Web 2.0

Lecture 8: Protocols for the Realtime Web

doc. Ing. Tomáš Vitvar, Ph.D.

tomas@vitvar.com • @TomasVitvar • http://vitvar.com

Czech Technical University in Prague

Faculty of Information Technologies • Software and Web Engineering • http://vitvar.com/courses/w20

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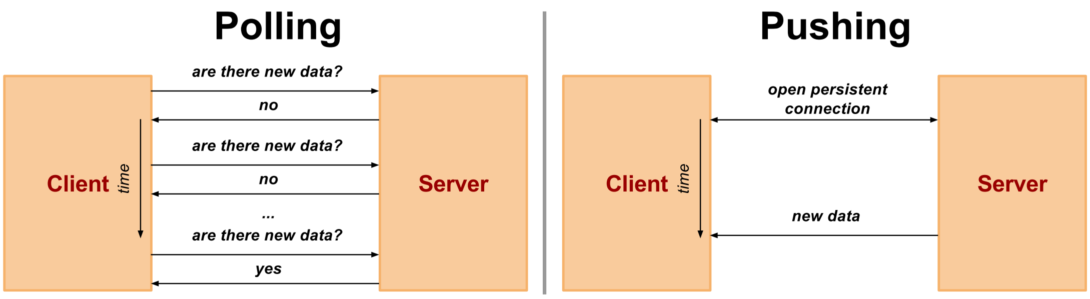
Overview

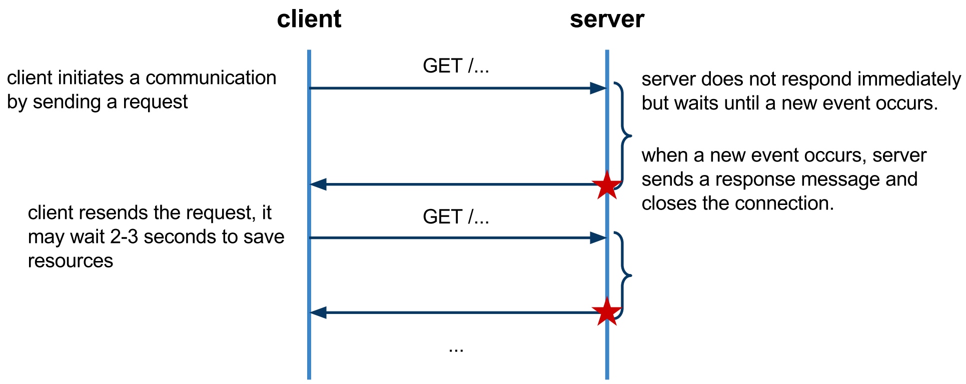
- Long-polling and Streaming
- WebSocket Protocol
- New I/O Model

Pushing and Polling



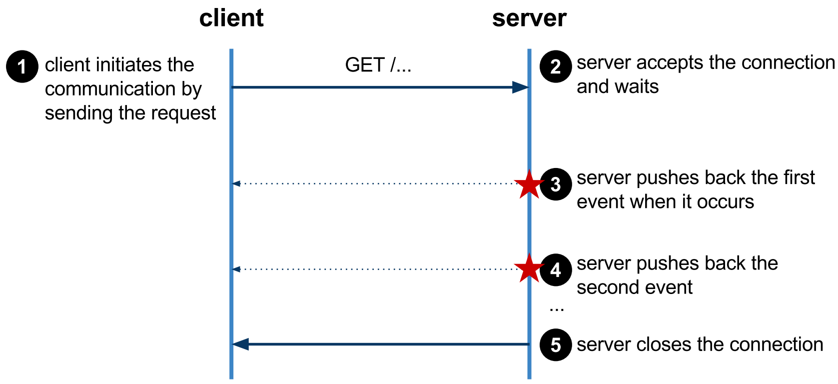
- Conceptual basis in messaging architectures
  - *event-driven architectures (EDA)*
- **HTTP is a request-response protocol**
  - *response cannot be sent without request*
  - *server cannot initiate the communication*
- **Polling** – client periodically checks for updates on the server
- **Pushing** – updates from the server (also called COMET)
  = **long polling** – server holds the request for some time
  = **streaming** – server sends updates without closing the socket

