
hyper-h2

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Hyper-h2 is a HTTP/2 protocol stack, written entirely in Python. The goal of Hyper-h2 is to be a common HTTP/2 stack for the Python ecosystem, usable in all programs regardless of concurrency model or environment.

To achieve this, Hyper-h2 is entirely self-contained: it does no I/O of any kind, leaving that up to a wrapper library to control. This ensures that it can seamlessly work in all kinds of environments, from single-threaded code to Twisted.

Its goal is to be 100% compatible with RFC 7540, implementing a complete HTTP/2 protocol stack build on a set of finite state machines. Its secondary goals are to be fast, clear, and efficient.

For usage examples, see [*Getting Started: Writing Your Own HTTP/2 Server*](#) or consult the examples in the repository.

1.1 Installation

Hyper-h2 is a pure-python project. This means installing it is extremely simple. To get the latest release from PyPI, simply run:

```
$ pip install h2
```

Alternatively, feel free to download one of the release tarballs from [our GitHub page](#), extract it to your favourite directory, and then run

```
$ python setup.py install
```

1.2 Getting Started: Writing Your Own HTTP/2 Server

This document explains how to get started writing fully-fledged HTTP/2 implementations using Hyper-h2 as the underlying protocol stack. It covers the basic concepts you need to understand, and talks you through writing a very simple HTTP/2 server.

This document assumes you're moderately familiar with writing Python, and have *some* understanding of how computer networks work. If you don't, you'll find it a lot easier if you get some understanding of those concepts first and then return to this documentation.

1.2.1 Connections

Hyper-h2's core object is the `H2Connection` object. This object is an abstract representation of the state of a single HTTP/2 connection, and holds all the important protocol state. When using Hyper-h2, this object will be the first thing you create and the object that does most of the heavy lifting.

The interface to this object is relatively simple. For sending data, you call the object with methods indicating what actions you want to perform: for example, you may want to send headers (you'd use the `send_headers` method),

or send data (you'd use the `send_data` method). After you've decided what actions you want to perform, you get some bytes out of the object that represent the HTTP/2-encoded representation of your actions, and send them out over the network however you see fit.

When you receive data from the network, you pass that data in to the `H2Connection` object, which returns a list of *events*. These events, covered in more detail later in [Events](#), define the set of actions the remote peer has performed on the connection, as represented by the HTTP/2-encoded data you just passed to the object.

Thus, you end up with a simple loop (which you may recognise as a more-specific form of an [event loop](#)):

1. First, you perform some actions.
2. You send the data created by performing those actions to the network.
3. You read data from the network.
4. You decode those into events.
5. The events cause you to trigger some actions: go back to step 1.

Of course, HTTP/2 is more complex than that, but in the very simplest case you can write a fairly effective HTTP/2 tool using just that kind of loop. Later in this document, we'll do just that.

Some important subtleties of `H2Connection` objects are covered in [Advanced Usage](#): see [Connections: Advanced](#) for more information. However, one subtlety should be covered, and that is this: Hyper-h2's `H2Connection` object doesn't do I/O. Let's talk briefly about why.

I/O

Any useful HTTP/2 tool eventually needs to do I/O. This is because it's not very useful to be able to speak to other computers using a protocol like HTTP/2 unless you actually *speak* to them sometimes.

However, doing I/O is not a trivial thing: there are lots of different ways to do it, and once you choose a way to do it your code usually won't work well with the approaches you *didn't* choose.

While there are lots of different ways to do I/O, when it comes down to it all HTTP/2 implementations transform bytes received into events, and events into bytes to send. So there's no reason to have lots of different versions of this core protocol code: one for Twisted, one for gevent, one for threading, and one for synchronous code.

This is why we said at the top that Hyper-h2 is a *HTTP/2 Protocol Stack*, not a *fully-fledged implementation*. Hyper-h2 knows how to transform bytes into events and back, but that's it. The I/O and smarts might be different, but the core HTTP/2 logic is the same: that's what Hyper-h2 provides.

Not doing I/O makes Hyper-h2 general, and also relatively simple. It has an easy-to-understand performance envelope, it's easy to test (and as a result easy to get correct behaviour out of), and it behaves in a reproducible way. These are all great traits to have in a library that is doing something quite complex.

This document will talk you through how to build a relatively simple HTTP/2 implementation using Hyper-h2, to give you an understanding of where it fits in your software.

1.2.2 Events

When writing a HTTP/2 implementation it's important to know what the remote peer is doing: if you didn't care, writing networked programs would be a lot easier!

Hyper-h2 encodes the actions of the remote peer in the form of *events*. When you receive data from the remote peer and pass it into your `H2Connection` object (see [Connections](#)), the `H2Connection` returns a list of objects, each one representing a single event that has occurred. Each event refers to a single action the remote peer has taken.

Some events are fairly high-level, referring to things that are more general than HTTP/2: for example, the *RequestReceived* event is a general HTTP concept, not just a HTTP/2 one. Other events are extremely HTTP/2-specific: for example, *PushedStreamReceived* refers to Server Push, a very HTTP/2-specific concept.

The reason these events exist is that Hyper-h2 is intended to be very general. This means that, in many cases, Hyper-h2 does not know exactly what to do in response to an event. Your code will need to handle these events, and make decisions about what to do. That's the major role of any HTTP/2 implementation built on top of Hyper-h2.

A full list of events is available in *Events*. For the purposes of this example, we will handle only a small set of events.

1.2.3 Writing Your Server

Armed with the knowledge you just obtained, we're going to write a very simple HTTP/2 web server. The goal of this server is to write a server that can handle a HTTP GET, and that returns the headers sent by the client, encoded in JSON. Basically, something a lot like httpbin.org/get. Nothing fancy, but this is a good way to get a handle on how you should interact with Hyper-h2.

For the sake of simplicity, we're going to write this using the Python standard library, in Python 3. In reality, you'll probably want to use an asynchronous framework of some kind: see the *examples directory* in the repository for some examples of how you'd do that.

Before we start, create a new file called `h2server.py`: we'll use that as our workspace. Additionally, you should install Hyper-h2: follow the instructions in *Installation*.

Step 1: Sockets

To begin with, we need to make sure we can listen for incoming data and send it back. To do that, we need to use the *standard library's socket module*. For now we're going to skip doing TLS: if you want to reach your server from your web browser, though, you'll need to add TLS and some other function. Consider looking at our examples in our *examples directory* instead.

Let's begin. First, open up `h2server.py`. We need to import the socket module and start listening for connections.

This is not a socket tutorial, so we're not going to dive too deeply into how this works. If you want more detail about sockets, there are lots of good tutorials on the web that you should investigate.

When you want to listen for incoming connections, the you need to *bind* an address first. So let's do that. Try setting up your file to look like this:

```
import socket

sock = socket.socket()
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(('0.0.0.0', 8080))
sock.listen(5)

while True:
    print(sock.accept())
```

In a shell window, execute this program (`python h2server.py`). Then, open another shell and run `curl http://localhost:8080/`. In the first shell, you should see something like this:

```
$ python h2server.py
(<socket.socket fd=4, family=AddressFamily.AF_INET, type=SocketKind.SOCK_STREAM,
→ proto=0, laddr=('127.0.0.1', 8080), raddr=('127.0.0.1', 58800)>, ('127.0.0.1',
→ 58800))
```

Run that `curl` command a few more times. You should see a few more similar lines appear. Note that the `curl` command itself will exit with an error. That's fine: it happens because we didn't send any data.

Now go ahead and stop the server running by hitting `Ctrl+C` in the first shell. You should see a `KeyboardInterrupt` error take the process down.

What's the program above doing? Well, first it creates a `socket` object. This socket is then *bound* to a specific address: `('0.0.0.0', 8080)`. This is a special address: it means that this socket should be listening for any traffic to TCP port 8080. Don't worry about the call to `setsockopt`: it just makes sure you can run this program repeatedly.

We then loop forever calling the `accept` method on the socket. The `accept` method blocks until someone attempts to connect to our TCP port: when they do, it returns a tuple: the first element is a new socket object, the second element is a tuple of the address the new connection is from. You can see this in the output from our `h2server.py` script.

At this point, we have a script that can accept inbound connections. This is a good start! Let's start getting HTTP/2 involved.

Step 2: Add a H2Connection

Now that we can listen for socket information, we want to prepare our HTTP/2 connection object and start handing it data. For now, let's just see what happens as we feed it data.

To make HTTP/2 connections, we need a tool that knows how to speak HTTP/2. Most versions of `curl` in the wild don't, so let's install a Python tool. In your Python environment, run `pip install hyper`. This will install a Python command-line HTTP/2 tool called `hyper`. To confirm that it works, try running this command and verifying that the output looks similar to the one shown below:

```
$ hyper GET https://nghttp2.org/httpbin/get
{'args': {},
 'headers': {'Host': 'nghttp2.org'},
 'origin': '10.0.0.2',
 'url': 'https://nghttp2.org/httpbin/get'}
```

Assuming it works, you're now ready to start sending HTTP/2 data.

Back in our `h2server.py` script, we're going to want to start handling data. Let's add a function that takes a socket returned from `accept`, and reads data from it. Let's call that function `handle`. That function should create a `H2Connection` object and then loop on the socket, reading data and passing it to the connection.

To read data from a socket we need to call `recv`. The `recv` function takes a number as its argument, which is the *maximum* amount of data to be returned from a single call (note that `recv` will return as soon as any data is available, even if that amount is vastly less than the number you passed to it). For the purposes of writing this kind of software the specific value is not enormously useful, but should not be overly large. For that reason, when you're unsure, a number like 4096 or 65535 is a good bet. We'll use 65535 for this example.

