Middleware Architectures 2

Lecture 7: HTTP/2

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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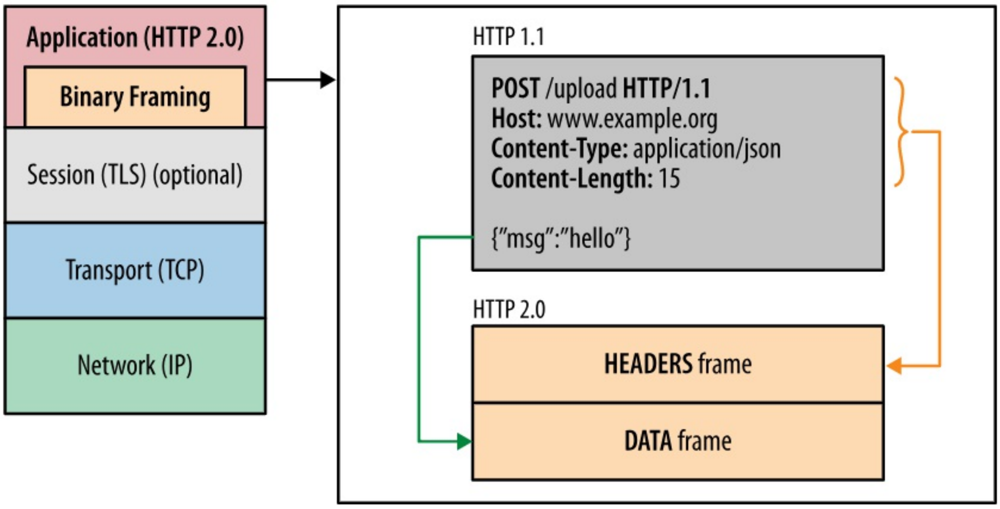
Overview

- Developed from SPDY (2009) experimental protocol by Google
  - *May 2015: RFC 7540 (HTTP/2) and RFC 7541 (HPACK)*
  - *HTTP/2 standards extend (not replace) the previous HTTP standards*
- HTTP/1.x limitations
  - *HTTP/1.x clients need to use multiple connections to achieve concurrency*
  - *unnecessary network traffic – request and response headers not compressed*
  - *no effective resource prioritization*
- Primary goals
  - *Reduction of latency*
  - *enabling full request and response multiplexing*
  - *minimize protocol overhead via efficient compression of HTTP header fields*
  - *support for request prioritization and server push*
- HTTP/2 does not modify application semantics of HTTP
  - *HTTP metods, URIs, header fields are the same*
  - *HTTP/2 modifies* ***how data is formatted and transported*** *in communication*
- Literature and source
  - *I. Grigorik: High Performance Browser Networking, O'Reilly Media, Inc. 2013. ISBN: 9781449344757*

Binary Framing Layer

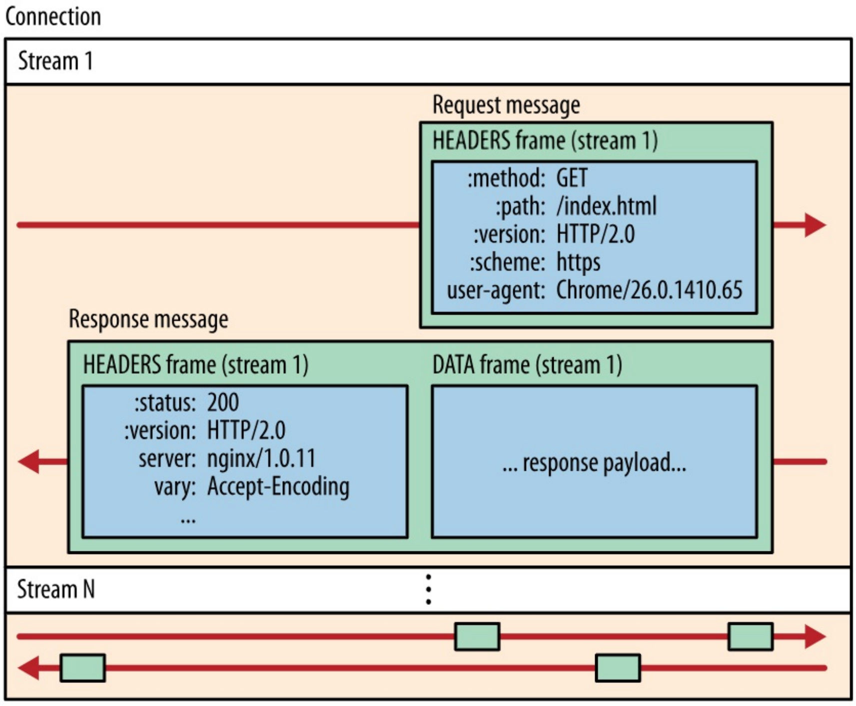
- Binary framing layer
  - *defines how HTTP messages are encapsulated and transferred*
  - *communication is split into messages and frames in binary format*



