# A Season with 

Tales of a Symmetry Autumn of Code participant

# Symmetry Autumn of Code

- Promoted by the D Language Foundation and Symmetry Investments
- Period of 4 months: September 2018 – January 2019
- One milestone each month
- 3 Participants, each one working on a different project

Objective?

Improving the D Ecosystem

# About me

- CS student in Italy, 24 years old
- Experienced in C, Python, some Java. Met D while trying to expand my experience in programming languages
- Before SAoC: ~1 year of D experiments
- Fond of language theory, concurrent program verification, networking protocols
- Looking forward to contribute to an Open Source codebase

# HTTP/2 in Vibe.d

- Work on the experimental *vibe-http* repository.
- Mentor: Sönke Ludwig
- Project idea found on Dlang's wiki page for GSoC 2018.
- HTTP/2 implementation had to be written almost from scratch.

HTTP/2? What does that 2 stand for?

# HTTP/1 vs HTTP/2

| | |
|---|---|
| Stateless:<br>One request per TCP Connection. | Stateful:<br>Connection state is mantained between requests. |
| Cleartext protocol:<br>Headers and data are transmitted without further serialization. | Binary Protocol:<br>Frames are serialized using the HPACK algorithm and trasmitted as binary. |
| Relies on TCP to implement flow control at the packet level. | Integrates flow control at the Frame level using a connection window. |
| Ordered and blocking. | Multiplexed using the concept of Streams. |

# Work Plan

HTTP/2 is composed roughly of 3 logic blocks:

- HTTP/1 to HTTP/2 Protocol switching
- The HPACK header compression algorithm
- Asynchronous handling of HTTP/2 Streams

Each block became a milestone in my work plan.

# Milestones

Milestones acted as checkpoints to ensure us participants had a plan to follow.

- Planned in advance while proposing an application to SAoC, with the help of our respective mentors
- Progress on a milestone was reported month by month
- Proposed by applicants, reviewed by organizers and mentors

# Working with a mentor

- Discussion topics: bugs found, implementation issues, high-level strategy.
- Means of communication: e-mails and GitHub PRs.
- Difficulties: adapting to the mentor's development cycle.
- Benefits: constant communication improved focus and commitment towards a complete project realization.

# Workflow

## September – October 2018

Dedicated to:

- Studying the available resources regarding HTTP/2, mainly RFC 7540 and RFC 7541.
- Reading through vibe's HTTP module to familiarize with it.
- Discussing an high-level strategy with my mentor.

Milestone: HTTP/1 to HTTP/2 Protocol Switching

# Workflow

October – November 2018

Dedicated to:

- Implementing the HPACK header compression algorithm.
- Digging deep into Phobos modules, especially std.range, std.algorithm and std.traits.
- Testing the obtained HPACK implementation.

Milestone: HPACK header compression algorithm

# Workflow

November – December 2018

Dedicated to:

- Devise an efficient strategy for asynchronous management of HTTP/2 Streams
- Compare performance and logic of different implementations in various languages (C, C++, Go)
- *Testing, bug fixing, testing, bug fixing, ...*

Milestone: HTTP/2 Streams and Multiplexing

# Workflow

## December 2018 - Ongoing

Work that is still being pursued:

- Complete the review of HTTP/2 Streams and Multiplexing so that it can be merged in *vibe-http*
- Profile web server performance and memory usage, trying to minimize dynamic allocations and remove as much *GC-dependent* code as possible.
- *Testing, bug fixing, testing, bug fixing, ...*

# *Accomplishments*

# Accomplishments

The introduction of HTTP/2 in *vibe-http* is geared towards building a new HTTP module to be merged in Vibe.d.

Modifying the existing codebase is still going to be a long process and has to be carried out with patience and care.

Yet, the new HTTP server lives, and talks with HTTP/1 and HTTP/2 clients succesfully...

...in an experimental way.

# Accomplishments

Protocol Switching: HTTP/2 is enabled transparently for cleartext HTTP connections and requires minimal changes for HTTPS ones.

```
void main() {          /** Example of HTTP/2 webserver initialization using TLS **/

        HTTPServerSettings settings;
        settings.port = 8000;
        settings.bindAddresses = ["127.0.0.1"];

        /** TLS Context initialization **/
        settings.tlsContext = createTLSContext(TLSContextKind.server);
        settings.tlsContext.useCertificateChainFile("server.crt");
        settings.tlsContext.usePrivateKeyFile("server.key");

        settings.tlsContext.alpnCallback(http2Callback);    /** Setup ALPN to accept HTTP/2 **/

        listenHTTP!requestHandler(settings);                /** start the event loop **/
        runApplication();
}
```

# Accomplishments

HPACK module: a simple interface based on std.range which can encode and decode arbitrarily long chunks of headers.

- Can be used as standalone library (outside *vibe-http*)
- The interface is @safe and *almost* @nogc, if it wasn't for those exceptions…
- Lightweight on CPU and memory resources, protecting from possible DoS attacks which exploit the heavy computational cost of the encoding algorithm.

# Accomplishments

HTTP/2 message exchanges:

- Handling multiple HTTP requests over the same connection by using asynchronous handlers based on Vibe.d's fibers.
- Complying with flow control restrictions and manage data dispatch while responding to other requests, by performing each dispatch on a separate task.
- Enforcing protocol correctness by mantaining a connection state, enforcing compliance with protocol rules defined in *RFC 7540*.

