Middleware Architectures 1

Lecture 3: Communication Protocols

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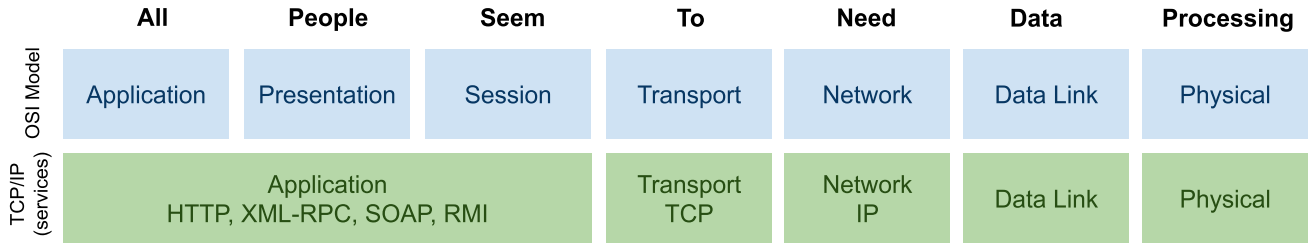
Overview

- Introduction to Application Protocols
  - *Synchronous and Asynchronous Communication*
  - *Introduction to HTTP*

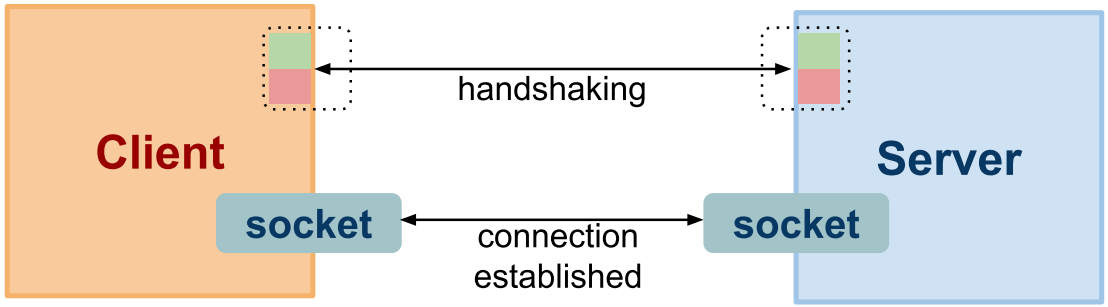
Application Protocols

- Remember this



- App protocols mostly on top of the TCP Layer
  - *use TCP socket for communication*
- Major protocols
  - *HTTP – most of the app protocols layered on HTTP*
    → widely spread
  - *RMI – Remote Method Invocation*
    → Java-specific; vendor-interoperability problem
    → may use HTTP underneath (among other things)
  - *XML-RPC and SOAP – Remote Procedure Call and SOAP*
    → HTTP-based
  - *WebSocket – new protocol part of HTML5*

Socket

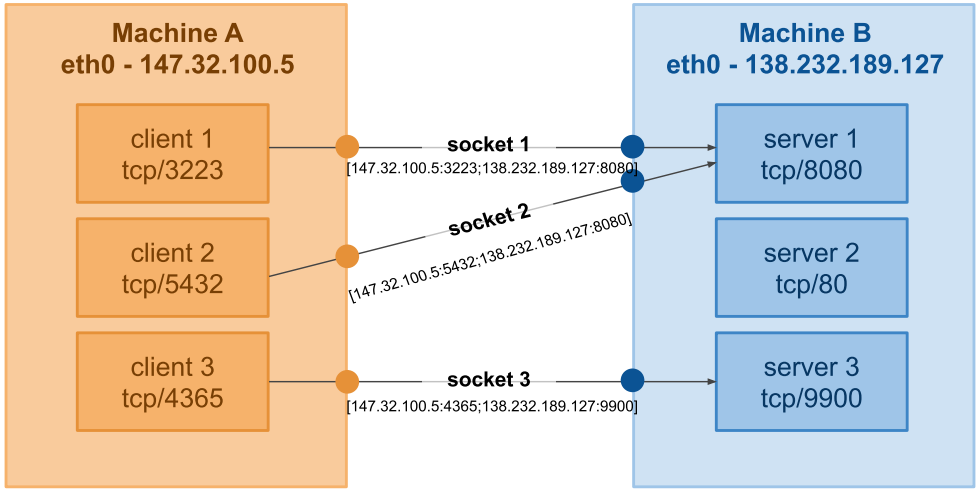


- Handshaking (connection establishment)
  - *The server listens at* `[dst_ip,dsp_port]`
  - *Three-way handshake:*
    - → *the client sends a connection request with TCP flags (SYN, x=rand)*
    - → *the server respons with its own TCP flags (SYN ACK, x+1 y=rand)*
    - → *the client acknowledges the response, can send data along (ACK, y+1 x+1)*
  - *Result is a socket (virtual communication channel) with unique identification:* `socket=[src_ip,src_port;dst_ip,dst_port]`
- Data transfer (resource usage)
  - *Client/server writes/reads data to/from the socket*
  - *TCP features: reliable delivery, correct order of packets, flow control*
- Connection close