HTTP/2 Communication

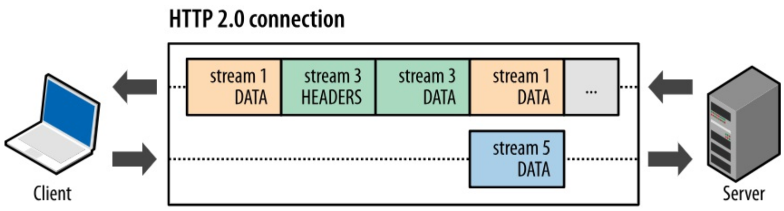
- Data exchange between the client and server
  - *break down of the communication into frames*
  - *frames are mapped to messages that belong to a particular stream*
  - *communication is* ***multiplexed within a single TCP connection****.*
- Stream
  - *bi-directional flow of bytes in a connection*
  - *may carry one or more messages*
  - *may have a priority*
- Message
  - *a sequence of frames*
  - *it maps to logical request or response message*
- Frame
  - *the smallest unit of communication*
  - *each has a frame header which identifies a stream to which it belongs.*

Streams, Messages, and Frames



Request and Response Multiplexing

- Parallel requests
  - *HTTP/1.x can use HTTP pipelining; they open multiple connections*
    - → *browser typically opens up six connections*
    - → *One response can be delivered at a time (response queuing) per connection*
      - → *Head of line blocking problem*
  - *HTTP/2 allows full request and response multiplexing*
    - → *Allows for parallel in-flight streams*
    - → *There are 3 parallel streams in the below example:*

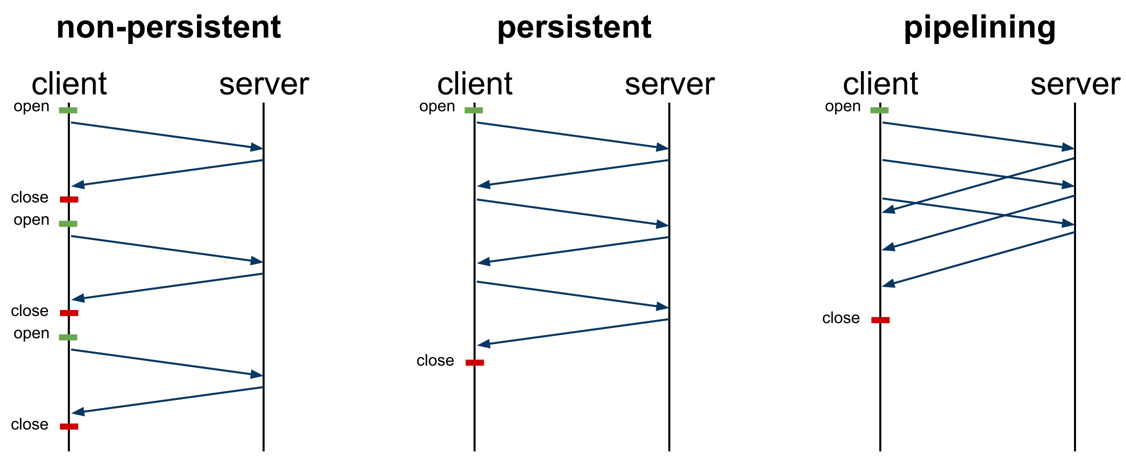


- Performance benefits
  - *Interleave requests/responses in parallel without blocking any one.*
  - *Deliver lower page load times by eliminating unnecessary latency*
  - *Improve utilization of available network capacity*