# Missing Bricks

- Review of the PR regarding stream multiplexing and flow control logic has yet to be completed, and will probably undergo some changes.
- Server Push, an additional feature of HTTP/2 which allows a server to send data without a previous request. Not a requirement for HTTP/2 functionality: postponed.
- *Testing, bug fixing, testing, bug fixing, …*

# Lessons Learned

## D for network protocols

Implementing HTTP/2 required application of some of the language features:

- Ranges as a serialization interface.
- Meta-Programming through mixins, CTFE and ADTs.
- Abstract concurrency paradigm based on Tasks.

# Ranges

## D for network protocols

Ranges proved to be a powerful abstraction to handle data serialization.

- HPACK interface: based on std.range and std.algorithm.
- Methods templatized on InputRange and OutputRange, usable outside of the HTTP/2 module.
- Support custom allocators by using stdx.allocator.
- Could be @nogc...

# Ranges

## D for network protocols

```
import vibe.http.internal.http2.hpack : decodeHPACK;


void exampleDecode(IN,OUT)(IN encodedSource, OUT dst) @safe
    if(isInputRange!IN && isOutputRange!OUT)
{

    const uint size = 4096;
    auto table = myCustomAllocator.make!(IndexingTable(size));

    decodeHPACK(encodedSource,  dst, table,
                                        myCustomAllocator, size);

}
```

# Meta-Programming

## D for network protocols

HPACK algorithm uses an indexing table (HT), chaining:

- A static, immutable table which is generated at compile time.
- A dynamic table built around a fixed-length ring buffer.

The indexing table provides an unified address space for the stored data, represented as an algebraic data type.

```
immutable size_t ST_SIZE = 61;
static immutable H2TableField[ST_SIZE+1] staticTable;

static this() {
        staticTable = [                                 // Static table initialization
                H2TableField(“hname”,”hvalue”),
                … ];
}

struct IndexingTable {                                  // Acts as unified interface
        private {  DynamicTable dTable; }               // dTable based on FixedRingBuffer
        …

        // H2TableSize is a { name: ADT(integers, ubyte, string) }
        H2TableField opIndex(const size_t idx) @safe
        {
                enforceHPACK(idx > 0 && idx < size);

                        if (idx < ST_SIZE+1) return staticTable[idx];
                        else return dTable[ dTable.index - (idx - ST_SIZE) + 1 ];
        }
        …
```

