Chapter 2: Interactive Web Applications

2.1 Interactivity and Multimedia in the WWW architecture

… (PHP) ...

2.5 Interactive Client-Side Scripting (HTML5/JavaScript)

2.6 Data Storage in Web Applications

2.7 Asynchronous Interactivity in the Web

- AJAX
- Reverse AJAX and Comet
- Web Sockets, Web Messaging
- Web Workers

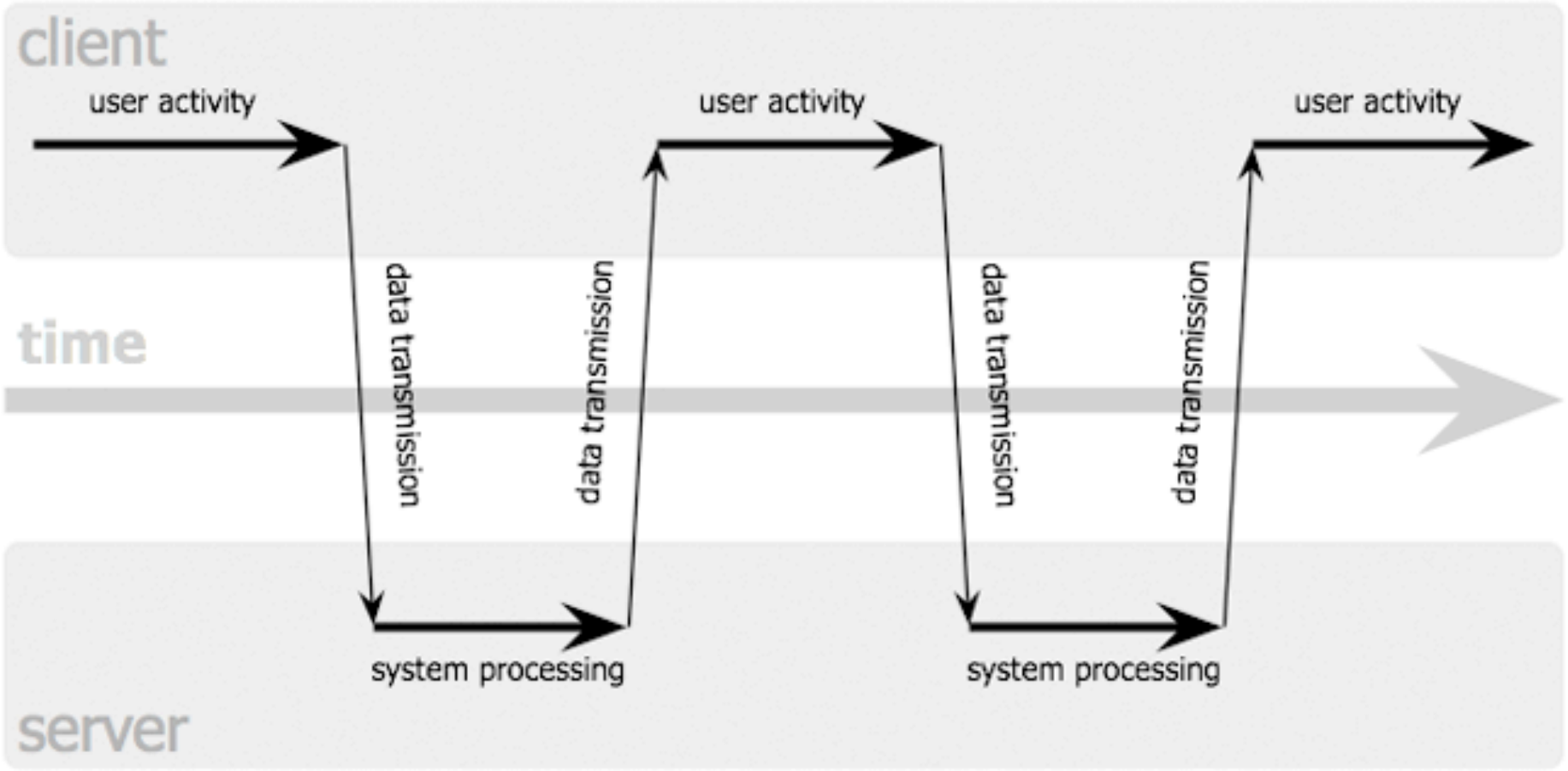
Literature:

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

Asynchronous JavaScript + HTML (AJAX)

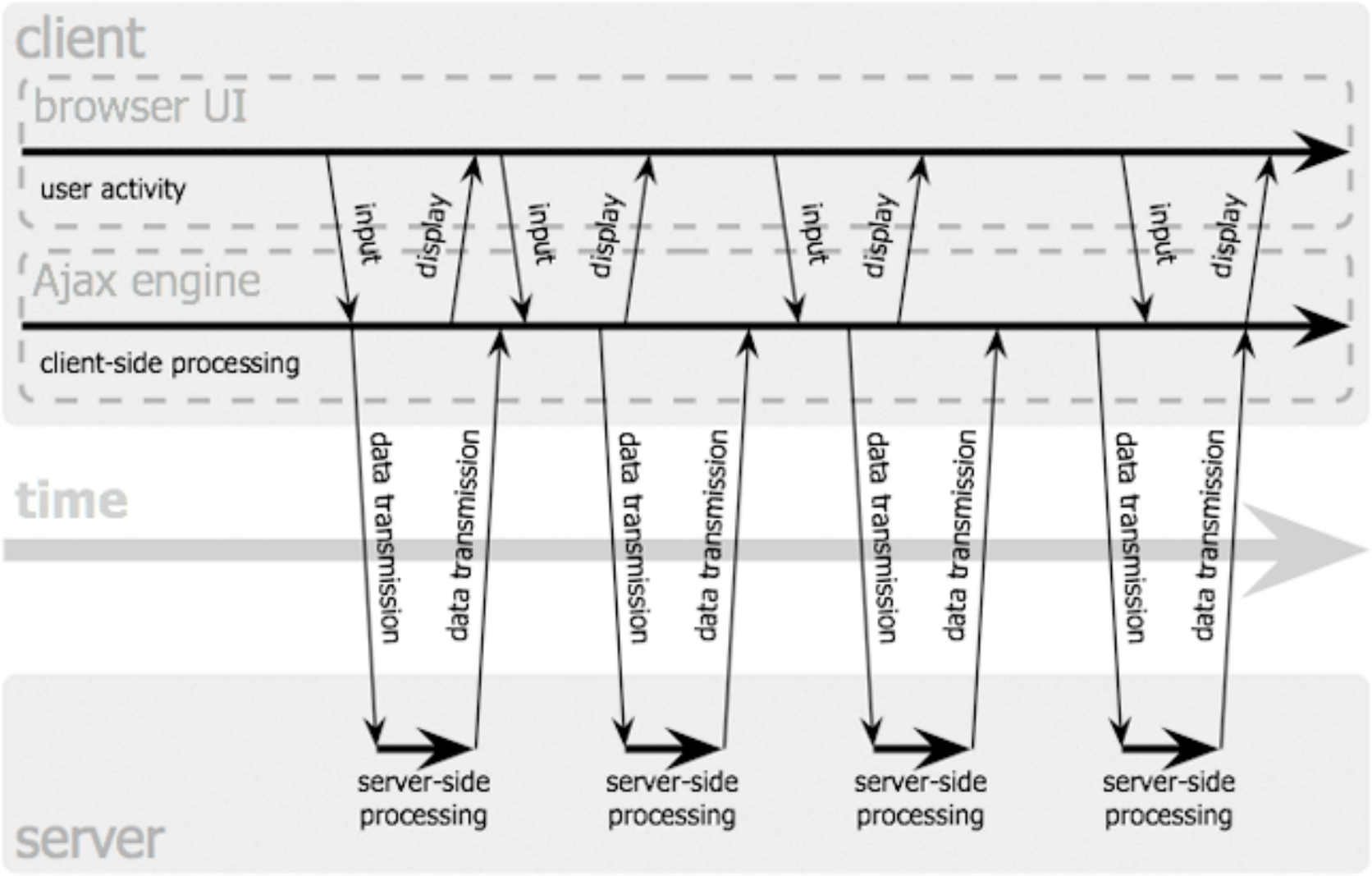
- James Garrett 2005:
  http://www.adaptivepath.com/ideas/essays/archives/000385.php
- Catchy name for an idea which was in use already at the time:
  - Google Suggest
  - Google Maps
- Basic idea:
  - Loading data from server is decoupled from changes in the presentation
- Advantages:
  - User can interact fluidly with the application
  - Information from server is fetched at regular intervals - display can always stay up-to-date
- AJAX is not a technology, it is a combination of known technologies
  - XHTML, CSS, DOM, XML, XSLT, JavaScript, XMLHttpRequest
- There are AJAX-like applications which use neither JavaScript nor HTML
  - E.g. using Flash and querying servers in the background