Request and Response Multiplexing Benefits

- Interleave multiple requests and responses
  – *Requests or responses are not blocked on any other requests or response*
- A single TCP connection
  – *Multiple requests and responses can be delivered in parallel*
- Remove HTTP/1.x workarounds
  – *Concatenated files*
  – *Image sprites*
  – *Domain sharding*
- Deliver lower page load times
  – *Eliminates unnecessary latency*
  – *Improves utilization of available newtork capacity*

HTTP/1.x Optimization



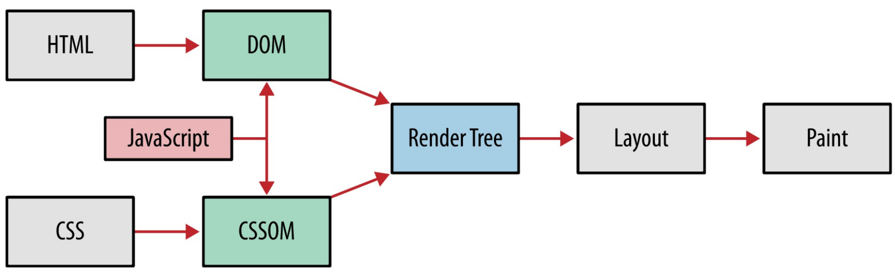
One connection

- Multiplexing allows for:
  - *all connections are persisted*
  - *only one connection required per origin*
- Advantages
  - *significant reduction of the overall protocol overhead*
  - *use of fewer connections reduces the memory and processing footprint along the full connection path (client, intermediaries, origin servers)*
  - *reduces operational costs and improves network capacity*

  - *Improves performance of HTTPS deployments*
    → fewer expensive TLS handshakes
    → better session reuse
    → overall reduction in required client and server resources

Browser Request Prioritization

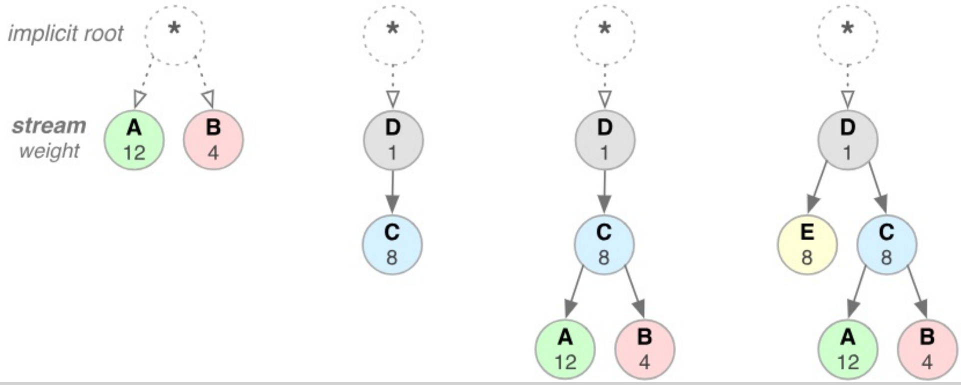
- Not all resources have equal priority when rendering a page
  - *HTTP/2 stream prioritization*
  - *Requests are prioritized based on type of asset, location on the page, and learned priority from previous visits*
    → If page loading was blocked on an asset, the asset priority gets increased
- DOM, CSSOM and JavaScript



  - *HTML document is critical to construct DOM*
  - *CCS is required to construct CSSOM*
  - *Both DOM and CSSOM construction can be blocked on JavaScript resources*
    → A script can issue `doc.write` *and block DOM parsing and construction*
    → A script can query for a computed style of an object; the script can block on CSS

Stream Prioritization

- Purpose
  - *Messages split into **frames** which are delivered in multiplexed **streams***
  - *The order in which frames are delivered is important for a good performance*
  - *Client can define stream prioritization*
    - → *optimizations in the browser, change prioritization based on user interaction*
- Streams' weights and dependency
  - *Each stream can be assigned an integer weight between 1 and 256.*
  - *Each stream may be given an explicit dependency on another stream.*



Stream Prioritization (cont.)