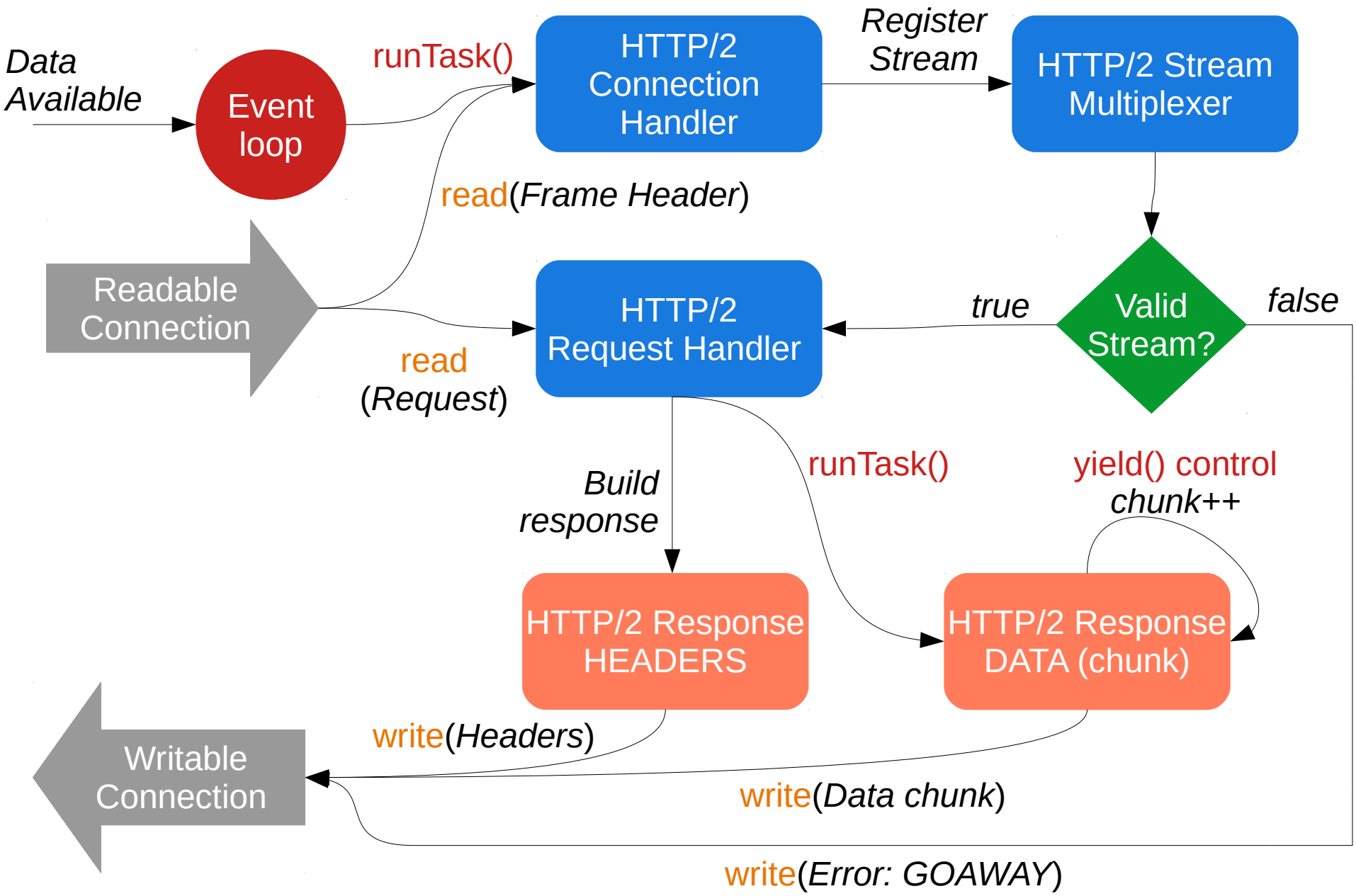
# Concurrency

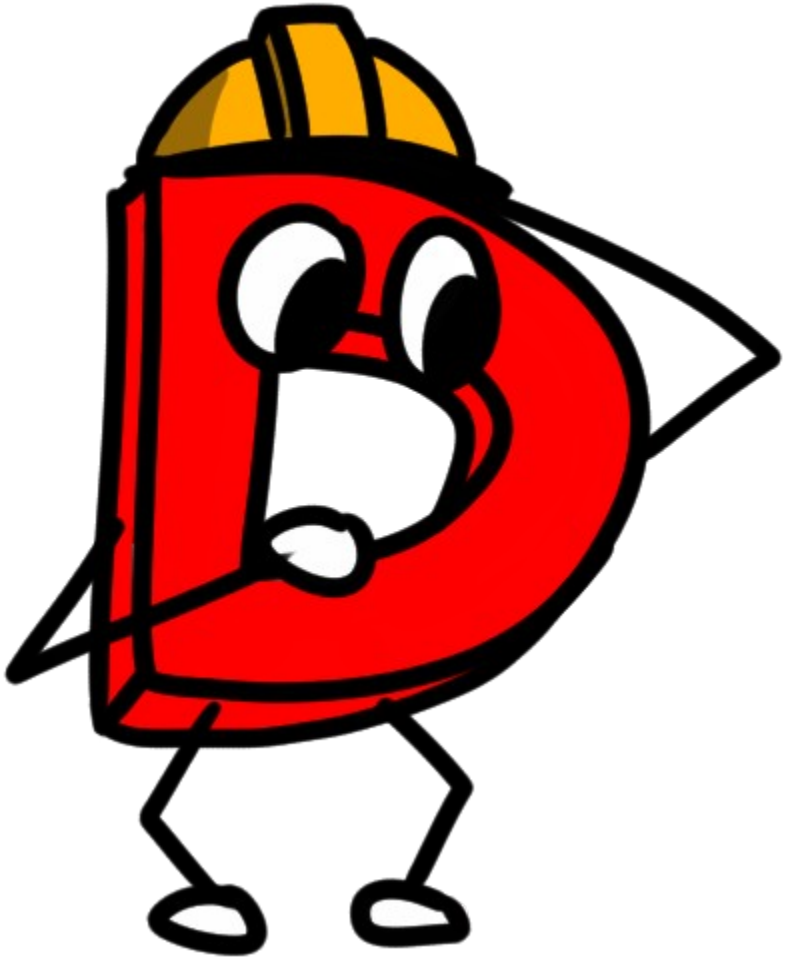
## D for network protocols

Vibe.d's concurrency paradigm:

- Uses the asynchronous I/O model, spawning Tasks (AKA Fibers) using the internal event loop.
- Supports message passing between Tasks.
- Allows for lightweight multiplexing of incoming requests over HTTP/2 Streams.

HTTP/2 Connection and Request handling is built around Tasks.


Data Available
Event loop
runTask()
HTTP/2 Connection Handler
Register Stream
HTTP/2 Stream Multiplexer
read(Frame Header)
Readable Connection
HTTP/2 Request Handler
true
Valid Stream?
false
read (Request)
Build response
runTask()
yield() control
chunk++
HTTP/2 Response HEADERS
HTTP/2 Response DATA (chunk)
write(Headers)
Writable Connection
write(Data chunk)
write(Error: GOAWAY)



# Experience Analysis

*A participant's perspective*

# Why SAoC?

- A great occasion to learn from experienced programmers and to get to know them
- Lightens the burden of starting as a OSS contributor
- Gain insights about the dynamics of a Open Source Software community

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- A great occasion to learn from experienced programmers and to get to know them
- Lightens the burden of starting as a OSS contributor
- Gain insights about the dynamics of a Open Source Software community
- All of that while being paid

# Starting as a contributor

*I want to start contributing to D, but:*

1. I can’t decide what to work on.
2. I don’t know who to talk to.
3. I have no experience and I am afraid of not completing my work.

How can SAoC/GSoC help me?

# Starting as a contributor

I can’t decide what to work on.

- The Dlang wiki provides idea pages, where community members listed possible useful projects. Mine: GSoC 2018 ideas page.
- Each project has an assigned mentor which can be contacted in case one wishes to start a collaboration.