The function should look something like this:

```
import h2.connection
import h2.config

def handle(sock):
    config = h2.config.H2Configuration(client_side=False)
    conn = h2.connection.H2Connection(config=config)

    while True:
        data = sock.recv(65535)
        print(conn.receive_data(data))
```

Let's update our main loop so that it passes data on to our new data handling function. Your `h2server.py` should end up looking a like this:

```
import socket

import h2.connection
import h2.config

def handle(sock):
    config = h2.config.H2Configuration(client_side=False)
    conn = h2.connection.H2Connection(config=config)

    while True:
        data = sock.recv(65535)
        if not data:
            break

        print(conn.receive_data(data))

sock = socket.socket()
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(('0.0.0.0', 8080))
sock.listen(5)

while True:
    handle(sock.accept()[0])
```

Running that in one shell, in your other shell you can run `hyper --h2 GET http://localhost:8080/`. That shell should hang, and you should then see the following output from your `h2server.py` shell:

```
$ python h2server.py
[<h2.events.RemoteSettingsChanged object at 0x10c4ee390>]
```

You'll then need to kill `hyper` and `h2server.py` with `Ctrl+C`. Feel free to do this a few times, to see how things behave.

So, what did we see here? When the connection was opened, we used the `recv` method to read some data from the socket, in a loop. We then passed that data to the connection object, which returned us a single event object: `RemoteSettingsChanged`.

But what we didn't see was anything else. So it seems like all `hyper` did was change its settings, but nothing else. If you look at the other `hyper` window, you'll notice that it hangs for a while and then eventually fails with a socket timeout. It was waiting for something: what?

Well, it turns out that at the start of a connection, both sides need to send a bit of data, called "the HTTP/2 preamble". We don't need to get into too much detail here, but basically both sides need to send a single block of HTTP/2 data that tells the other side what their settings are. `hyper` did that, but we didn't.

Let's do that next.

Step 3: Sending the Preamble

Hyper-h2 makes doing connection setup really easy. All you need to do is call the `initiate_connection` method, and then send the corresponding data. Let's update our `handle` function to do just that:

```
def handle(sock):
    config = h2.config.H2Configuration(client_side=False)
    conn = h2.connection.H2Connection(config=config)
    conn.initiate_connection()
    sock.sendall(conn.data_to_send())

    while True:
        data = sock.recv(65535)
        print(conn.receive_data(data))
```

The big change here is the call to `initiate_connection`, but there's another new method in there: `data_to_send`.

When you make function calls on your `H2Connection` object, these will often want to cause HTTP/2 data to be written out to the network. But Hyper-h2 doesn't do any I/O, so it can't do that itself. Instead, it writes it to an internal buffer. You can retrieve data from this buffer using the `data_to_send` method. There are some subtleties about that method, but we don't need to worry about them right now: all we need to do is make sure we're sending whatever data is outstanding.

Your `h2server.py` script should now look like this:

```
import socket

import h2.connection
import h2.config

def handle(sock):
    config = h2.config.H2Configuration(client_side=False)
    conn = h2.connection.H2Connection(config=config)
    conn.initiate_connection()
    sock.sendall(conn.data_to_send())

    while True:
        data = sock.recv(65535)
        if not data:
            break

        print(conn.receive_data(data))

sock = socket.socket()
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(('0.0.0.0', 8080))
sock.listen(5)

while True:
    handle(sock.accept()[0])
```

With this change made, rerun your `h2server.py` script and hit it with the same hyper command: `hyper --h2 GET http://localhost:8080/`. The hyper command still hangs, but this time we get a bit more output from our `h2server.py` script:

```
$ python h2server.py
[<h2.events.RemoteSettingsChanged object at 0x10292d390>]
[<h2.events.SettingsAcknowledged object at 0x102b3a160>]
[<h2.events.RequestReceived object at 0x102b3a3c8>, <h2.events.StreamEnded object at 0x102b3a400>]
```

So, what's happening?

The first thing to note is that we're going around our loop more than once now. First, we receive some data that triggers a *RemoteSettingsChanged* event. Then, we get some more data that triggers a *SettingsAcknowledged* event. Finally, even more data that triggers *two* events: *RequestReceived* and *StreamEnded*.

So, what's happening is that *hyper* is telling us about its settings, acknowledging ours, and then sending us a request. Then it ends a *stream*, which is a HTTP/2 communications channel that holds a request and response pair.

A stream isn't done until it's either *reset* or both sides *close* it: in this sense it's bi-directional. So what the *StreamEnded* event tells us is that *hyper* is closing its half of the stream: it won't send us any more data on that stream. That means the request is done.

So why is *hyper* hanging? Well, we haven't sent a response yet: let's do that.

Step 4: Handling Events

What we want to do is send a response when we receive a request. Happily, we get an event when we receive a request, so we can use that to be our signal.

Let's define a new function that sends a response. For now, this response can just be a little bit of data that prints "it works!".

The function should take the *H2Connection* object, and the event that signaled the request. Let's define it.

```
def send_response(conn, event):
    stream_id = event.stream_id
    conn.send_headers(
        stream_id=stream_id,
        headers=[
            (':status', '200'),
            ('server', 'basic-h2-server/1.0')
        ],
    )
    conn.send_data(
        stream_id=stream_id,
        data=b'it works!',
        end_stream=True
    )
```

So while this is only a short function, there's quite a lot going on here we need to unpack. Firstly, what's a stream ID? Earlier we discussed streams briefly, to say that they're a bi-directional communications channel that holds a request and response pair. Part of what makes HTTP/2 great is that there can be lots of streams going on at once, sending and receiving different requests and responses. To identify each stream, we use a *stream ID*. These are unique across the lifetime of a connection, and they go in ascending order.

Most *H2Connection* functions take a stream ID: they require you to actively tell the connection which one to use. In this case, as a simple server, we will never need to choose a stream ID ourselves: the client will always choose one for us. That means we'll always be able to get the one we need off the events that fire.

Next, we send some *headers*. In HTTP/2, a response is made up of some set of headers, and optionally some data. The headers have to come first: if you're a client then you'll be sending *request* headers, but in our case these headers are our *response* headers.

Mostly these aren't very exciting, but you'll notice once special header in there: `:status`. This is a HTTP/2-specific header, and it's used to hold the HTTP status code that used to go at the top of a HTTP response. Here, we're saying the response is 200 OK, which is successful.

To send headers in Hyper-h2, you use the *send_headers* function.

Next, we want to send the body data. To do that, we use the `send_data` function. This also takes a stream ID. Note that the data is binary: Hyper-h2 does not work with unicode strings, so you *must* pass bytestrings to the `H2Connection`. The one exception is headers: Hyper-h2 will automatically encode those into UTF-8.

The last thing to note is that on our call to `send_data`, we set `end_stream` to `True`. This tells Hyper-h2 (and the remote peer) that we're done with sending data: the response is over. Because we know that `hyper` will have ended its side of the stream, when we end ours the stream will be totally done with.

We're nearly ready to go with this: we just need to plumb this function in. Let's amend our `handle` function again:

```
import h2.events
import h2.config

def handle(sock):
    config = h2.config.H2Configuration(client_side=False)
    conn = h2.connection.H2Connection(config=config)
    conn.initiate_connection()
    sock.sendall(conn.data_to_send())

    while True:
        data = sock.recv(65535)
        if not data:
            break

        events = conn.receive_data(data)
        for event in events:
            if isinstance(event, h2.events.RequestReceived):
                send_response(conn, event)

        data_to_send = conn.data_to_send()
        if data_to_send:
            sock.sendall(data_to_send)
```

The changes here are all at the end. Now, when we receive some events, we look through them for the `RequestReceived` event. If we find it, we make sure we send a response.

Then, at the bottom of the loop we check whether we have any data to send, and if we do, we send it. Then, we repeat again.

With these changes, your `h2server.py` file should look like this:

```
import socket

import h2.connection
import h2.events
import h2.config

def send_response(conn, event):
    stream_id = event.stream_id
    conn.send_headers(
        stream_id=stream_id,
        headers=[
            (':status', '200'),
            ('server', 'basic-h2-server/1.0')
        ],
    )
    conn.send_data(
        stream_id=stream_id,
        data=b'it works!',
```

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```

        end_stream=True
    )

def handle(sock):
    config = h2.config.H2Configuration(client_side=False)
    conn = h2.connection.H2Connection(config=config)
    conn.initiate_connection()
    sock.sendall(conn.data_to_send())

    while True:
        data = sock.recv(65535)
        if not data:
            break

        events = conn.receive_data(data)
        for event in events:
            if isinstance(event, h2.events.RequestReceived):
                send_response(conn, event)

        data_to_send = conn.data_to_send()
        if data_to_send:
            sock.sendall(data_to_send)

sock = socket.socket()
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(('0.0.0.0', 8080))
sock.listen(5)

while True:
    handle(sock.accept()[0])

```

Alright. Let's run this, and then run our hyper command again.

This time, nothing is printed from our server, and the hyper side prints `it works!`. Success! Try running it a few more times, and we can see that not only does it work the first time, it works the other times too!

We can speak HTTP/2! Let's add the final step: returning the JSON-encoded request headers.

Step 5: Returning Headers

If we want to return the request headers in JSON, the first thing we have to do is find them. Handily, if you check the documentation for *RequestReceived* you'll find that this event carries, in addition to the stream ID, the request headers.

This means we can make a really simple change to our `send_response` function to take those headers and encode them as a JSON object. Let's do that:

```

import json

def send_response(conn, event):
    stream_id = event.stream_id
    response_data = json.dumps(dict(event.headers)).encode('utf-8')

    conn.send_headers(
        stream_id=stream_id,

```

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```

        headers=[
            (':status', '200'),
            ('server', 'basic-h2-server/1.0'),
            ('content-length', str(len(response_data))),
            ('content-type', 'application/json'),
        ],
    )
    conn.send_data(
        stream_id=stream_id,
        data=response_data,
        end_stream=True
    )

```

This is a really simple change, but it's all we need to do: a few extra headers and the JSON dump, but that's it.

Section 6: Bringing It All Together

This should be all we need!

