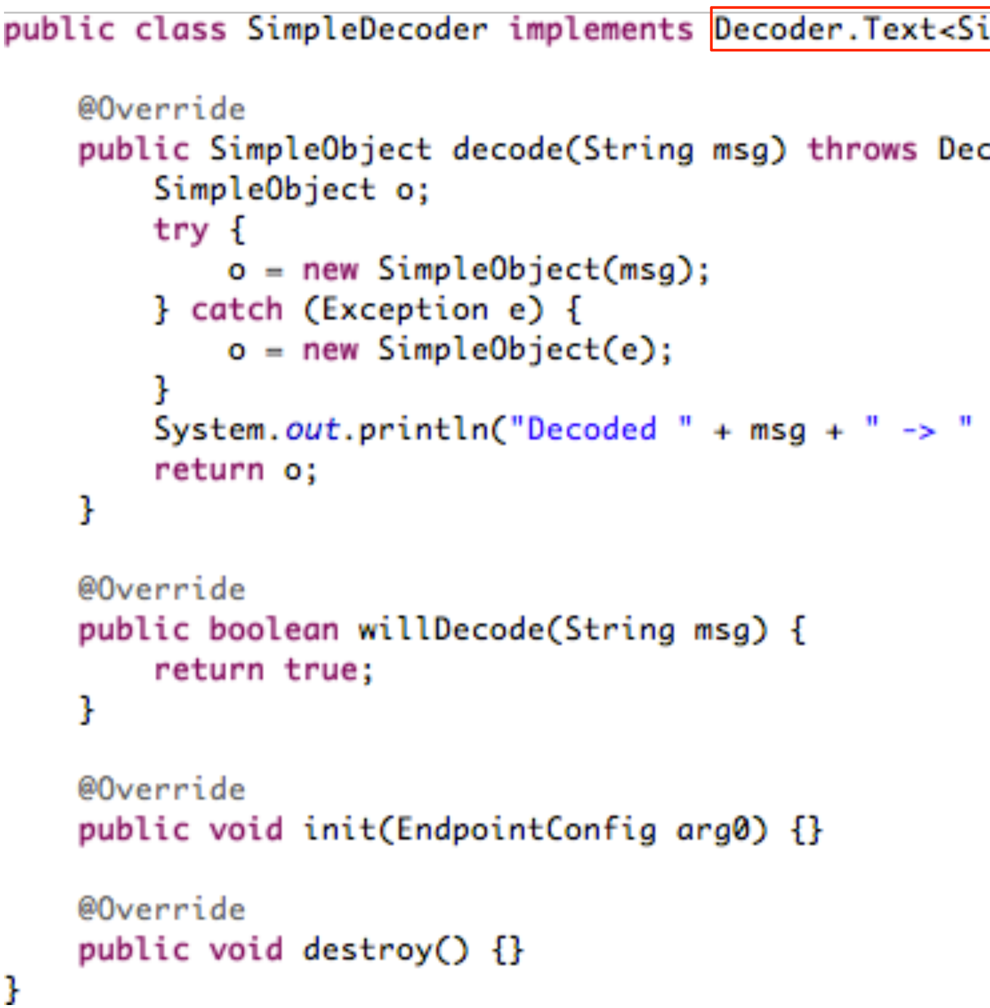
```
@OnMessage
public void receiveMessage(SimpleObject o, Session session)
    throws IOException, EncodeException {

    if (o.shouldStop()) {
        session.close();
    } else {
        session.getBasicRemote().sendObject(o);
    }
}
```