Classical Synchronous Web Application Model



Jesse James Garrett / adaptivepath.com

Asynchronous Web Application Model



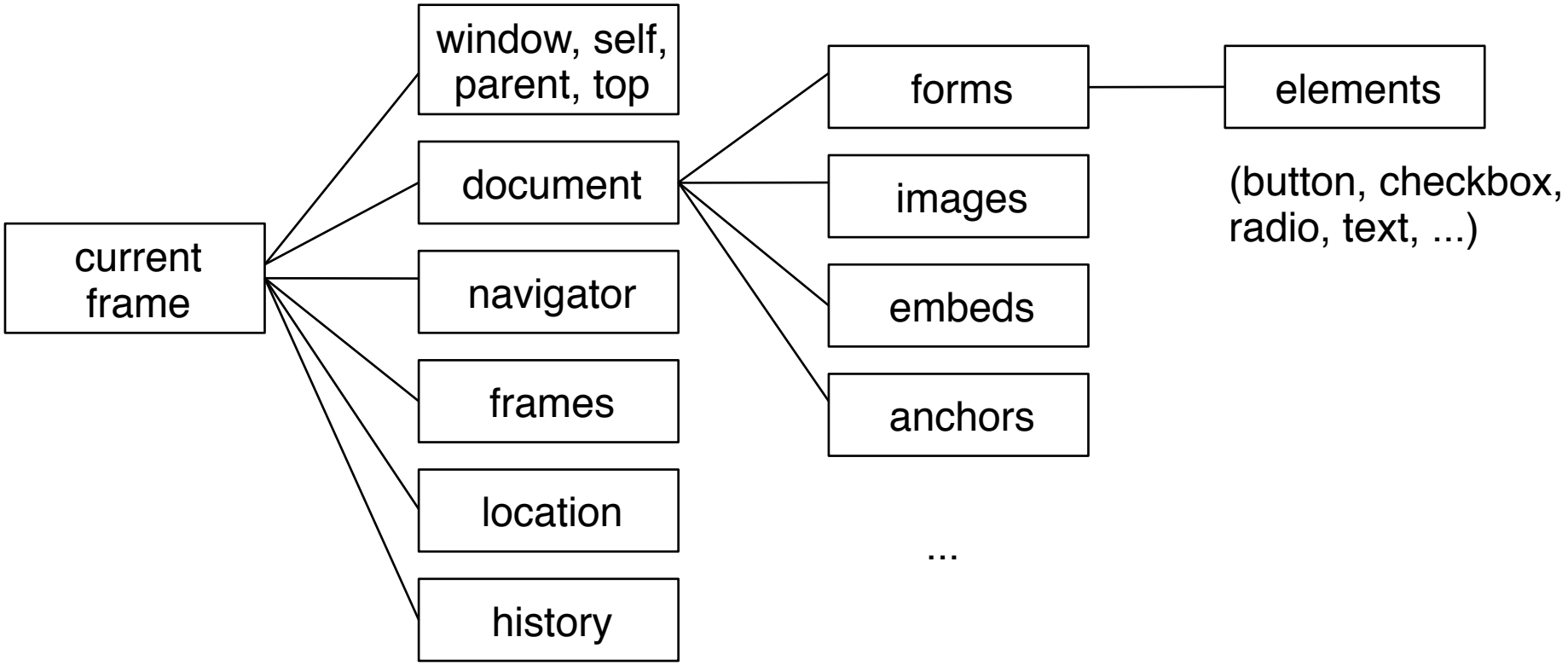
Jesse James Garrett / adaptivepath.com

AJAX and Client-Side Scripting

- AJAX applications are programs executed in the Web browser
  - Require a runtime environment
  - Usually programmed in JavaScript
- AJAX applications need to modify or construct HTML to be displayed in the browser
  - Requires access to loaded/displayed HTML
  - *Domain Object Model* (DOM) is used for accessing and manipulating page content
- HTML5 Canvas is an interesting candidate for dynamic display of content in the browser

JavaScript Object Tree

- Elements of the displayed document and other information can be accessed and manipulated
- Navigation:
  - Mostly selection by "id"
  - Starting point is often "document" object



DOM Reminder

- DOM is a collection of functions which make it possible to access and manipulate HTML and XML documents in the browser
- DOM is a standardized API
  (Application Programming Interface)
  - Usable with several programming languages
- Examples of DOM object properties and methods:
  `nodeName, nodeValue, nodeType, attributes`
  `getElementbyId()`
  `parentNode, hasChildNodes();`
  `childNodes, firstChild, lastChild, previousSibling, nextSibling;`
  `createElement(); createTextNode();`
  `insertBefore(), replaceChild(), removeChild(), appendChild();`
- Not in DOM but useful and fast:
  `innerHTML`