New Connection Costs

- Creating a new TCP connection is expensive
  - *It requires to complete a full roundtrip*
  - *It is limited by a network latency, not bandwidth*
- Example
  - *Distance from London to New York is approx. 5500 km*
  - *Communication over a fibre link will take at least 28ms one way*
  - *Three-way handskake will take a minimum of 56ms*
- Connection reuse is critical for any app running over TCP
  - *HTTP Keep-alive*
  - *HTTP pipelining*
- TCP Fast Open (TFO)
  - *TFO allows to speed up the opening of successfive TCP connections*
  - *TCP cookie stored on the client that was established on initial connection*
  - *The client sends the TCP cookie with SYN packet*
  - *The server verifies the TCP cookie and can send the data without final ACK*
  - *Can reduce network transaction latency by 15%*
  - *TFO is supported by Linux in 3.7+ kernels*

Addressing in Application Protocol



- IP addressing: IP is an address of a machine interface
  - *A machine can have multiple interfaces (eth0, eth1, bond0, ...)*
- TCP addressing: TCP port is an address of an app running on a machine and listening on a machine interface
  - *Multiple applications with different TCP ports may listen on a machine interface*
- Application addressing
  - *Additional mechanisms to address entities within an application*
  - *They are out of scope of IP/TCP, they are app specific*
    → *for example, Web apps served by a single Web server*

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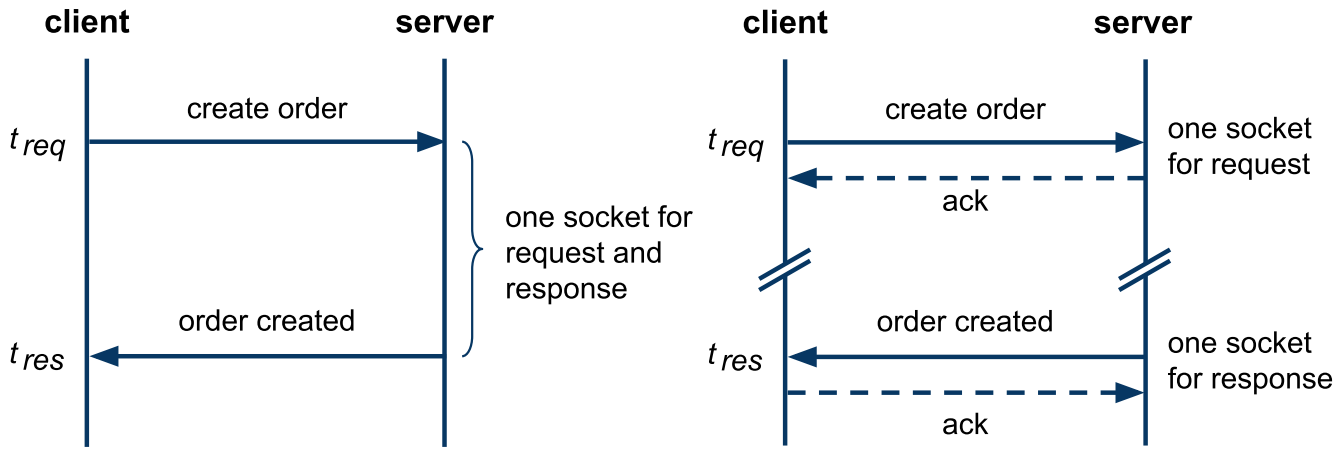
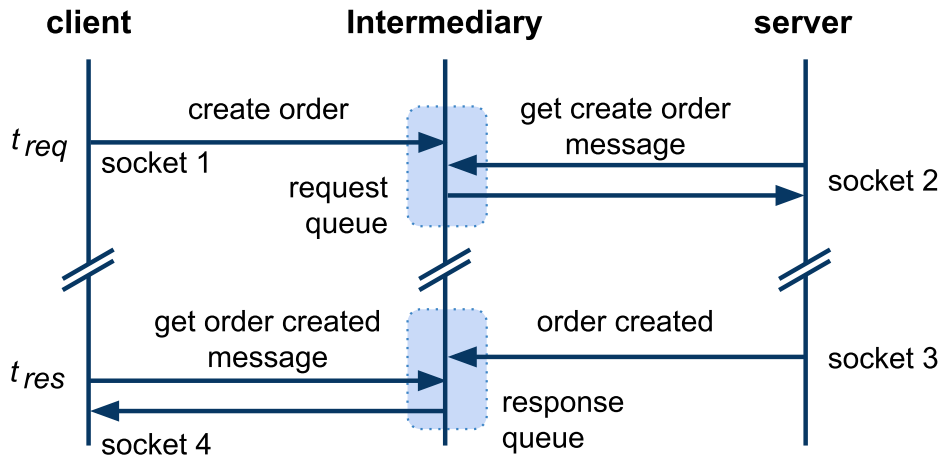
Synchronous and Asynchronous Communication