Let's take all the work we just did and throw that into our `h2server.py` file, which should now look like this:

```

import json
import socket

import h2.connection
import h2.events
import h2.config

def send_response(conn, event):
    stream_id = event.stream_id
    response_data = json.dumps(dict(event.headers)).encode('utf-8')

    conn.send_headers(
        stream_id=stream_id,
        headers=[
            (':status', '200'),
            ('server', 'basic-h2-server/1.0'),
            ('content-length', str(len(response_data))),
            ('content-type', 'application/json'),
        ],
    )
    conn.send_data(
        stream_id=stream_id,
        data=response_data,
        end_stream=True
    )

def handle(sock):
    config = h2.config.H2Configuration(client_side=False)
    conn = h2.connection.H2Connection(config=config)
    conn.initiate_connection()
    sock.sendall(conn.data_to_send())

    while True:
        data = sock.recv(65535)
        if not data:

```

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```

        break

    events = conn.receive_data(data)
    for event in events:
        if isinstance(event, h2.events.RequestReceived):
            send_response(conn, event)

    data_to_send = conn.data_to_send()
    if data_to_send:
        sock.sendall(data_to_send)

sock = socket.socket()
sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
sock.bind(('0.0.0.0', 8080))
sock.listen(5)

while True:
    handle(sock.accept()[0])

```

Now, execute `h2server.py` and then point `hyper` at it again. You should see something like the following output from `hyper`:

```

$ hyper --h2 GET http://localhost:8080/
{":scheme": "http", ":authority": "localhost", ":method": "GET", ":path": "/" }

```

Here you can see the HTTP/2 request ‘special headers’ that `hyper` sends. These are similar to the `:status` header we have to send on our response: they encode important parts of the HTTP request in a clearly-defined way. If you were writing a client stack using Hyper-h2, you’d need to make sure you were sending those headers.

Congratulations!

Congratulations! You’ve written your first HTTP/2 server! If you want to extend it, there are a few directions you could investigate:

- We didn’t handle a few events that we saw were being raised: you could add some methods to handle those appropriately.
- Right now our server is single threaded, so it can only handle one client at a time. Consider rewriting this server to use threads, or writing this server again using your favourite asynchronous programming framework.

If you plan to use threads, you should know that a `H2Connection` object is deliberately not thread-safe. As a possible design pattern, consider creating threads and passing the sockets returned by `accept` to those threads, and then letting those threads create their own `H2Connection` objects.

- Take a look at some of our long-form code examples in [Code Examples](#).
- Alternatively, try playing around with our examples in our repository’s [examples directory](#). These examples are a bit more fully-featured, and can be reached from your web browser. Try adjusting what they do, or adding new features to them!
- You may want to make this server reachable from your web browser. To do that, you’ll need to add proper TLS support to your server. This can be tricky, and in many cases requires [PyOpenSSL](#) in addition to the other libraries you have installed. Check the [Eventlet example](#) to see what PyOpenSSL code is required to TLS-ify your server.

1.3 Negotiating HTTP/2

RFC 7540 specifies three methods of negotiating HTTP/2 connections. This document outlines how to use Hyper-h2 with each one.

1.3.1 HTTPS URLs (ALPN)

Starting HTTP/2 for HTTPS URLs is outlined in RFC 7540 Section 3.3. In this case, the client and server use a TLS extension to negotiate HTTP/2: ALPN. How to use ALPN is currently not covered in this document: please consult the documentation for either the `ssl` module in the standard library, or the `PyOpenSSL` third-party modules, for more on this topic.

This method is the simplest to use once the TLS connection is established. To use it with Hyper-h2, after you've established the connection and confirmed that HTTP/2 has been negotiated with ALPN, create a `H2Connection` object and call `H2Connection.initiate_connection`. This will ensure that the appropriate preamble data is placed in the data buffer. You should then immediately send the data returned by `H2Connection.data_to_send` on your TLS connection.

At this point, you're free to use all the HTTP/2 functionality provided by Hyper-h2.

Note: Although Hyper-h2 is not concerned with negotiating protocol versions, it is important to note that support for ALPN is not available in the standard library of Python versions < 2.7.9. As a consequence, clients may encounter various errors due to protocol versions mismatch.

Server Setup Example

This example uses the APIs as defined in Python 3.5. If you are using an older version of Python you may not have access to the APIs used here. As noted above, please consult the documentation for the `ssl` module to confirm.

```
1  # -*- coding: utf-8 -*-
2  """
3  Server HTTPS Setup
4  ~~~~~
5
6  This example code fragment demonstrates how to set up a HTTP/2 server that
7  negotiates HTTP/2 using NPN and ALPN. For the sake of maximum explanatory value
8  this code uses the synchronous, low-level sockets API: however, if you're not
9  using sockets directly (e.g. because you're using asyncio), you should focus on
10 the set up required for the SSLContext object. For other concurrency libraries
11 you may need to use other setup (e.g. for Twisted you'll need to use
12 IProtocolNegotiationFactory).
13
14 This code requires Python 3.5 or later.
15 """
16 import h2.config
17 import h2.connection
18 import socket
19 import ssl
20
21
22 def establish_tcp_connection():
23     """
24     This function establishes a server-side TCP connection. How it works isn't
```

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```

25     very important to this example.
26     """
27     bind_socket = socket.socket()
28     bind_socket.bind('', 443)
29     bind_socket.listen(5)
30     return bind_socket.accept()[0]
31
32
33 def get_http2_ssl_context():
34     """
35     This function creates an SSLContext object that is suitably configured for
36     HTTP/2. If you're working with Python TLS directly, you'll want to do the
37     exact same setup as this function does.
38     """
39     # Get the basic context from the standard library.
40     ctx = ssl.create_default_context(purpose=ssl.Purpose.CLIENT_AUTH)
41
42     # RFC 7540 Section 9.2: Implementations of HTTP/2 MUST use TLS version 1.2
43     # or higher. Disable TLS 1.1 and lower.
44     ctx.options |= (
45         ssl.OP_NO_SSLv2 | ssl.OP_NO_SSLv3 | ssl.OP_NO_TLSv1 | ssl.OP_NO_TLSv1_1
46     )
47
48     # RFC 7540 Section 9.2.1: A deployment of HTTP/2 over TLS 1.2 MUST disable
49     # compression.
50     ctx.options |= ssl.OP_NO_COMPRESSION
51
52     # RFC 7540 Section 9.2.2: "deployments of HTTP/2 that use TLS 1.2 MUST
53     # support TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256". In practice, the
54     # blocklist defined in this section allows only the AES GCM and ChaCha20
55     # cipher suites with ephemeral key negotiation.
56     ctx.set_ciphers("ECDHE+AESGCM:ECDHE+CHACHA20:DHE+AESGCM:DHE+CHACHA20")
57
58     # We want to negotiate using NPN and ALPN. ALPN is mandatory, but NPN may
59     # be absent, so allow that. This setup allows for negotiation of HTTP/1.1.
60     ctx.set_alpn_protocols(["h2", "http/1.1"])
61
62     try:
63         ctx.set_npn_protocols(["h2", "http/1.1"])
64     except NotImplementedError:
65         pass
66
67     return ctx
68
69
70 def negotiate_tls(tcp_conn, context):
71     """
72     Given an established TCP connection and a HTTP/2-appropriate TLS context,
73     this function:
74
75     1. wraps TLS around the TCP connection.
76     2. confirms that HTTP/2 was negotiated and, if it was not, throws an error.
77     """
78     tls_conn = context.wrap_socket(tcp_conn, server_side=True)
79
80     # Always prefer the result from ALPN to that from NPN.
81     # You can only check what protocol was negotiated once the handshake is

```

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```

82     # complete.
83     negotiated_protocol = tls_conn.selected_alpn_protocol()
84     if negotiated_protocol is None:
85         negotiated_protocol = tls_conn.selected_npn_protocol()
86
87     if negotiated_protocol != "h2":
88         raise RuntimeError("Didn't negotiate HTTP/2!")
89
90     return tls_conn
91
92
93 def main():
94     # Step 1: Set up your TLS context.
95     context = get_http2_ssl_context()
96
97     # Step 2: Receive a TCP connection.
98     connection = establish_tcp_connection()
99
100    # Step 3: Wrap the connection in TLS and validate that we negotiated HTTP/2
101    tls_connection = negotiate_tls(connection, context)
102
103    # Step 4: Create a server-side H2 connection.
104    config = h2.config.H2Configuration(client_side=False)
105    http2_connection = h2.connection.H2Connection(config=config)
106
107    # Step 5: Initiate the connection
108    http2_connection.initiate_connection()
109    tls_connection.sendall(http2_connection.data_to_send())
110
111    # The TCP, TLS, and HTTP/2 handshakes are now complete. You can enter your
112    # main loop now.

```

Client Setup Example

The client example is very similar to the server example above. The `SSLContext` object requires some minor changes, as does the `H2Connection`, but the bulk of the code is the same.

```

1  # -*- coding: utf-8 -*-
2  """
3  Client HTTPS Setup
4  ~~~~~
5
6  This example code fragment demonstrates how to set up a HTTP/2 client that
7  negotiates HTTP/2 using NPN and ALPN. For the sake of maximum explanatory value
8  this code uses the synchronous, low-level sockets API: however, if you're not
9  using sockets directly (e.g. because you're using asyncio), you should focus on
10 the set up required for the SSLContext object. For other concurrency libraries
11 you may need to use other setup (e.g. for Twisted you'll need to use
12 IProtocolNegotiationFactory).
13
14 This code requires Python 3.5 or later.
15 """
16 import h2.connection
17 import socket
18 import ssl

```

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```

19
20
21 def establish_tcp_connection():
22     """
23     This function establishes a client-side TCP connection. How it works isn't
24     very important to this example. For the purpose of this example we connect
25     to localhost.
26     """
27     return socket.create_connection(('localhost', 443))
28
29
30 def get_http2_ssl_context():
31     """
32     This function creates an SSLContext object that is suitably configured for
33     HTTP/2. If you're working with Python TLS directly, you'll want to do the
34     exact same setup as this function does.
35     """
36     # Get the basic context from the standard library.
37     ctx = ssl.create_default_context(purpose=ssl.Purpose.SERVER_AUTH)
38
39     # RFC 7540 Section 9.2: Implementations of HTTP/2 MUST use TLS version 1.2
40     # or higher. Disable TLS 1.1 and lower.
41     ctx.options |= (
42         ssl.OP_NO_SSLv2 | ssl.OP_NO_SSLv3 | ssl.OP_NO_TLSv1 | ssl.OP_NO_TLSv1_1
43     )
44
45     # RFC 7540 Section 9.2.1: A deployment of HTTP/2 over TLS 1.2 MUST disable
46     # compression.
47     ctx.options |= ssl.OP_NO_COMPRESSION
48
49     # RFC 7540 Section 9.2.2: "deployments of HTTP/2 that use TLS 1.2 MUST
50     # support TLS_ECDHE_RSA_WITH_AES_128_GCM_SHA256". In practice, the
51     # blocklist defined in this section allows only the AES GCM and ChaCha20
52     # cipher suites with ephemeral key negotiation.
53     ctx.set_ciphers("ECDHE+AESGCM:ECDHE+CHACHA20:DHE+AESGCM:DHE+CHACHA20")
54
55     # We want to negotiate using NPN and ALPN. ALPN is mandatory, but NPN may
56     # be absent, so allow that. This setup allows for negotiation of HTTP/1.1.
57     ctx.set_alpn_protocols(["h2", "http/1.1"])
58
59     try:
60         ctx.set_npn_protocols(["h2", "http/1.1"])
61     except NotImplementedError:
62         pass
63
64     return ctx
65
66
67 def negotiate_tls(tcp_conn, context):
68     """
69     Given an established TCP connection and a HTTP/2-appropriate TLS context,
70     this function:
71
72     1. wraps TLS around the TCP connection.
73     2. confirms that HTTP/2 was negotiated and, if it was not, throws an error.
74     """
75     # Note that SNI is mandatory for HTTP/2, so you *must* pass the