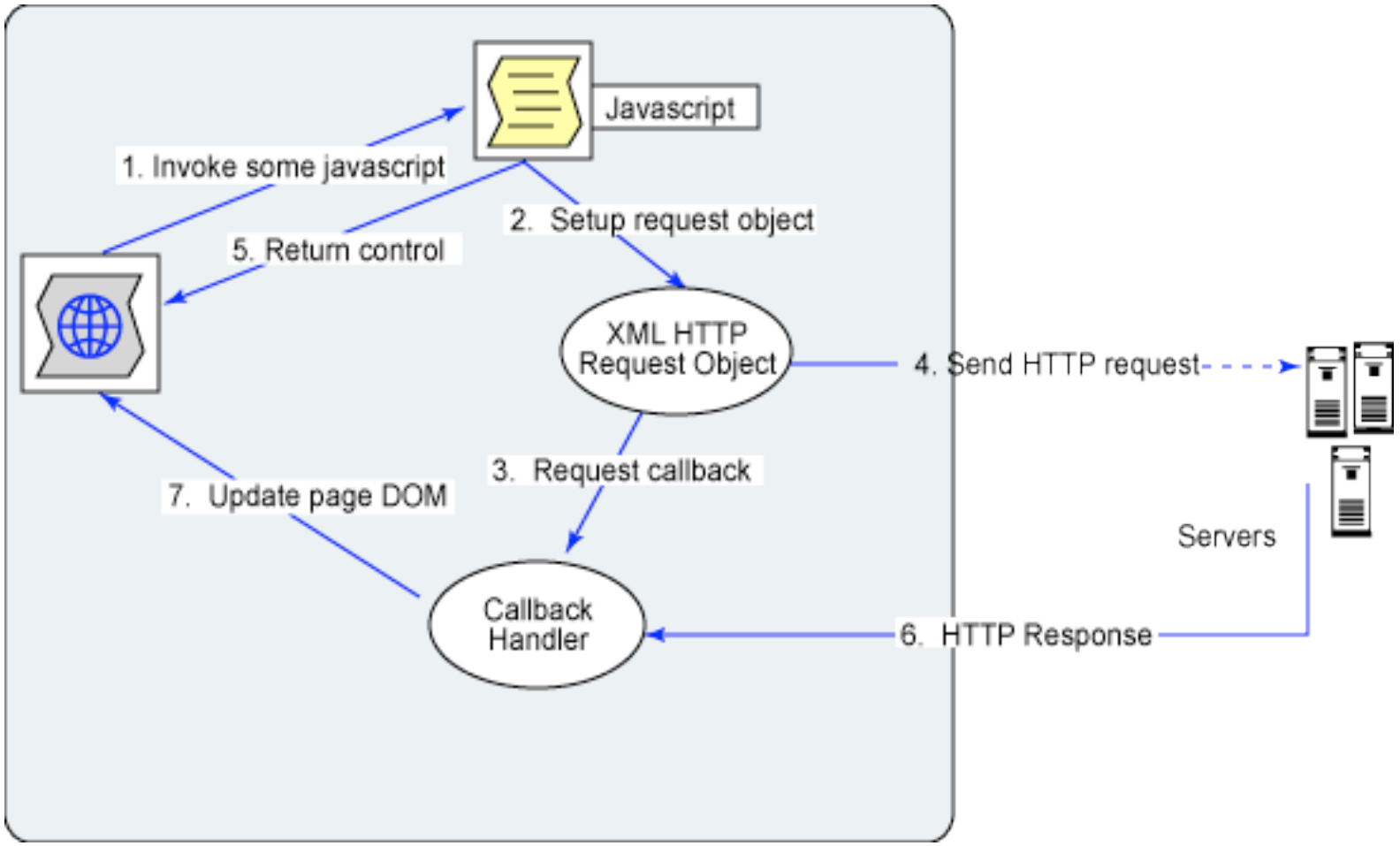
AJAX and Server-Side Scripting

- AJAX applications make particular sense when the data loaded from the server changes dynamically
  - PHP scripts or other server-side dynamics
  - Database connectivity
- 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
- For ease of understanding:
  - First examples in the following deal with static content

Request Construction and Handling

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

Basic Control Flow



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

XMLHttpRequest (XHR)

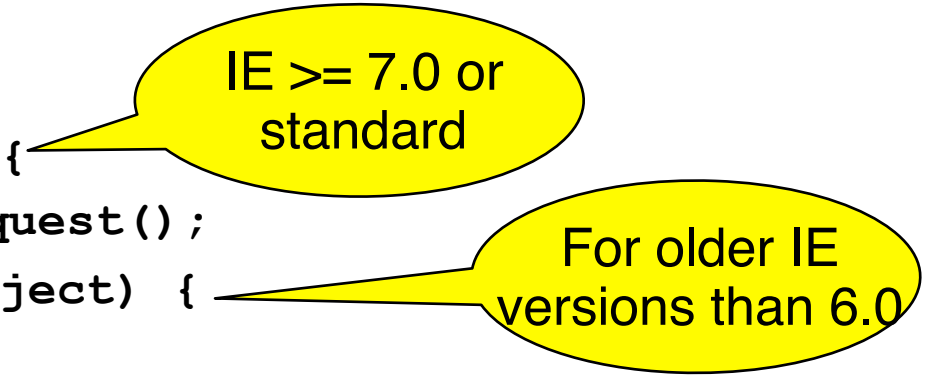
- Outlook Web Access for Internet Explorer 5 (end 90s):
  - XMLHttpRequest object invented at Microsoft
  - Realized as ActiveX object
- Mozilla 1.4 (Netscape 7.1) and derivates (including Firefox):
  - Native XMLHttpRequest object for JavaScript
  - Independent of Active X
- Other manufacturers:
  - Followed step by step: Konqueror, Apple Safari, Opera, iCab
- Since Internet Explorer 7 ActiveX no longer required
  - Just JavaScript
- Under W3C standardization (Level 2 Working Draft August 2011)
- Long term situation for creating XMLHttpRequest object will be:

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

- Currently we have to fight with browser incompatibilities!
  - Frameworks like *Prototype* or *jQuery* can help

Platform Independent Creation of XMLHttpRequest

```
var XMLHTTP = null;
if (window.XMLHttpRequest) {
    XMLHTTP = new XMLHttpRequest();
} else if (window.ActiveXObject) {
    try {
        XMLHTTP = new ActiveXObject("Msxml2.XMLHTTP");
    } catch (ex) {
        try {
            XMLHTTP = new ActiveXObject("Microsoft.XMLHTTP");
        } catch (ex) {}
    }
}
```



Construction of an HTTP Request

- `open()` method of XMLHttpRequest object
  - Note: No interaction with the server yet, despite the name!
- 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:

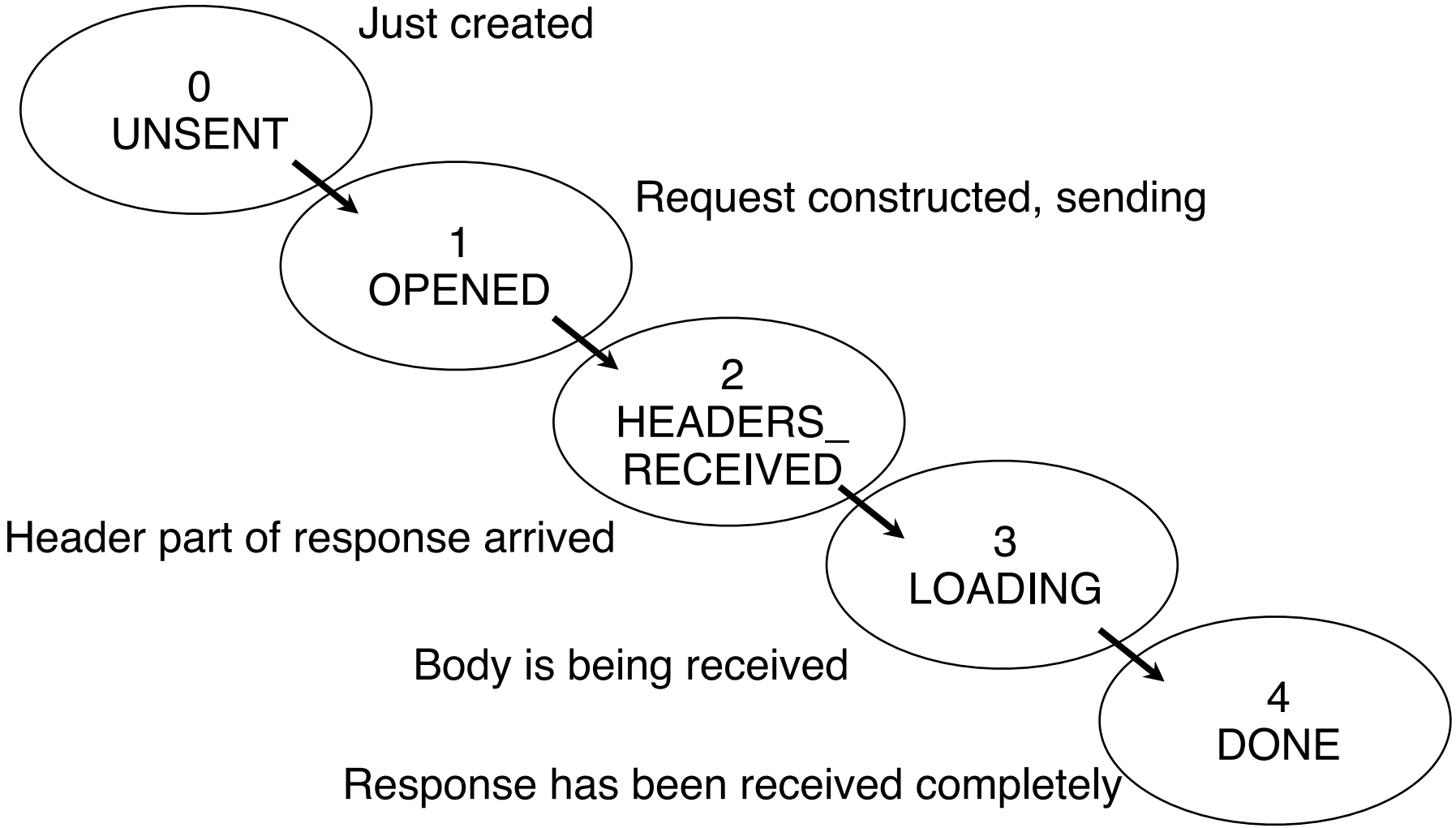
```
XMLHTTP.open("GET", "fibonacci.php?fib=12")
XMLHTTP.open("POST", "/start.html", false, un, pwd);
```

Sending a Request

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

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

States of an XMLHttpRequest Object



Asynchronous Reaction by Event Handler

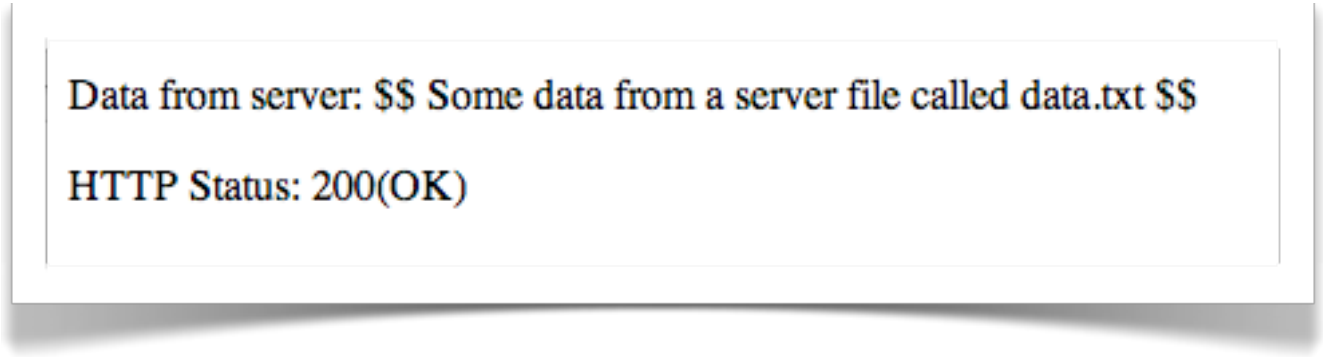
- In order to react to the received response:
  - Function has to be called when state 4 is reached
- Registering an event handler:
  - Callback function, called when event takes place
- Registering an Ajax event handler:
  - Callback method registered with **`XMLHttpRequest`** object
  - Event **`readystatechange`**, called at *any* state change
  - Usual JavaScript code variants for event handler registration
    - » **`XMLHTTP.onreadystatechange =`** ***`function;`***
      `XMLHTTP.addEventListener`
      `("readystatechange",` ***`function`***`);`
- Testing for the current state by attributes of **`XMLHttpRequest`** object:
  - **`readystate`** gives current state (as number)
  - **`status`** gives return code, **`statusText`** gives associated text
- Returned response: **`responseText`** and **`responseXml`** attributes

Example: Very Simple Request

```
...
<body>
<script type = "text/javascript">
  var XMLHTTP = new XMLHttpRequest();

  function dataOutput() {
    if (XMLHTTP.readyState == 4) {
     var d = document.getElementById("data");
     d.innerHTML += XMLHTTP.responseText;
    }
  }

  window.onload = function() {
    XMLHTTP.open("GET", "data.txt", true);
    XMLHTTP.addEventListener("readystatechange", dataOutput);
    XMLHTTP.send(null);
  }
</script>

<p id="data">Data from server: </p>

</body>
```

Local Data and Server Data

- Preceding example:
  - Loads data locally
  - Like URI `"file:data.txt"`
  - HTTP status code is "0", status text is empty
- Usage of HTTP in the request:
  - `XMLHTTP.open ("GET", "http://localhost/~hussmann/data.txt", true);`
  - HTTP status code is 200, status text is "OK" (if the file exists on the server)



simplerequest_server.html

AJAX and XML

- The server response (essentially text):
  - Should have a formal syntax
  - Needs to be analyzed to interpret the response
  - Plain data (strings, numbers) only for small examples
- XML
  - Supports arbitrarily structured information
  - Is fully supported by JavaScript and DOM
- Servers should return data as XML
- Problem (currently):
  - Browser incompatibilities