# Starting as a contributor

I don’t know who to talk to.

- Post on the D forum
- Ask on IRC
- Write a simple proposal and send it by e-mail to the maintainers of the project of your interest.

*Edit: See @wilzbach presentation*

# Tackling a huge project

## Issues

The first time on a well-established codebase might signify:

- Not knowing where to start.
- Little understanding of the internal logic of the project.
- Little familiarity with the development process.
- A lot of time to be spent reading.

# Tackling a huge project

## Useful Resources

Never be afraid of reading! My case:

- RFCs which detailed the structure of what I had to build.
- Code documentation for Phobos, Vibe.d, and particular projects.
- Similar projects: Webservers which already introduced support for HTTP/2.
- Hints: Forum posts, IRC discussions.

# Tackling a huge project

## Asking for help

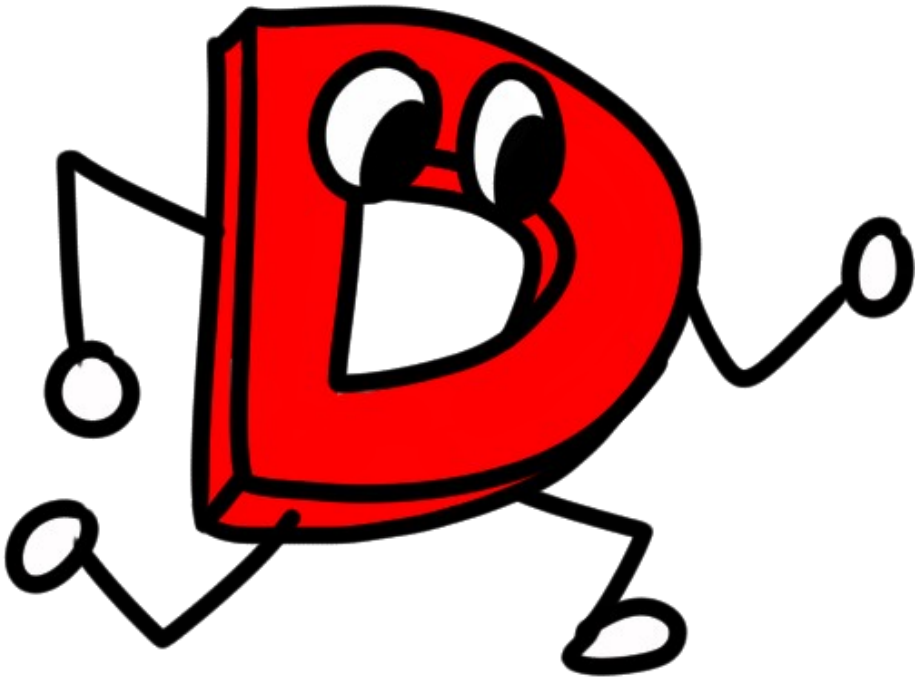
Mentoring: key to a succesful project kick-off.

*What if my mentor cannot help?*

- Write as many forum posts as you need
- Discuss the issues on IRC

Let your needs be heard!

# Notes for the future



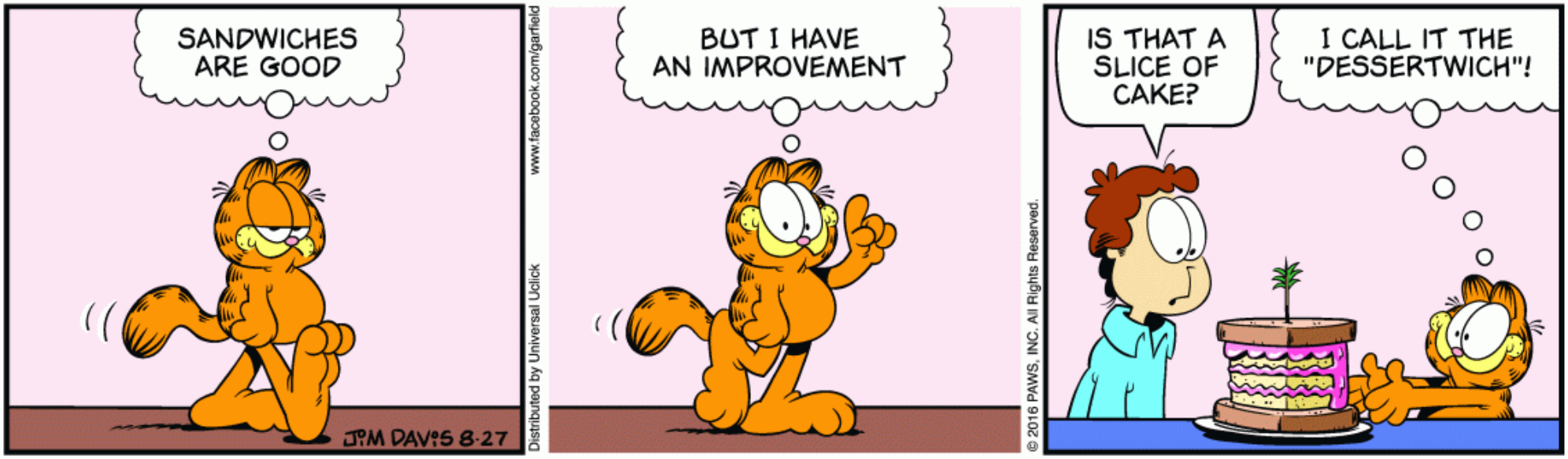
# Benefits of SAoC

- Spreading D usage
- Pushing development of D features
- Fixing bugs thanks to fresh eyes and minds
- Bringing new people inside the community

# Risks of SAoC

- Participants might drop early
- Work might require more time than planned
- Newly introduced features might be orphaned after the experience ends

# Possible Improvements?




*Garfield*

# Possible Improvements

## Looking forward to future editions

- Increase communication with the participant using the community channels.
- Improve means of gathering ideas.
- Determine if project comparison is needed, and clarify a base for that.

