# Chapter 3: Web Paradigms and Interactivity

3.1 AJAX: Asynchronous Interactivity in the Web

3.2 Paradigms for Web-Based Communication

3.3 Reverse AJAX and COMET

3.4 Web Sockets and Web Messaging

3.5 Web Workers

Literature:

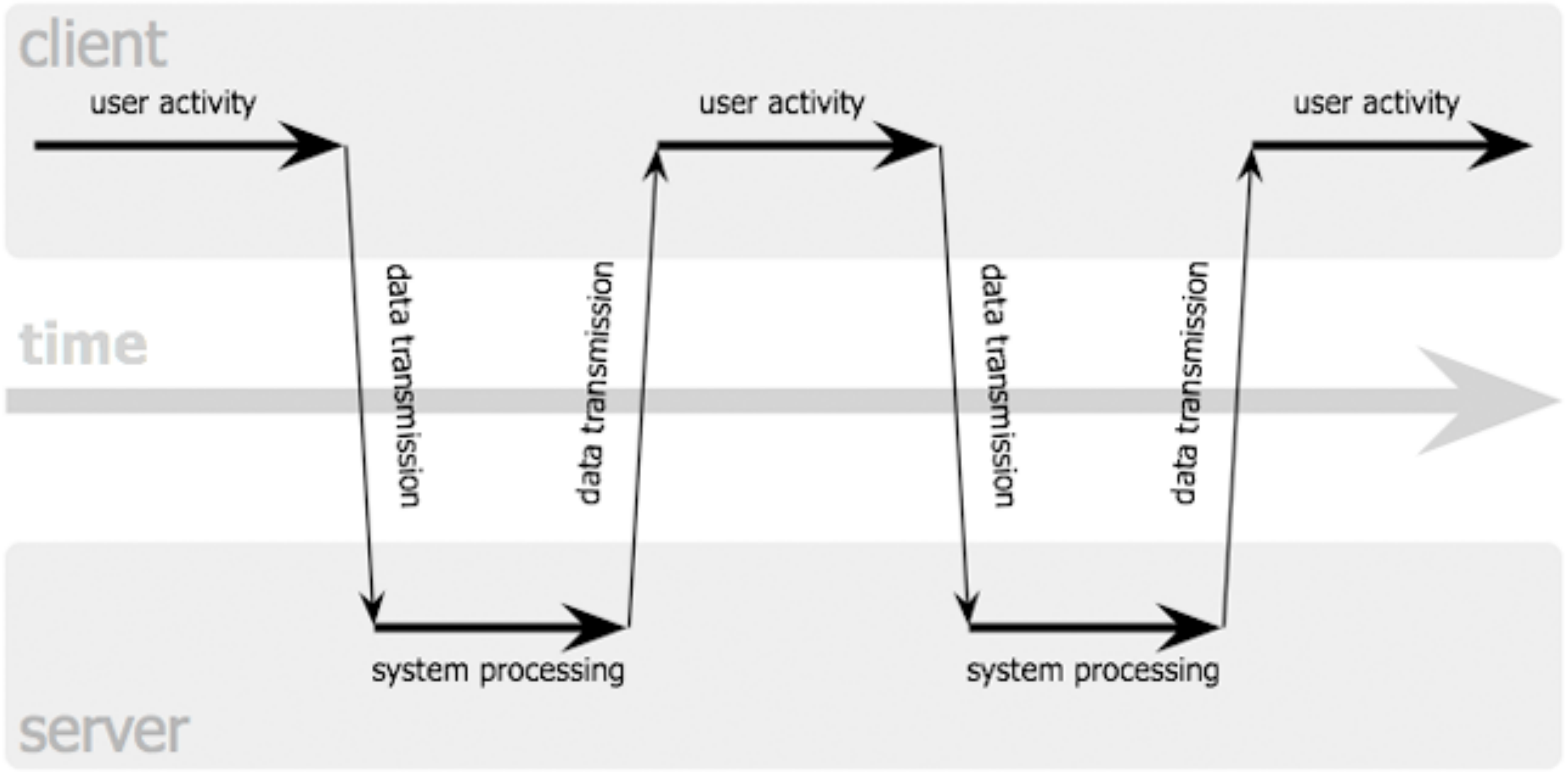
Christian Wenz: Ajax - schnell und kompakt. entwickler.press 2007

B. Brinzarea-Iamandi et al.: AJAX and PHP - Building Modern Web Applications, 2nd ed., Packt Publishing 2009

# Asynchronous JavaScript + XML (AJAX)

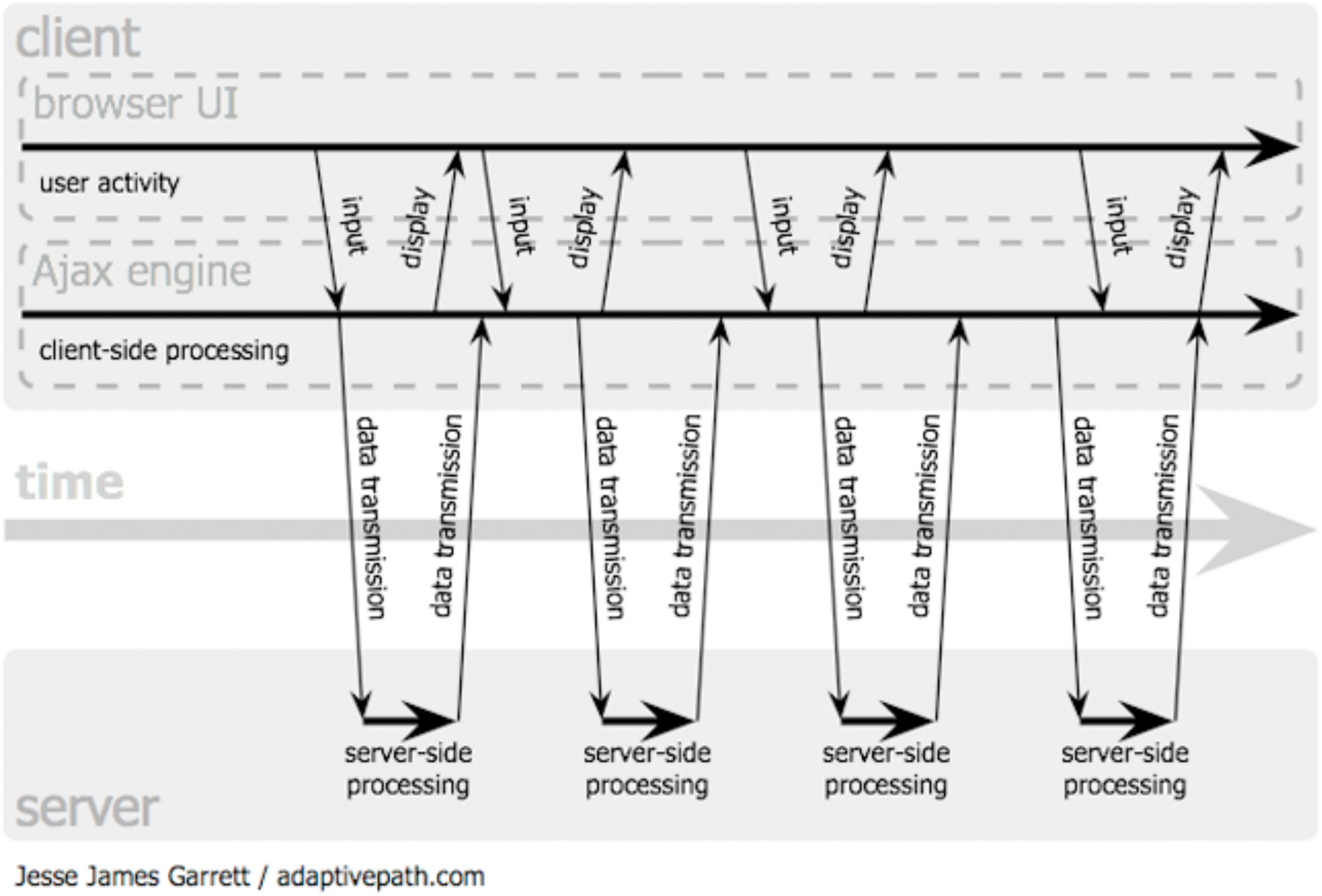
- James Garrett 2005: “Ajax: A New Approach to Web Applications”
  http://www.adaptivepath.com/ideas/ajax-new-approach-web-applications/
  - New name for an idea in use already at the time
- Decouple server communication from page reload
  - Fluid interaction
  - Presented display always stays up-to-date
- AJAX is ***not a technology!***
  - Combination of known technologies:
    XHTML, CSS, DOM, XML, XSLT, JavaScript, XMLHttpRequest
  - Idea is neither bound to JavaScript nor to XML!
  - E.g. using JSON encoding instead of XML