Encoder: dealing with data

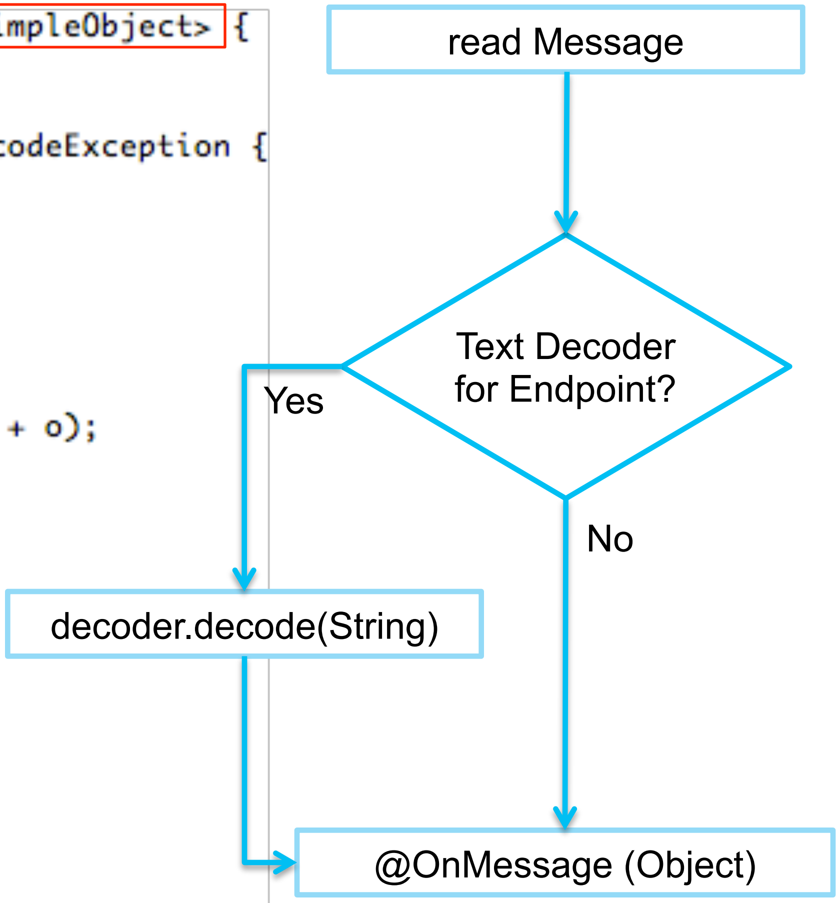


```java
public class SimpleEncoder implements Encoder.Text<SimpleObject> {

    @Override
    public String encode(SimpleObject simple) throws EncodeException {
        System.out.println("Encoding " + simple);
        return simple.toString();
    }

    @Override
    public void init(EndpointConfig arg0) {}

    @Override
    public void destroy() {}
}
```

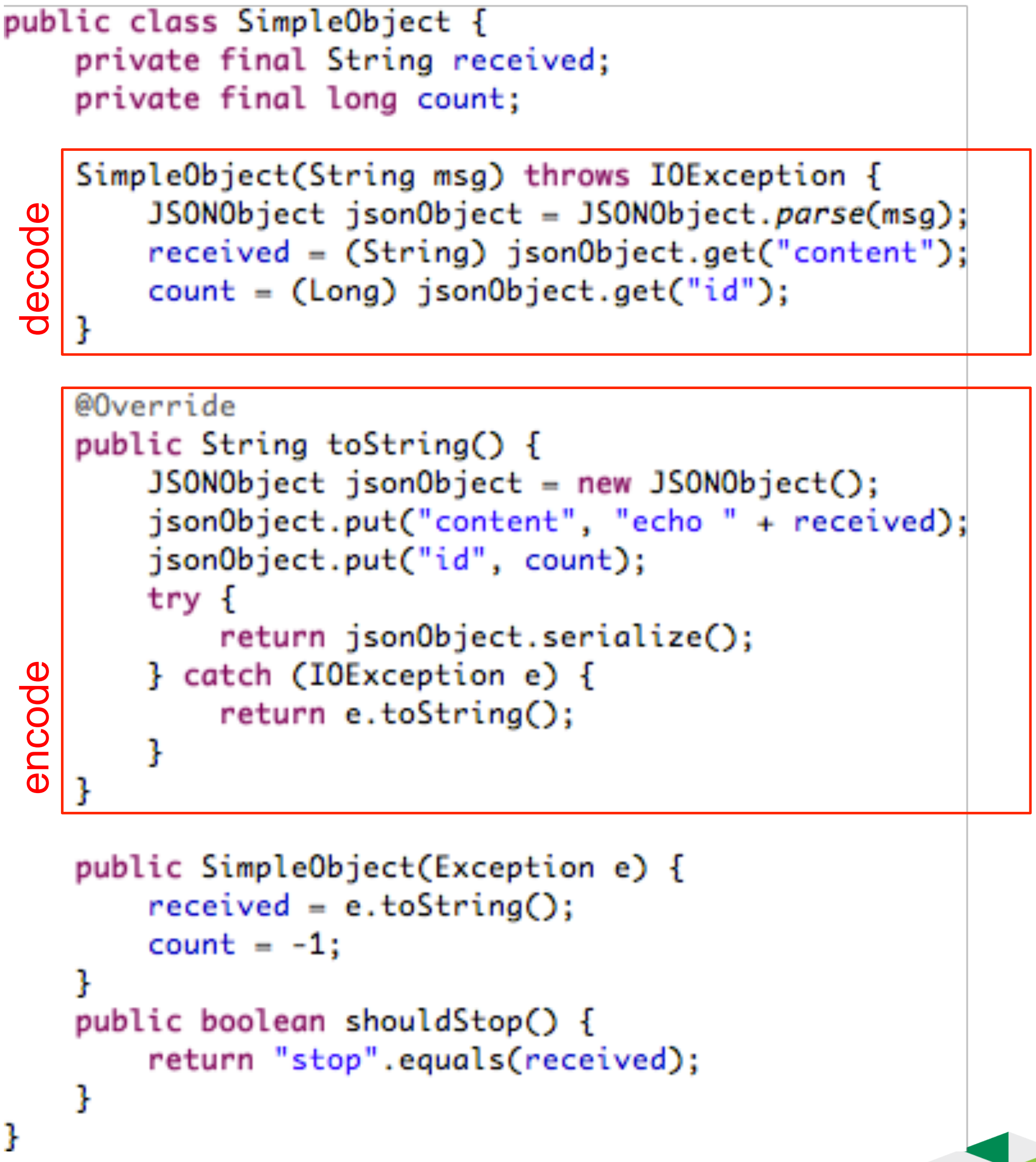
Decoder: dealing with data



```
public class SimpleDecoder implements Decoder.Text<SimpleObject> {

    @Override
    public SimpleObject decode(String msg) throws DecodeException {
        SimpleObject o;
        try {
            o = new SimpleObject(msg);
        } catch (Exception e) {
            o = new SimpleObject(e);
        }
        System.out.println("Decoded " + msg + " -> " + o);
        return o;
    }

    @Override
    public boolean willDecode(String msg) {
        return true;
    }

    @Override
    public void init(EndpointConfig arg0) {}

    @Override
    public void destroy() {}
}
```