HTTP Long Polling



- Server holds long-poll requests
  - *server responds when an event or a timeout occurs*
  - *saves computing resources at the server as well as network resources*
  - *can be applied over HTTP persistent and non-persistent communication*
- Issues:
  - *maximum time of the request processing at the server*
  - *concurrent requests processing at the server*

HTTP Streaming



- server deffers the response until an event or timeout is available
- when an event is available, server sends it back to client as part of the response; this does not terminate the connection
- server is able to send pieces of response w/o terminating the conn.
  – *using* `transfer-encoding` *header in HTTP 1.1*
  – *using End of File in HTTP 1.0*
  (server omits `content-lenght` *in the response)*

Chunked Response

- Transfer encoding `chunked`
  – *It allows to send multiple sets of data over a single connection*
  – *a chunk represents data for the event*

```
HTTP/1.1 200 OK
Content-Type: text/plain
Transfer-Encoding: chunked

25
This is the data in the first chunk

1C
and this is the second one

0
```

  – *Each chunk starts with hexadecimal value for length*
  – *End of response is marked with the chunk length of 0*
- Steps:
  – *server sends HTTP headers and the first chunk (step 3)*
  – *server sends second and subsequent chunk of data (step 4)*
  – *server terminates the connection (step 5)*

Issues with Chunked Response

- Chunks vs. Events
  - *chunks cannot be considered as app messages (events)*
  - *intermediaries might "re-chunk" the message stream*
    → *e.g., combining different chunks into a longer one*
- Client Buffering
  - *clients may buffer all data chunks before they make the response available to the client application*
- HTTP streaming in browsers
  - *Server-sent events*

Server-Sent Events

- W3C specification
  - *part of HTML5 specs, see Server-Sent Events*
  - *API to handle HTTP streaming in browsers by using DOM events*
  - *transparent to underlying HTTP streaming mechanism*
    → *can use both chunked messages and EOF*
  - *same origin policy applies*
- `EventSource` interface
  - *event handlers:* `onopen`, `onmessage`, `onerror`
  - *constructor* `EventSource(url)` – *creates and opens the stream*
  - *method* `close()` – *closes the connection*
  - *attribute* `readyState`
    → `CONNECTING` – *The connection has not yet been established, or it was closed and the user agent is reconnecting.*
    → `OPEN` – *The user agent has an open connection and is dispatching events as it receives them.*
    → `CLOSED` – *The conn. is not open, the user agent is not reconnecting.*

Example

- Initiating `EventSource`

```
if (window.EventSource != null) {
  var source = new EventSource('your_event_stream.php');
} else {
  // Result to xhr polling :(
}
```

- Defining event handlers

```
source.addEventListener('message', function(e) {
  // fires when new event occurs, e.data contains the event data
}, false);

source.addEventListener('open', function(e) {
  // Connection was opened
}, false);

source.addEventListener('error', function(e) {
  if (e.readyState == EventSource.CLOSED) {
    // Connection was closed
  }
}, false);
```

– *when the conn. is closed, the browser reconnects every ~3 seconds*
→ *can be changed using* `retry` *attribute in the message data*

Event Stream Format

- Format
  – *response's* `content-type` *must be* `text/event-stream`
  – *every line starts with* `data:`, *event message terminates with 2* `\n` *chars.*
  – *every message may have associated* `id` *(is optional)*

```
id: 12345\n
data: first line\n
data: second line\n\n
```

- JSON data in multiple lines of the message

```
data: {\n
data: "msg": "hello world",\n
data: "id": 12345\n
data: }\n\n
```

- Changing the reconnection time
  – *default is 3 seconds*

```
retry: 10000\n
data: hello world\n\n
```

Server-side implementation

- Java Servlet
  - *method* `doGet`

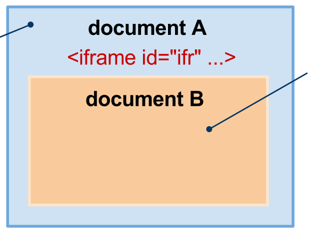
```java
public void doGet(HttpServletRequest req, HttpServletResponse resp)
    throws IOException {

    // set http headers
    resp.setContentType("text/event-stream");
    resp.setHeader("cache-control", "no-cache");

    // current time in milliseconds
    long ms = System.currentTimeMillis();

    // push data to the client for 20 seconds
    // client should reconnect when the connection is closed
    while (System.currentTimeMillis() - ms < 20000) {
        resp.getWriter().print("data: servlet runs for " +
            (System.currentTimeMillis() - ms)/1000 + " seconds.\n\n");
        resp.getWriter().flush();
        try {
            Thread.sleep(4000);
        } catch (InterruptedException e) {
            // do nothing;
        }
    }
}
```