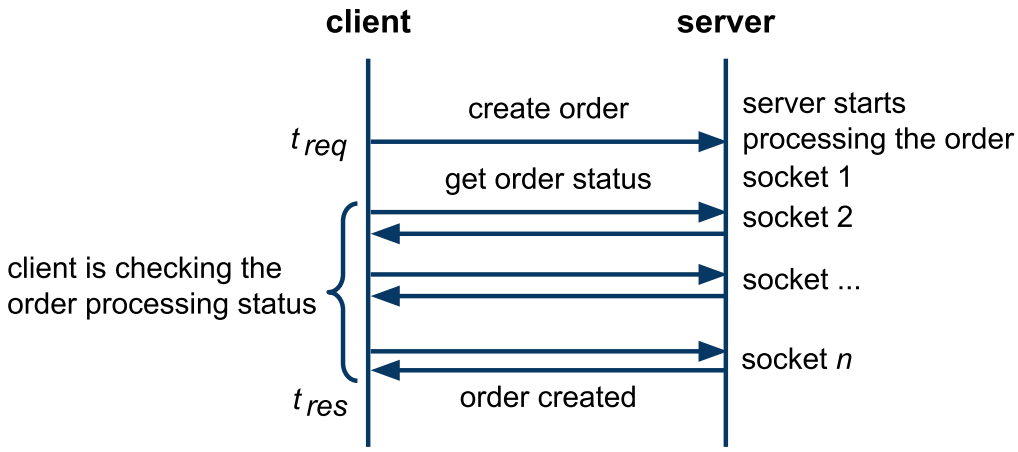
- Synchronous
  - *one socket, $|t_{req} - t_{res}|$ is small*
  - *easy to implement and deploy, only standard firewall config*
  - *only the server defines endpoint*
- Asynchronous
  - *request, response each has socket, client and server define endpoints*
  - *$|t_{req} - t_{res}|$ can be large (hours, even days)*
  - *harder to do across network elements (private/public networks issue)*

Asynchronous via Intermediary



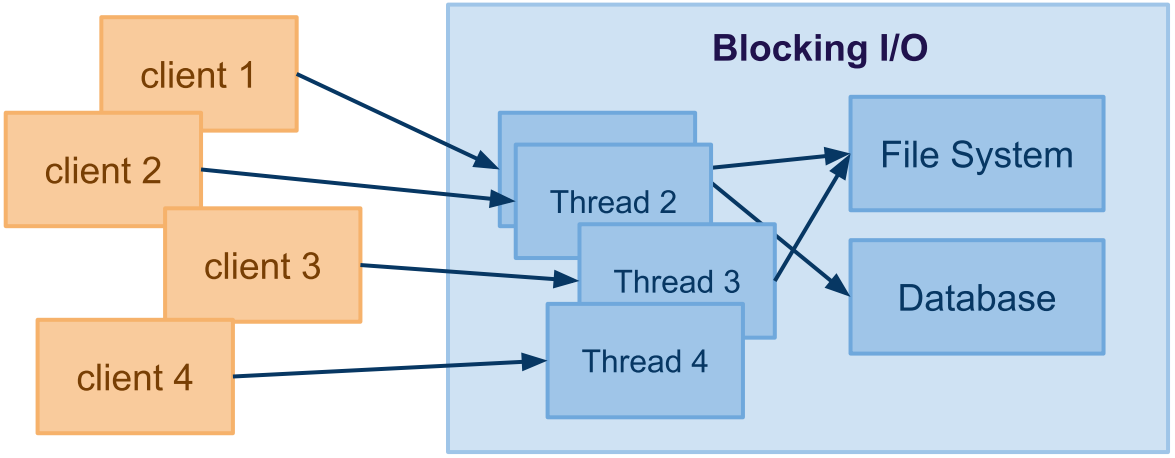
- Intermediary
  - *A component that decouples a client-server communication*
  - *It increases reliability and performance*
    - → *The server may not be available when a client sends a request*
    - → *There can be multiple servers that can handle the request*
- Further Concepts
  - *Message Queues (MQ) – queue-based communication*
  - *Publish/Subscribe (P/S) – event-driven communication*