```

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```

76     # server_hostname argument.
77     tls_conn = context.wrap_socket(tcp_conn, server_hostname='localhost')
78
79     # Always prefer the result from ALPN to that from NPN.
80     # You can only check what protocol was negotiated once the handshake is
81     # complete.
82     negotiated_protocol = tls_conn.selected_alpn_protocol()
83     if negotiated_protocol is None:
84         negotiated_protocol = tls_conn.selected_npn_protocol()
85
86     if negotiated_protocol != "h2":
87         raise RuntimeError("Didn't negotiate HTTP/2!")
88
89     return tls_conn
90
91
92 def main():
93     # Step 1: Set up your TLS context.
94     context = get_http2_ssl_context()
95
96     # Step 2: Create a TCP connection.
97     connection = establish_tcp_connection()
98
99     # Step 3: Wrap the connection in TLS and validate that we negotiated HTTP/2
100    tls_connection = negotiate_tls(connection, context)
101
102    # Step 4: Create a client-side H2 connection.
103    http2_connection = h2.connection.H2Connection()
104
105    # Step 5: Initiate the connection
106    http2_connection.initiate_connection()
107    tls_connection.sendall(http2_connection.data_to_send())
108
109    # The TCP, TLS, and HTTP/2 handshakes are now complete. You can enter your
110    # main loop now.

```

1.3.2 HTTP URLs (Upgrade)

Starting HTTP/2 for HTTP URLs is outlined in [RFC 7540 Section 3.2](#). In this case, the client and server use the HTTP Upgrade mechanism originally described in [RFC 7230 Section 6.7](#). The client sends its initial HTTP/1.1 request with two extra headers. The first is `Upgrade: h2c`, which requests upgrade to cleartext HTTP/2. The second is a `HTTP2-Settings` header, which contains a specially formatted string that encodes a HTTP/2 Settings frame.

To do this with Hyper-h2 you have two slightly different flows: one for clients, one for servers.

Clients

For a client, when sending the first request you should manually add your Upgrade header. You should then create a `H2Connection` object and call `H2Connection.initiate_upgrade_connection` with no arguments. This method will return a bytestring to use as the value of your HTTP2-Settings header.

If the server returns a 101 status code, it has accepted the upgrade, and you should immediately send the data returned by `H2Connection.data_to_send`. Now you should consume the entire 101 header block. All data after the 101 header block is HTTP/2 data that should be fed directly to `H2Connection.receive_data` and handled as normal with Hyper-h2.

If the server does not return a 101 status code then it is not upgrading. Continue with HTTP/1.1 as normal: you may throw away your `H2Connection` object, as it is of no further use.

The server will respond to your original request in HTTP/2. Please pay attention to the events received from Hyper-h2, as they will define the server's response.

Client Example

The code below demonstrates how to handle a plaintext upgrade from the perspective of the client. For the purposes of keeping the example code as simple and generic as possible it uses the synchronous socket API that comes with the Python standard library: if you want to use asynchronous I/O, you will need to translate this code to the appropriate idiom.

```

1  # -*- coding: utf-8 -*-
2  """
3  Client Plaintext Upgrade
4  ~~~~~
5
6  This example code fragment demonstrates how to set up a HTTP/2 client that uses
7  the plaintext HTTP Upgrade mechanism to negotiate HTTP/2 connectivity. For
8  maximum explanatory value it uses the synchronous socket API that comes with
9  the Python standard library. In product code you will want to use an actual
10 HTTP/1.1 client if possible.
11
12 This code requires Python 3.5 or later.
13 """
14 import h2.connection
15 import socket
16
17
18 def establish_tcp_connection():
19     """
20     This function establishes a client-side TCP connection. How it works isn't
21     very important to this example. For the purpose of this example we connect
22     to localhost.
23     """
24     return socket.create_connection(('localhost', 80))
25
26
27 def send_initial_request(connection, settings):
28     """
29     For the sake of this upgrade demonstration, we're going to issue a GET
30     request against the root of the site. In principle the best request to
31     issue for an upgrade is actually ``OPTIONS *``, but this is remarkably
32     poorly supported and can break in weird ways.
33     """
34     # Craft our initial request per RFC 7540 Section 3.2. This requires two
35     # special header fields: the Upgrade headre, and the HTTP2-Settings header.
36     # The value of the HTTP2-Settings header field comes from h2.
37     request = (
38         b"GET / HTTP/1.1\r\n" +
39         b"Host: localhost\r\n" +
40         b"Upgrade: h2c\r\n" +
41         b"HTTP2-Settings: " + settings + b"\r\n" +
42         b"\r\n"
43     )
44     connection.sendall(request)

```

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```

45
46
47 def get_upgrade_response(connection):
48     """
49     This function reads from the socket until the HTTP/1.1 end-of-headers
50     sequence (CRLF CRLF) is received. It then checks what the status code of the
51     response is.
52
53     This is not a substitute for proper HTTP/1.1 parsing, but it's good enough
54     for example purposes.
55     """
56     data = b''
57     while b'\r\n\r\n' not in data:
58         data += connection.recv(8192)
59
60     headers, rest = data.split(b'\r\n\r\n', 1)
61
62     # An upgrade response begins HTTP/1.1 101 Switching Protocols. Look for the
63     # code. In production code you should also check that the upgrade is to
64     # h2c, but here we know we only offered one upgrade so there's only one
65     # possible upgrade in use.
66     split_headers = headers.split()
67     if split_headers[1] != b'101':
68         raise RuntimeError("Not upgrading!")
69
70     # We don't care about the HTTP/1.1 data anymore, but we do care about
71     # any other data we read from the socket: this is going to be HTTP/2 data
72     # that must be passed to the H2Connection.
73     return rest
74
75
76 def main():
77     """
78     The client upgrade flow.
79     """
80     # Step 1: Establish the TCP connection.
81     connection = establish_tcp_connection()
82
83     # Step 2: Create H2 Connection object, put it in upgrade mode, and get the
84     # value of the HTTP2-Settings header we want to use.
85     h2_connection = h2.connection.H2Connection()
86     settings_header_value = h2_connection.initiate_upgrade_connection()
87
88     # Step 3: Send the initial HTTP/1.1 request with the upgrade fields.
89     send_initial_request(connection, settings_header_value)
90
91     # Step 4: Read the HTTP/1.1 response, look for 101 response.
92     extra_data = get_upgrade_response(connection)
93
94     # Step 5: Immediately send the pending HTTP/2 data.
95     connection.sendall(h2_connection.data_to_send())
96
97     # Step 6: Feed the body data to the connection.
98     events = connection.receive_data(extra_data)
99
100     # Now you can enter your main loop, beginning by processing the first set
101     # of events above. These events may include ResponseReceived, which will

```

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```

102     # contain the response to the request we made in Step 3.
103     main_loop(events)

```

Servers

If the first request you receive on a connection from the client contains an Upgrade header with the h2c token in it, and you're willing to upgrade, you should create a `H2Connection` object and call `H2Connection.initiate_upgrade_connection` with the value of the HTTP2-Settings header (as a bytestring) as the only argument.

Then, you should send back a 101 response that contains h2c in the Upgrade header. That response will inform the client that you're switching to HTTP/2. Then, you should immediately send the data that is returned to you by `H2Connection.data_to_send` on the connection: this is a necessary part of the HTTP/2 upgrade process.

At this point, you may now respond to the original HTTP/1.1 request in HTTP/2 by calling the appropriate methods on the `H2Connection` object. No further HTTP/1.1 may be sent on this connection: from this point onward, all data sent by you and the client will be HTTP/2 data.

Server Example

The code below demonstrates how to handle a plaintext upgrade from the perspective of the server. For the purposes of keeping the example code as simple and generic as possible it uses the synchronous socket API that comes with the Python standard library: if you want to use asynchronous I/O, you will need to translate this code to the appropriate idiom.