Other Technologies

- Cross-document messaging

script in document A

```
var o document.getElementById("ifr");
o.contentWindow.postMessage("Hello world",
   "http://example.org/")
```



script in document B

```
window.addEventListener('message', receiver, false);
function receiver(e) {
  if (e.origin == 'http://example.com') {
    if (e.data == 'Hello world') {
      e.source.postMessage('Hello', e.origin);
    } else {
      alert(e.data);
    }
  }
}
```

  - *The use of Cross Document Messaging for streaming*
    1. *The client loads a streaming resource in a hidden* `iframe`
    2. *The server pushes a JavaScript code to the* `iframe`
    3. *The browser executes the code as it arrives from the server*
    4. *The embedded iframe's code posts a message to the upper document*
- Channel API
  - *Google Technology for streaming API for AppEngine*
  - *not based on HTTP streaming*
  - *utilizes XMPP capabilities + hidden iframe at client-side*

Overview

- Long-polling and Streaming
- WebSocket Protocol
- New I/O Model

WebSocket

- Specifications
  – *IETF defines WebSocket Protocol*
  – *W3C defines WebSocket API*
- Design principles
  – *a new protocol*
    → browsers, web servers, and proxy servers need to support it
  – *a layer on top of TCP*
  – *bi-directional communication between client and servers*
    → low-latency apps without HTTP overhead
  – *Web origin-based security model for browsers*
    → same origin policy, cross-origin resource sharing
  – *support multiple server-side endpoints*
- Two phases
  – *Handshake – as an* ***upgrade*** *of a HTTP connection*
  – *data transfer – the protocol-specific on-the-wire data transfer*

Handshake – Request

- Request
  - *client sends a following HTTP request to upgrade the connection to WebSocket*

```
GET /chat HTTP/1.1
Host: server.example.com
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Key: dGhlIHNhbXBsZSBub25jZQ==
Sec-WebSocket-Origin: http://example.com
Sec-WebSocket-Protocol: chat, superchat
Sec-WebSocket-Version: 7
```

  - `Connection` – *request to upgrade the protocol*
  - `Upgrade` – *protocol to upgrade to*
  - `Sec-WebSocket-Key` – *a client key for later validation*
  - `Sec-WebSocket-Origin` – *origin of the request*
  - `Sec-WebSocket-Protocol` – *list of sub-protocols that client supports (proprietary)*

Handshake – Response

- Response
  - *server accepts the request and responds as follows*

```
HTTP/1.1 101 Switching Protocols
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Accept: s3pPLMBiTxaQ9kYGzzhZRbK+xOo=
Sec-WebSocket-Protocol: chat
```

    → `101 Switching Protocols` – *status code for a successful upgrade*
    → `Sec-WebSocket-Protocol` – *a sub-protocol that the server selected from the list of protocols in the request*
    → `Sec-WebSocket-Accept` – *a key to prove it has received a client WebSocket handshake request*
  - *Formula to compute* `Sec-WebSocket-Accept`

```
Sec-WebSocket-Accept = Base64Encode(SHA-1(Sec-WebSocket-Key +
  "258EAFA5-E914-47DA-95CA-C5AB0DC85B11"))
```

    → `SHA-1` – *hashing function*
    → `Base64Encode` – *Base64 encoding function*
    → `"258EAFA5-E914-47DA-95CA-C5AB0DC85B11"` – *magic number*

Data Transfer

- After successful handshake
  - *socket between the client and the "resource" at the server is established*
  - *client and the server can both read and write from/to the socket*
  - *No HTTP headers overhead*
- Data Framing
  - *defines a format for data transmitted in TCP packets*
  - *payload length, closing frame, ping, pong, type of data (text/binary), etc. and payload (message data)*