# Communication

Mentors might be busy!

- Causes delays on milestone delivery
- Need for someone to follow participants in need of help
- Need for participants to properly document their progress so that others can jump in

# Communication

Helps quantify the impact of the project

- Encourage periodic reporting of the progress made to the whole community.
- Encourage forum posts and discussion during the experience.

Aim: motivate the participants

# Fostering Ideas

*wiki.dlang.org* pages are often left to rot.

# Fostering Ideas

**RIP**

- https://wiki.dlang.org/Project_Ideas
- https://wiki.dlang.org/Wish_list
- https://wiki.dlang.org/Language_design_discussions
- Project pages that should be updated or removed, e.g. https://wiki.dlang.org/Calypso

# Fostering Ideas

Maintain one reference page

- Periodically refreshed with new / updated ideas
- Periodically cleansed from old projects
- Linked from the dlang.org website directly
- Makes contributors autonomous in finding a project
- Used as reference regarding planned and desired work

# Project Comparison

How to compare work from different participants?

- Projects have different requirements
- Milestone design is left to each participant
- Communication channels are various (e-mail, forum, IRC, Slack…)
- Development process is not unique for all projects

# Project Comparison

Objectively judging a project needs some sort of data quantification.

- LoC written?
- Pull Requests submitted?
- Communication activity?

I've gathered some data from Francesco Mecca: SAoC Participant, Fork-Based GC for DRuntime

# Project Comparison

## Fork-based GC

- Study of GC implementations, from *Sociomantic* to Phobos
- Design of test suites and benchmark suites
- Implementation of fork-based GC against the current DRuntime (~ 500 LoC)
- Study of the use cases suitable for a fork-based GC
- Multiple rebase cycles against upstream DRuntime

# Project Comparison

| | Fork-based GC for DRuntime | HTTP/2 in Vibe.d |
|---|---|---|
| Pull Requests opened | 4 | 17 |
| Pull Requests opened, reviewed and merged | 3 | 16 |
| Number of e-mails exchanged with respective mentors | 128 | 24 |
| Lines of Code written and submitted | 1111 | 6563 |
| Lines of Code written, reviewed and merged | 572 | 4988 |

# Project Comparison

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# Project Comparison

Numerical data is not sufficient.

- Some projects might require more design than actual keyboard work
- Some might require more benchmarks or testing
- Some might depend on the code submission method

# Project Comparison

***HTTP/2 in Vibe.d***

***Actual implementation***

***Discussion, design, benchmarks...***

# Project Comparison

***Fork-based GC for DRuntime***

***Actual implementation***

***Discussion, design, benchmarks...***

# Project Comparison

What's the point in comparing projects then?

Possible reasons:

- Strengthen competition between participants to enhance work done
- Award one or more participants as "winner" as an additional benefit
- ? ← Needs more discussion

Not needed for actual project completion!

# Project Comparison

How to ensure project completion?

- Careful planning: give all the necessary time for milestones to be laid down
- Ensure mentors are available and willing
- When selecting participants, consider interest and proposal over technical preparation and CV
- Require a significant amount of documentation, so that work doesn’t get lost!

# Conclusions

## Symmetry Autumn of Code

- Is a great occasion to introduce new people into the D community
- Can be an alternative and stimulating approach to starting as a contributor
- Needs more guarantees: use communication, gathering of idea, project evaluation.

# Thank you!
# Questions?

# Acknowledgements


## Heartfelt thanks to:

- The D Language Foundation and Symmetry Investments for making SAoC possible.
- Mike Parker and everyone who worked to organize and manage the experience.
- Sönke Ludwig, who helped me through the process as my mentor.
- The D community who created invaluable resources through discussion on the forum, the blog, all the IRC channels… Keep it up!
- Francesco Mecca, who helped me as a participant of SAoC and long-time fellow developer.
- Andrea, who's been by my side the whole time.

