Web 2.0
Lecture 8: Protocols for the Realtime Web

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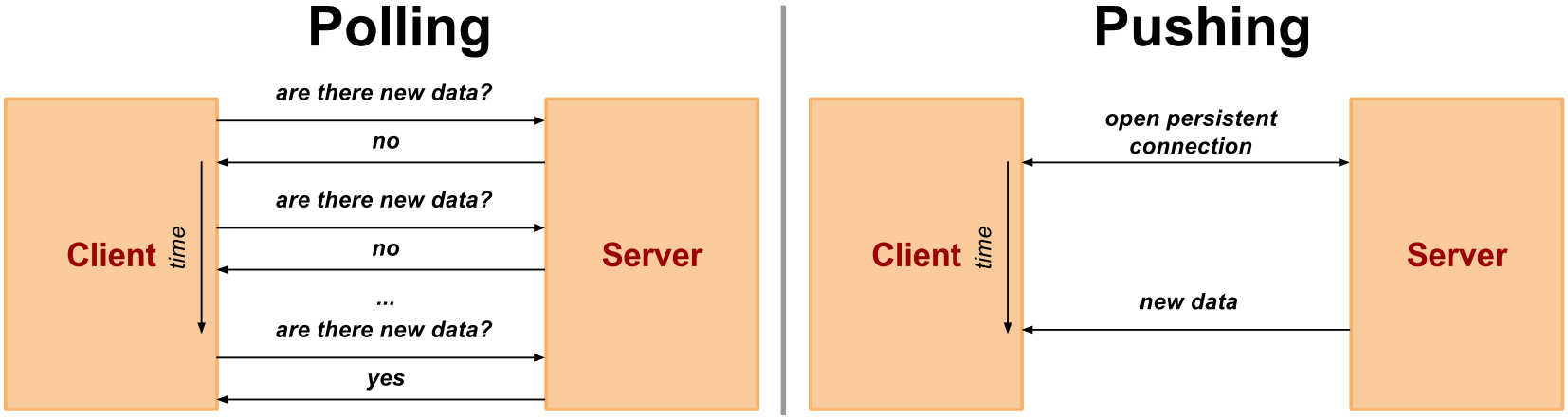
Overview

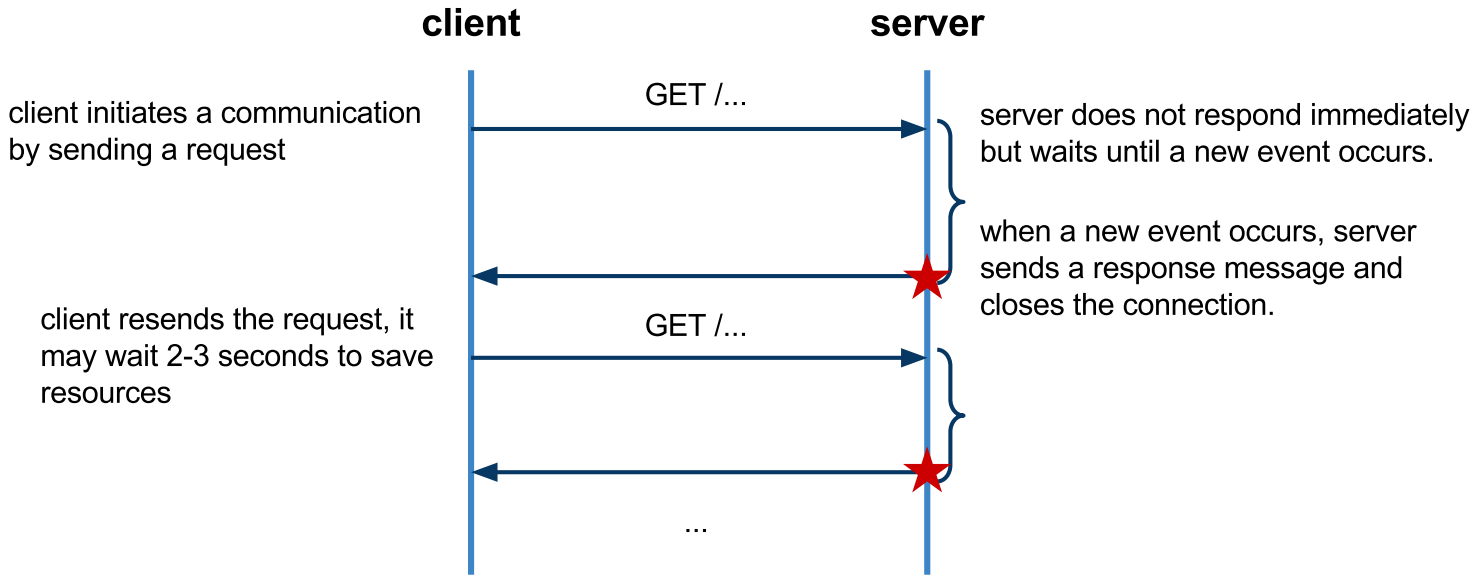
- Long-polling and Streaming
- WebSocket Protocol
- New I/O Model