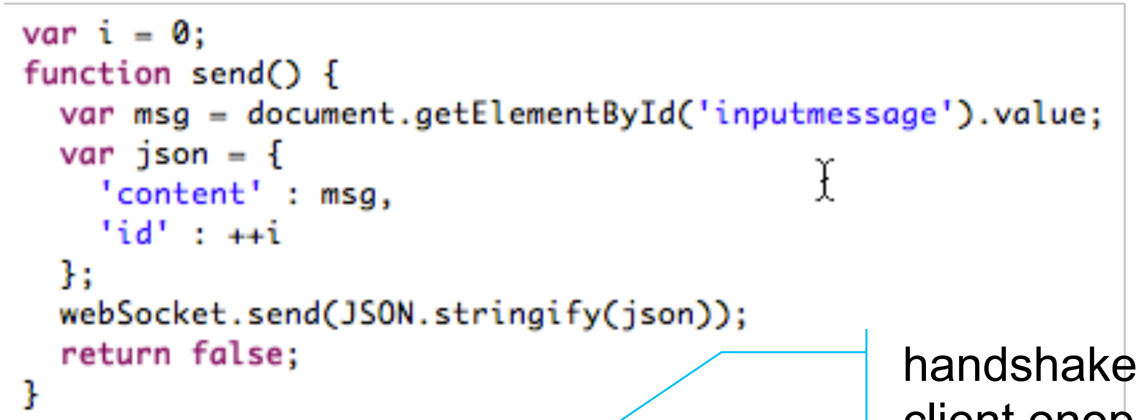


SimpleObject

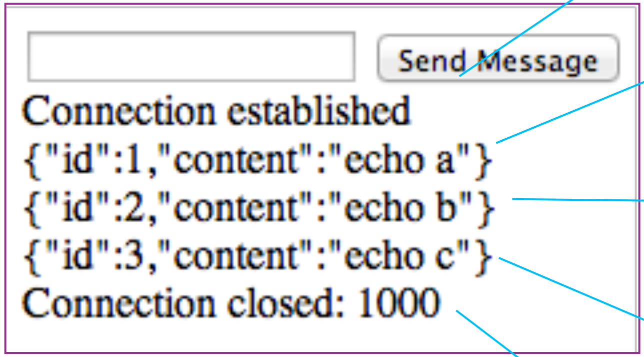


```
public class SimpleObject {
    private final String received;
    private final long count;

    SimpleObject(String msg) throws IOException {
        JSONObject jsonObject = JSONObject.parse(msg);
        received = (String) jsonObject.get("content");
        count = (Long) jsonObject.get("id");
    }

    @Override
    public String toString() {
        JSONObject jsonObject = new JSONObject();
        jsonObject.put("content", "echo " + received);
        jsonObject.put("id", count);
        try {
            return jsonObject.serialize();
        } catch (IOException e) {
            return e.toString();
        }
    }

    public SimpleObject(Exception e) {
        received = e.toString();
        count = -1;
    }
    public boolean shouldStop() {
        return "stop".equals(received);
    }
}
```