# References

- **SAoC Project Repository**

  vibe-http: https://github.com/vibe-d/vibe-http

  vibe-hpack: https://github.com/gallafrancesco/vibe-hpack (merged in vibe-http)

- **[RFC 7540] Hypertext Transfer Protocol Version 2 (HTTP/2)**

  https://tools.ietf.org/html/rfc7540

- **[RFC 7541] HPACK: Header Compression for HTTP/2**

  https://tools.ietf.org/html/rfc7541

- **GSoC 2018 Ideas Page**

  https://wiki.dlang.org/GSOC_2018_Ideas

- **SAoC 2018 Ideas Page**

  https://wiki.dlang.org/SAOC_2018_ideas

- **DLang's Blog posts about SAoC**

  Presentation, https://dlang.org/blog/symmetry-autumn-of-code/

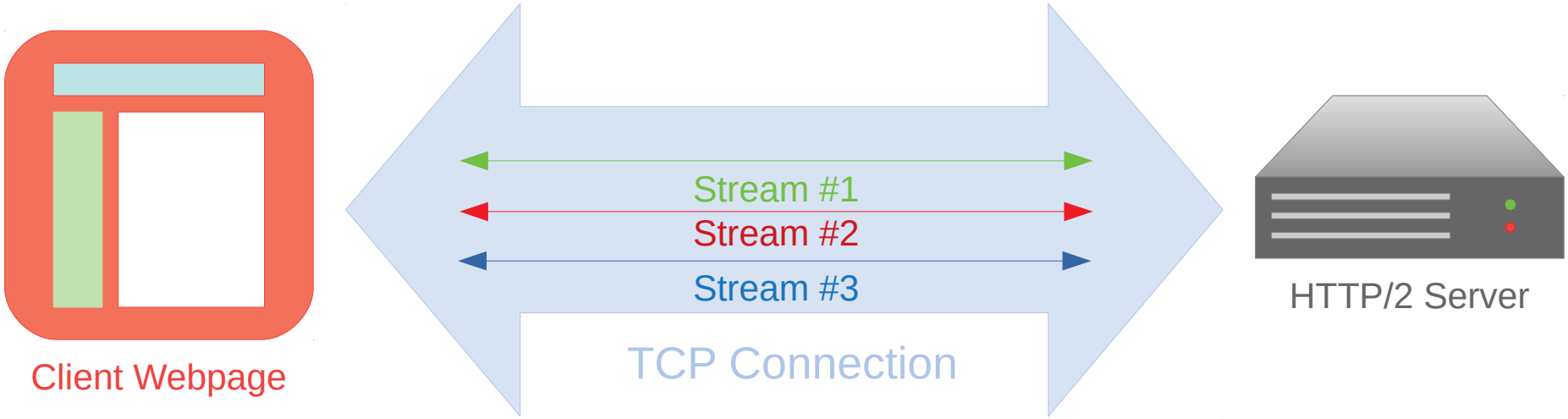
  Updates, https://dlang.org/blog/2018/09/15/symmetry-autumn-of-code-is-underway/

# Appendix: HTTP/2

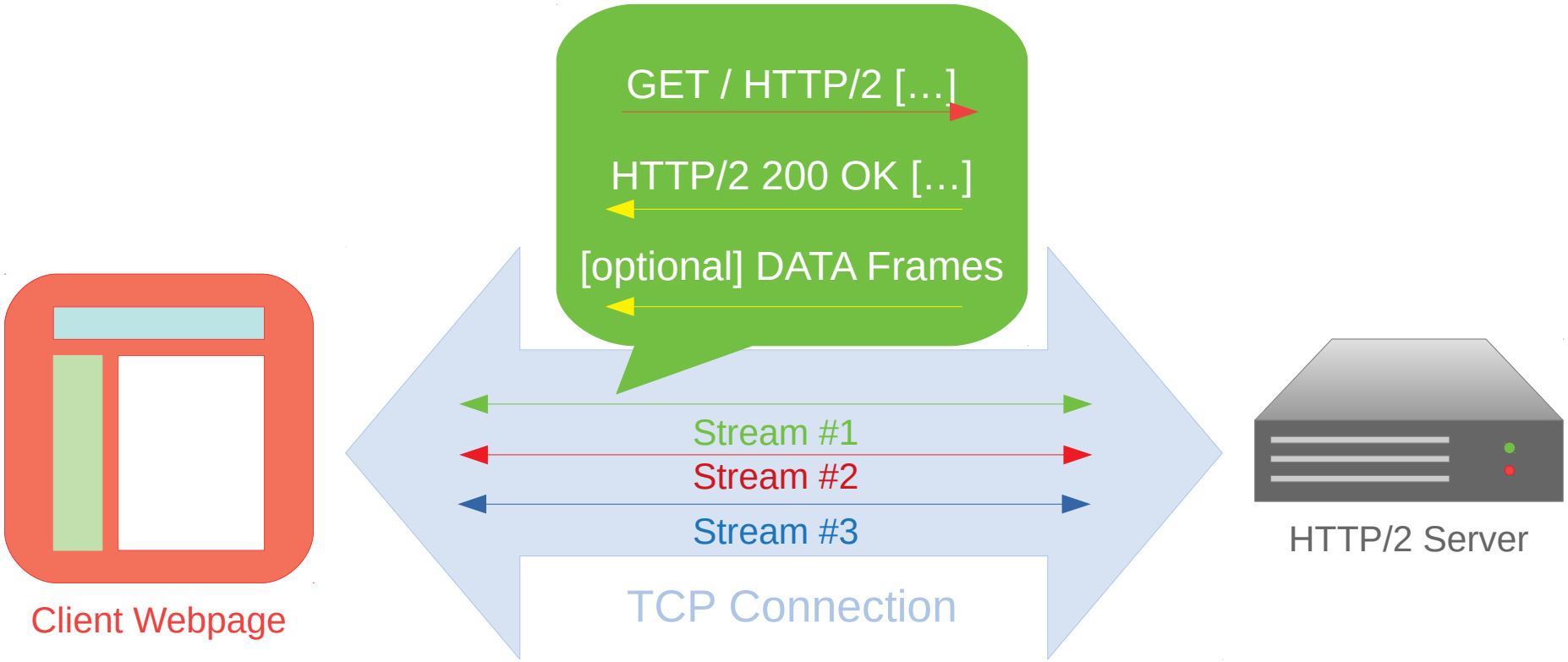
- Stateful, connection-aware protocol
- Server and client communicate through HTTP requests embedded in Frames.
- A request / response cycle of Frames is called a Stream.
- Streams can be multiplexed over the same TCP connection.
- Exploits Huffman coding to compress Frame headers through the HPACK algorithm.