Example XML Data

```
<?xml version="1.0" encoding="UTF-8"?>
<ResultSet totalResultsAvailable="24900000"
   totalResultsReturned="10">
  <Result>
    <Title>AJAX - Wikipedia</Title>
    <Summary>Background about the web development technique for
   creating interactive web applications.</Summary>
    <Url>http://en.wikipedia.org/wiki/AJAX</Url>
  </Result>
  <Result>
    <Title>Ajax: A New Approach to Web Applications</Title>
    <Summary>Essay by Jesse James Garrett from Adaptive Path.</
   Summary>
    <Url>http://www.adaptivepath.com/p...s/000385.php</Url>
  </Result>
  <Result>
    <Title>AFC Ajax</Title>
    <Summary>Official site. Club information, match reports, news,
   and much more.</Summary>
    <Url>http://www.ajax.nl/</Url>
  </Result>
</ResultSet>
```

From C.Wenz

AJAX Program Creating a HTML Table from XML

- HTML text template (coded in HTML on the result page):

```
<body>
  <p>
    <span id="number">0</span> of
    <span id="total">0</span> hits:
  </p>

  <table id="hits">
    <thead>
     <tr><th>Title</th><th>Description</th><th>URL</th></tr>
    </thead>
  </table>
</body>
```

Script has to fill the missing data from XML response.
Basic structure of script as above.

Adapted from C.Wenz

Transformer Callback Function (1)

```
function dataOutput() {
  if (XMLHTTP.readyState == 4) {
    var xml = XMLHTTP.responseXML;

    var number = document.getElementById("number");
    var total = document.getElementById("total");
    number.innerHTML = xml.documentElement.getAttribute
     ("totalResultsReturned");
    total.innerHTML = xml.documentElement.getAttribute
     ("totalResultsAvailable");

    var hits = document.getElementById("hits");
    var tbody = document.createElement("tbody");

    var results = xml.getElementsByTagName("Result");
    ...
```

Transformer Callback Function (2)

```
... for (var i=0; i<results.length; i++) {
      var line = document.createElement("tr");
      var title = document.createElement("td");
      var description = document.createElement("td");
      var url = document.createElement("td");
      var titletext, descriptiontext, urltext;
      for (var j=0; j<result[i].childNodes.length; j++) {
        var node = results[i].childNodes[j];
        switch (node.nodeName) {
          case "Title":
            titletext = document.createTextNode(
              node.firstChild.nodeValue);
            break;
          case "Summary":
            descriptiontext = document.createTextNode(
              node.firstChild.nodeValue);
            break;
          case "Url":
            urltext = document.createTextNode(
              node.firstChild.nodeValue);
            break;
        }
      }
```

Transformer Callback Function (2)

```
... for (var i=0; i<ergebnisse.length; i++) {
      ...
      for (var j=0; j<ergebnisse[i].childNodes.length; j++) {
      ...
      title.appendChild(titletext);
      description.appendChild(descriptiontext);
      url.appendChild(urltext);

      line.appendChild(title);
      line.appendChild(description);
      line.appendChild(url);
      tbody.appendChild(line);
    }
    hits.appendChild(tbody);
  }
}
```

ajaxXML.html

AJAJ? – Simple Serialization with JSON

- XML Serialization of data
  - Tends to be long
  - Many redundant elements
  - Occupies a lot of bandwidth
- Alternative Serialization: JSON (JavaScript Object Notation)

```
{
"ResultSet":
  {
  "totalResultsAvailable": "24900000",
  "totalResultsReturned": 10,
  "Result":
    [
      {
      "Title": "AJAX - Wikipedia",
      "Url":"http:\/\/en.wikipedia.org\/wiki\/AJAX"
      },
      {
      "Title":"Ajax: A New Approach to Web Applications",
      "Url":"http:\/\/www.adaptivepath.com\/p.../000385.php"
      }
    ]
  }
}
```

A More Realistic Example

- Using a Web service for post code lookup
  - **http://www.geonames.org/ postalCodeLookupJSON? postalcode=*pc* & country=*cy***
  - Returns a JSON text object containing descriptions about the location
    - » Administrative region names, place name, latitude, longitude
- Example:
  - **http://www.geonames.org/postalCodeLookupJSON? postalcode=80333&country=DE**
  - gives the following result:
  - **{"postalcodes": [{"adminCode3":"09162","adminName2":"Oberbayern", "adminName3":"München","adminCode2":"091", "postalcode":"80333","adminCode1":"BY", "countryCode":"DE", "lng":11.5668,"placeName":"München", "lat":48.1452,"adminName1":"Bayern"}]}**

Post Code Example (1)

- HTML:

```
<!html> ...
<body>
  <label for="country">Country</label>
  <select id="country">
    <option value="DE" selected>Germany</option><
    <option value="UK">UK</option>
  </select><br/>
  <label for="postalCode">Postal Code</label>
  <input type="text" id="postalCode" value="82327"><br/>
  <input type="button" id="search"
       value="Search place name"><br/>
  <label for="placeName">Name</label>
       <input type="text" id="placeName" size=28>
</body>
```

- followed by JavaScript...:

Post Code Example (2)

- … followed by JavaScript:

```
<script type = "text/javascript">
  var XMLHTTP = new XMLHttpRequest();
  XMLHTTP.addEventListener
    ("readystatechange", dataOutput);
  function dataOutput() {
    if (XMLHTTP.readyState == 4) {
      var p = document.getElementById("placeName");
      var resultobj =
        JSON.parse(XMLHTTP.responseText);
      p.value = resultobj.postalcodes[0].placeName;
    }
  }
```

- ...continued...

Post Code Example (3)

...continued:

```
    function search() {
      var country =
        document.getElementById("country").value;
      var postalCode =
        document.getElementById("postalCode").value;
        XMLHTTP.open("GET", "http://www.geonames.org/
          postalCodeLookupJSON?postalcode="+postalCode
          +"&country="+country, true);
        XMLHTTP.send(null);
    }
    var f = document.getElementById("search");
    f.addEventListener("click", search, false);
</script>
```

postcode_direct.html

Postcode Lookup “As You Type”

- Using the preceding example, change two lines:

```
var tf = document.getElementById("postalCode");
tf.addEventListener("input", search, false);
```

- Continuousy sending requests when a character is typed
- Can evaluate incomplete input
  - Example: UK/LA1 (complete for instance to LA1 4WY)

postcode_live.html

JavaScript Frameworks to Simplify AJAX Code

- Example: “jQuery” framework
  - Well-known, frequently used
  - Contains many helpful functions for Web applications
  - In particular targeted at simplification of DOM usage

```
$(function() {
  $('#search').click(function() {
    var url = 'http://www.geonames.org/postalCodeLookupJSON?
      postalcode=' + $('#postalCode').val()
      + '&country=' + $('#country').val() + '&callback=?'
    $.getJSON(url, function(data) {
      $('#placeName').val(data.postalcodes[0].placeName);
      });
  });
});
```

postcode_jquery.html
original author Mathieu Carbou

Sajax: PHP Framework for AJAX

- Example for a framework supporting Ajax
- Sajax (Simple Ajax)
  - http://sajax.info
  - Open Source
  - Framework (library) for several scripting languages, including PHP
- Abstracts from technical details of AJAX
  - Write AJAX applications without knowing about XMLHttpRequest
- Basic idea:
  - Create a server-side dynamic function (in PHP)
  - "Export" this function with Sajax (**`sajax_export('`*`functionname`*`')`**)
  - In the JavaScript section of the page, call **`sajax_show_javascript()`** (a PHP function generating JavaScript)
  - Corresponding to the server-side function, now a JavaScript function exists (**`x_`*`functionname`***) which calls the server-side function asynchronously (i.e. a callback function is given as parameter)