```

1  # -*- coding: utf-8 -*-
2  """
3  Server Plaintext Upgrade
4  ~~~~~
5
6  This example code fragment demonstrates how to set up a HTTP/2 server that uses
7  the plaintext HTTP Upgrade mechanism to negotiate HTTP/2 connectivity. For
8  maximum explanatory value it uses the synchronous socket API that comes with
9  the Python standard library. In product code you will want to use an actual
10 HTTP/1.1 server library if possible.
11
12 This code requires Python 3.5 or later.
13 """
14 import h2.config
15 import h2.connection
16 import re
17 import socket
18
19
20 def establish_tcp_connection():
21     """
22     This function establishes a server-side TCP connection. How it works isn't
23     very important to this example.
24     """
25     bind_socket = socket.socket()
26     bind_socket.bind(('', 443))
27     bind_socket.listen(5)
28     return bind_socket.accept()[0]

```

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```

29
30
31 def receive_initial_request(connection):
32     """
33     We're going to receive a request. For the sake of this example, we're going
34     to assume that the first request has no body. If it doesn't have the
35     Upgrade: h2c header field and the HTTP2-Settings header field, we'll throw
36     errors.
37
38     In production code, you should use a proper HTTP/1.1 parser and actually
39     serve HTTP/1.1 requests!
40
41     Returns the value of the HTTP2-Settings header field.
42     """
43     data = b''
44     while not data.endswith(b'\r\n\r\n'):
45         data += connection.recv(8192)
46
47     match = re.search(b'Upgrade: h2c\r\n', data)
48     if match is None:
49         raise RuntimeError("HTTP/2 upgrade not requested!")
50
51     # We need to look for the HTTP2-Settings header field. Again, in production
52     # code you shouldn't use regular expressions for this, but it's good enough
53     # for the example.
54     match = re.search(b'HTTP2-Settings: (\\S+)\r\n', data)
55     if match is None:
56         raise RuntimeError("HTTP2-Settings header field not present!")
57
58     return match.group(1)
59
60
61 def send_upgrade_response(connection):
62     """
63     This function writes the 101 Switching Protocols response.
64     """
65     response = (
66         b"HTTP/1.1 101 Switching Protocols\r\n"
67         b"Upgrade: h2c\r\n"
68         b"\r\n"
69     )
70     connection.sendall(response)
71
72
73 def main():
74     """
75     The server upgrade flow.
76     """
77     # Step 1: Establish the TCP connection.
78     connection = establish_tcp_connection()
79
80     # Step 2: Read the response. We expect this to request an upgrade.
81     settings_header_value = receive_initial_request(connection)
82
83     # Step 3: Create a H2Connection object in server mode, and pass it the
84     # value of the HTTP2-Settings header field.
85     config = h2.config.H2Configuration(client_side=False)

```

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```

86     h2_connection = h2.connection.H2Connection(config=config)
87     h2_connection.initiate_upgrade_connection(
88         settings_header=settings_header_value
89     )
90
91     # Step 4: Send the 101 Switching Protocols response.
92     send_upgrade_response(connection)
93
94     # Step 5: Send pending HTTP/2 data.
95     connection.sendall(h2_connection.data_to_send())
96
97     # At this point, you can enter your main loop. The first step has to be to
98     # send the response to the initial HTTP/1.1 request you received on stream
99     # 1.
100    main_loop()

```

1.3.3 Prior Knowledge

It's possible that you as a client know that a particular server supports HTTP/2, and that you do not need to perform any of the negotiations described above. In that case, you may follow the steps in *HTTPS URLs (ALPN)*, ignoring all references to ALPN: there's no need to perform the upgrade dance described in *HTTP URLs (Upgrade)*.

1.4 Code Examples

This section of the documentation contains long-form code examples. These are intended as references for developers that would like to get an understanding of how Hyper-h2 fits in with various Python I/O frameworks.

1.4.1 Example Servers

Asyncio Example Server

This example is a basic HTTP/2 server written using *asyncio*, using some functionality that was introduced in Python 3.5. This server represents basically just the same JSON-headers-returning server that was built in the *Getting Started: Writing Your Own HTTP/2 Server* document.

This example demonstrates some basic asyncio techniques.

```

1  # -*- coding: utf-8 -*-
2  """
3  asyncio-server.py
4  ~~~~~
5
6  A fully-functional HTTP/2 server using asyncio. Requires Python 3.5+.
7
8  This example demonstrates handling requests with bodies, as well as handling
9  those without. In particular, it demonstrates the fact that DataReceived may
10 be called multiple times, and that applications must handle that possibility.
11 """
12 import asyncio
13 import io
14 import json

```

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```

15 import ssl
16 import collections
17 from typing import List, Tuple
18
19 from h2.config import H2Configuration
20 from h2.connection import H2Connection
21 from h2.events import (
22     ConnectionTerminated, DataReceived, RemoteSettingsChanged,
23     RequestReceived, StreamEnded, StreamReset, WindowUpdated
24 )
25 from h2.errors import ErrorCodes
26 from h2.exceptions import ProtocolError, StreamClosedError
27 from h2.settings import SettingCodes
28
29
30 RequestData = collections.namedtuple('RequestData', ['headers', 'data'])
31
32
33 class H2Protocol(asyncio.Protocol):
34     def __init__(self):
35         config = H2Configuration(client_side=False, header_encoding='utf-8')
36         self.conn = H2Connection(config=config)
37         self.transport = None
38         self.stream_data = {}
39         self.flow_control_futures = {}
40
41     def connection_made(self, transport: asyncio.Transport):
42         self.transport = transport
43         self.conn.initiate_connection()
44         self.transport.write(self.conn.data_to_send())
45
46     def connection_lost(self, exc):
47         for future in self.flow_control_futures.values():
48             future.cancel()
49         self.flow_control_futures = {}
50
51     def data_received(self, data: bytes):
52         try:
53             events = self.conn.receive_data(data)
54         except ProtocolError as e:
55             self.transport.write(self.conn.data_to_send())
56             self.transport.close()
57         else:
58             self.transport.write(self.conn.data_to_send())
59             for event in events:
60                 if isinstance(event, RequestReceived):
61                     self.request_received(event.headers, event.stream_id)
62                 elif isinstance(event, DataReceived):
63                     self.receive_data(event.data, event.stream_id)
64                 elif isinstance(event, StreamEnded):
65                     self.stream_complete(event.stream_id)
66                 elif isinstance(event, ConnectionTerminated):
67                     self.transport.close()
68                 elif isinstance(event, StreamReset):
69                     self.stream_reset(event.stream_id)
70                 elif isinstance(event, WindowUpdated):
71                     self.window_updated(event.stream_id, event.delta)

```

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```

72         elif isinstance(event, RemoteSettingsChanged):
73             if SettingCodes.INITIAL_WINDOW_SIZE in event.changed_settings:
74                 self.window_updated(None, 0)
75
76         self.transport.write(self.conn.data_to_send())
77
78     def request_received(self, headers: List[Tuple[str, str]], stream_id: int):
79         headers = collections.OrderedDict(headers)
80         method = headers[':method']
81
82         # Store off the request data.
83         request_data = RequestData(headers, io.BytesIO())
84         self.stream_data[stream_id] = request_data
85
86     def stream_complete(self, stream_id: int):
87         """
88         When a stream is complete, we can send our response.
89         """
90         try:
91             request_data = self.stream_data[stream_id]
92         except KeyError:
93             # Just return, we probably 405'd this already
94             return
95
96         headers = request_data.headers
97         body = request_data.data.getvalue().decode('utf-8')
98
99         data = json.dumps(
100             {"headers": headers, "body": body}, indent=4
101         ).encode("utf8")
102
103         response_headers = (
104             (':status', '200'),
105             ('content-type', 'application/json'),
106             ('content-length', str(len(data))),
107             ('server', 'asyncio-h2'),
108         )
109         self.conn.send_headers(stream_id, response_headers)
110         asyncio.ensure_future(self.send_data(data, stream_id))
111
112     def receive_data(self, data: bytes, stream_id: int):
113         """
114         We've received some data on a stream. If that stream is one we're
115         expecting data on, save it off. Otherwise, reset the stream.
116         """
117         try:
118             stream_data = self.stream_data[stream_id]
119         except KeyError:
120             self.conn.reset_stream(
121                 stream_id, error_code=ErrorCodes.PROTOCOL_ERROR
122             )
123         else:
124             stream_data.data.write(data)
125
126     def stream_reset(self, stream_id: int):
127         """
128         A stream reset was sent. Stop sending data.

```

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```

129         """
130         if stream_id in self.flow_control_futures:
131             future = self.flow_control_futures.pop(stream_id)
132             future.cancel()
133
134     async def send_data(self, data, stream_id):
135         """
136         Send data according to the flow control rules.
137         """
138         while data:
139             while self.conn.local_flow_control_window(stream_id) < 1:
140                 try:
141                     await self.wait_for_flow_control(stream_id)
142                 except asyncio.CancelledError:
143                     return
144
145             chunk_size = min(
146                 self.conn.local_flow_control_window(stream_id),
147                 len(data),
148                 self.conn.max_outbound_frame_size,
149             )
150
151             try:
152                 self.conn.send_data(
153                     stream_id,
154                     data[:chunk_size],
155                     end_stream=(chunk_size == len(data))
156                 )
157             except (StreamClosedError, ProtocolError):
158                 # The stream got closed and we didn't get told. We're done
159                 # here.
160                 break
161
162             self.transport.write(self.conn.data_to_send())
163             data = data[chunk_size:]
164
165     async def wait_for_flow_control(self, stream_id):
166         """
167         Waits for a Future that fires when the flow control window is opened.
168         """
169         f = asyncio.Future()
170         self.flow_control_futures[stream_id] = f
171         await f
172
173     def window_updated(self, stream_id, delta):
174         """
175         A window update frame was received. Unblock some number of flow control
176         Futures.
177         """
178         if stream_id and stream_id in self.flow_control_futures:
179             f = self.flow_control_futures.pop(stream_id)
180             f.set_result(delta)
181         elif not stream_id:
182             for f in self.flow_control_futures.values():
183                 f.set_result(delta)
184
185         self.flow_control_futures = {}

```

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```

186
187
188 ssl_context = ssl.create_default_context(ssl.Purpose.CLIENT_AUTH)
189 ssl_context.options |= (
190     ssl.OP_NO_TLSv1 | ssl.OP_NO_TLSv1_1 | ssl.OP_NO_COMPRESSION
191 )
192 ssl_context.load_cert_chain(certfile="cert.crt", keyfile="cert.key")
193 ssl_context.set_alpn_protocols(["h2"])
194
195 loop = asyncio.get_event_loop()
196 # Each client connection will create a new protocol instance
197 coro = loop.create_server(H2Protocol, '127.0.0.1', 8443, ssl=ssl_context)
198 server = loop.run_until_complete(coro)
199
200 # Serve requests until Ctrl+C is pressed
201 print('Serving on {}'.format(server.sockets[0].getsockname()))
202 try:
203     loop.run_forever()
204 except KeyboardInterrupt:
205     pass
206
207 # Close the server
208 server.close()
209 loop.run_until_complete(server.wait_closed())
210 loop.close()

```

Twisted Example Server

This example is a basic HTTP/2 server written for the [Twisted](#) asynchronous networking framework. This is a relatively fleshed out example, and in particular it makes sure to obey HTTP/2 flow control rules.

This server differs from some of the other example servers by serving files, rather than simply sending JSON responses. This makes the example lengthier, but also brings it closer to a real-world use-case.