Pushing and Polling



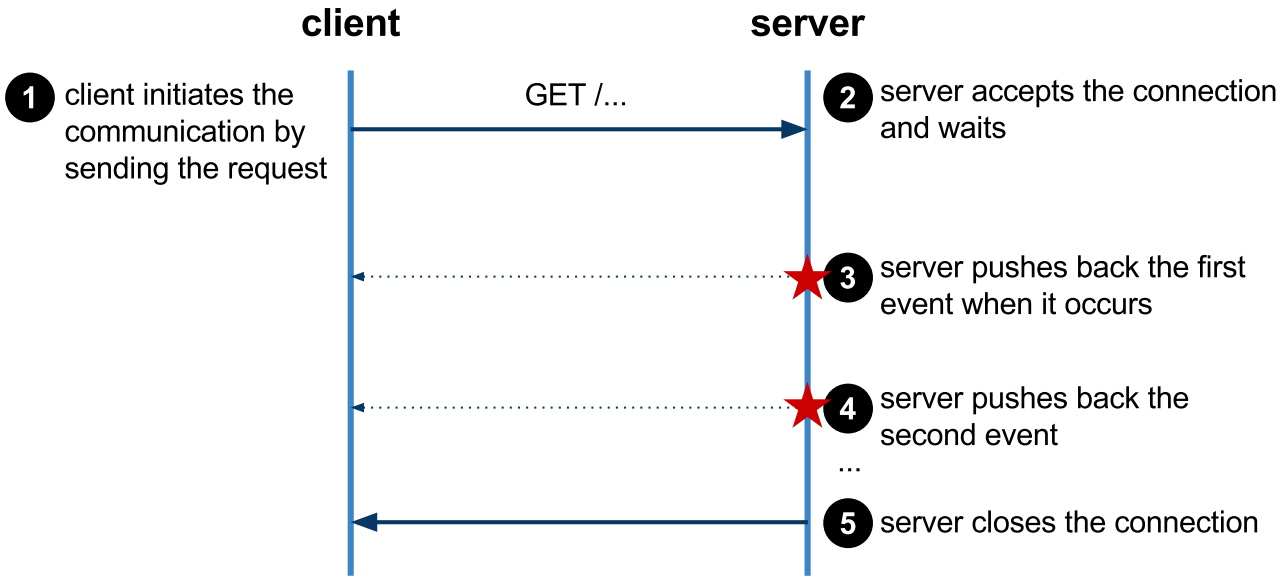
- Conceptual basis in messaging architectures
  - *event-driven architectures (EDA)*
- **HTTP is a request-response protocol**
  - *response cannot be sent without request*
  - *server cannot initiate the communication*
- **Polling** – client periodically checks for updates on the server
- **Pushing** – 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*

```
1  HTTP/1.1 200 OK
2  Content-Type: text/plain
3  Transfer-Encoding: chunked
4
5  25
6  This is the data in the first chunk
7
8  1C
9  and this is the second one
10
11 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`

```
1  if (window.EventSource != null) {
2    var source = new EventSource('your_event_stream.php');
3  } else {
4    // Result to xhr polling :(
5  }
```

- Defining event handlers

```
1  source.addEventListener('message', function(e) {
2    // fires when new event occurs, e.data contains the event data
3  }, false);
4
5  source.addEventListener('open', function(e) {
6    // Connection was opened
7  }, false);
8
9  source.addEventListener('error', function(e) {
10   if (e.readyState == EventSource.CLOSED) {
11     // Connection was closed
12   }
13 }, 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)*

```
1 id: 12345\n
2 data: first line\n
3 data: second line\n\n
```

- JSON data in multiple lines of the message

```
1 data: {\n
2 data: "msg": "hello world",\n
3 data: "id": 12345\n
4 data: }\n\n
```