# HTTP/2

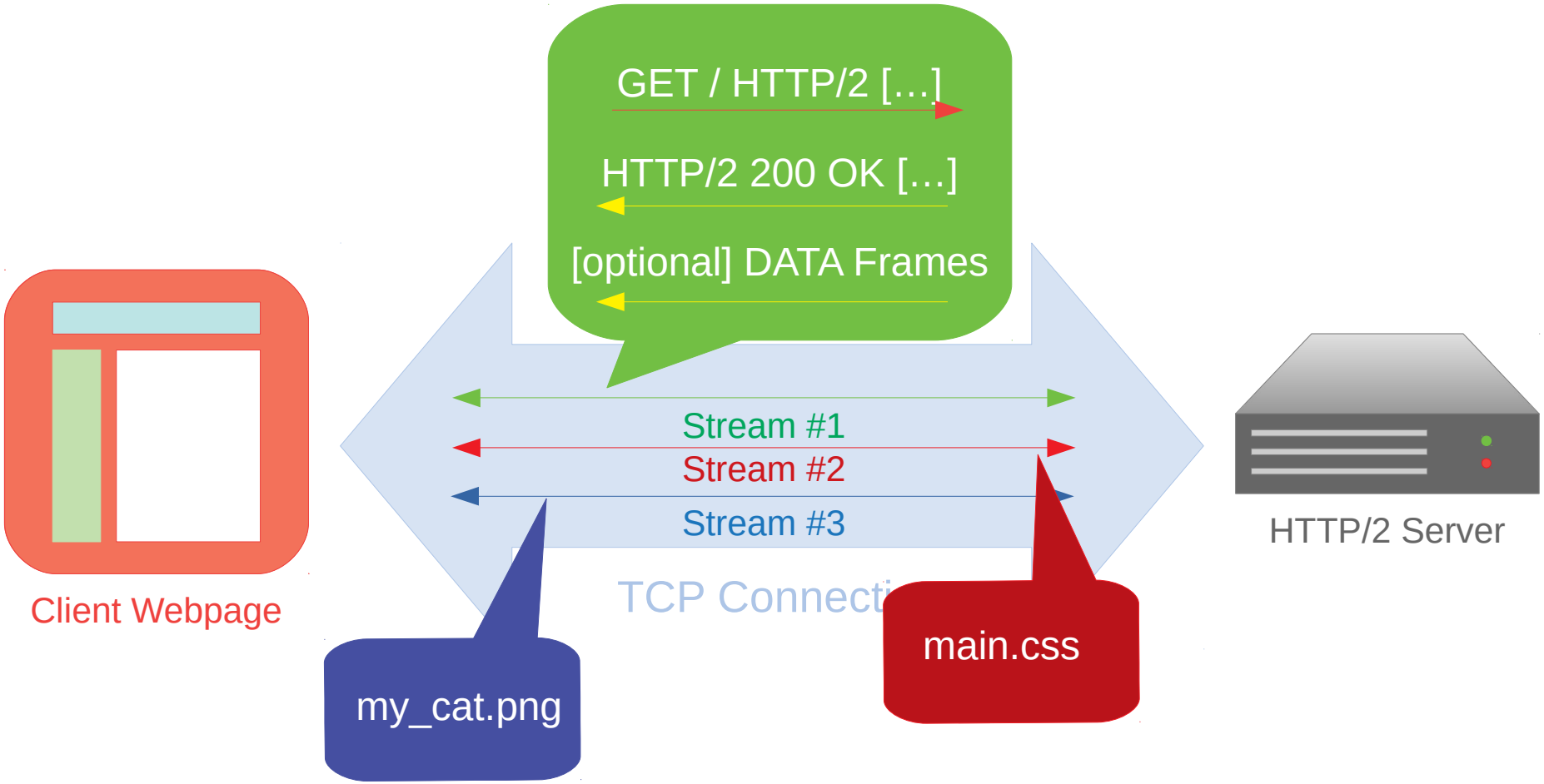
A stream is a request / response cycle, has finite lifetime and cannot be reused.