## Classical Synchronous Web Application Model

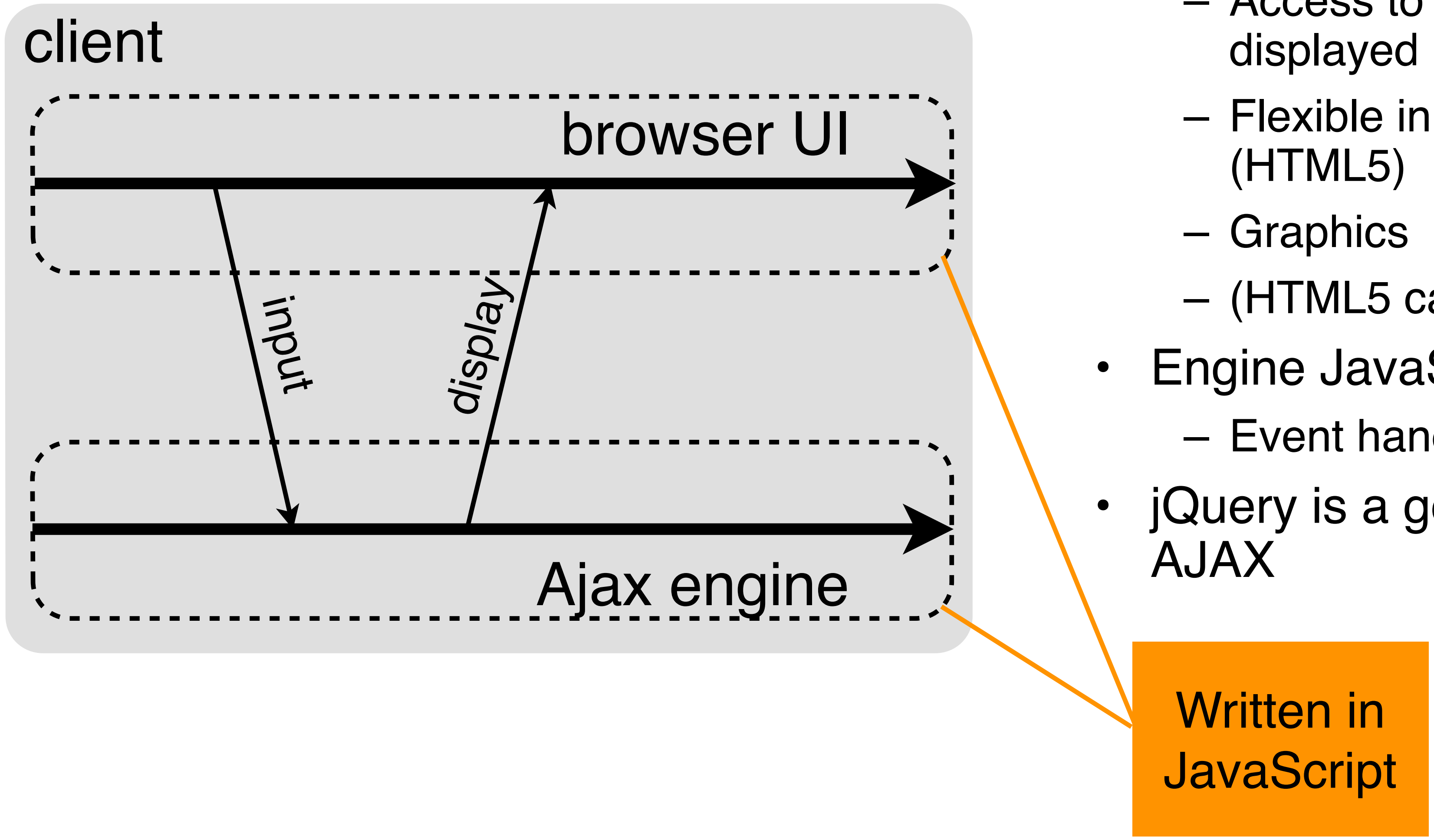


Jesse James Garrett / adaptivepath.com

# Asynchronous Web Application Model

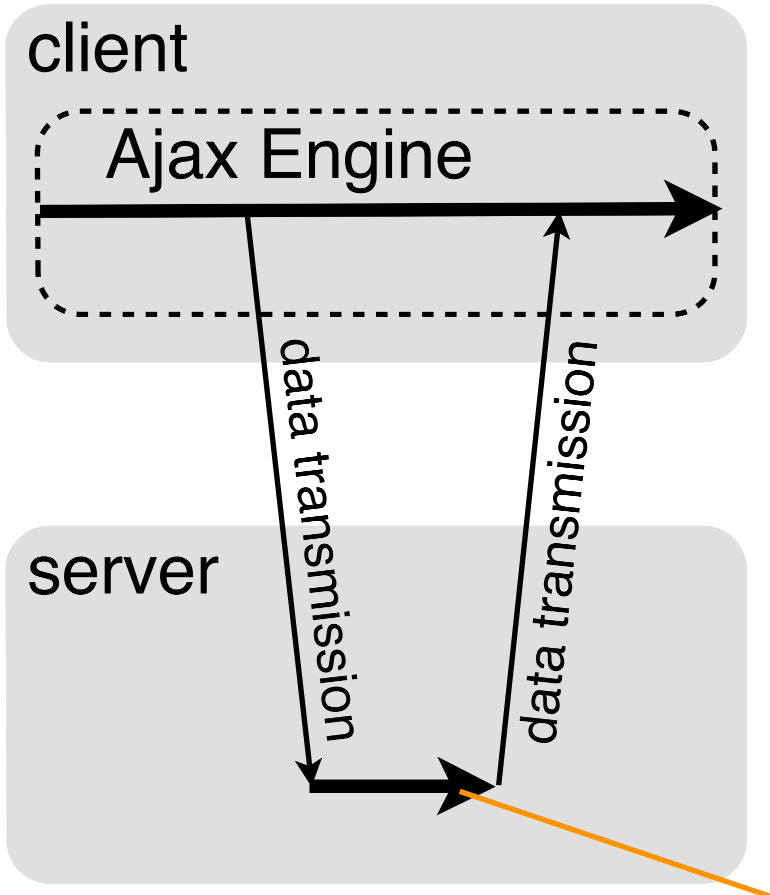


# AJAX and Client-Side Scripting



- UI JavaScript
  - Access to loaded/ displayed HTML via DOM
  - Flexible input elements (HTML5)
  - Graphics
  - (HTML5 canvas)
- Engine JavaScript
  - Event handling
- jQuery is a good fit for AJAX

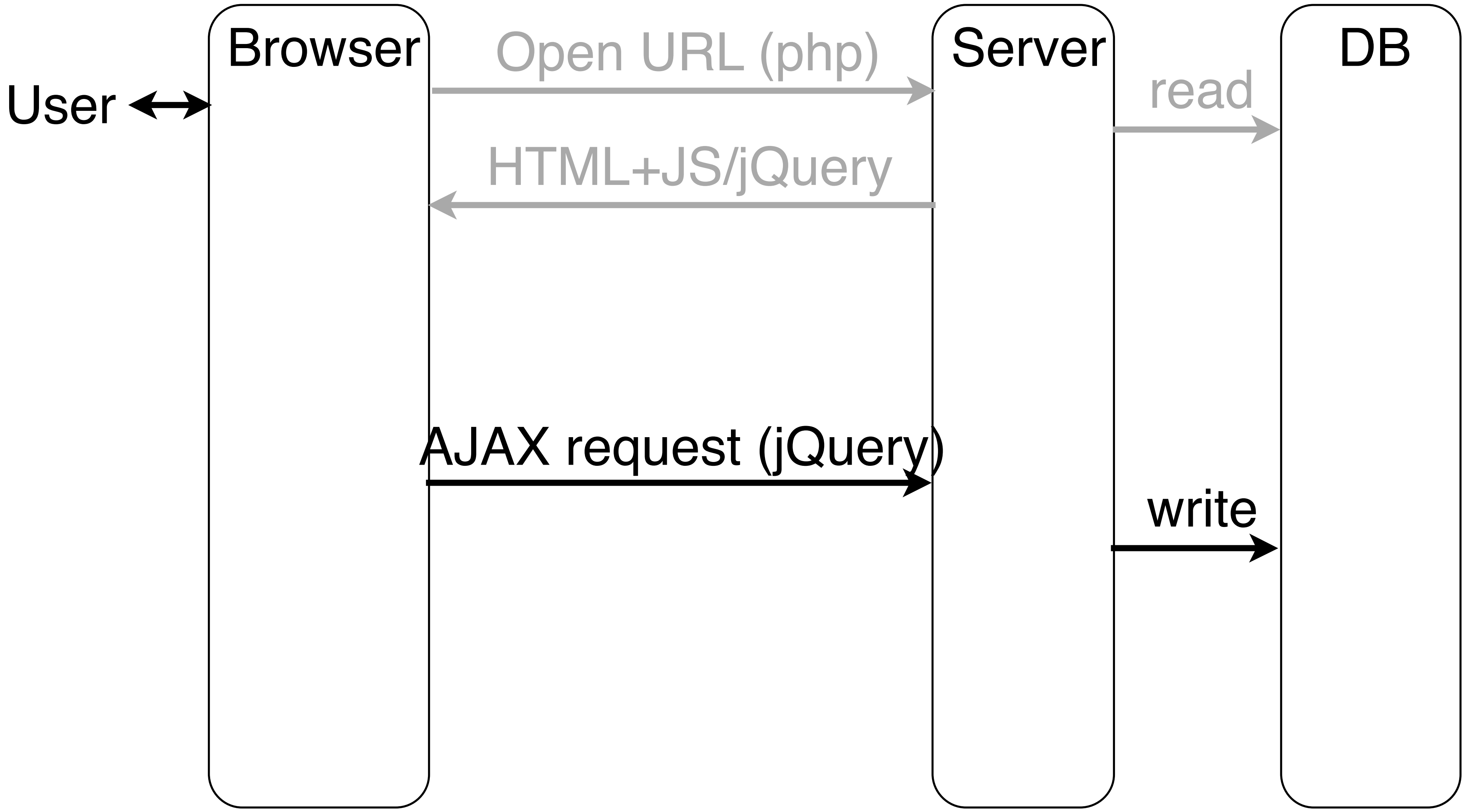
# AJAX and Server-Side Scripting



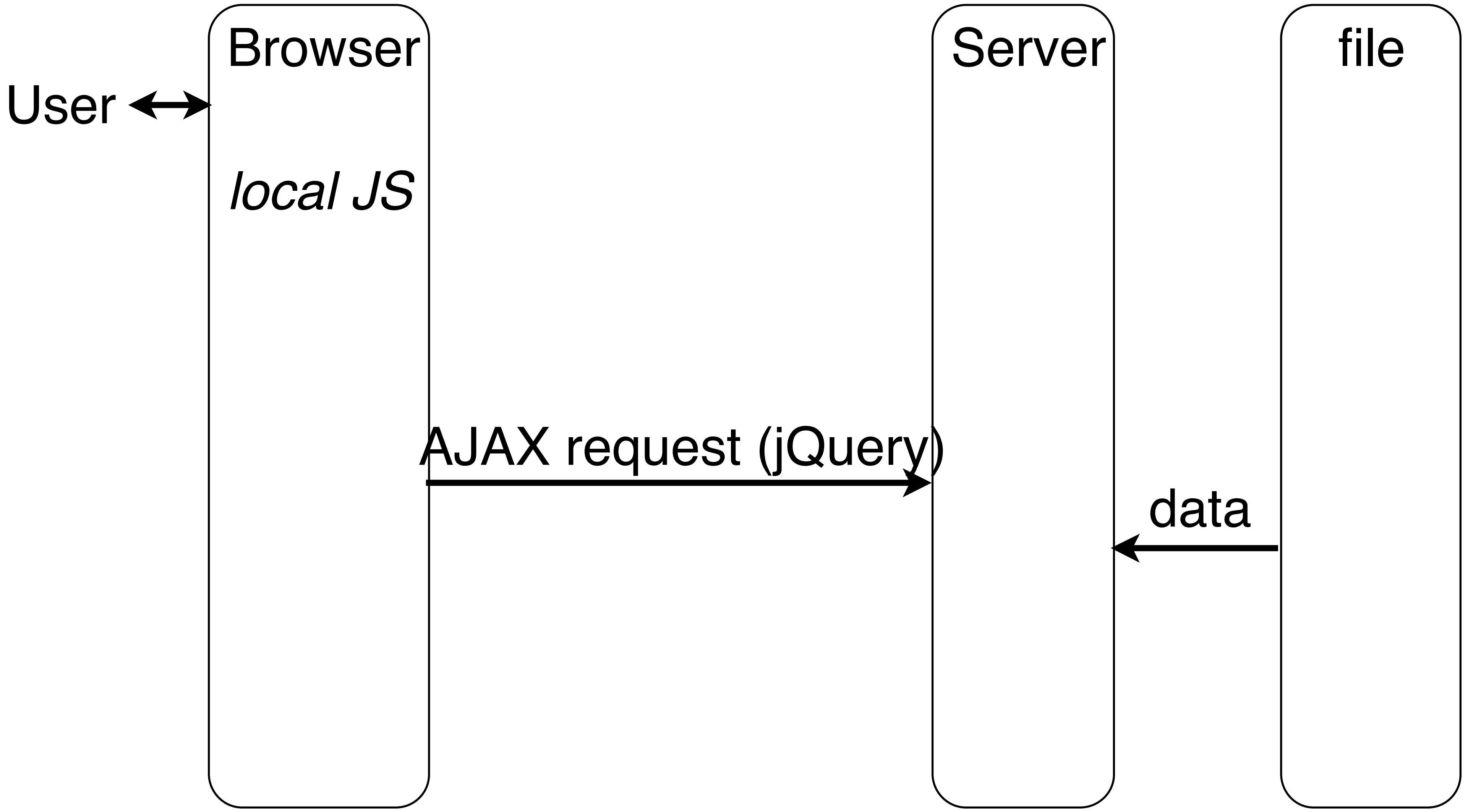
- Typical examples for asynchronous server interaction:
  - Assistance in form filling (search suggestions, post or bank code decoding)
  - Real-time data (news ticker, stock prices)
  - Event notification (incoming mail, update of presence status)
  - Live chat