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

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

Server-side implementation

- Java Servlet
  - *method* `doGet`

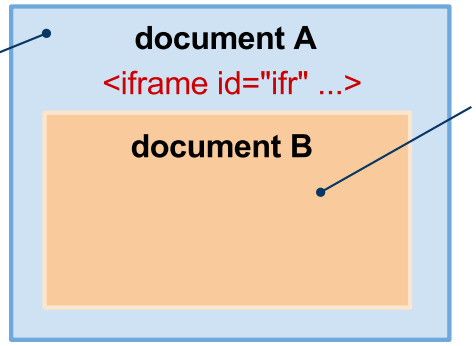
```
1  public void doGet(HttpServletRequest req, HttpServletResponse resp)
2      throws IOException {
3
4      // set http headers
5      resp.setContentType("text/event-stream");
6      resp.setHeader("cache-control", "no-cache");
7
8      // current time in milliseconds
9      long ms = System.currentTimeMillis();
10
11     // push data to the client for 20 seconds
12     // client should reconnect when the connection is closed
13     while (System.currentTimeMillis() - ms < 20000) {
14         resp.getWriter().print("data: servlet runs for " +
15             (System.currentTimeMillis() - ms)/1000 + " seconds.\n\n");
16         resp.getWriter().flush();
17         try {
18             Thread.sleep(4000);
19         } catch (InterruptedException e) {
20             // do nothing;
21         }
22     }
23 }
```

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

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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*

```
1  GET /chat HTTP/1.1
2  Host: server.example.com
3  Upgrade: websocket
4  Connection: Upgrade
5  Sec-WebSocket-Key: dGhlIHNhbXBsZSBub25jZQ==
6  Sec-WebSocket-Origin: http://example.com
7  Sec-WebSocket-Protocol: chat, superchat
8  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*

```
1  HTTP/1.1 101 Switching Protocols
2  Upgrade: websocket
3  Connection: Upgrade
4  Sec-WebSocket-Accept: s3pPLMBiTxaQ9kYGzzhZRbK+xOo=
5  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`

```
1  Sec-WebSocket-Accept = Base64Encode(SHA-1(Sec-WebSocket-Key +
2    "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

```
1  // ws is a new URL schema for WebSocket protocol; 'chat' is a sub-protocol
2  var connection = new WebSocket('ws://server.example.org/chat', 'chat');
3
4  // When the connection is open, send some data to the server
5  connection.onopen = function () {
6    // connection.protocol contains sub-protocol selected by the server
7    console.log('subprotocol is: ' + connection.protocol);
8    connection.send('data');
9  };
10
11 // Log errors
12 connection.onerror = function (error) {
13   console.log('WebSocket Error ' + error);
14 };
15
16 // Log messages from the server
17 connection.onmessage = function (e) {
18   console.log('Server: ' + e.data);
19 };
20
21 ...
22
23 // closes the connection
24 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

```
1  // creates a new socket
2  var socket = new io.Socket();
3
4  // event handlers
5  socket.on('connect', function(){
6    socket.send('hi!');
7  })
8  socket.on('message', function(data){
9    alert(data);
10 })
11 socket.on('disconnect', function(){})
```