WebSocket API

- Client-side API
  - *clients to utilize WebSocket, supported by Chrome, Safari*
  - *Hides complexity of WebSocket protocol for the developer*
- JavaScript example

```
// ws is a new URL schema for WebSocket protocol; 'chat' is a sub-protocol
var connection = new WebSocket('ws://server.example.org/chat', 'chat');

// When the connection is open, send some data to the server
connection.onopen = function () {
  // connection.protocol contains sub-protocol selected by the server
  console.log('subprotocol is: ' + connection.protocol);
  connection.send('data');
};

// Log errors
connection.onerror = function (error) {
  console.log('WebSocket Error ' + error);
};

// Log messages from the server
connection.onmessage = function (e) {
  console.log('Server: ' + e.data);
};

...

// closes the connection
connection.close()
```

Sockets.IO

- Many options for streaming
  - *long-polling, streaming, iframe, WebSockets*
  - *Not all browsers support WebSockets*
  - *Socket.IO – a layer providing a unified API*
- Sockets.IO
  - *API and JavaScript implementation*
  - *checks the availability of WebSocket protocol*
    → fallback to long-polling or other technologies when not available

```
// creates a new socket
var socket = new io.Socket();

// event handlers
socket.on('connect', function(){
  socket.send('hi!');
})
socket.on('message', function(data){
  alert(data);
})
socket.on('disconnect', function(){})
```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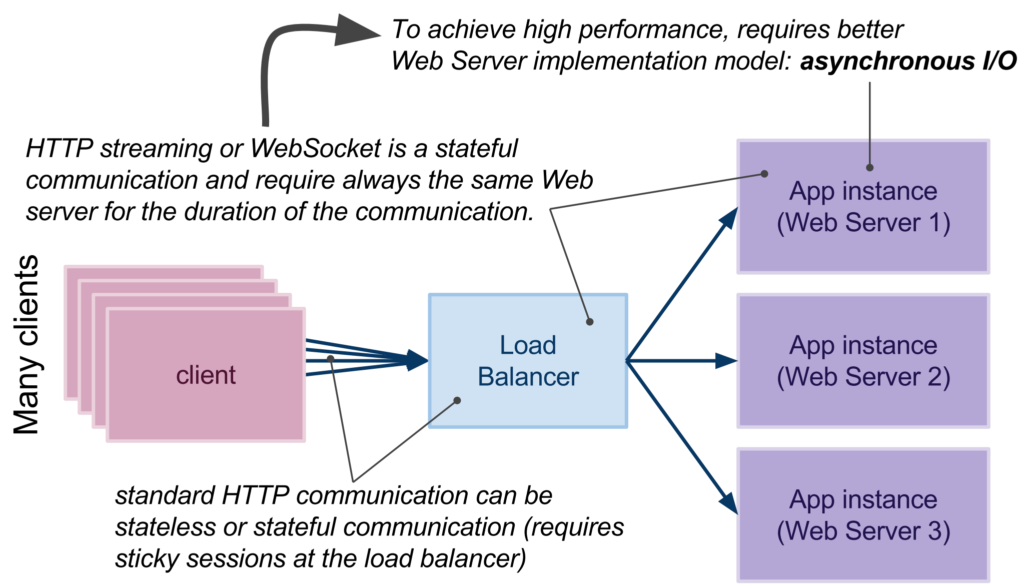
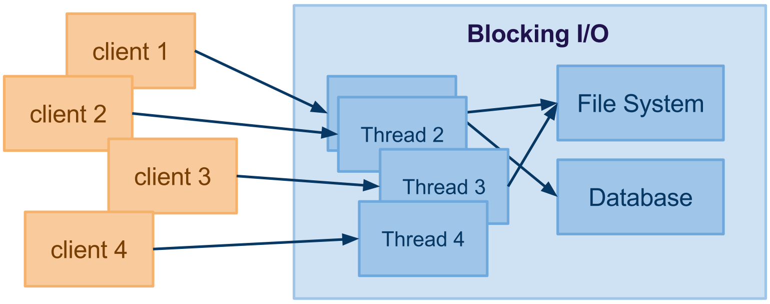
Highly Scalable Web Servers