Any language for server-side processing (e.g. PHP, also JavaScript)

## Example 1 (Last Lecture), Using jQuery



## Example 2 (Very Simple Request), Using jQuery



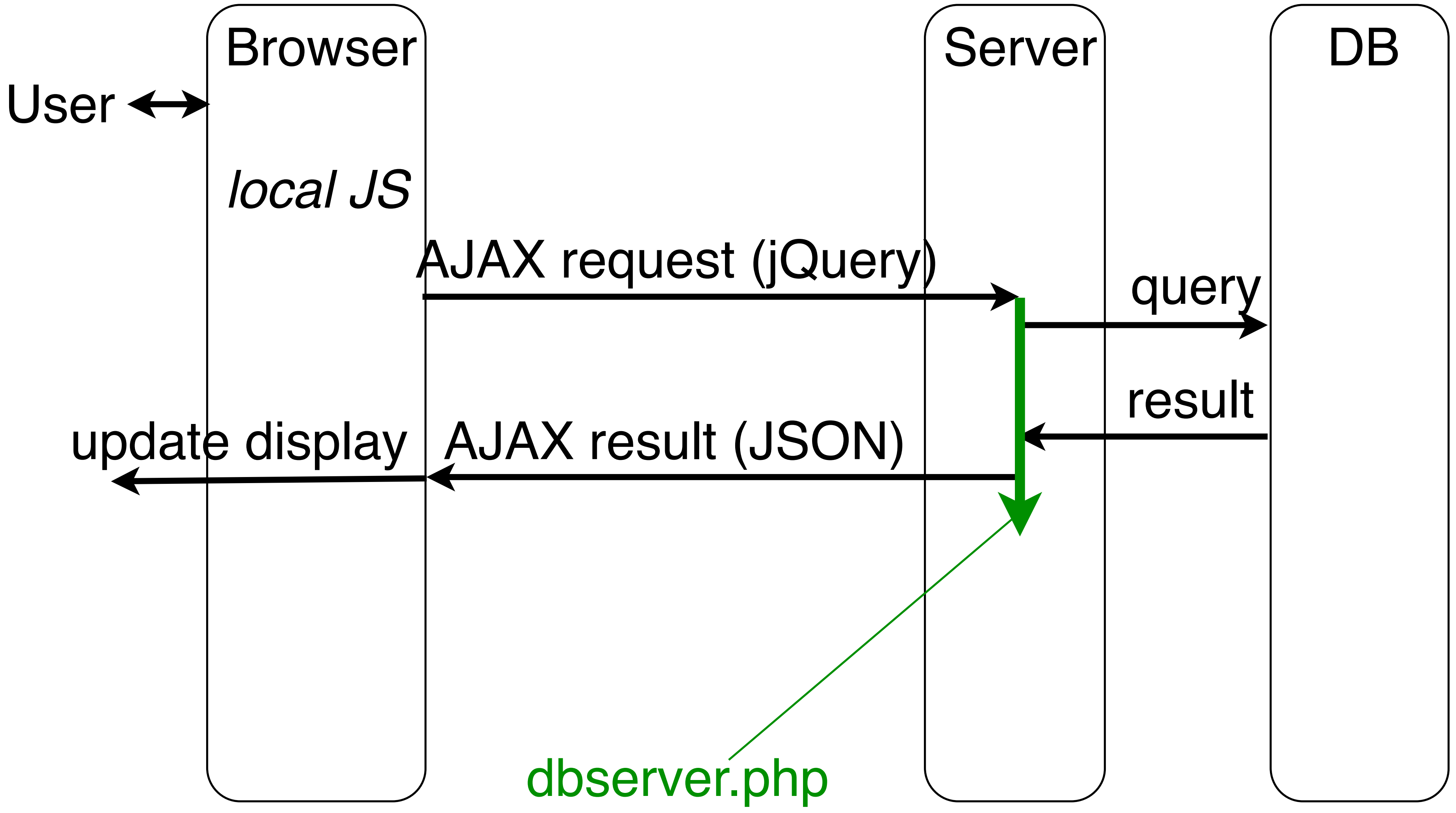
## Example 2 (Very Simple Request), Using jQuery

```
<p>The following text is replaced with data retrieved from
server (data.txt):</p>
<hr/>
<p id='text'>Text to be inserted here</p>
<hr/>
<script type='text/javascript'> …
     $(document).ready( function() {
          $.ajax({
               type: 'GET',
               url: "http://localhost/~hussmann/data.txt",
               success: function(data, status) {
                    alert("Status: "+status);
                    $('#text').html(data);
               }
          });
     });
</script>
```

Callback Function

jquery/ajaxreq_simple_txt.html

## Example 3 (Answered Request), Using jQuery

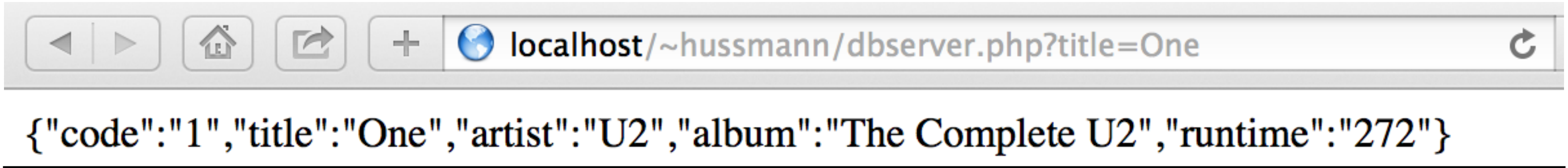


## Example 3 (Answered Request), DB Server

```
<?php
  $db = new mysqli('localhost','root','demopw','music');
  if ($db->connect_error) {
    die('Failed to connect: '.$db->connect_error);
  };
  $title = $_REQUEST['title'];
  $query = "SELECT * FROM mysongs WHERE title='$title'";
  $result = $db->query($query)
    or die ('Query failed'.$db->error);
  $row = $result->fetch_assoc();
  echo json_encode($row);

  $result->free();
  $db->close();
?>
```

dbserver.php


localhost/~hussmann/dbserver.php?title=One

```
{"code":"1","title":"One","artist":"U2","album":"The Complete U2","runtime":"272"}
```

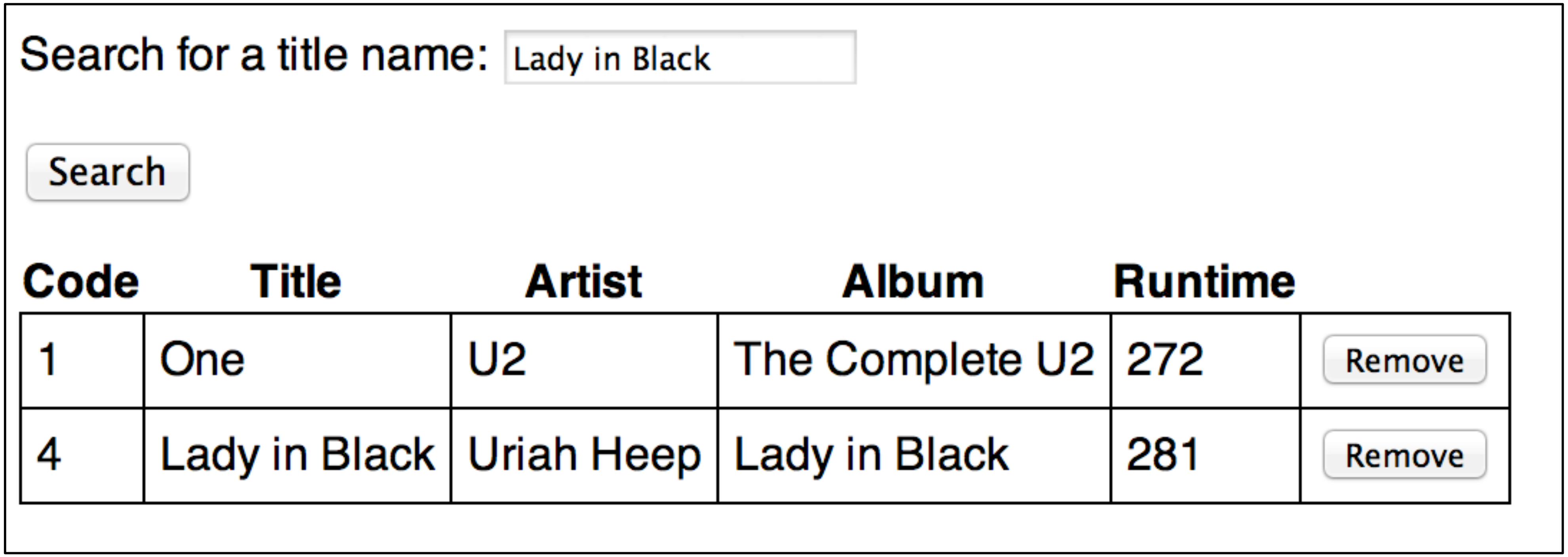
## Example 3 (Answered Request), Request

```
<input id='inp_title' type='text' size='20'></input><br/>
<input id='btn' type='button' value='Search'></input>
<table id='results' class='result_displ'>
  <thead>...</thead>
  <tbody></tbody>
</table>

<script type='text/javascript'> ...
  $('#btn').click( function() {
     $.ajax({
      type: 'GET',
      url: 'http://localhost/~hussmann/dbserver.php',
      data: {title: $('#inp_title').val()},
      dataType: 'json',
      success: function(data) {
          $('#results tbody').append(
              '<tr><td>'+data.code+'</td>'+ ...</tr>'
          );
     });
   });
```