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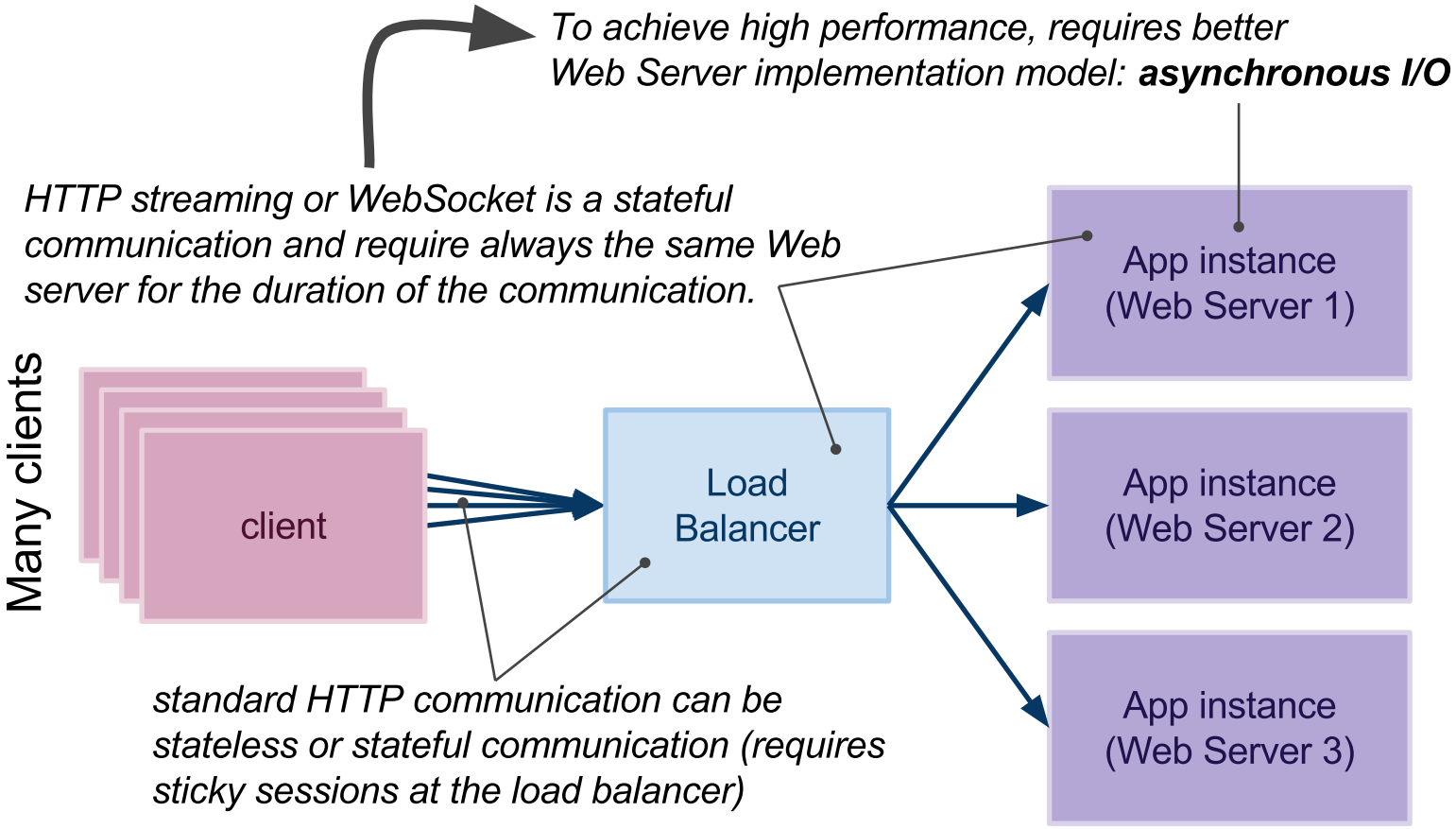
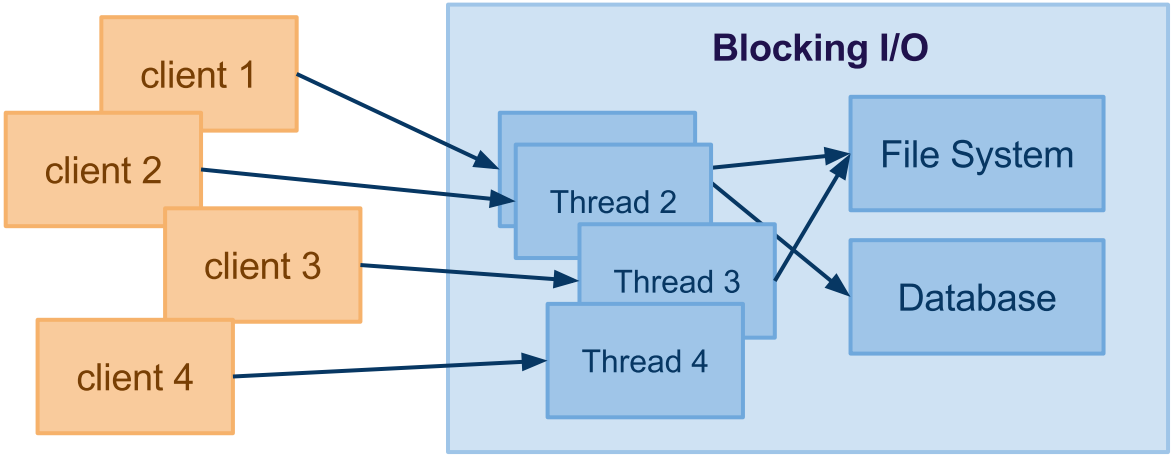
Highly Scalable Web Servers