# HTTP/2

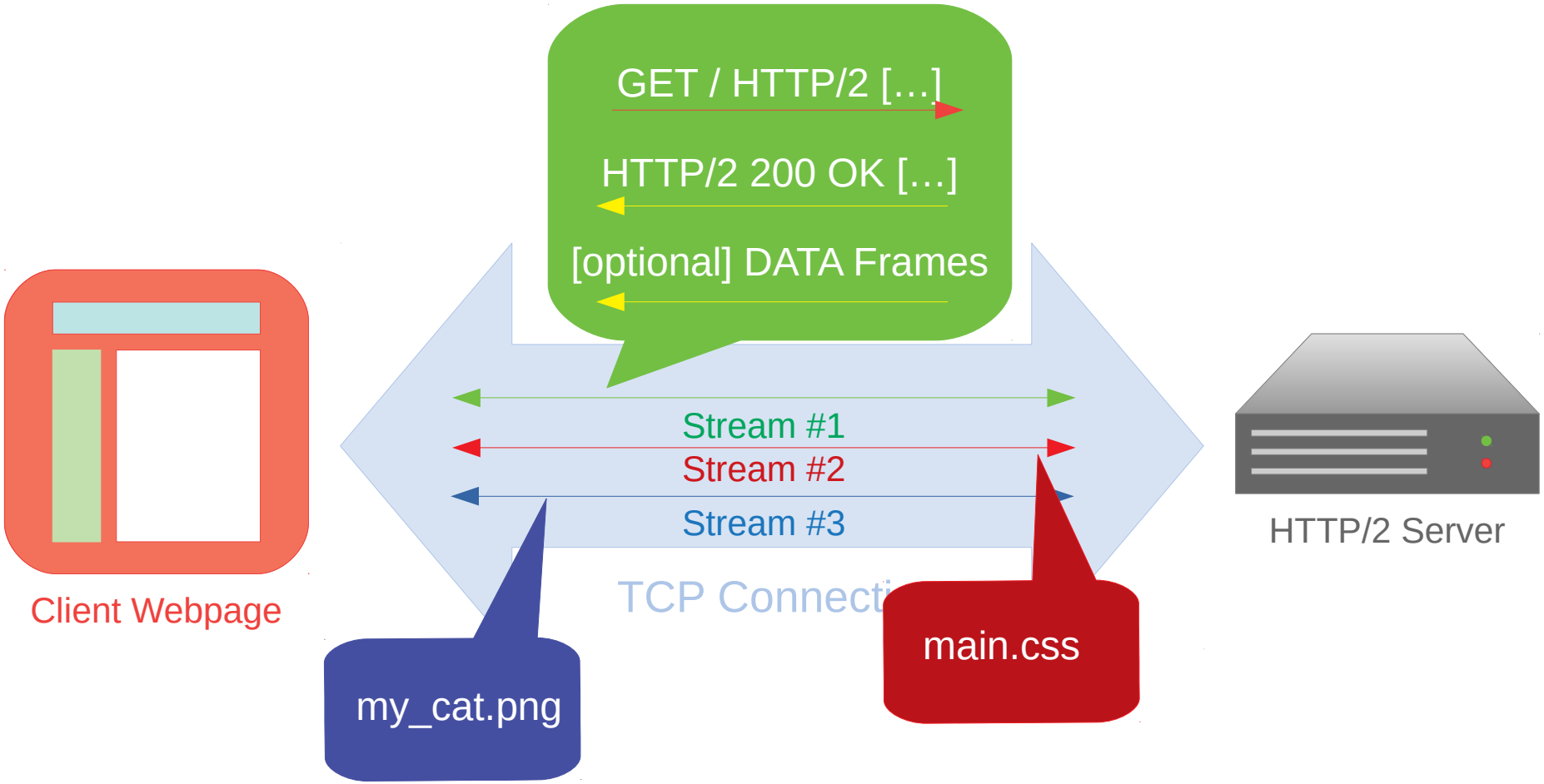

GET / HTTP/2 […]
HTTP/2 200 OK […]
[optional] DATA Frames
Stream #1
Stream #2
Stream #3
TCP Connection
Client Webpage
HTTP/2 Server

# HTTP/2


GET / HTTP/2 […]
HTTP/2 200 OK […]
[optional] DATA Frames
Stream #1
Stream #2
Stream #3
TCP Connecti
Client Webpage
HTTP/2 Server
my_cat.png
main.css

# HTTP/2

No ordering forced: Stream responses can interleave!



# Reasons behind HTTP/2

Well-known FreeBSD developer: *"The protocol has [...] layering violations, inconsistencies, needless complexity, bad compromises" [1]*

Is he right? Yes:

- HTTP/2 maintains stateful connections over TCP, which is already connection-aware.
- Encodes all headers as binary, using more memory and computing power than HTTP/1.1
- Not intrinsically safer: web browser only implement it over TLS.

*[1] HTTP/2.0 - The IETF is Phoning It In, Poul-Henning Kamp, acmqueue vol. 13 issue 2, 2015*

# Reasons behind HTTP/2

What the hell did you work on then?

HTTP/2 is controversial yet HTTP/1.1 is not built to scale efficiently when faced with:

- Large requests (high number of header fields): lots of noise for a simple GET
- Dynamic webpages which require more than one HTTP request. HTTP/1.1 sends each request on a separate TCP connection (often destroying TCP flow control mechanism)

HTTP/2 is useful for "*heavy*" HTTP servers.

# Reasons behind HTTP/2

A great number of existing web servers support HTTP/2.

- Not all implementations are equal (some details of stream prioritization and flow control can be different)
- Not all websites need HTTP/2: my blog doesn't, your online platformer might.
- Having HTTP/2 in Vibe.d means being able to compete with existing web servers as a standalone application. *Benefits: increased development surface, larger test base: solid framework in the long run.*