jquery/ajaxreq_result_jsn.html

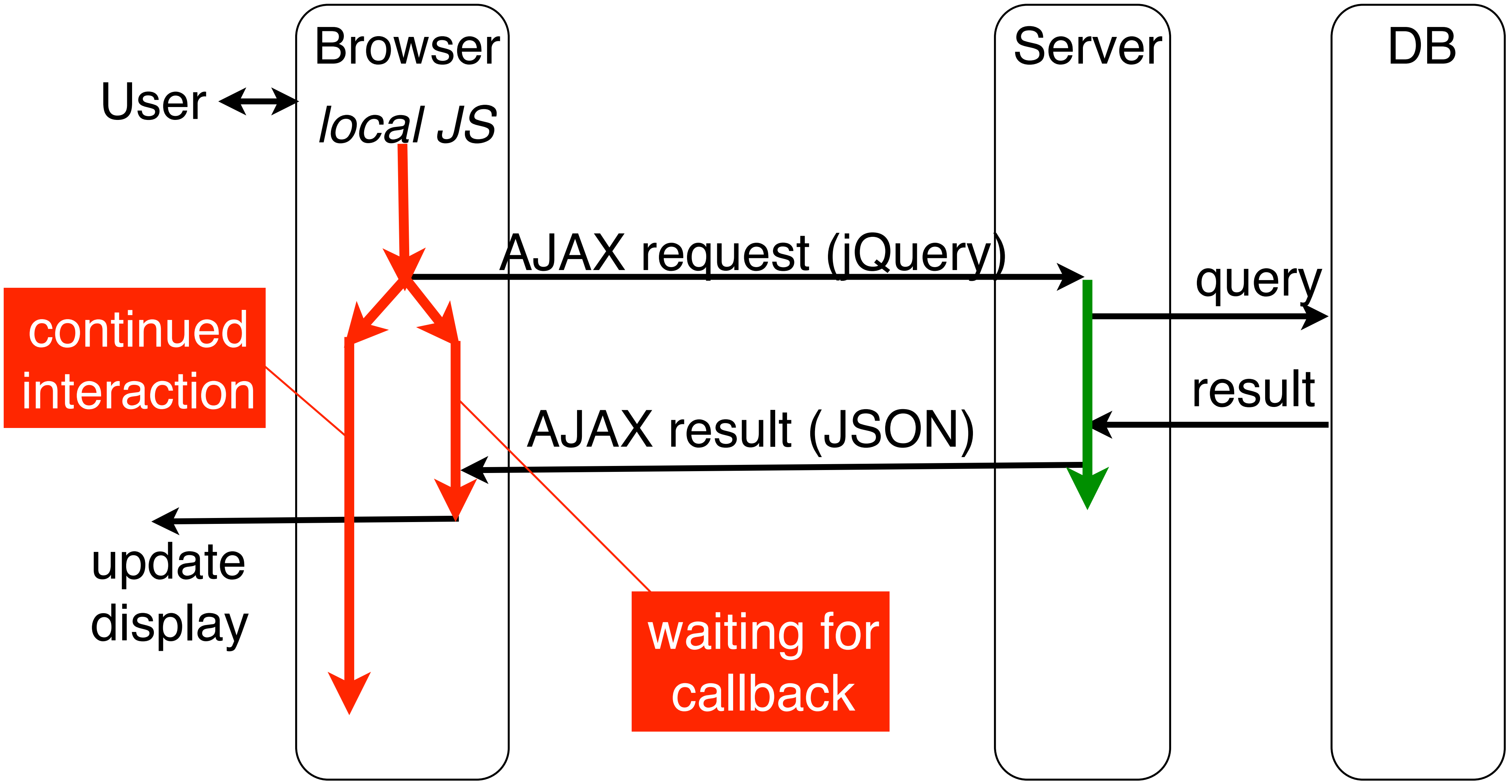
# Building a List of Search Results


Search for a title name: Lady in Black

Search

| Code | Title | Artist | Album | Runtime | |
|---|---|---|---|---|---|
| 1 | One | U2 | The Complete U2 | 272 | Remove |
| 4 | Lady in Black | Uriah Heep | Lady in Black | 281 | Remove |

# Example 3 (Answered Request), Asynchronous!



## Demonstrating Asynchronicity of Handling

- Make the database server respond slowly:

  `sleep(5);` before sending the answer
- Make the currently displayed results interactive:
  - "Remove" button in each row
  - Can be operated while waiting for server!

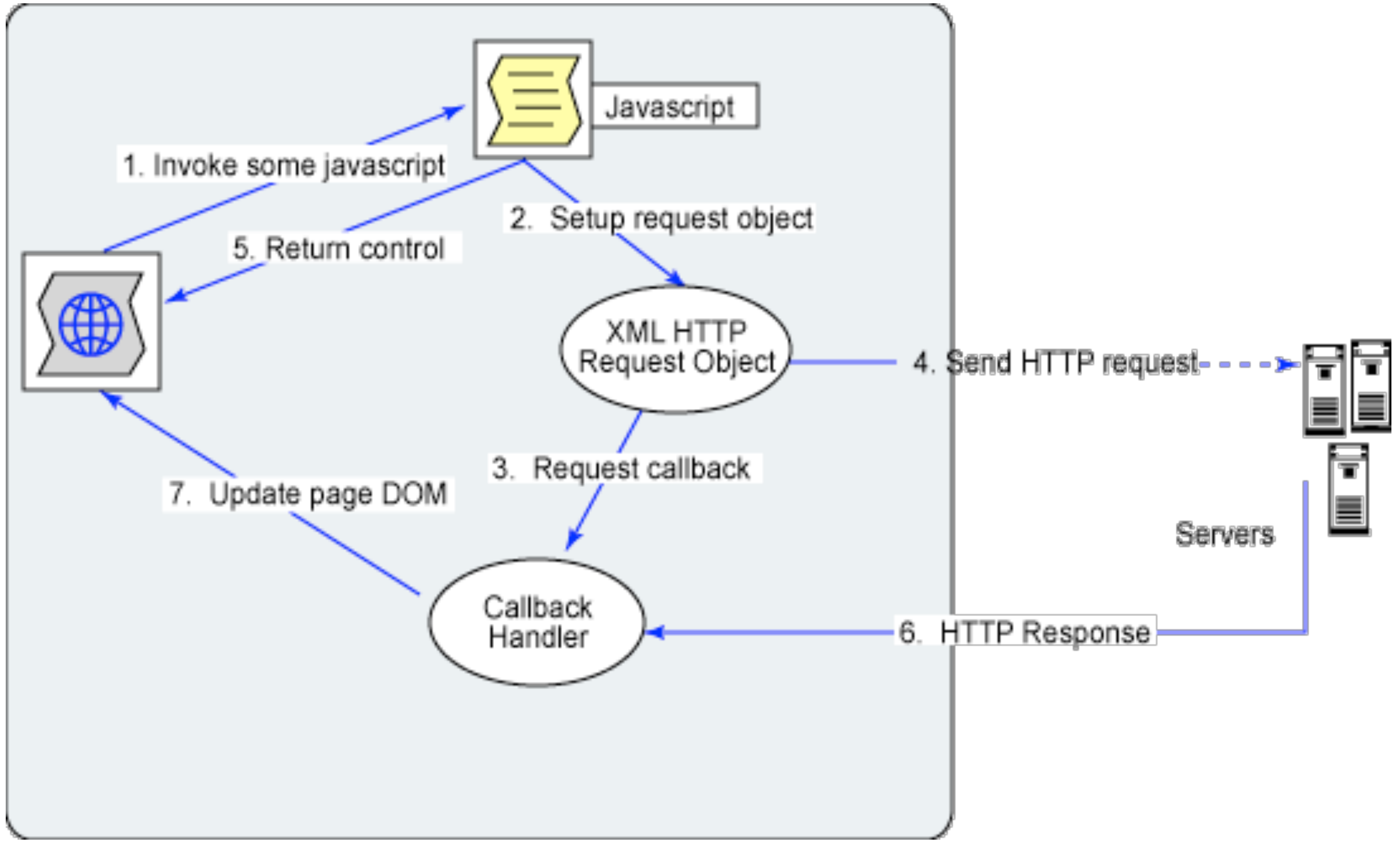
```
$('#results tbody').append(
   '<tr><td>'+data.code+'</td>'+ … +
   '<td><input type="button" value="Remove"></input></td></tr>'
).last().find('input').click( function() {
     $(this).parents('tr').remove();
   });
```

jquery/ajaxreq_result_jsn_slow.html

## AJAX Functionality (Without Using jQuery)

- Main functionalities required:
  - Construction of a request
  - Sending a request to the server
  - Waiting (asynchronously) until server responds
  - Calling functions to analyze server response
- All in one single object:
  - XMLHttpRequest

## Basic Control Flow



http://www.ibm.com/developerworks, Dojo framework

## XMLHttpRequest (XHR)

- Outlook Web Access for Internet Explorer 5 (end 90s):
  - XMLHttpRequest object invented at Microsoft
  - Realized as ActiveX object
- Nowadays in all modern browsers
  - Just JavaScript, including Internet Explorer >7
- Under W3C standardization (Level 2 Working Draft January 2012)

```
var XMLHTTP = new XMLHttpRequest();
```

- Historic browser incompatibilities have to be handled
  - Built into frameworks like *Prototype* or *jQuery*

## Construction of an HTTP Request

- `open()` method of XMLHttpRequest object
  - Note: No interaction with the server yet!
- Required parameters:
  - HTTP method: GET, POST or HEAD
  - URL to send the request to
- Optional parameters:
  - Boolean indication whether to use asynchronous or synchronous treatment (default asynchronous = true)
  - Username and password for authentication
- Examples:

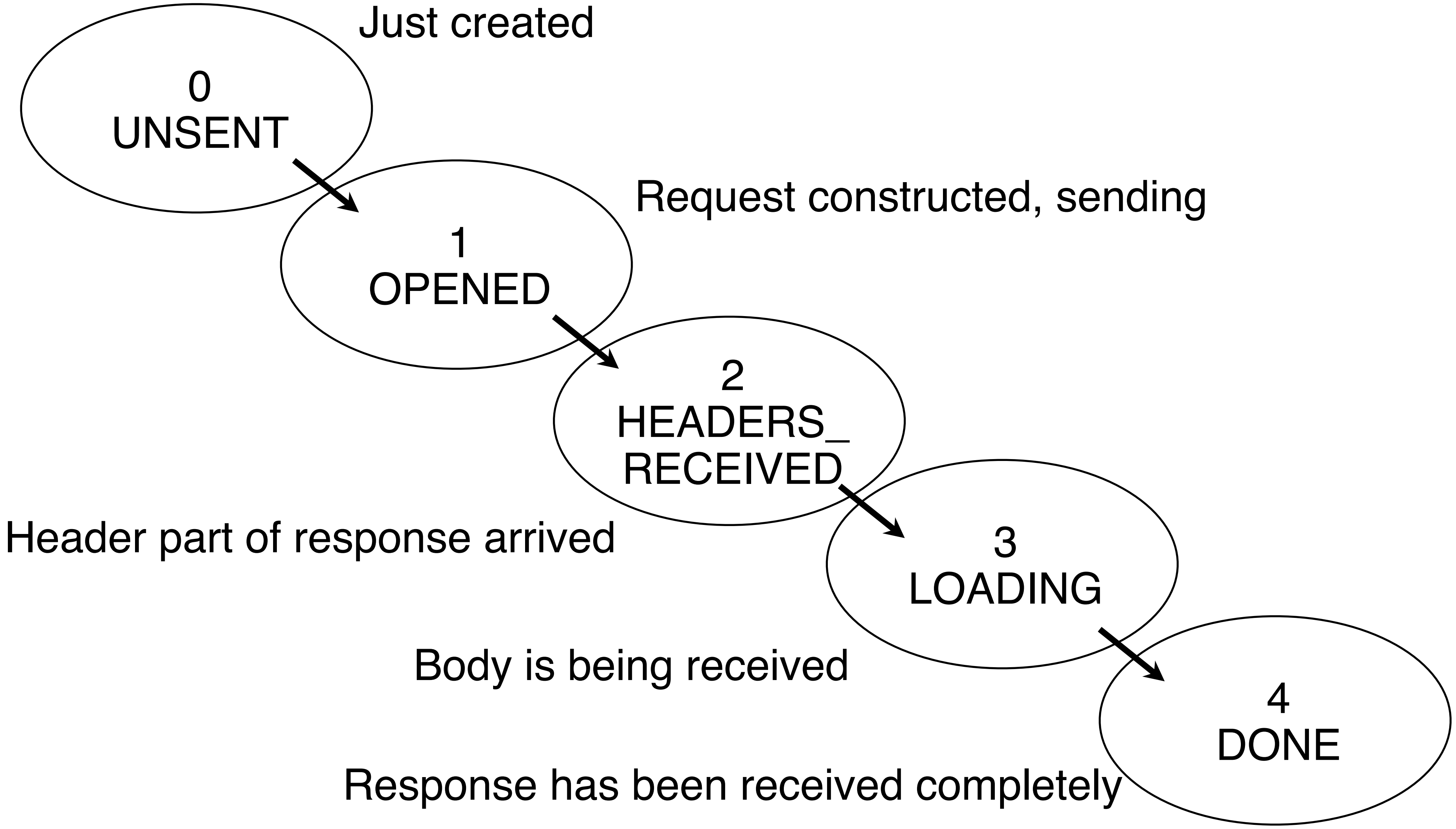
```
XMLHTTP.open("GET", "fibonacci.php?fib=12")
XMLHTTP.open("POST", "/start.html", false, un, pwd);
```

# Sending a Request

- Before sending: **`XMLHTTP.setRequestHeader()`**
  - Setting headers for the request
  - Needed for POST method: **`Content-Type`** (MIME type)

- **`XMLHTTP.send()`**
  - Sends request to server
- Parameter:
  - In the simplest case (in particular for GET method): **`null`**
  - For POST method: "Request entity body" given as parameter

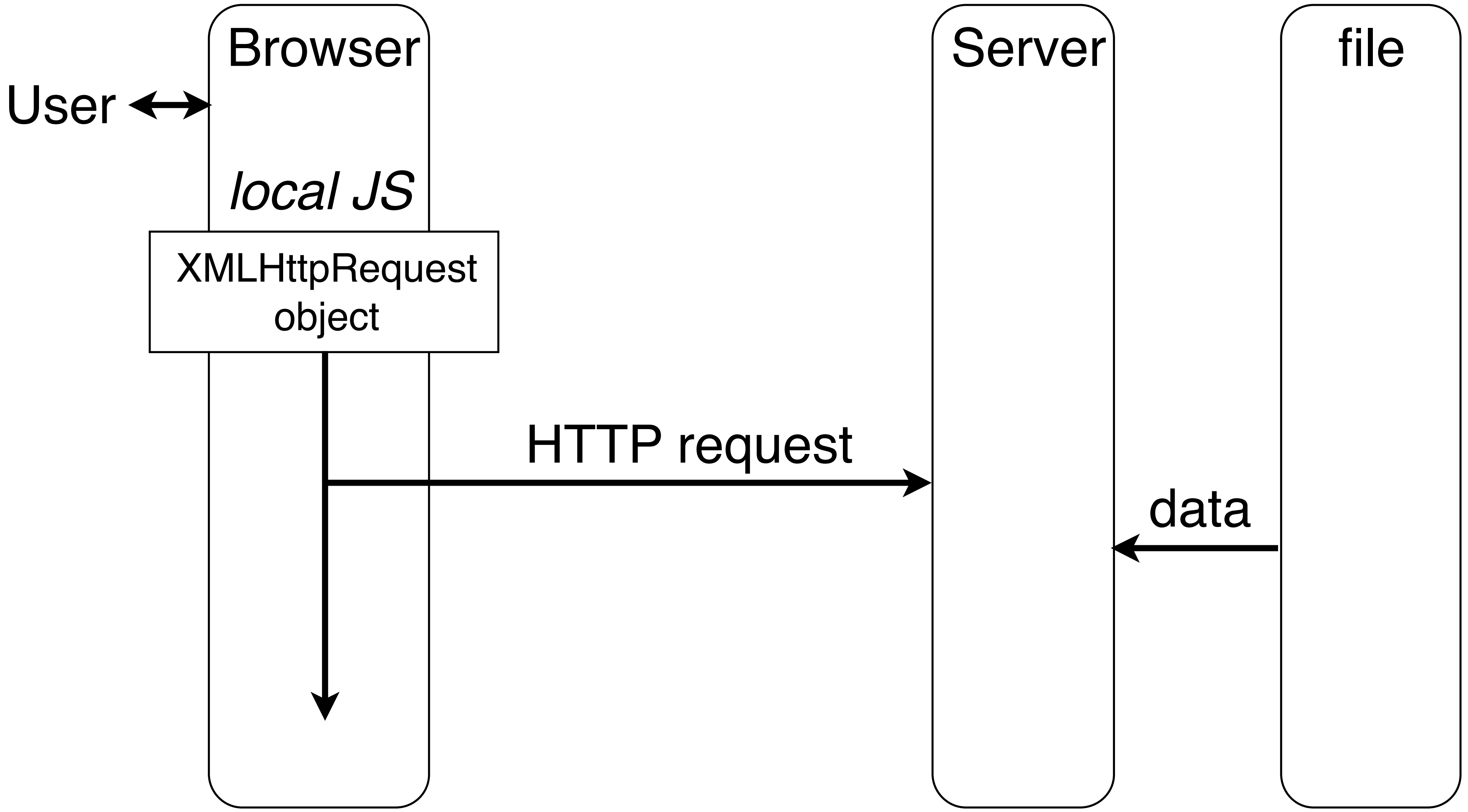
# States of an XMLHttpRequest Object


Just created
0
UNSENT
Request constructed, sending
1
OPENED
2
HEADERS_
RECEIVED
Header part of response arrived
3
LOADING
Body is being received
4
DONE
Response has been received completely

## Asynchronous Reaction by Event Handler

- Registering an event handler for **`XMLHttpRequest`** state changes
  - Event **`readystatechange`** of **`XMLHttpRequest`** object
  - Callback function, called at *any* state change:
    - »
      ```
      XMLHTTP.addEventListener
         ("readystatechange", function);
      ```
- Testing for the relevant state change:
  - **`readystate`** attribute of **`XMLHttpRequest`** object gives current state (as number)
- Other attributes:
  - **`status`** gives return code
  - **`statusText`** gives associated text
  - **`responseText`** and **`responseXml`** give response content

# Example 2 (Very Simple Request), Without jQuery



# Example 2 (Very Simple Request)

```
<body>
  <p>The following text is replaced with data retrieved from
  server (data.txt):</p>
  <hr/>
  <p id='text'>Text to be inserted here</p>
  <hr/>
…
  <script type = "text/javascript">
    var XMLHTTP = new XMLHttpRequest();
    document.addEventListener("DOMContentLoaded",function() {
      XMLHTTP.open("GET",
         "http://localhost/~hussmann/data.txt", true);
      XMLHTTP.addEventListener("readystatechange",function() {
        if (XMLHTTP.readyState == 4) {
          alert("Status: "+XMLHTTP.statusText);
          var d = document.getElementById("text");
          d.innerHTML = XMLHTTP.responseText;
        }
      }, false);
      XMLHTTP.send(null);
     }, false);
  </script>
</body>
```

ajax/simplerequest.html

## Example 3 (Simplified) with Pure AJAX

```
<?php
        header("Content-type: text/xml");

        $db = new mysqli('localhost','root','demopw','music');
        $title = $_REQUEST['title'];
        $query = "SELECT * FROM mysongs WHERE title='$title'";

        $xml = "<?xml version=\"1.0\" encoding=\"iso-8859-1\"?>\n";
        $xml .= "<songs>\n";
        while ($row = $result->fetch_assoc()) {
                $xml .= "\t\t<song>\n";
                foreach ($row as $tag => $value) {
                        $xml .= "\t\t\t<" . $tag . ">\n";
                        $xml .= "\t\t\t\t" . $value . "\n";
                        $xml .= "\t\t\t</" . $tag . ">\n";
                };
                $xml .= "\t\t</song>\n";
        };
        $xml .= "</songs>\n";

        echo $xml;

        $result->free();
        $db->close();

?>
```

PHP server (accessing database), returning XML Text

php/dbserver_xml.php

## Example Server Output (XML) for Example 3

Request

```
GET /~hussmann/dbserver_xml.php
      ?title=One HTTP/1.1
Host: localhost:80
```