- Concurrent connections
  - *servers must serve a huge amount of concurrent connections*
  - *Highly scalable Web apps*
    - *→ many concurrent requests at the same time*
    - *→ QPS: 10-100 or more (GAE scales up to 500 QPS)*
  - *more significant with new trends regarding streaming (HTTP and WebSocket)*
- Web server implementation models:
  Synchronous I/O vs. Asynchronous I/O
  - *synchronous I/O (aka blocking I/O)*
    - *→ traditional: server creates a thread for every connection*
  - *asynchronous I/O (aka non-blocking I/O)*
    - *→ new one, server handles processing of requests separately from incoming connections*

Web App Scalability

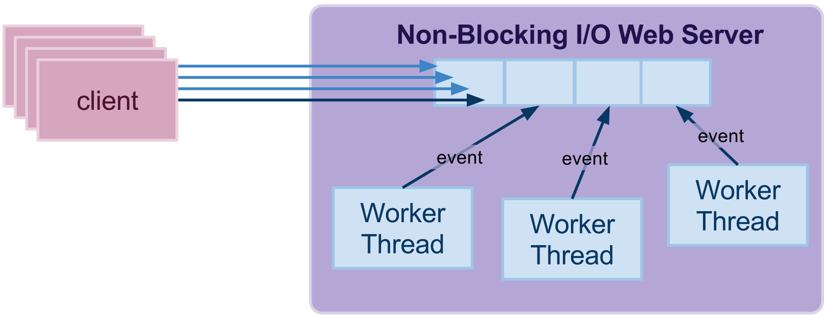


Synchronous I/O Model



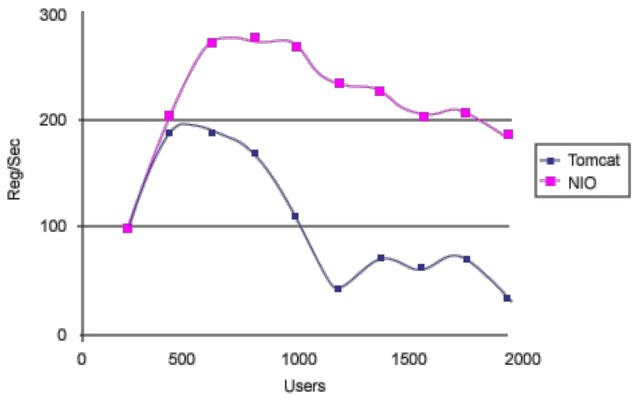
- every request served by a single thread
  – *reserved for the whole processing, the thread is "blocked"*
- when processing of the request is fast, scales well
  – *OS maintains a pool of threads that are reused for new requests*
- when processing of the request requires other interactions with DB/FS or network communication is slow → scaling is bad
  – *more significant with streaming (long polling or HTTP streaming)*
- OS may create couple of hundreds of threads (~1000 is very large)
  – *app may serve over 1K clients easily*

Asynchronous I/O Model



- requests/connections maintained by the OS
- Web server reacts on the events
  – *such as new socket, read, write*
  – *it may create a working thread to perform required processing*
  – *Web server may control the number of Worker Threads*
- significantly less number of working threads as opposed to blocking I/O

Performance Experiment



Non-blocking vs. blocking performance (number of requests per second served by the server vs. number of users), source The Servlet API and NIO: Together at last

- Tomcat – Java-based, uses I/O blocking communication
  – *configured to run up to 2,000 threads*
- NIO – a Web server implemented using Java.NIO (Java New I/O)
  – *only 4 working threads*
- simple HTTP `GET` serving textual content

Emerging Technologies

- Node.js
  – *NodeJS – event-driven I/O framework on JavaScript V8 engine*
  → every I/O as event:

```
// pseudo code; ask for the last edited time of a file
stat( 'somefile', function( result ) {
  // use the result here
} );
...

// web server
var http = require('http');
http.createServer(function (req, res) {
  res.writeHead(200, {'Content-Type': 'text/plain'});
  res.end('Hello World\n');
}).listen(8080, "127.0.0.1");
console.log('Server running at http://127.0.0.1:8080/');
```

  – *runs in Linux/Unix/OS X environments*
  – *Executes your server-side JavaScript code*
  – *Socket.IO as a modul provides a streaming layer*
- Java.NIO
  – *Java New I/O, standard in Java SE 7*