Problems with AJAX

- Back button
  - Browsers do not store dynamically modified pages in history
- Polling
  - Browsers send more requests at a more regular pace;
    i.e the base assumptions for Internet traffic engineering change
- Bookmarks
  - It is difficult to set a bookmark at a specific state of a dynamically created flow of pages
  - Solution attempts use the document-internal anchors (#)
- Indexing by search engines

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- Reverse AJAX and Comet
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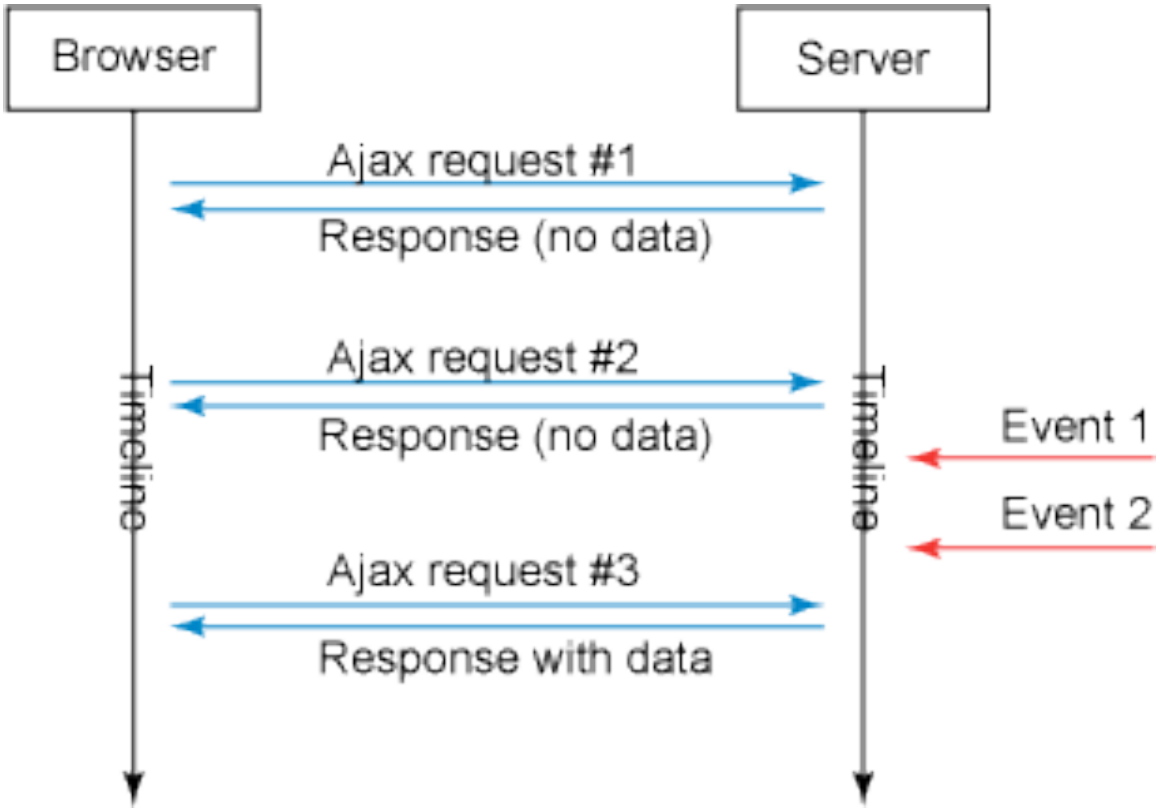
Literature:

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

Client- and Server-Side Events

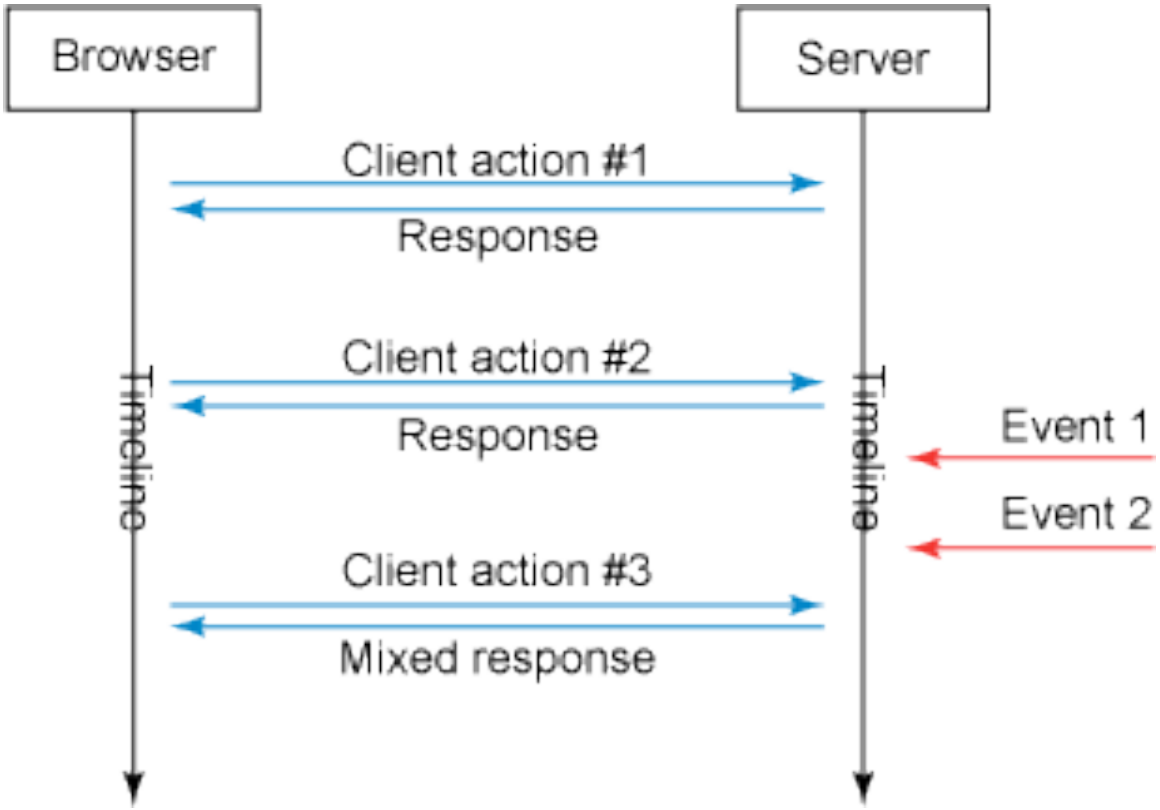
- Cause for asynchronous handling of information: Unpredictable events
  - Dynamic changes of information base independently of browser reloads
- Client-side asynchronous events:
  - Caused by user interaction (other than submitting a request)
  - Examples: Typing into a text field, pointing to a location
  - Asynchronous reaction: Load associated information
  - Client *pulls* information from server
- Server-side asynchronous events:
  - Caused by external party
  - Examples: Incoming mail, user going offline
  - Asynchronous reaction: Update local information
  - Server pushes information to client
- Traditional Ajax is adequate for client-side events
- For server-side events, we have to look for *Reverse Ajax*