Response

```
HTTP/1.1 200 OK
Date: Wed, 29 Oct 2014 19:29:41 GMT
Server: Apache/2.2.26 (Unix) DAV/2 PHP/5.4.30
X-Powered-By: PHP/5.4.30
Content-Length: 248
Content-Type: text/xml

<?xml version="1.0" encoding="iso-8859-1"?>
<songs>
      <song>
         <code>
            1
         </code>
         <title>
            One
         </title>
         <artist>
            U2
         </artist>
         <album>
            The Complete U2
         </album>
         <runtime>
            272
         </runtime>
      </song>
</songs>
```

## Example 3 with Pure AJAX – HTML

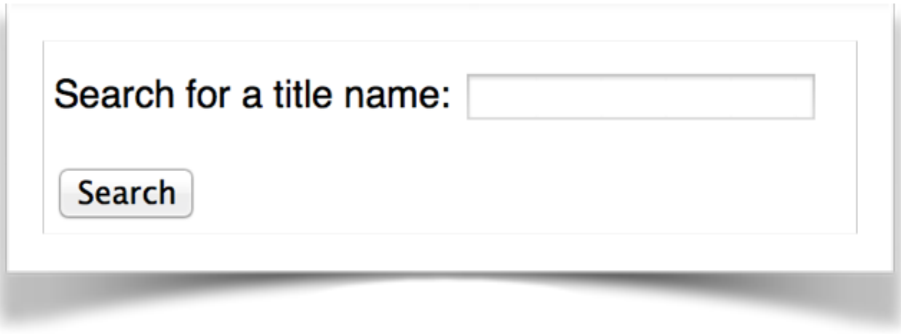
```
<html>
   <head>
      <title>Pure Ajax Request with XML encoded result</title>
      <style>...</style>
   </head>

   <body id="bodytext">
      <p>
         Search for a title name:
         <input id="inp_title" type="text" size="20"></input><br/>
      </p>
      <p>
         <input id="btn" type="button" value="Search"></input>
      </p>

   </body>

   <script type = "text/javascript">
       JavaScript code
   </script>

</html>
```


Search for a title name:

ajax/req_result_XML.html

# Example 3 with Pure AJAX – HTTP Request

```
var XMLHTTP = new XMLHttpRequest();
var btn = document.getElementById("btn"); //not needed
var inp_title = document.getElementById("inp_title"); //not needed
var bodytext = document.getElementById("bodytext"); // not needed

btn.addEventListener("click", function() {
   XMLHTTP.open("GET", "http://localhost/~hussmann/dbserver_xml.php
      title="+inp_title.value);
   XMLHTTP.send(null);
}, false);

XMLHTTP.addEventListener("readystatechange", function() {
   if (XMLHTTP.readyState == 4) {
      DOM JavaScript code
      }
   }
}, false);
```

ajax/req_result_XML.html

# Example 3 with Pure AJAX – DOM JavaScript

```
var xml = XMLHTTP.responseXML;
var songs = xml.getElementsByTagName("song");
if (songs.length > 0) {
   var artist = songs[0].
      getElementsByTagName("artist")[0].firstChild.nodeValue;
   var album = songs[0].
      getElementsByTagName("album")[0].firstChild.nodeValue;
   var line = document.createElement("p");
   var text = document.createTextNode(
     "Artist: "+artist+"; "+"Album: "+album);
   line.appendChild(text);
   bodytext.appendChild(line);
}
```

Read XML (tree)
Modify/write HTML (tree)

ajax/req_result_XML.html

## AJAX: Potential and Problems

- Potential:
  - Reaction to any user action (e.g. mouse move, typing)
  - Enables classic GUIs for "Web Apps"
- Problems:
  - Back button
  - Bookmarks
  - Search engines

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## Basic Web Paradigms: Documents

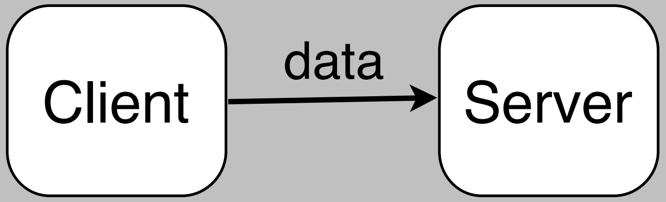
- HTML:
  - Originally intended for scientific papers: Limited structure
  - Purely static
  - Not object-oriented
- HTML5:
  - More flexible structure, graphics output, input elements, media playback
- DOM:
  - Dynamic changes of documents
- CSS:
  - Separation content/presentation, presentation classes
- JavaScript:
  - Dynamic changes, object-orientation

## Basic Web Paradigms: Communication

- HTTP:
  - Request-response architecture:
    - Requests have to be initiated by client
  - Restricted parameter syntax (keyword-value pairs)
  - Synchronicity: Client has to wait for response
- AJAX:
  - Enables asynchronous handling of requests in client
- Basic restriction to request ➔ response remains!
  - “Client-driven” architecture

## Types of Client-Server Interaction

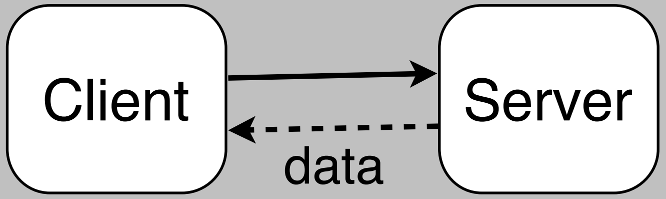
Client-driven



*Send data to server*

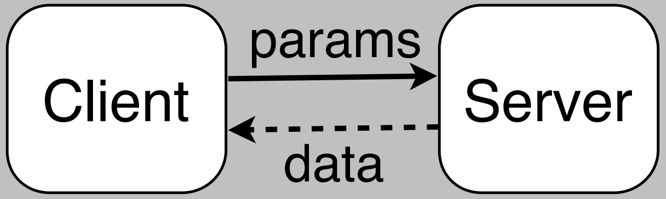
Example 1: Sending shopping cart contents

Other examples: Location update, logging



*Pull data from server*

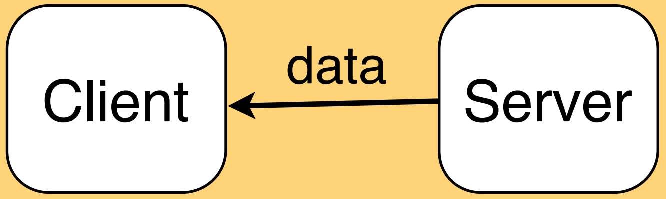
Example 2: Very simple request



*Pull selected data from server*

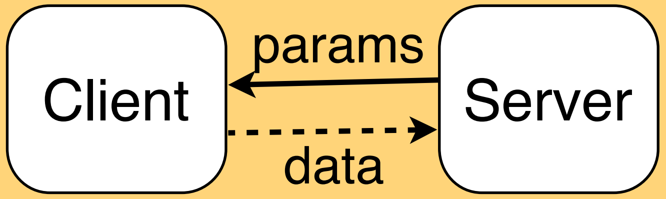
Example 3: Database query

Manifold other examples



*Push data from server to client*

Examples: New mail, breaking news, chat



*Request data from client*

Examples: Status inquiry, security check

Server-driven

## Server-Driven Applications in the Web

- Frequent and easy solution: ***Polling***
  - Client sends requests to server in regular intervals
- Disadvantages:
  - Redundant load to client, server, network
  - Changes traffic characteristics
  - Limited time resolution for real-time events
- Alternatives:
  - (a) “Reverse AJAX”/”COMET” – Tricking the Web architecture
  - (b) Going beyond traditional HTTP

