Web 2.0

Lecture 6: HTTP/2

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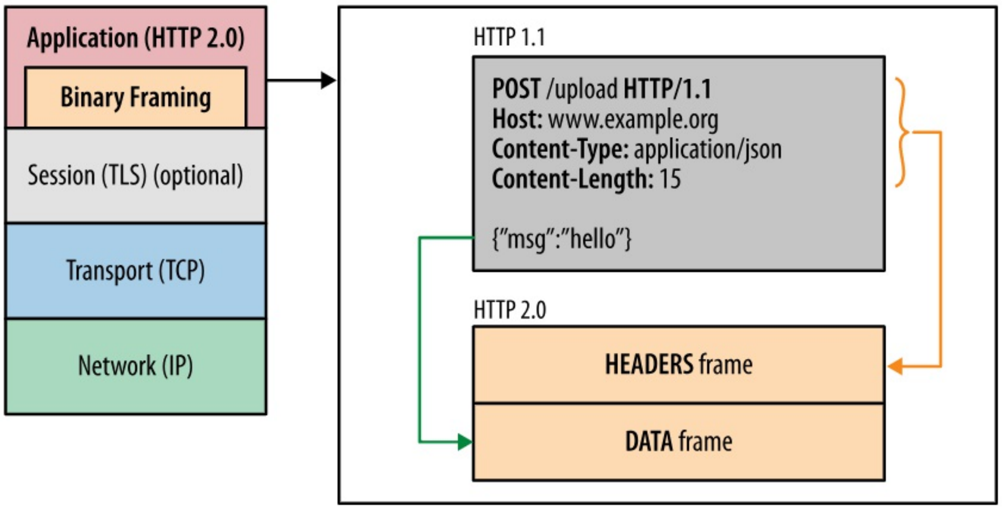
Overview

- 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 client/server communication*

Binary Framing Layer

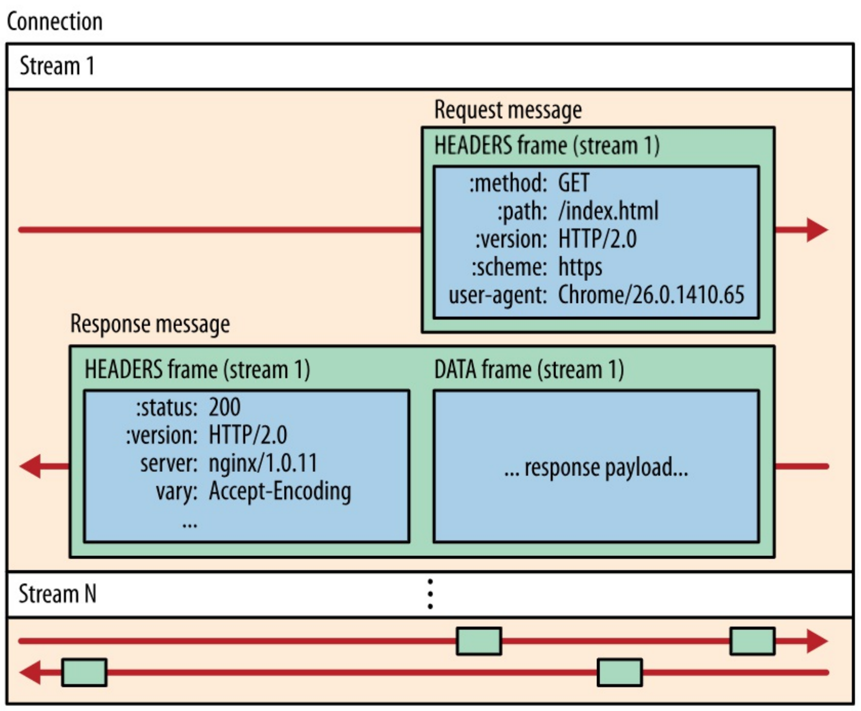
- Binary framing layer
  – *defines how HTTP messages are encapsulated and transferred*
  – *communication is split into messages and frames in binary format*



HTTP/2 Communication

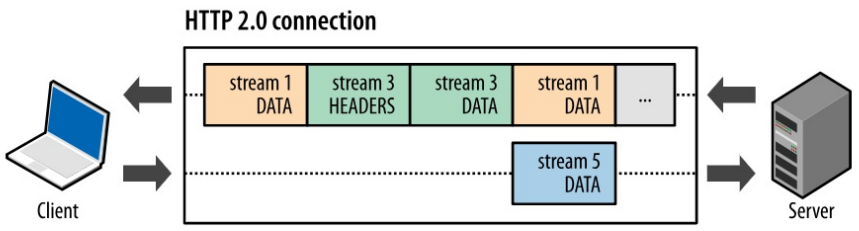
- Data exchange between the client and server
  – *break down of the communication into frames*
  – *frames are mapped to messages that belong to a particular stream*
  – *communication is **multiplexed within a single TCP connection**.*
- Stream
  – *bi-directional flow of bytes in a connection*
  – *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