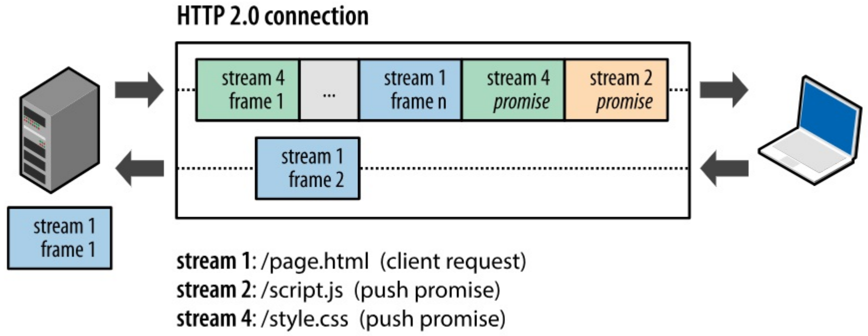
- Dependency
  - *referencing the unique identifier of another stream as its parent*
  - *if the identifier is omitted the stream is dependent on the "root stream"*
  - *The parent stream should be allocated resources ahead of its dependencies.*
    - → *"Please process and deliver response D before response C"*
- Weights
  - *Sibling streams have resources allocated as per their weights*
  - *Example*
    - → *Sum all the weights:* `4 + 12 = 16`
    - → *Divide each stream weight by the total weight:* `A = 12/16`, `B = 4/16`
    - → *Stream* `A` *receives* `3/4` *and stream* `B` *receives* `1/4` *of available resources;*

Flow control

- Prevent sender from receiving data it doest not want
  - *Receiver is busy or under heavy load*
  - *Receiver is willing to allocate fixed amount of resources for a stream*
- Examples
  - *Client request a video stream; a user pauses the stream*
    → the client wants to pause the stream delivery to avoid buffering
  - *A proxy server has a fast downstream and slow upstream*
    → the proxy server can control how quickly the downstream delivers data to match the speed of upstream
    → better control of resource usage
  - *Similar problems as in TCP flow control*
    → TCP flow control has no app-level API to regulate delivery of streams
- Flow control
  - *Sender and receiver both advertise stream flow control window in bytes*
    = the size of the available buffer space to hold the incoming data
  - *exhanged by special* `SETTINGS` *and* `WINDOW_UPDATE` *frames*
  - *Flow control is hop-by-hop, not end-to-end*
    → an intermediary can set its own flow control

Server push

- Ability to send multiple responses for a single request
  - *A response to the request is sent back*
  - *Additonal resources can be pushed without client requesting them*
  - *Hypertext – "server knows what the client will need"*



- Similar to resource inlining
  - *A resource is pushed to the client in HTML/CSS resource*
- Performance benefits
  - *Cached by the client, reused across pages, multiplexed, declined by the client*

Push promise

- PUSH_PROMISE frames
  – *A singnal that the server intents to push resources to the client*
  – *The client needs to know which resources the server intends to push to avoid creating duplicate requests for these resources.*
- After the client receives PUSH_PROMISE
  – *it may decline the stream (via* RST_STREAM *frame)*
    → *For example, when the resource is already in the cache*
    → *As for inline resources, this is not possible, the client always receives them*
  – *it can limit the number of concurrently pushed streams*
  – *it can adjust the initial flow control window to control how much data is pushed when the stream is first opened*
  – *it can disable server push entirely*
- pushed resources must obey the same-origin policy

Header compression

- Purpose
  – *Each HTTP request/response contains a set of headers (metadata)*
  – *HTTP/1.x – metadata sent as plain text, adds 500-800 bytes per transfer*
- HTTP/2 provides
  – *Request and response metadata are compressed using HPACK format*
    → *header fields encoded via a static Huffman code – reduces size*
    → *client and server maintain an* ***indexed list of previously seen header fields***