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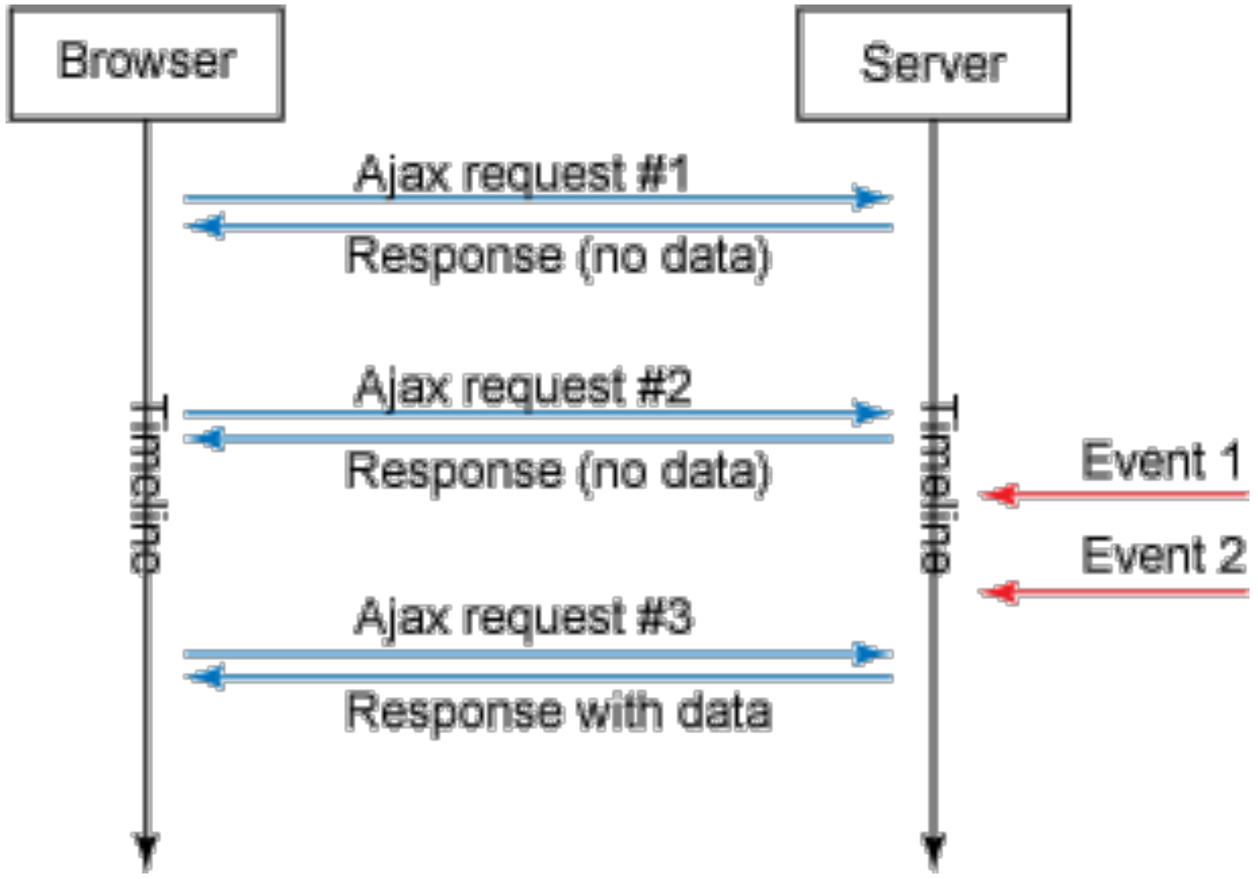
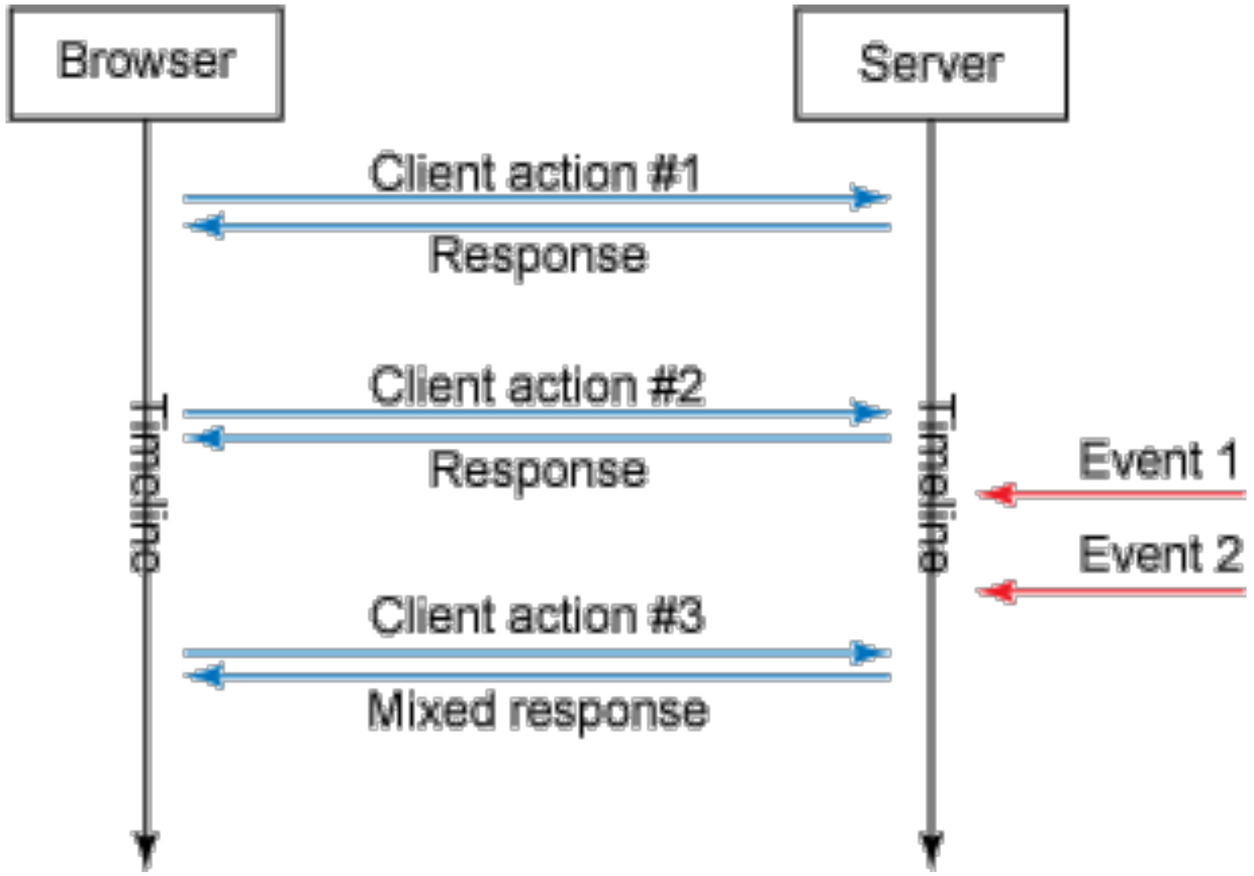
Mathieu Carbou: Reverse Ajax, Part 1: Introduction to Comet, http://www.ibm.com/developerworks/web/library/wa-reverseajax1/

## Reverse Ajax with HTTP Polling



- Server event information pulled by client through regular polling
- Easily realizable in JavaScript using “setInterval()”
- High network load, imprecise timing

# Reverse Ajax with Piggyback Polling

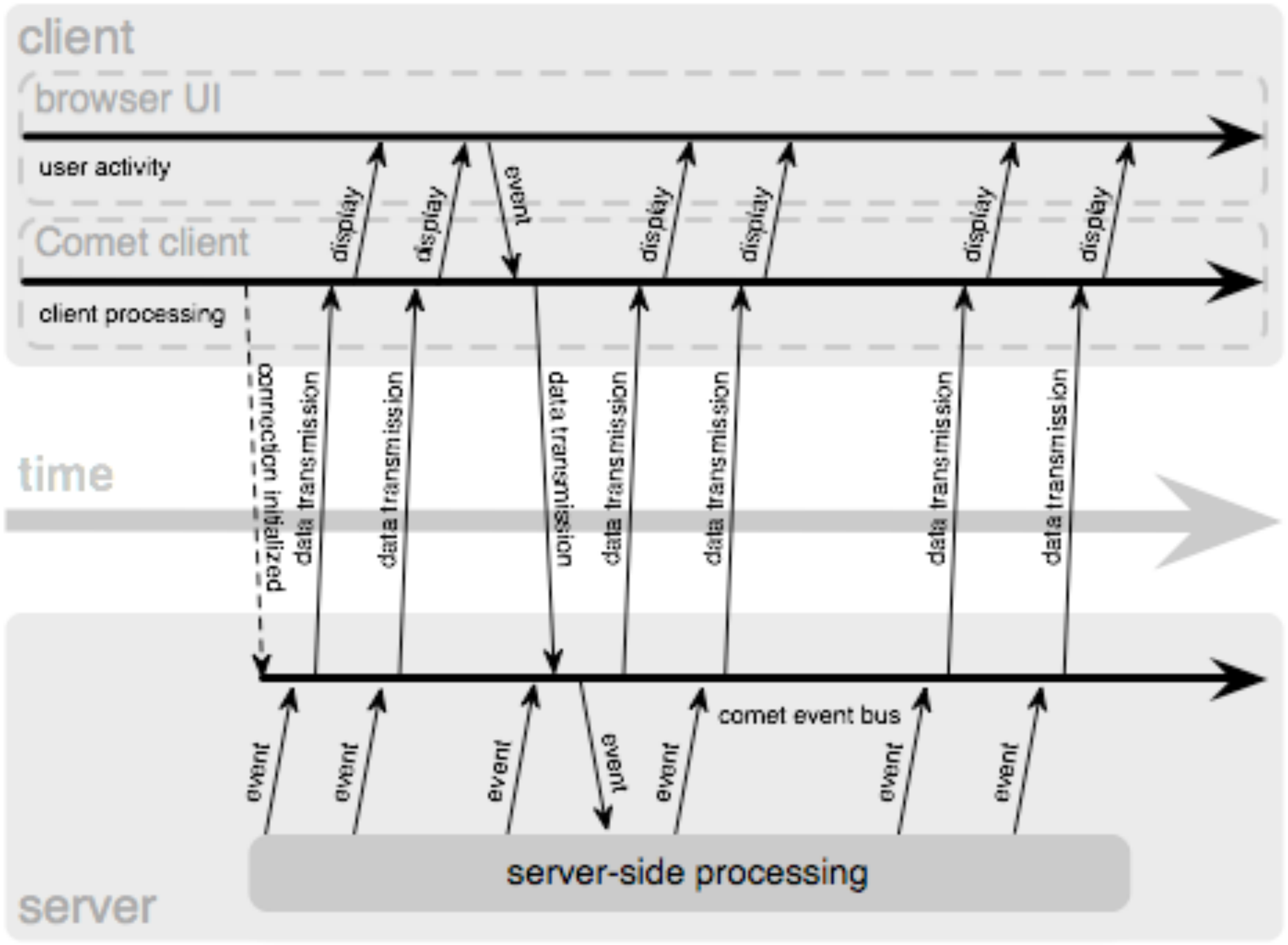


- Assuming different needs for information exchange between client and server
- Whenever a client-triggered request is processed, additional information about latest server-side events is added to the response

## Reverse Ajax with the Comet Model

- Proper support for asynchronous server-side events:
  - Availability of a channel for the server to push information to the client
  - Server-client connections maintained over a long period of time
- Alex Russell 2006 (Blog) http://infrequently.org/2006/03/comet-low-latency-data-for-the-browser/
  - Web Applications exist which use server-side events and long-lived client-server connections (Gmail GTalk, Meebo)
  - "Lacking a better term, I've taken to calling this style of event-driven, server-push data streaming "Comet". It doesn't stand fo anything, and I'm not sure that it should."
  - Other terms for the same idea: Ajax Push, HTTP Streaming, HTTP server push
    - » Sometimes also Reverse Ajax...