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

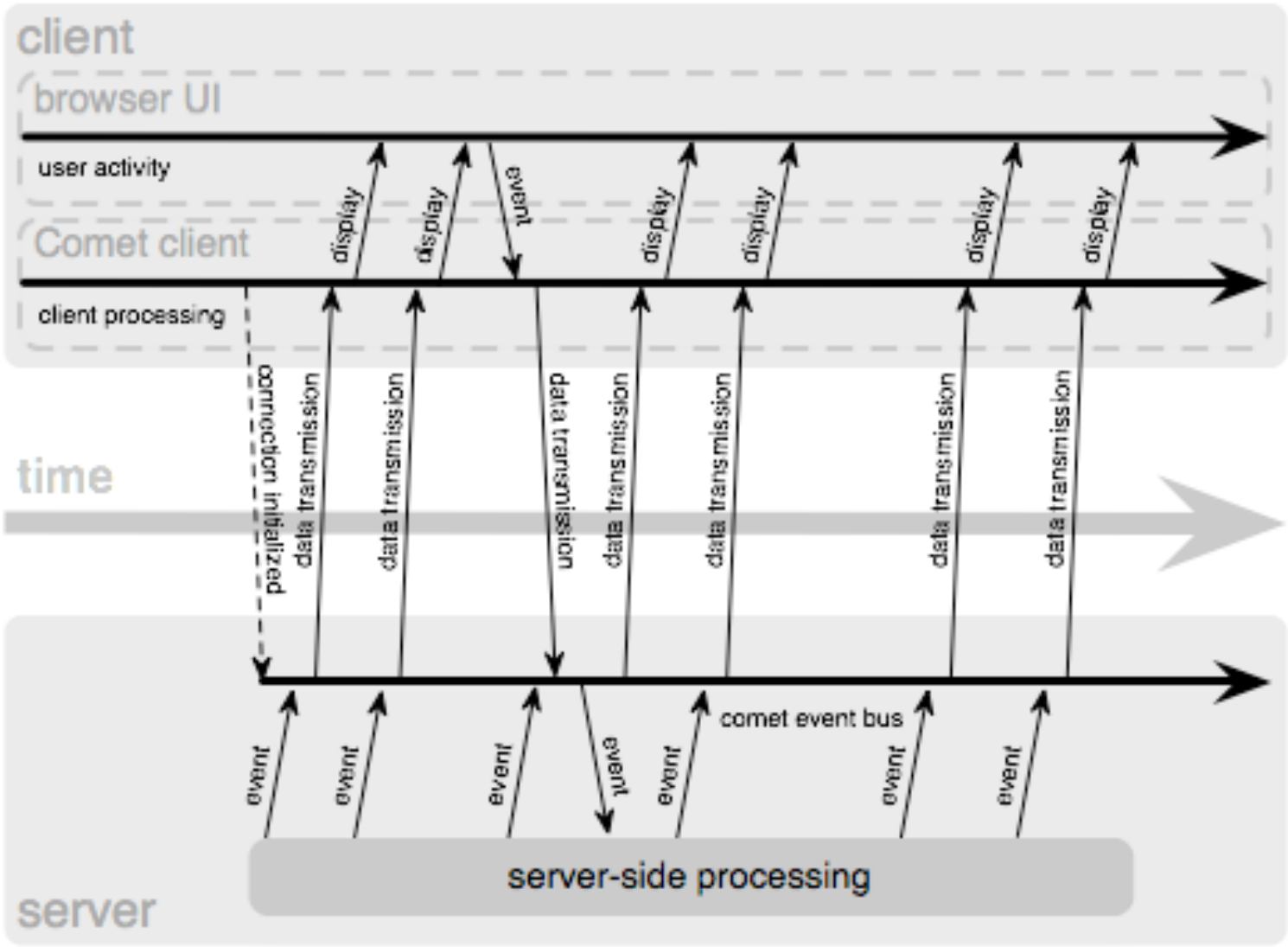


- Assuming different needs for information exchange between client and server
- Whenever a client-triggered request is processed, additional information about latest server-side events is added to the response