```

1  # -*- coding: utf-8 -*-
2  """
3  twisted-server.py
4  ~~~~~
5
6  A fully-functional HTTP/2 server written for Twisted.
7  """
8  import functools
9  import mimetypes
10 import os
11 import os.path
12 import sys
13
14 from OpenSSL import crypto
15 from twisted.internet.defer import Deferred, inlineCallbacks
16 from twisted.internet.protocol import Protocol, Factory
17 from twisted.internet import endpoints, reactor, ssl
18 from h2.config import H2Configuration
19 from h2.connection import H2Connection
20 from h2.events import (
21     RequestReceived, DataReceived, WindowUpdated

```

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```

22 )
23 from h2.exceptions import ProtocolError
24
25
26 def close_file(file, d):
27     file.close()
28
29
30 READ_CHUNK_SIZE = 8192
31
32
33 class H2Protocol(Protocol):
34     def __init__(self, root):
35         config = H2Configuration(client_side=False)
36         self.conn = H2Connection(config=config)
37         self.known_proto = None
38         self.root = root
39
40         self._flow_control_deferreds = {}
41
42     def connectionMade(self):
43         self.conn.initiate_connection()
44         self.transport.write(self.conn.data_to_send())
45
46     def dataReceived(self, data):
47         if not self.known_proto:
48             self.known_proto = True
49
50         try:
51             events = self.conn.receive_data(data)
52         except ProtocolError:
53             if self.conn.data_to_send:
54                 self.transport.write(self.conn.data_to_send())
55             self.transportloseConnection()
56         else:
57             for event in events:
58                 if isinstance(event, RequestReceived):
59                     self.requestReceived(event.headers, event.stream_id)
60                 elif isinstance(event, DataReceived):
61                     self.dataFrameReceived(event.stream_id)
62                 elif isinstance(event, WindowUpdated):
63                     self.windowUpdated(event)
64
65             if self.conn.data_to_send:
66                 self.transport.write(self.conn.data_to_send())
67
68     def requestReceived(self, headers, stream_id):
69         headers = dict(headers) # Invalid conversion, fix later.
70         assert headers[b':method'] == b'GET'
71
72         path = headers[b':path'].lstrip(b'/')
73         full_path = os.path.join(self.root, path)
74
75         if not os.path.exists(full_path):
76             response_headers = (
77                 (':status', '404'),
78                 ('content-length', '0'),

```

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```

79         ('server', 'twisted-h2'),
80     )
81     self.conn.send_headers(
82         stream_id, response_headers, end_stream=True
83     )
84     self.transport.write(self.conn.data_to_send())
85 else:
86     self.sendFile(full_path, stream_id)
87
88     return
89
90 def dataFrameReceived(self, stream_id):
91     self.conn.reset_stream(stream_id)
92     self.transport.write(self.conn.data_to_send())
93
94 def sendFile(self, file_path, stream_id):
95     filesize = os.stat(file_path).st_size
96     content_type, content_encoding = mimetypes.guess_type(
97         file_path.decode('utf-8')
98     )
99     response_headers = [
100         (':status', '200'),
101         ('content-length', str(filesize)),
102         ('server', 'twisted-h2'),
103     ]
104     if content_type:
105         response_headers.append(('content-type', content_type))
106     if content_encoding:
107         response_headers.append(('content-encoding', content_encoding))
108
109     self.conn.send_headers(stream_id, response_headers)
110     self.transport.write(self.conn.data_to_send())
111
112     f = open(file_path, 'rb')
113     d = self._send_file(f, stream_id)
114     d.addErrback(functools.partial(close_file, f))
115
116 def windowUpdated(self, event):
117     """
118     Handle a WindowUpdated event by firing any waiting data sending
119     callbacks.
120     """
121     stream_id = event.stream_id
122
123     if stream_id and stream_id in self._flow_control_deferreds:
124         d = self._flow_control_deferreds.pop(stream_id)
125         d.callback(event.delta)
126     elif not stream_id:
127         for d in self._flow_control_deferreds.values():
128             d.callback(event.delta)
129
130     self._flow_control_deferreds = {}
131
132     return
133
134 @inlineCallbacks
135 def _send_file(self, file, stream_id):

```

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```

136     """
137     This callback sends more data for a given file on the stream.
138     """
139     keep_reading = True
140     while keep_reading:
141         while not self.conn.remote_flow_control_window(stream_id):
142             yield self.wait_for_flow_control(stream_id)
143
144         chunk_size = min(
145             self.conn.remote_flow_control_window(stream_id), READ_CHUNK_SIZE
146         )
147         data = file.read(chunk_size)
148         keep_reading = len(data) == chunk_size
149         self.conn.send_data(stream_id, data, not keep_reading)
150         self.transport.write(self.conn.data_to_send())
151
152         if not keep_reading:
153             break
154
155     file.close()
156
157     def wait_for_flow_control(self, stream_id):
158         """
159         Returns a Deferred that fires when the flow control window is opened.
160         """
161         d = Deferred()
162         self._flow_control_deferreds[stream_id] = d
163         return d
164
165
166     class H2Factory(Factory):
167         def __init__(self, root):
168             self.root = root
169
170         def buildProtocol(self, addr):
171             print(H2Protocol)
172             return H2Protocol(self.root)
173
174
175 root = sys.argv[1].encode('utf-8')
176
177 with open('server.crt', 'r') as f:
178     cert_data = f.read()
179 with open('server.key', 'r') as f:
180     key_data = f.read()
181
182 cert = crypto.load_certificate(crypto.FILETYPE_PEM, cert_data)
183 key = crypto.load_privatekey(crypto.FILETYPE_PEM, key_data)
184 options = ssl.CertificateOptions(
185     privateKey=key,
186     certificate=cert,
187     acceptableProtocols=[b'h2'],
188 )
189
190 endpoint = endpoints.SSL4ServerEndpoint(reactor, 8080, options, backlog=128)
191 endpoint.listen(H2Factory(root))
192 reactor.run()

```

Eventlet Example Server

This example is a basic HTTP/2 server written using the `eventlet` concurrent networking framework. This example is notable for demonstrating how to configure `PyOpenSSL`, which `eventlet` uses for its TLS layer.

In terms of HTTP/2 functionality, this example is very simple: it returns the request headers as a JSON document to the caller. It does not obey HTTP/2 flow control, which is a flaw, but it is otherwise functional.

```

1  # -*- coding: utf-8 -*-
2  """
3  eventlet-server.py
4  ~~~~~
5
6  A fully-functional HTTP/2 server written for Eventlet.
7  """
8  import collections
9  import json
10
11  import eventlet
12
13  from eventlet.green.OpenSSL import SSL, crypto
14  from h2.config import H2Configuration
15  from h2.connection import H2Connection
16  from h2.events import RequestReceived, DataReceived
17
18
19  class ConnectionManager(object):
20      """
21      An object that manages a single HTTP/2 connection.
22      """
23      def __init__(self, sock):
24          config = H2Configuration(client_side=False)
25          self.sock = sock
26          self.conn = H2Connection(config=config)
27
28      def run_forever(self):
29          self.conn.initiate_connection()
30          self.sock.sendall(self.conn.data_to_send())
31
32          while True:
33              data = self.sock.recv(65535)
34              if not data:
35                  break
36
37              events = self.conn.receive_data(data)
38
39              for event in events:
40                  if isinstance(event, RequestReceived):
41                      self.request_received(event.headers, event.stream_id)
42                  elif isinstance(event, DataReceived):
43                      self.conn.reset_stream(event.stream_id)
44
45              self.sock.sendall(self.conn.data_to_send())
46
47      def request_received(self, headers, stream_id):
48          headers = collections.OrderedDict(headers)
49          data = json.dumps({'headers': headers}, indent=4).encode('utf-8')
50

```

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```

51         response_headers = (
52             (':status', '200'),
53             ('content-type', 'application/json'),
54             ('content-length', str(len(data))),
55             ('server', 'eventlet-h2'),
56         )
57         self.conn.send_headers(stream_id, response_headers)
58         self.conn.send_data(stream_id, data, end_stream=True)
59
60
61     def alpn_callback(conn, protos):
62         if b'h2' in protos:
63             return b'h2'
64
65         raise RuntimeError("No acceptable protocol offered!")
66
67
68     def npn_advertise_cb(conn):
69         return [b'h2']
70
71
72     # Let's set up SSL. This is a lot of work in PyOpenSSL.
73     options = (
74         SSL.OP_NO_COMPRESSION |
75         SSL.OP_NO_SSLv2 |
76         SSL.OP_NO_SSLv3 |
77         SSL.OP_NO_TLSv1 |
78         SSL.OP_NO_TLSv1_1
79     )
80     context = SSL.Context(SSL.SSLv23_METHOD)
81     context.set_options(options)
82     context.set_verify(SSL.VERIFY_NONE, lambda *args: True)
83     context.use_privatekey_file('server.key')
84     context.use_certificate_file('server.crt')
85     context.set_npn_advertise_callback(npn_advertise_cb)
86     context.set_alpn_select_callback(alpn_callback)
87     context.set_cipher_list(
88         "ECDHE+AESGCM"
89     )
90     context.set_tmp_ecdh(crypto.get_elliptic_curve(u'prime256v1'))
91
92     server = eventlet.listen(('0.0.0.0', 443))
93     server = SSL.Connection(context, server)
94     pool = eventlet.GreenPool()
95
96     while True:
97         try:
98             new_sock, _ = server.accept()
99             manager = ConnectionManager(new_sock)
100             pool.spawn_n(manager.run_forever)
101         except (SystemExit, KeyboardInterrupt):
102             break

```

Gevent Example Server

This example is a basic HTTP/2 server written using `gevent`, a powerful coroutine-based Python networking library that uses `greenlet` to provide a high-level synchronous API on top of the `libev` or `libuv` event loop.

This example is inspired by the `curio` one and also demonstrates the correct use of HTTP/2 flow control with Hyper-h2 and how `gevent` can be simple to use.