JavaScript and invocation



```
var i = 0;
function send() {
  var msg = document.getElementById('inputmessage').value;
  var json = {
    'content' : msg,
    'id' : ++i
  };
  webSocket.send(JSON.stringify(json));
  return false;
}
```



```
Connection established
{"id":1,"content":"echo a"}
{"id":2,"content":"echo b"}
{"id":3,"content":"echo c"}
Connection closed: 1000
```

handshake
client onopen method invoked

client sent {"content":"a","id":1}
server returned {"id":1,"content":"echo a"}

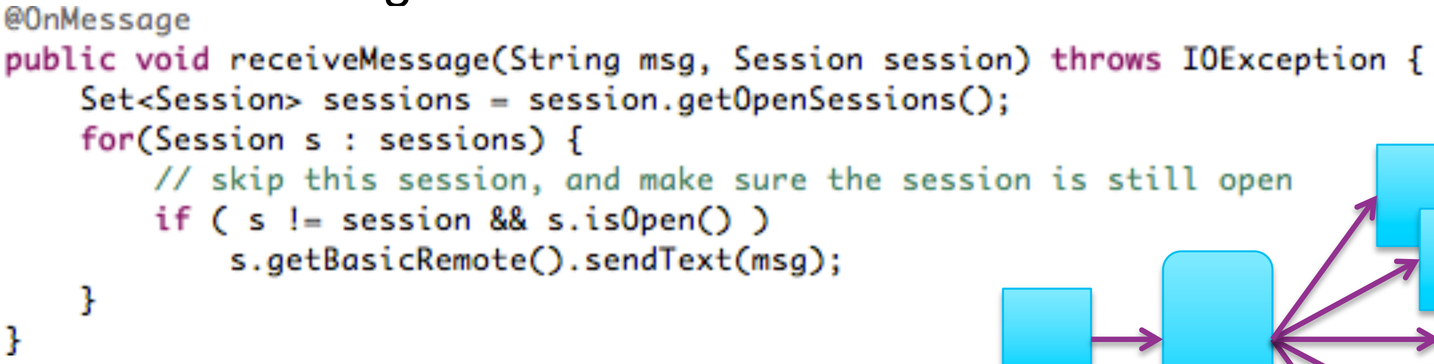
client sent {"content":”b","id”:2}
server returned {"id”:2,"content":"echo b"}

client sent {"content":”c","id”:3}
server returned {"id”:3,"content":"echo c"}

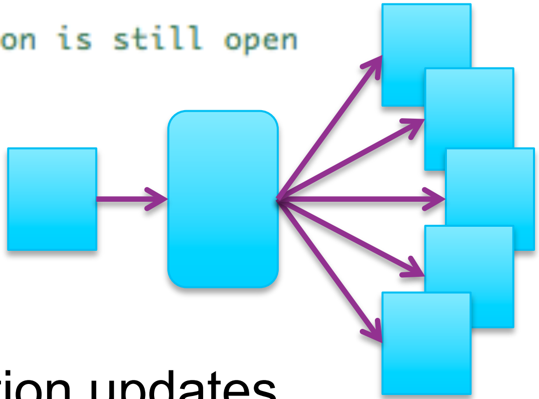
client sent {"content":”stop","id”:4}
server closed connection
client onclose method invoked

Message broadcasting

- Broadcast a message to all the sessions connected to a given Server Endpoint
  - Receive a message
  - Find all current sessions associated with the current endpoint
  - Send the message to all of the other WebSocket sessions



```
@OnMessage
public void receiveMessage(String msg, Session session) throws IOException {
    Set<Session> sessions = session.getOpenSessions();
    for(Session s : sessions) {
        // skip this session, and make sure the session is still open
        if ( s != session && s.isOpen() )
            s.getBasicRemote().sendText(msg);
    }
}
```



- Uses:
  - Multiplayer video games
  - Social networking: chats/tweets/GPS location updates
  - Whiteboard collaborations/meetings
  - ...