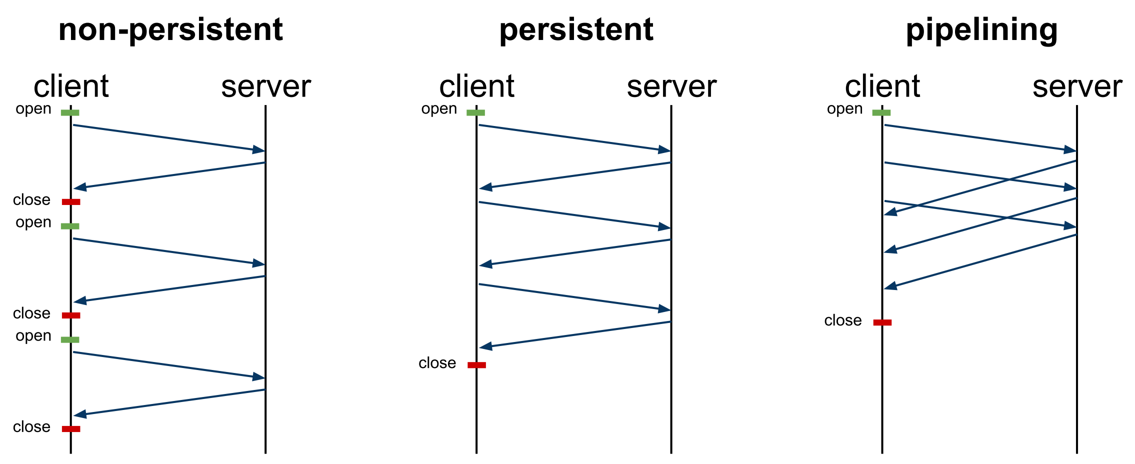
Request and response multiplexing

- Parallel requests
  – *HTTP/1.x can use HTTP pipelining; they open multiple connections*
  → browser typically opens up six connections
  – *HTTP/2 allows full request and response multiplexing*
  → Allows for parallel in-flight streams



- 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*

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*

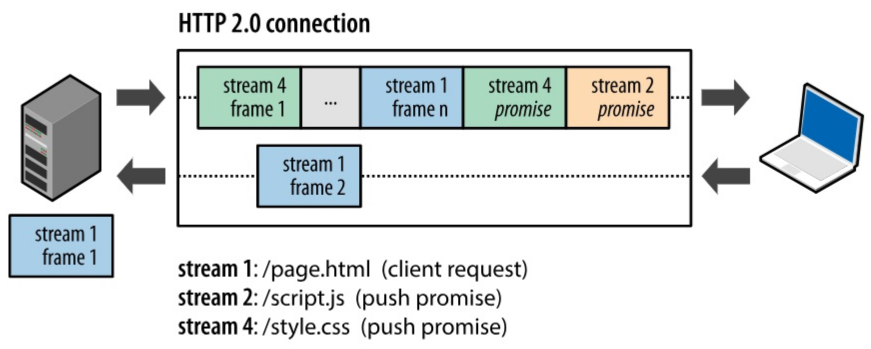
  – *Improves performance of HTTPS deployments*
    → *fewer expensive TLS handshakes*
    → *better session reuse*
    → *overall reduction in required client and server resources*

Flow control

- Prevent sender from receiving data it doest not want
  - *Receiver is busy or under heavy load*
  - *Receiver can allocate fixed amount of resources for particular 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 control*
- 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"*



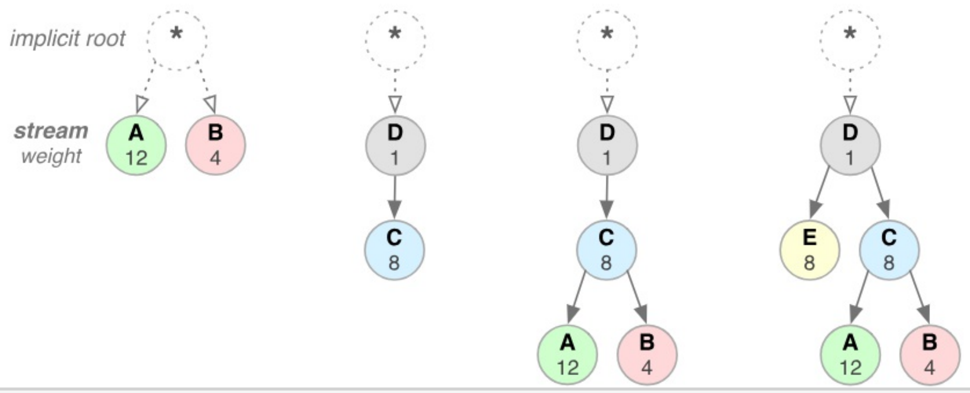
- Similar to resource inlining
  - *A resource is pushed to the client in HTML/CSS resource*
- Performance benefits
  - *Cached by the client, reused across pages, multiplexed, declined by the client*

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

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.*

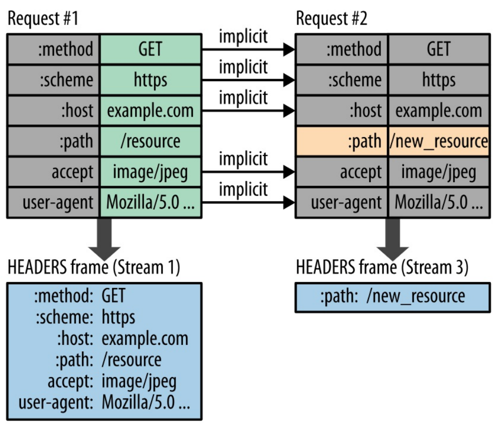


Stream Prioritization (cont.)

- 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;*

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 sing HPACK format*
    - → *header fields encoded via a static Huffman code – reduces size*
    - → *client and server maintain an* ***indexed list of previously seen header fields***


Request #1
:method
GET
:scheme
https
:host
example.com
:path
/resource
accept
image/jpeg
user-agent
Mozilla/5.0 ...
implicit
implicit
implicit
implicit
implicit
Request #2
:method
GET
:scheme
https
:host
example.com
:path
/new_resource
accept
image/jpeg
user-agent
Mozilla/5.0 ...
HEADERS frame (Stream 1)
:method: GET
:scheme: https
:host: example.com
:path: /resource
accept: image/jpeg
user-agent: Mozilla/5.0 ...
HEADERS frame (Stream 3)
:path: /new_resource