- 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

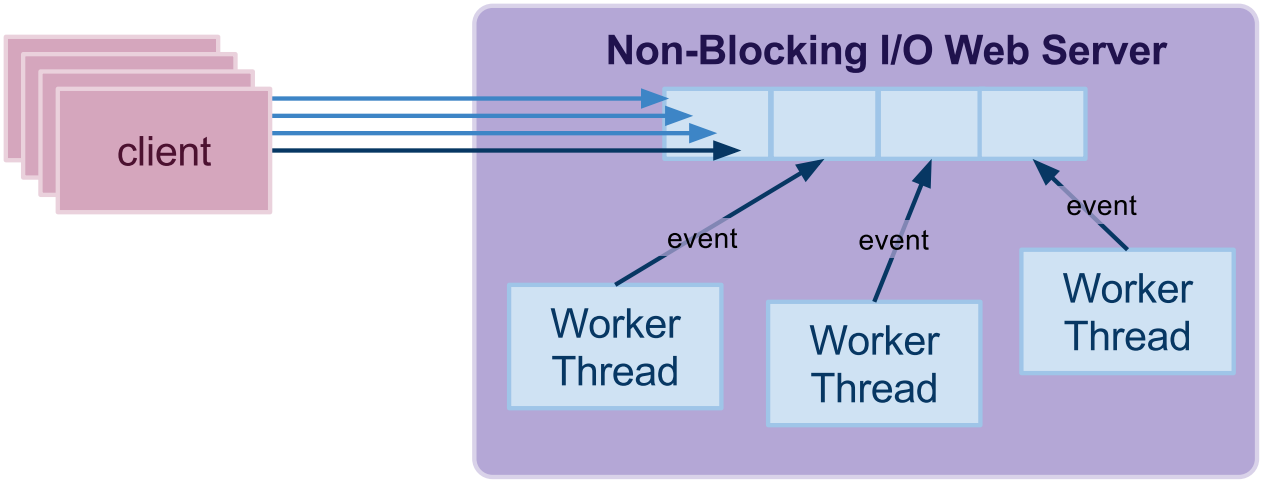


Synchronous I/O Model



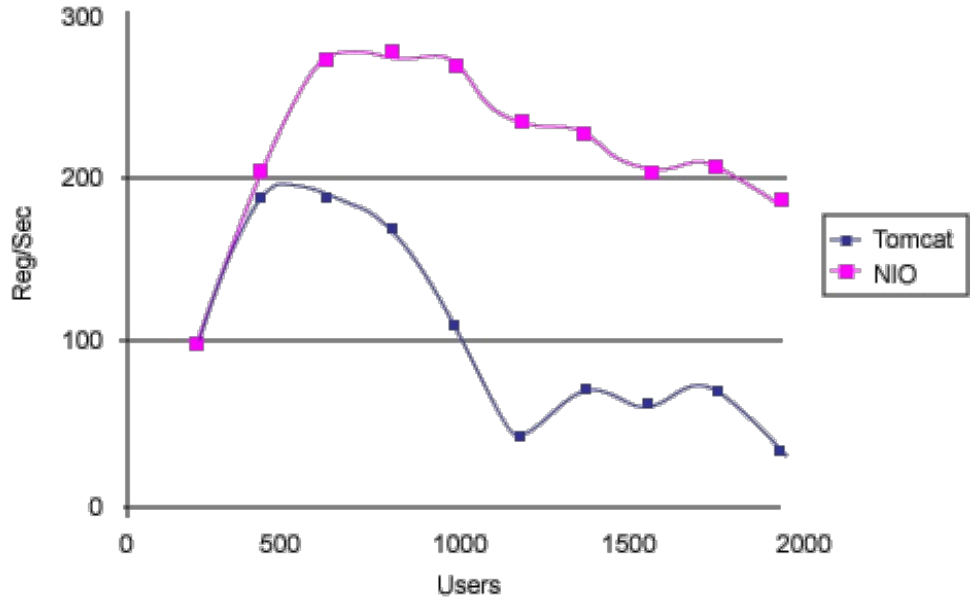
- every request served by a single thread
  - *reserved for the whole processing, the thread is "blocked"*
- when processing of the request is fast, scales well
  - *OS maintains a pool of threads that are reused for new requests*
- when processing of the request requires other interactions with DB/FS 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:

```
1  // pseudo code; ask for the last edited time of a file
2  stat( 'somefile', function( result ) {
3    // use the result here
4  } );
5  ...
6
7  // web server
8  var http = require('http');
9  http.createServer(function (req, res) {
10   res.writeHead(200, {'Content-Type': 'text/plain'});
11   res.end('Hello World\n');
12 }).listen(8080, "127.0.0.1");
13 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*