WebSockets have everything this application needs..

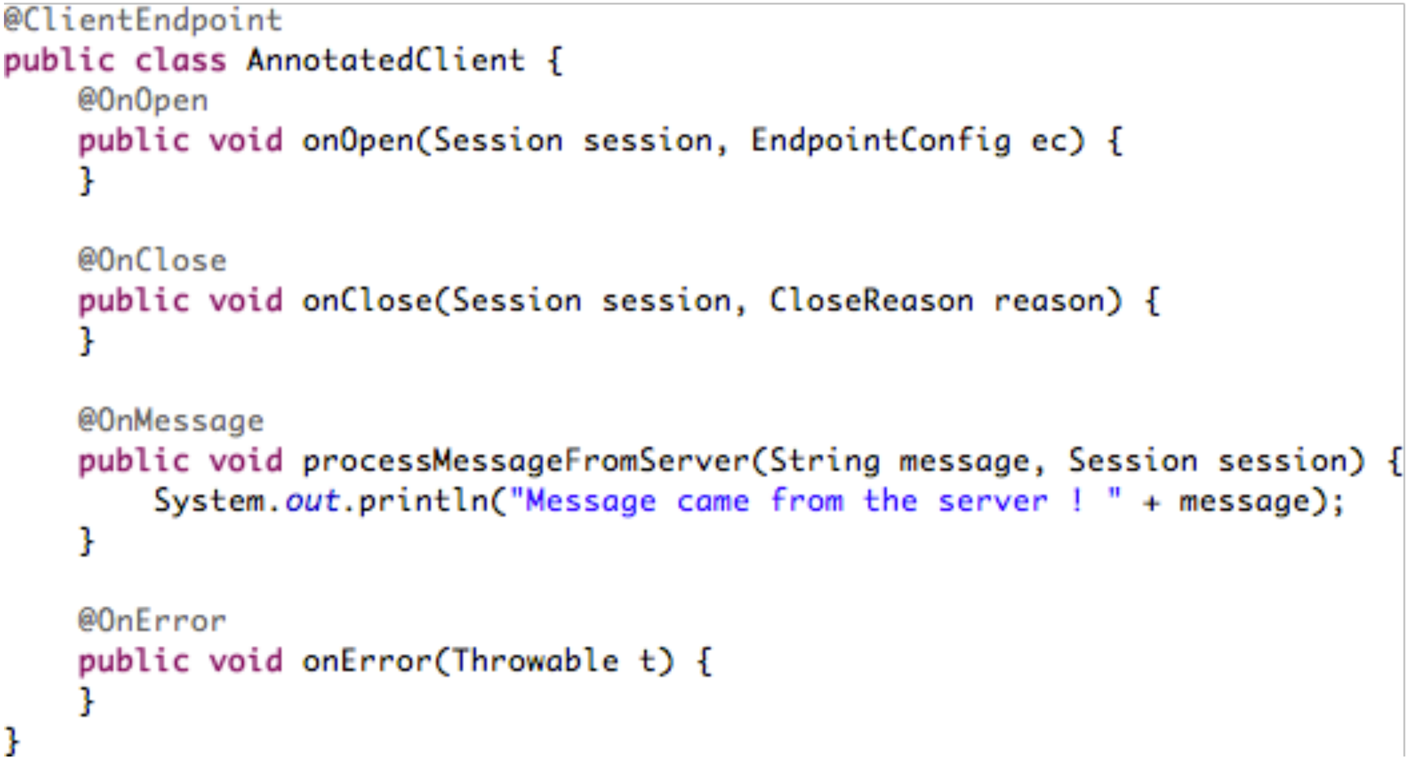
- Why wouldn’t you use them?
  - Older devices / browsers don’t support WebSockets
  - May be a challenge to degrade gracefully so older devices still have a decent experience
- Trouble with proxies..
  - wss:// recommended over ws://
    - Some proxy servers do not inspect encrypted traffic: just pass through