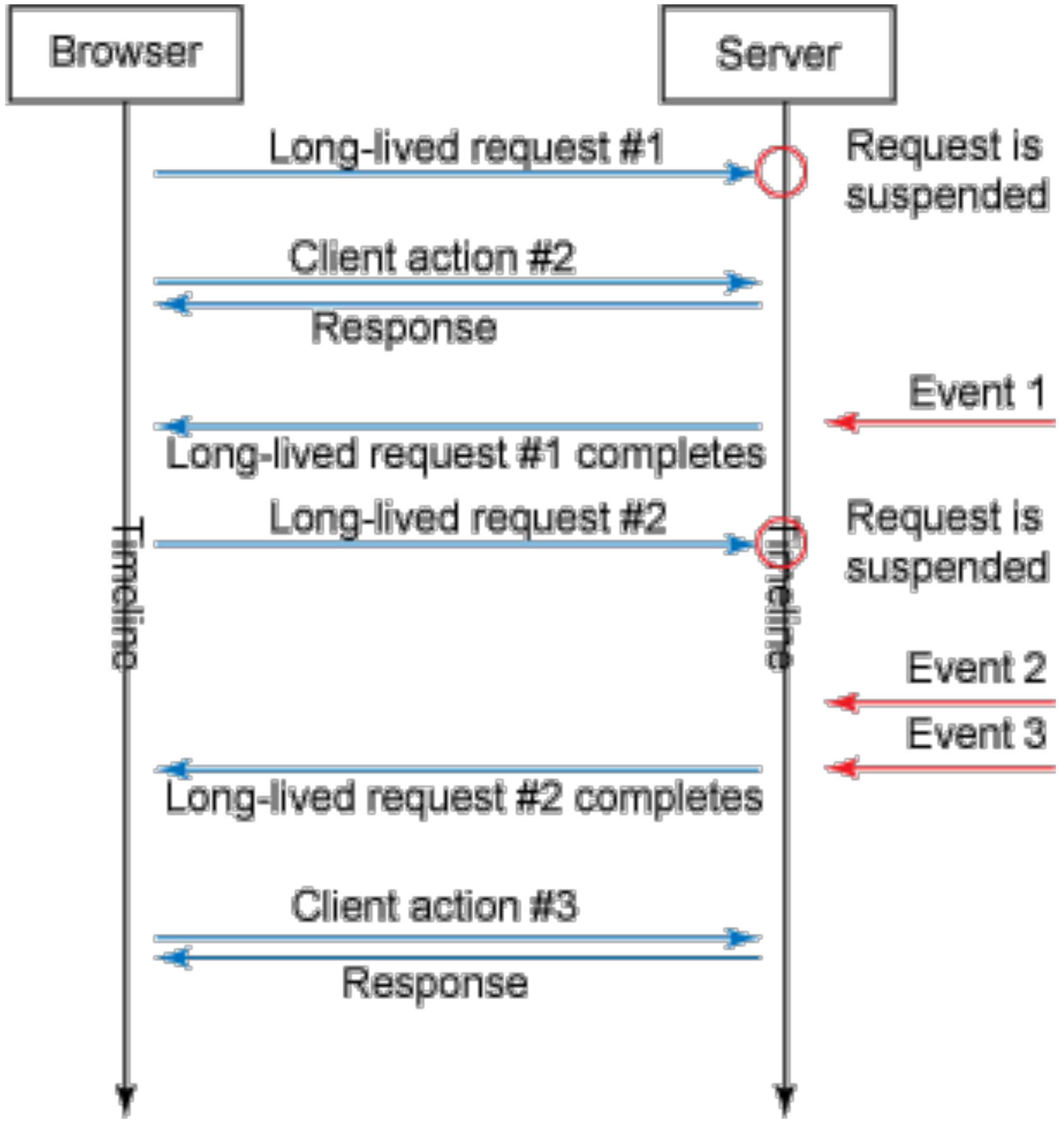
# Comet Web Application Model



## Connection Management in Comet

- Comet based on *HTTP Streaming*:
  - Single TCP/IP connection kept open between client and server
  - For instance using the “multipart response” supported by many browsers
    - » Origin: “server push” feature by Netscape in 1995,  
      e.g. to send new versions of an image by the server
    - » Response is “stretched over time”
- Comet based on *Long Polling*:
  - Standard XMLHttpRequest sent by client
  - Server suspends response until event happens
    - » Specific programming techniques on server required
    - » Storing the request context
  - As soon as client receives response (and processes it), client sends new request (which is suspended again)
  - Relatively easy to realize with current browsers and XMLHttpRequest

# Reverse Ajax with Comet



- Client request is suspended at server
- Server responds to the request each time a new server-side event happens

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Mathieu Carbou: Reverse Ajax, Part 2: Web Sockets,
http://www.ibm.com/developerworks/web/library/wa-reverseajax2/

http://websocket.org

## General Idea and General Problem

- Idea:
  - Web client (browser) communicates
    at the *same time* and
    in the *same data space* with
    several different hosts
- Security problem: “Cross-site scripting”
  - Web application A gets access to data from Web application B
  - In the worst case including authentication data
- Current principle in browsers:
  - Only one Web application at a time communicates with a browser instance
  - Being relaxed in new approaches (under security precautions)

## WebSockets

- Originated in HTML5 (WHAT Working Group)
  - HTML5 Web Sockets specification
  - Full-duplex communication channel between client and server
  - Establishment (“handshake”) client-initiated, over HTTP
  - One connection for bi-directional communication, very small latency
    - “sub 500 millisecond” latency
    - Near real-time!
  - Able to traverse firewalls and proxies (port 80)
  - Secure connection can be used (HTTP/S)
- WebSockets have been separated out of HTML5
  - API developed by W3C, protocol (“ws:”) standardized as IETF RFC 6455
  - Browser support:
    - Earlier unsecure version disabled
    - RFC 6455 supported in all modern major browsers

# WebSocket Client API (JavaScript)

- Connect to an endpoint (WebSocket handshake):

```
var myWebSocket =
  new WebSocket("ws://www.websockets.org");
```

- Associate event handlers to established connection:

```
myWebSocket.addEventListener("open", function);
myWebSocket.addEventListener("message", function);
myWebSocket.addEventListener("close", function);
```

- Send message to server over established connection:

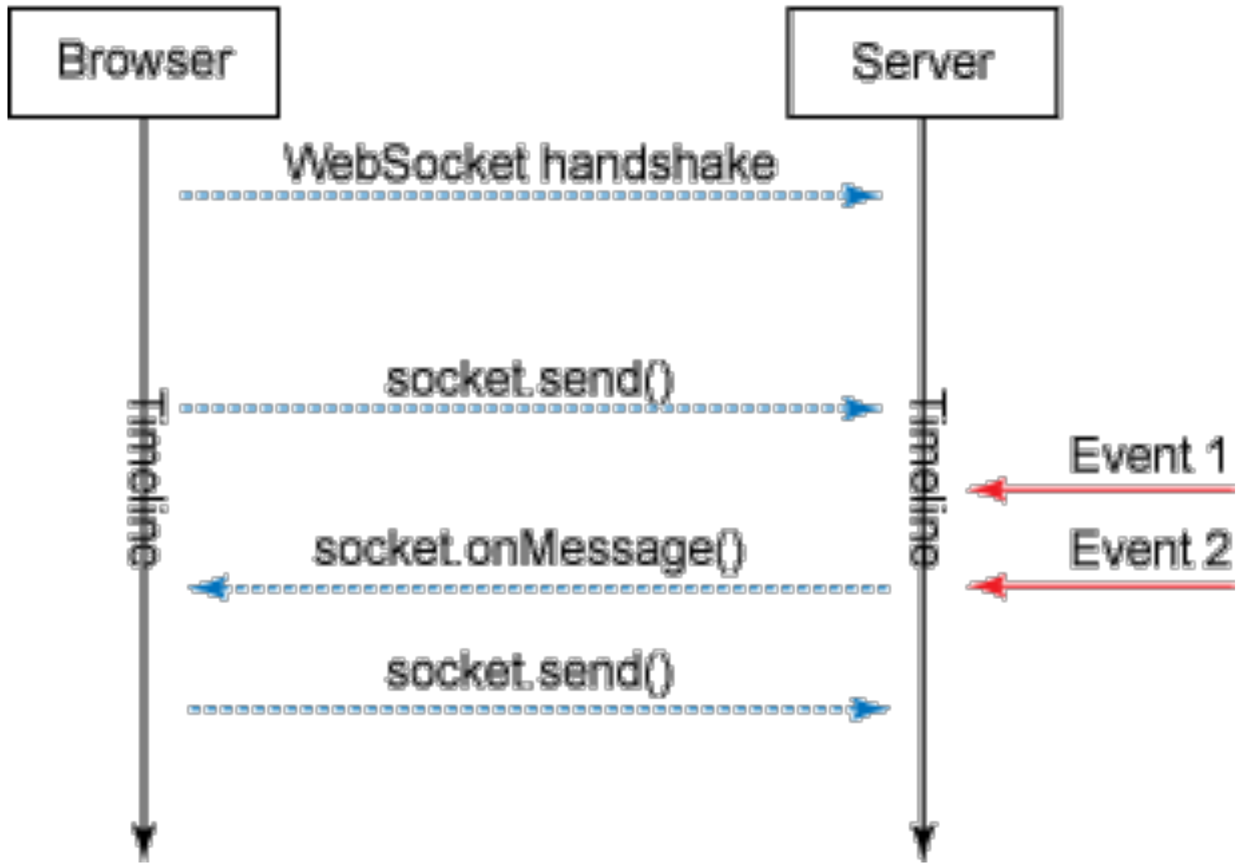
```
myWebSocket.send("hello");
```

- Disconnect from endpoint:

```
myWebSocket.close();
```

- Demos: https://www.websocket.org/echo.html

# Reverse Ajax with WebSockets



- Simple, low-latency solution
- New standard, not yet widely used – probably the way to go in future
- *Abstraction APIs* help to keep programs independent of transport
  – See e.g. socket.IO

## Web Messaging

- HTML5 Web Messaging
  - Standardized by W3C, driven by Google
  - Candidate recommendation May 01, 2012
- Document A, if knowing about another document B, can send a (text) message to document B (on a different domain)
- Specific *iframe* in document A calls `postMessage()` referring to domain and window of document B.
- Document B can handle the event in event handler
  - Gets information about origin, ***which needs to be checked***
  - Document B checks format of message and takes additional precautions
- Simple to use, high security risks

# Chapter 3: Web Paradigms and Interactivity

3.1 AJAX: Asynchronous Interactivity in the Web

3.2 Paradigms for Web-Based Communication

3.3 Reverse AJAX and COMET

3.4 Web Sockets and Web Messaging

3.5 Web Workers

Literature:

B. Lawson, R. Sharp: Introducing HTML5, New Riders 2011

## Threading in Web Browsers

- Thread = Sequence of instructions to be executed
- Traditionally, Web browsing is *single-threaded*
- Complex Web applications (and multimedia) require *multi-threading*
  - Example: Asynchronous interaction in Ajax and Reverse Ajax
  - Example: Playing back a movie/sound, being still able to control it
  - Example: Synchronizing a movie with subtitles or animations
  - Example: Long loading time for multimedia document
    – user has decided to do something else
  - Example: Independent animations on a single page
    (content and advertisement)
- Web Worker:
  - Specification for light-weight JavaScript threads in browsers
  - Originated by WHATWG, now separated from HTML5
  - Supported e.g. in Safari, Chrome, Opera and Firefox

# Principles for Using Web Workers

- Creating a new worker:
  - **`var worker = new Worker("my_worker.js");`**
- Sending a message to the worker:
  - **`worker.postMessage("hello worker");`**
- Receiving a message from the worker:
  - **`worker.addEventListener("Message",`** ***`function`*****`, false);`**
  - ***`function`*** **`(event) { … event.data … }`**
- What a worker can do:
  - Communicate, including Web Messaging and Web Sockets
  - Send and process Ajax requests
  - Establish timers
  - Basic JavaScript (but ***no*** DOM access)
  - Web SQL databases
  - Web Workers (!)
- Shared Worker: Working with multiple documents