```

1  # -*- coding: utf-8 -*-
2  """
3  gevent-server.py
4  =====
5
6  A simple HTTP/2 server written for gevent serving static files from a directory_
   ↳ specified as input.
7  If no directory is provided, the current directory will be used.
8  """
9  import mimetypes
10 import sys
11 from functools import partial
12 from pathlib import Path
13 from typing import Tuple, Dict, Optional
14
15 from gevent import socket, ssl
16 from gevent.event import Event
17 from gevent.server import StreamServer
18 from h2 import events
19 from h2.config import H2Configuration
20 from h2.connection import H2Connection
21
22
23 def get_http2_tls_context() -> ssl.SSLContext:
24     ctx = ssl.create_default_context(purpose=ssl.Purpose.CLIENT_AUTH)
25     ctx.options |= (
26         ssl.OP_NO_SSLv2 | ssl.OP_NO_SSLv3 | ssl.OP_NO_TLSv1 | ssl.OP_NO_TLSv1_1
27     )
28
29     ctx.options |= ssl.OP_NO_COMPRESSION
30     ctx.set_ciphers('ECDHE+AESGCM:ECDHE+CHACHA20:DHE+AESGCM:DHE+CHACHA20')
31     ctx.load_cert_chain(certfile='localhost.crt', keyfile='localhost.key')
32     ctx.set_alpn_protocols(['h2'])
33     try:
34         ctx.set_npn_protocols(['h2'])
35     except NotImplementedError:
36         pass
37
38     return ctx
39
40
41 class H2Worker:
42
43     def __init__(self, sock: socket, address: Tuple[str, str], source_dir: str =_
   ↳ None):
44         self._sock = sock
45         self._address = address
46         self._flow_control_events: Dict[int, Event] = {}
47         self._server_name = 'gevent-h2'
48         self._connection: Optional[H2Connection] = None

```

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```

49     self._read_chunk_size = 8192  # The maximum amount of a file we'll send in a
↳ single DATA frame
50
51     self._check_sources_dir(source_dir)
52     self._sources_dir = source_dir
53
54     self._run()
55
56     def _initiate_connection(self):
57         config = H2Configuration(client_side=False, header_encoding='utf-8')
58         self._connection = H2Connection(config=config)
59         self._connection.initiate_connection()
60         self._sock.sendall(self._connection.data_to_send())
61
62     @staticmethod
63     def _check_sources_dir(sources_dir: str) -> None:
64         p = Path(sources_dir)
65         if not p.is_dir():
66             raise NotADirectoryError(f'{sources_dir} does not exists')
67
68     def _send_error_response(self, status_code: str, event: events.RequestReceived) ->
↳ None:
69         self._connection.send_headers(
70             stream_id=event.stream_id,
71             headers=[
72                 (':status', status_code),
73                 ('content-length', '0'),
74                 ('server', self._server_name),
75             ],
76             end_stream=True
77         )
78         self._sock.sendall(self._connection.data_to_send())
79
80     def _handle_request(self, event: events.RequestReceived) -> None:
81         headers = dict(event.headers)
82         if headers[':method'] != 'GET':
83             self._send_error_response('405', event)
84             return
85
86         file_path = Path(self._sources_dir) / headers[':path'].lstrip('/')
87         if not file_path.is_file():
88             self._send_error_response('404', event)
89             return
90
91         self._send_file(file_path, event.stream_id)
92
93     def _send_file(self, file_path: Path, stream_id: int) -> None:
94         """
95         Send a file, obeying the rules of HTTP/2 flow control.
96         """
97         file_size = file_path.stat().st_size
98         content_type, content_encoding = mimetypes.guess_type(str(file_path))
99         response_headers = [
100             (':status', '200'),
101             ('content-length', str(file_size)),
102             ('server', self._server_name)
103         ]

```

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```

104     if content_type:
105         response_headers.append(('content-type', content_type))
106     if content_encoding:
107         response_headers.append(('content-encoding', content_encoding))
108
109     self._connection.send_headers(stream_id, response_headers)
110     self._sock.sendall(self._connection.data_to_send())
111
112     with file_path.open(mode='rb', buffering=0) as f:
113         self._send_file_data(f, stream_id)
114
115     def _send_file_data(self, file_obj, stream_id: int) -> None:
116         """
117         Send the data portion of a file. Handles flow control rules.
118         """
119         while True:
120             while self._connection.local_flow_control_window(stream_id) < 1:
121                 self._wait_for_flow_control(stream_id)
122
123                 chunk_size = min(self._connection.local_flow_control_window(stream_id),
124 → self._read_chunk_size)
125                 data = file_obj.read(chunk_size)
126                 keep_reading = (len(data) == chunk_size)
127
128                 self._connection.send_data(stream_id, data, not keep_reading)
129                 self._sock.sendall(self._connection.data_to_send())
130
131                 if not keep_reading:
132                     break
133
134     def _wait_for_flow_control(self, stream_id: int) -> None:
135         """
136         Blocks until the flow control window for a given stream is opened.
137         """
138         event = Event()
139         self._flow_control_events[stream_id] = event
140         event.wait()
141
142     def _handle_window_update(self, event: events.WindowUpdated) -> None:
143         """
144         Unblock streams waiting on flow control, if needed.
145         """
146         stream_id = event.stream_id
147
148         if stream_id and stream_id in self._flow_control_events:
149             g_event = self._flow_control_events.pop(stream_id)
150             g_event.set()
151         elif not stream_id:
152             # Need to keep a real list here to use only the events present at this_
153 → time.
154             blocked_streams = list(self._flow_control_events.keys())
155             for stream_id in blocked_streams:
156                 g_event = self._flow_control_events.pop(stream_id)
157                 g_event.set()
158
159     def _run(self) -> None:
160         self._initiate_connection()

```

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```

159
160     while True:
161         data = self._sock.recv(65535)
162         if not data:
163             break
164
165         h2_events = self._connection.receive_data(data)
166         for event in h2_events:
167             if isinstance(event, events.RequestReceived):
168                 self._handle_request(event)
169             elif isinstance(event, events.DataReceived):
170                 self._connection.reset_stream(event.stream_id)
171             elif isinstance(event, events.WindowUpdated):
172                 self._handle_window_update(event)
173
174         data_to_send = self._connection.data_to_send()
175         if data_to_send:
176             self._sock.sendall(data_to_send)
177
178
179 if __name__ == '__main__':
180     files_dir = sys.argv[1] if len(sys.argv) > 1 else f'{Path().cwd()}'
181     server = StreamServer(('127.0.0.1', 8080), partial(H2Worker, source_dir=files_
182     ↪dir),
183                               ssl_context=get_http2_tls_context())
184
185     try:
186         server.serve_forever()
187     except KeyboardInterrupt:
188         server.close()

```

Curio Example Server

This example is a basic HTTP/2 server written using [curio](#), David Beazley's example of how to build a concurrent networking framework using Python 3.5's new `async/await` syntax.

This example is notable for demonstrating the correct use of HTTP/2 flow control with Hyper-h2. It is also a good example of the brand new syntax.

```

1  #!/usr/bin/env python3.5
2  # -*- coding: utf-8 -*-
3  """
4  curio-server.py
5  ~~~~~
6
7  A fully-functional HTTP/2 server written for curio.
8
9  Requires Python 3.5+.
10 """
11 import mimetypes
12 import os
13 import sys
14
15 from curio import Event, spawn, socket, ssl, run
16
17 import h2.config

```

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```

18 import h2.connection
19 import h2.events
20
21
22 # The maximum amount of a file we'll send in a single DATA frame.
23 READ_CHUNK_SIZE = 8192
24
25
26 async def create_listening_ssl_socket(address, certfile, keyfile):
27     """
28     Create and return a listening TLS socket on a given address.
29     """
30     ssl_context = ssl.create_default_context(ssl.Purpose.CLIENT_AUTH)
31     ssl_context.options |= (
32         ssl.OP_NO_TLSv1 | ssl.OP_NO_TLSv1_1 | ssl.OP_NO_COMPRESSION
33     )
34     ssl_context.set_ciphers("ECDHE+AESGCM")
35     ssl_context.load_cert_chain(certfile=certfile, keyfile=keyfile)
36     ssl_context.set_alpn_protocols(["h2"])
37
38     sock = socket.socket()
39     sock.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
40     sock = await ssl_context.wrap_socket(sock)
41     sock.bind(address)
42     sock.listen()
43
44     return sock
45
46
47 async def h2_server(address, root, certfile, keyfile):
48     """
49     Create an HTTP/2 server at the given address.
50     """
51     sock = await create_listening_ssl_socket(address, certfile, keyfile)
52     print("Now listening on %s:%d" % address)
53
54     async with sock:
55         while True:
56             client, _ = await sock.accept()
57             server = H2Server(client, root)
58             await spawn(server.run())
59
60
61 class H2Server:
62     """
63     A basic HTTP/2 file server. This is essentially very similar to
64     SimpleHTTPServer from the standard library, but uses HTTP/2 instead of
65     HTTP/1.1.
66     """
67     def __init__(self, sock, root):
68         config = h2.config.H2Configuration(
69             client_side=False, header_encoding='utf-8'
70         )
71         self.sock = sock
72         self.conn = h2.connection.H2Connection(config=config)
73         self.root = root
74         self.flow_control_events = {}

```

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```

75
76 async def run(self):
77     """
78     Loop over the connection, managing it appropriately.
79     """
80     self.conn.initiate_connection()
81     await self.sock.sendall(self.conn.data_to_send())
82
83     while True:
84         # 65535 is basically arbitrary here: this amounts to "give me
85         # whatever data you have".
86         data = await self.sock.recv(65535)
87         if not data:
88             break
89
90         events = self.conn.receive_data(data)
91         for event in events:
92             if isinstance(event, h2.events.RequestReceived):
93                 await spawn(
94                     self.request_received(event.headers, event.stream_id)
95                 )
96             elif isinstance(event, h2.events.DataReceived):
97                 self.conn.reset_stream(event.stream_id)
98             elif isinstance(event, h2.events.WindowUpdated):
99                 await self.window_updated(event)
100
101         await self.sock.sendall(self.conn.data_to_send())
102
103 async def request_received(self, headers, stream_id):
104     """
105     Handle a request by attempting to serve a suitable file.
106     """
107     headers = dict(headers)
108     assert headers[':method'] == 'GET'
109
110     path = headers[':path'].lstrip('/')
111     full_path = os.path.join(self.root, path)
112
113     if not os.path.exists(full_path):
114         response_headers = (
115             (':status', '404'),
116             ('content-length', '0'),
117             ('server', 'curio-h2'),
118         )
119         self.conn.send_headers(
120             stream_id, response_headers, end_stream=True
121         )
122         await self.sock.sendall(self.conn.data_to_send())
123     else:
124         await self.send_file(full_path, stream_id)
125
126 async def send_file(self, file_path, stream_id):
127     """
128     Send a file, obeying the rules of HTTP/2 flow control.
129     """
130     filesize = os.stat(file_path).st_size
131     content_type, content_encoding = mimetypes.guess_type(file_path)