Asynchronous via Polling



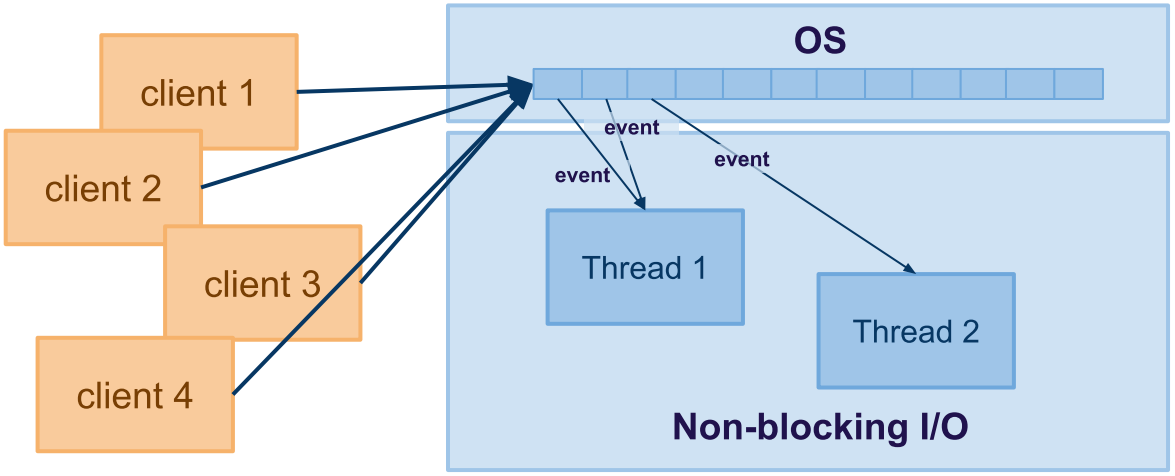
- Polling – only clients open sockets
  - *A client performs multiple request-response interactions*
    - → *The first interaction initiates a process on the server*
    - → *Subsequent interactions check for the processing status*
    - → *The last interaction retrieves the processing result*
- Properties of environments
  - *A server cannot open a socket with the client (network restrictions)*
  - *Typically on the Web (a client runs in a browser)*

Blocking (Synchronous) I/O



- Inbound connection
  - *A server creates a thread for every inbound connection*
  - *For example, 1K connections = 1K threads, big overhead*
  - *A thread is reserved for the entire duration of the request processing*
- Outbound connection
  - *A thread is blocked when outbound connection is made*
  - *When outbound connection is slow, the scalability is poor*

Non-Blocking (Asynchrnous) I/O



- Inbound connections
  - *The connection is maintained by the OS, not the server app*
  - *The Web app registers events, OS triggers events when they occur*
  - *The app may create working threads and controls their number*
- Outound connections
  - *The app registers a callback that is called when the data is available*
  - *Event loop*

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Hypertext Transfer Protocol – HTTP

- Application protocol, basis of Web architecture
  - *Part of HTTP, URI, and HTML family*
  - *Request-response protocol*
- One socket for single request-response
  - *original specification*
  - *have changed due to performance issues*
    - → *many concurrent requests*
    - → *overhead when establishing same connections*
    - → *HTTP 1.1 offers persistent connection and pipelining*
- HTTP is stateless
  - *Multiple HTTP requests cannot be normally related at the server*
    - → *"problems" with state management*
    - → *REST goes back to the original HTTP idea*

HTTP Request and Response

- Request Syntax

```
method uri http-version <crlf>
(header : value <crlf>)*
<crlf>
[ data ]
```