WebSockets and Proxy Servers

- WebSocket protocol is unaware of proxies / firewalls
- Proxy servers required to strip certain headers when forwarding
  - *Some proxies adjusted to leave Connection / Upgrade headers*
- Hop-by-Hop Upgrade
  - Proxy server sends the request to the next hop
  - Upgrade header is only good for one link
    - *Proxy server updated to propagate the Upgrade headers...*
- HTTP CONNECT
  - Proxy to forward the TCP Connection to the destination
    - SSL tunneling
  - *Some proxies still analyze traffic: would choke on websocket frame*
  - *Some proxies restrict CONNECT to SSL*
  - *SSL termination*

WebSockets for Rich Clients

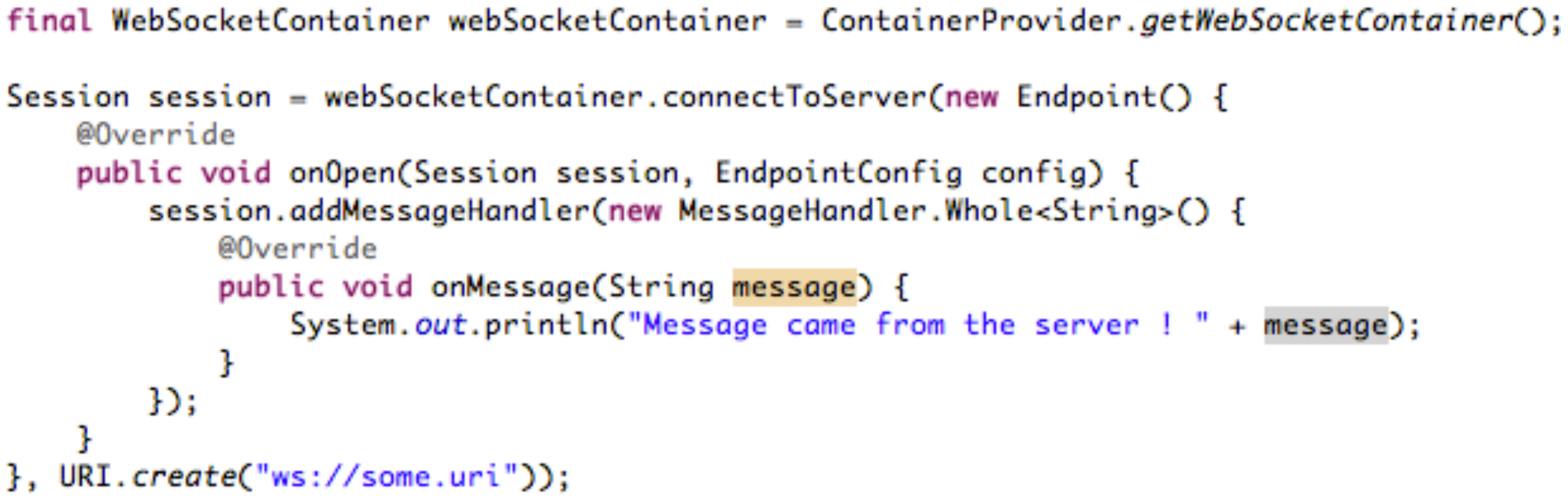
- Java API for a rich Client is similar to API for Server
- Annotations:



```java
@ClientEndpoint
public class AnnotatedClient {
    @OnOpen
    public void onOpen(Session session, EndpointConfig ec) {
    }

    @OnClose
    public void onClose(Session session, CloseReason reason) {
    }

    @OnMessage
    public void processMessageFromServer(String message, Session session) {
        System.out.println("Message came from the server ! " + message);
    }

    @OnError
    public void onError(Throwable t) {
    }
}
```

WebSockets for Rich Clients

- Java API for a rich Client is similar to API for Server
- Programmatic:



```
final WebSocketContainer webSocketContainer = ContainerProvider.getWebSocketContainer();

Session session = webSocketContainer.connectToServer(new Endpoint() {
    @Override
    public void onOpen(Session session, EndpointConfig config) {
        session.addMessageHandler(new MessageHandler.Whole<String>() {
            @Override
            public void onMessage(String message) {
                System.out.println("Message came from the server ! " + message);
            }
        });
    }
}, URI.create("ws://some.uri"));
```

Questions?

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	Tue, 02:15 PM - 03:15 PM, Venetian Marcello 4503
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	Wed, 02:15 PM - 03:15 PM, Venetian Palazzo N
AAD-1520	IBM WebSphere Application Server Liberty Profile
	Wed, 10:30 AM - 11:30 AM, Venetian San Polo 3501 B

Thank You

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