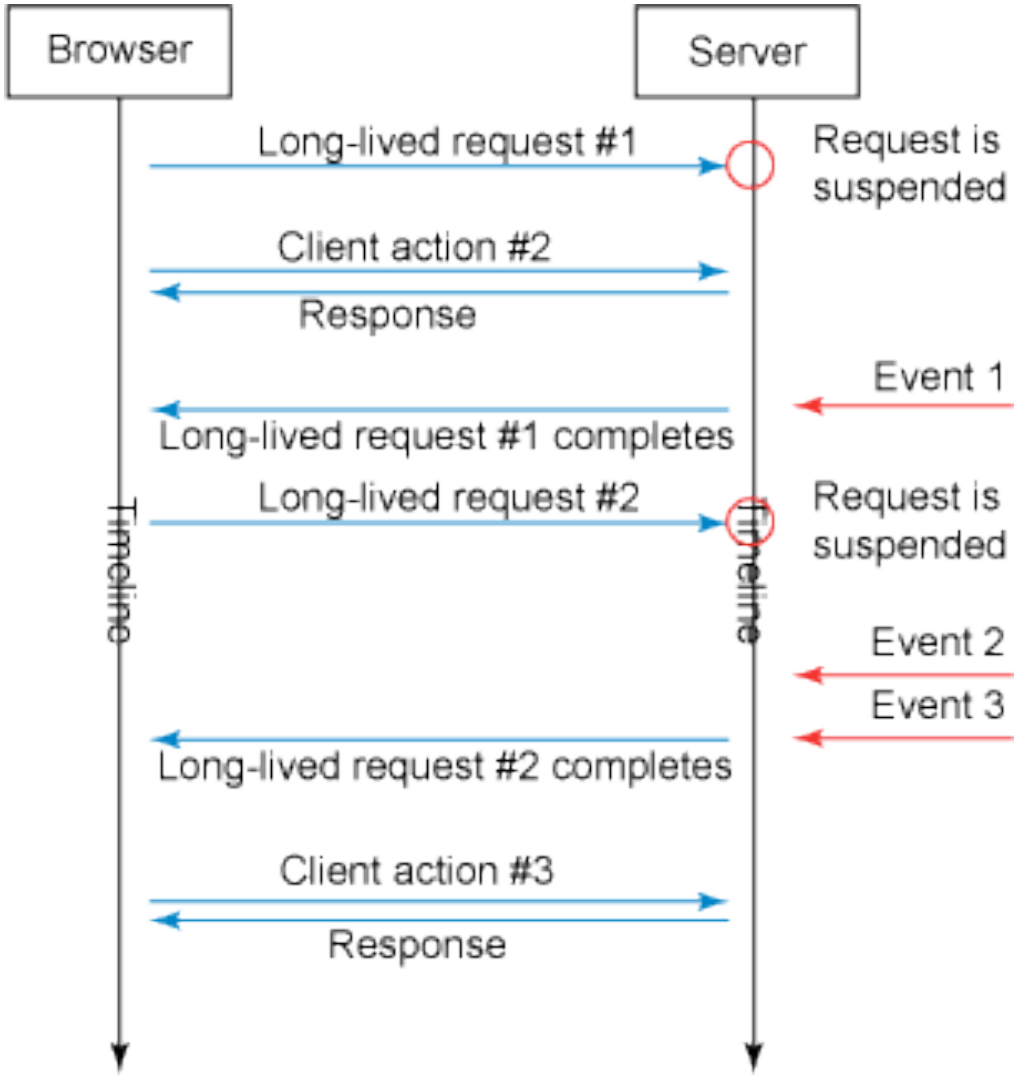
Reverse Ajax with the Comet Model

- Proper support for asynchronous server-side events:
  - Requires availability of a channel for the server to push new information to the client
  - Server-client connections needs to be 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 for anything, and I’m not sure that it should.”
    (Both Ajax and Comet are brands for household cleaners.)
  - Other terms for the same idea: Ajax Push, HTTP Streaming, HTTP server push
    - » Sometimes also Reverse Ajax...

Comet Web Application Model



Reverse Ajax with Comet



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

Connection Management in Comet

- Comet based on *HTTP Streaming*:
  - A single TCP/IP connection is kept open between client and server
  - For instance using the “multipart response” supported by many browsers
    - » Going back to the “server push” feature implemented 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

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Literature:

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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
  - See “post code” example
- 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)

Web Messaging

- HTML5 Web Messaging
  - Draft by W3C, driven by Google
  - Most recent version October 25, 2011
- 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

WebSockets

- Originated in HTML5 (WHAT Working Group)
  - HTML5 Web Sockets specification
  - Full-duplex communication channel between client and server
  - One connection for bi-directional communication, very small latency
    - » “sub 500 millisecond” latency
  - Able to traverse firewalls and proxies
  - Secure connection be used (HTTP/S)
- Has been separated out of HTML5 and submitted to IETF
  - Browser support still limited (mainly Safari & Chrome)
    - » Firefox does not yet support Web sockets
  - Server support still limited (mainly Jetty & Glassfish)
    - » Tomcat does not yet support Web sockets

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);
  -- or myWebSocket.onopen = ...
myWebSocket.addEventListener("message", function);
  -- or myWebSocket.onmessage = ...
myWebSocket.addEventListener("close", function);
  -- or myWebSocket.onclose = ...
```

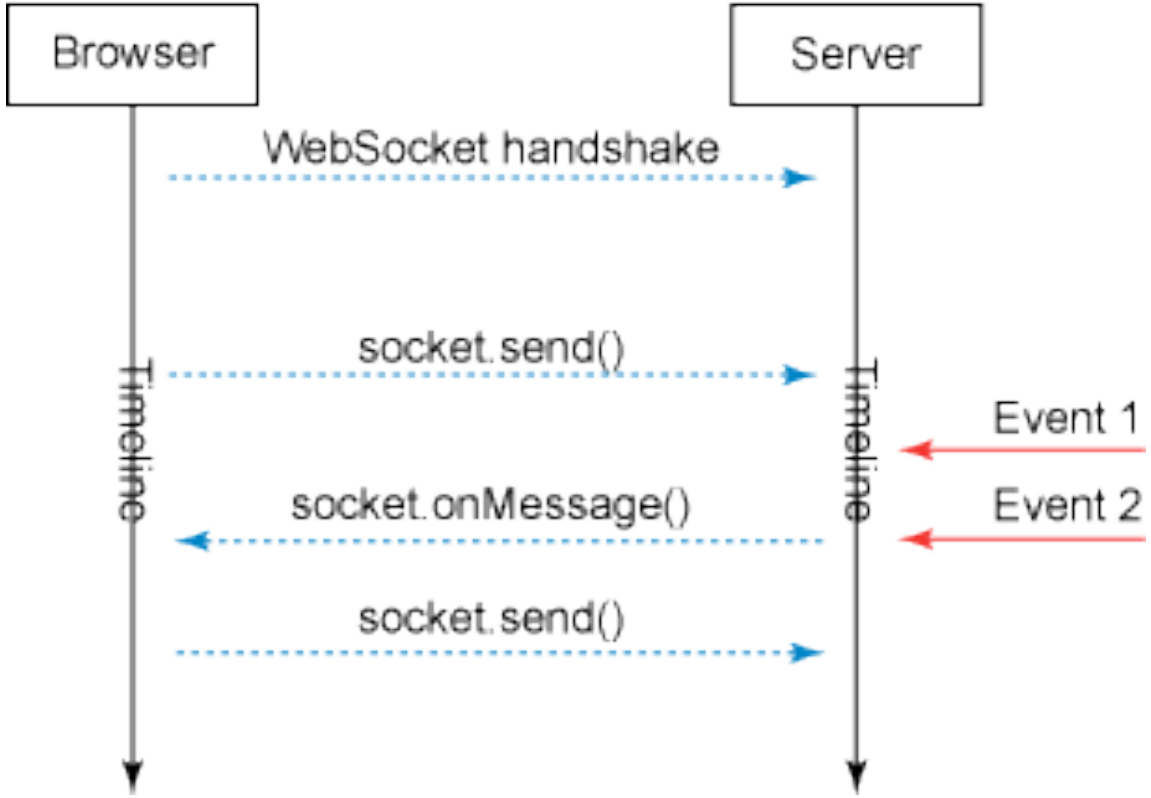
- Send message to server over established connection:

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

- Disconnect from endpoint:

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

Reverse Ajax with WebSockets



- Simple, low-latency solution
- New standard, not yet widely supported
- Some security concerns hinder further spreading

Abstraction APIs: Example Socket.IO

- Abstraction APIs abstract away from the concrete transport mechanism
- Socket.IO API (JavaScript)
  - Chooses between
    Web Sockets
    Flash Sockets
    Comet Long Polling,
    Comet HTTP Streaming
    forever iFrames
    JSONP polling
    depending on circumstances
  - Originally developed for Node JS (JavaScript engine for servers)
  - Symmetrical usage of JavaScript on client and server side
    - » or usage of Java servlets on server side

Chapter 2: Interactive Web Applications

2.5 Interactive Client-Side Scripting (HTML5/JavaScript)

2.6 Data Storage in Web Applications

2.7 Asynchronous Interactivity in the Web

- AJAX
- Reverse AJAX and Comet
- Web Sockets, Web Messaging
- Web Workers

Literature:

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

Threading in Web Browsers

- Thread = Sequence of instructions to be executed
  - May be in parallel to other threads
  - May be part of a larger process (together with other threads)
- 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 t 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