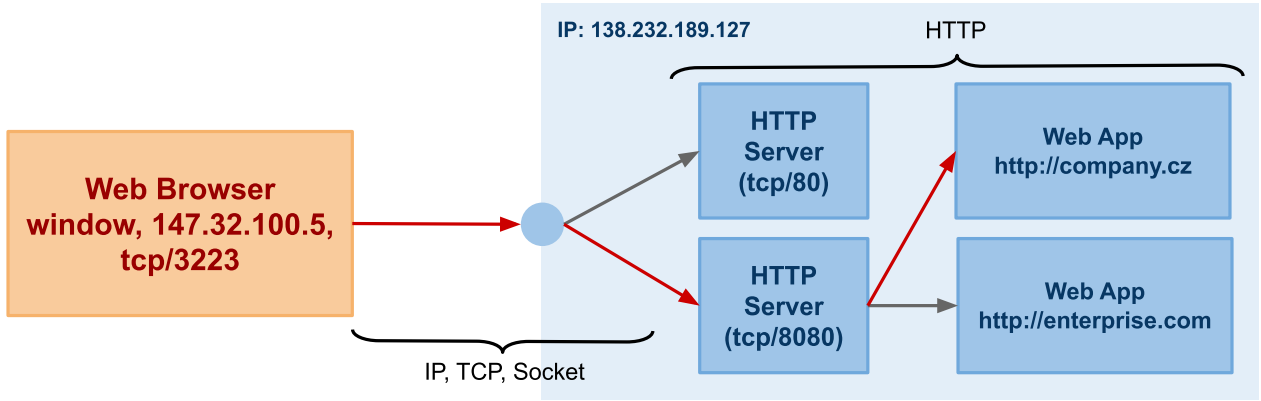
- Response Syntax

```
http-version response-code [ message ]  <crlf>
(header : value <crlf>)*
<crlf>
[ data ]
```

- Semantics of terms

```
method         = "GET" | "POST" | "DELETE" | "PUT" | "HEAD" | "OPTIONS"
uri            = [ path ] [ ";" params ] [ "?" query ]
http-version   = "HTTP/1.0" | "HTTP/1.1"
response-code  = valid response code
header : value = valid HTTP header and its value
data           = resource state representation (hypertext)
```

Serving HTTP Request



- IP and TCP addressing
  1. *User enters URL* `http://company.cz:8080/orders` *to the browser*
  2. *Browser gets an IP address for* `company.cz`, `IP:138.232.189.127`
  3. *Browser and Web Server creates a socket*
     `[147.32.100.5:3223;138.232.189.127:8080]`
- Application addressing
  4. *Browser sends HTTP request, that is, writes following data to the socket*

```
1 GET /orders HTTP/1.1
2 Host: company.cz
```

  5. *Web server passes the request to the web application* `company.cz` *which serves* `GET orders` *and that writes a response back to the socket.*

Virtual Web Server

- Virtual server
  - *Configuration of a named virtual web server*
  - *Web server uses host request header to distinguish among multiple virtual web servers on a single physical host.*
- Apache virtual Web server configuration
  - *Two virtual servers hosted on a single physical host*

```
1  # all IP addresses will be used for named virtual hosts
2  NameVirtualHost *:80
3
4  <VirtualHost *:80>
5          ServerName company.com
6          ServerAdmin admin@company.com
7          DocumentRoot /var/www/apache/company.com
8  </VirtualHost>
9
10 <VirtualHost *:80>
11         ServerName firm.cz
12         ServerAdmin admin@firm.cz
13         DocumentRoot /var/www/apache/firm.cz
14 </VirtualHost>
```

Better Support for HTTP Testing

- Use `curl` to test HTTP protocol

```
Usage: curl [options...] <url>

-X/--request <command>          Specify request command to use
-H/--header <line>              Custom header to pass to server
-d/--data <data>                HTTP POST data
-b/--cookie <name=string/file>  Cookie string or file to read cookies from
-v/--verbose                    Make the operation more talkative
```

- Example

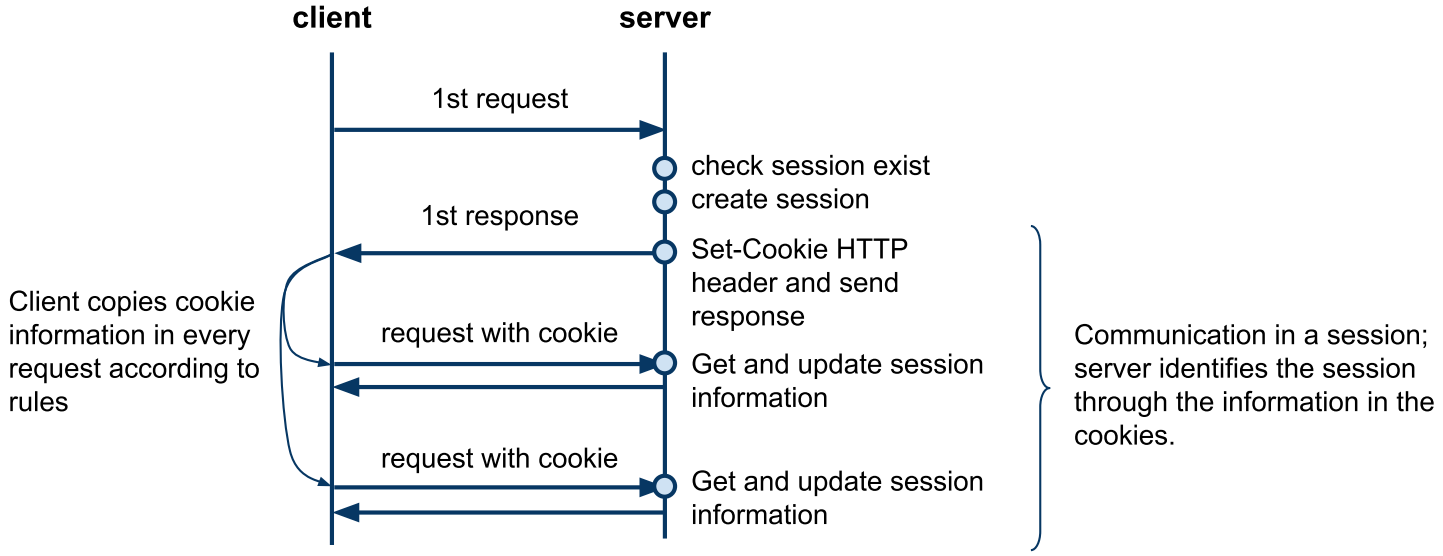
```
curl -v -H "Host: company.cz"  127.0.0.1:8080

* About to connect() to 127.0.0.1 port 8080
*   Trying 127.0.0.1... connected
* Connected to 127.0.0.1 port 8080
> GET / HTTP/1.1
> User-Agent: curl/7.20.0 (i386-apple-darwin10.3.2) libcurl/7.20.0 OpenSSL/0.9.8n
> Accept: */*
> Host: company.cz
>
< HTTP/1.1 201 OK
< Connection: keep-alive
< Content-Type: plain/text
<
< This is the response...
```

State Management

- HTTP is a stateless protocol – original design
  - *No information to relate multiple interactions at server-side*
    - → *Except* `Authorization` *header is copied in every request*
    - → *IP addresses do not work, one public IP can be shared by multiple clients*
- Solutions to check for a valid state at server-side
  - ***Cookies*** *– obvious and the most common workaround*
    - → *RFC 2109 – HTTP State Management Mechanism*
    - → *Allow clients and servers to talk in a context called* ***sessions***
  - ***Hypertext*** *– original HTTP design principle*
    - → *App states represented by resources (hypermedia), links define transitions between states*
    - → *Adopted by the REST principle* ***statelessness***

Interaction with Cookies

- Request-response interaction with cookies
  - *Session is a logical channel maintained by the server*



- Stateful Server
  - *Server remembers the session information in a server memory*
  - *Server memory is a non-persistent storage, when server restarts the memory content is lost!*

Set-Cookie and Cookie Headers

- `Set-Cookie` response header

```
set-cookie = "Set-Cookie:" cookie ("," cookie)*
  cookie     = NAME "=" VALUE (";" cookie-av)*
  cookie-av = "Comment" "=" value
            | "Domain" "=" value
            | "Max-Age" "=" value
            | "Path" "=" value
```

  - `domain` – *a domain for which the cookie is applied*
  - `Max-Age` – *number of seconds the cookie is valid*
  - `Path` – *URL path for which the cookie is applied*

- `Cookie` request header. A client sends the cookie in a request if:
  - `domain` *matches the origin server's fully-qualified host name*
  - `path` *matches a prefix of the request-URI*
  - `Max-Age` *has not expired*

```
cookie  = "Cookie:" cookie-value (";" cookie-value)*
  cookie-value    = NAME "=" VALUE [";" path] [";" domain]
  path            = "$Path" "=" value
  domain          = "$Domain" "=" value
```

  - `domain`, *and* `path` *are values from corresponding attributes of the* `Set-Cookie` *header*