```

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```

132     response_headers = [
133         (':status', '200'),
134         ('content-length', str(filesize)),
135         ('server', 'curio-h2'),
136     ]
137     if content_type:
138         response_headers.append(('content-type', content_type))
139     if content_encoding:
140         response_headers.append(('content-encoding', content_encoding))
141
142     self.conn.send_headers(stream_id, response_headers)
143     await self.sock.sendall(self.conn.data_to_send())
144
145     with open(file_path, 'rb', buffering=0) as f:
146         await self._send_file_data(f, stream_id)
147
148     async def _send_file_data(self, fileobj, stream_id):
149         """
150         Send the data portion of a file. Handles flow control rules.
151         """
152         while True:
153             while self.conn.local_flow_control_window(stream_id) < 1:
154                 await self.wait_for_flow_control(stream_id)
155
156                 chunk_size = min(
157                     self.conn.local_flow_control_window(stream_id),
158                     READ_CHUNK_SIZE,
159                 )
160
161                 data = fileobj.read(chunk_size)
162                 keep_reading = (len(data) == chunk_size)
163
164                 self.conn.send_data(stream_id, data, not keep_reading)
165                 await self.sock.sendall(self.conn.data_to_send())
166
167                 if not keep_reading:
168                     break
169
170     async def wait_for_flow_control(self, stream_id):
171         """
172         Blocks until the flow control window for a given stream is opened.
173         """
174         evt = Event()
175         self.flow_control_events[stream_id] = evt
176         await evt.wait()
177
178     async def window_updated(self, event):
179         """
180         Unblock streams waiting on flow control, if needed.
181         """
182         stream_id = event.stream_id
183
184         if stream_id and stream_id in self.flow_control_events:
185             evt = self.flow_control_events.pop(stream_id)
186             await evt.set()
187         elif not stream_id:
188             # Need to keep a real list here to use only the events present at

```

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```

189         # this time.
190         blocked_streams = list(self.flow_control_events.keys())
191         for stream_id in blocked_streams:
192             event = self.flow_control_events.pop(stream_id)
193             await event.set()
194         return
195
196
197 if __name__ == '__main__':
198     host = sys.argv[2] if len(sys.argv) > 2 else "localhost"
199     print("Try GETting:")
200     print("    On OSX after 'brew install curl --with-c-ares --with-libidn --with-
↳ nghttp2 --with-openssl':")
201     print("/usr/local/opt/curl/bin/curl --tlsv1.2 --http2 -k https://localhost:5000/
↳ bundle.js")
202     print("Or open a browser to: https://localhost:5000/")
203     print("    (Accept all the warnings)")
204     run(h2_server((host, 5000), sys.argv[1],
205                  "{}.crt.pem".format(host),
206                  "{}.key".format(host)), with_monitor=True)

```

Tornado Example Server

This example is a basic HTTP/2 server written using the [Tornado](#) asynchronous networking library.

The server returns the request headers as a JSON document to the caller, just like the example from the *Getting Started: Writing Your Own HTTP/2 Server* document.

```

1  #!/usr/bin/env python
2  # -*- coding: utf-8 -*-
3  """
4  tornado-server.py
5  ~~~~~
6
7  A fully-functional HTTP/2 server written for Tornado.
8  """
9  import collections
10 import json
11 import ssl
12
13 import tornado.gen
14 import tornado.ioloop
15 import tornado.iostream
16 import tornado.tcpserver
17
18 from h2.config import H2Configuration
19 from h2.connection import H2Connection
20 from h2.events import RequestReceived, DataReceived
21
22
23 def create_ssl_context(certfile, keyfile):
24     ssl_context = ssl.create_default_context(ssl.Purpose.CLIENT_AUTH)
25     ssl_context.options |= (
26         ssl.OP_NO_TLSv1 | ssl.OP_NO_TLSv1_1 | ssl.OP_NO_COMPRESSION
27     )

```

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```

28     ssl_context.set_ciphers("ECDHE+AESGCM")
29     ssl_context.load_cert_chain(certfile=certfile, keyfile=keyfile)
30     ssl_context.set_alpn_protocols(["h2"])
31     return ssl_context
32
33
34 class H2Server(tornado.tcpserver.TCPServer):
35
36     @tornado.gen.coroutine
37     def handle_stream(self, stream, address):
38         handler = EchoHeadersHandler(stream)
39         yield handler.handle()
40
41
42 class EchoHeadersHandler(object):
43
44     def __init__(self, stream):
45         self.stream = stream
46
47         config = H2Configuration(client_side=False)
48         self.conn = H2Connection(config=config)
49
50     @tornado.gen.coroutine
51     def handle(self):
52         self.conn.initiate_connection()
53         yield self.stream.write(self.conn.data_to_send())
54
55         while True:
56             try:
57                 data = yield self.stream.read_bytes(65535, partial=True)
58                 if not data:
59                     break
60
61                 events = self.conn.receive_data(data)
62                 for event in events:
63                     if isinstance(event, RequestReceived):
64                         self.request_received(event.headers, event.stream_id)
65                     elif isinstance(event, DataReceived):
66                         self.conn.reset_stream(event.stream_id)
67
68                 yield self.stream.write(self.conn.data_to_send())
69
70             except tornado.iostream.StreamClosedError:
71                 break
72
73     def request_received(self, headers, stream_id):
74         headers = collections.OrderedDict(headers)
75         data = json.dumps({'headers': headers}, indent=4).encode('utf-8')
76
77         response_headers = (
78             (':status', '200'),
79             ('content-type', 'application/json'),
80             ('content-length', str(len(data))),
81             ('server', 'tornado-h2'),
82         )
83         self.conn.send_headers(stream_id, response_headers)
84         self.conn.send_data(stream_id, data, end_stream=True)

```

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```

85
86
87 if __name__ == '__main__':
88     ssl_context = create_ssl_context('server.crt', 'server.key')
89     server = H2Server(ssl_options=ssl_context)
90     server.listen(8888)
91     io_loop = tornado.ioloop.IOLoop.current()
92     io_loop.start()

```

Example HTTP/2-only WSGI Server

This example is a more complex HTTP/2 server that acts as a WSGI server, passing data to an arbitrary WSGI application. This example is written using `asyncio`. The server supports most of PEP-3333, and so could in principle be used as a production WSGI server: however, that's *not recommended* as certain shortcuts have been taken to ensure ease of implementation and understanding.

The main advantages of this example are:

1. It properly demonstrates HTTP/2 flow control management.
2. It demonstrates how to plug hyper-h2 into a larger, more complex application.

```

1  # -*- coding: utf-8 -*-
2  """
3  asyncio-server.py
4  ~~~~~
5
6  A fully-functional WSGI server, written using hyper-h2. Requires asyncio.
7
8  To test it, try installing httpbin from pip (`pip install httpbin`) and then
9  running the server (`python asyncio-server.py httpbin:app`).
10
11  This server does not support HTTP/1.1: it is a HTTP/2-only WSGI server. The
12  purpose of this code is to demonstrate how to integrate hyper-h2 into a more
13  complex application, and to demonstrate several principles of concurrent
14  programming.
15
16  The architecture looks like this:
17
18  +-----+
19  |      1x HTTP/2 Server Thread      |
20  |      (running asyncio)             |
21  +-----+
22  +-----+
23  |      N WSGI Application Threads    |
24  |      (no asyncio)                  |
25  +-----+
26
27  Essentially, we spin up an asyncio-based event loop in the main thread. This
28  launches one HTTP/2 Protocol instance for each inbound connection, all of which
29  will read and write data from within the main thread in an asynchronous manner.
30
31  When each HTTP request comes in, the server will build the WSGI environment
32  dictionary and create a ``Stream`` object. This object will hold the relevant
33  state for the request/response pair and will act as the WSGI side of the logic.
34  That object will then be passed to a background thread pool, and when a worker

```

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is available the WSGI logic will begin to be executed. This model ensures that the asyncio web server itself is never blocked by the WSGI application.

The WSGI application and the HTTP/2 server communicate via an asyncio queue, together with locks and threading events. The locks themselves are implicit in asyncio's "call_soon_threadsafe", which allows for a background thread to register an action with the main asyncio thread. When the asyncio thread eventually takes the action in question it sets as threading event, signaling to the background thread that it is free to continue its work.

To make the WSGI application work with flow control, there is a very important invariant that must be observed. Any WSGI action that would cause data to be emitted to the network *MUST* be accompanied by a threading Event that is not set until that data has been written to the transport. This ensures that the WSGI application **blocks** until the data is actually sent. The reason we require this invariant is that the HTTP/2 server may choose to re-order some data chunks for flow control reasons: that is, the application for stream X may have actually written its data first, but the server may elect to send the data for stream Y first. This means that it's vital that there not be **two** writes for stream X active at any one point or they may get reordered, which would be particularly terrible.

Thus, the server must cooperate to ensure that each threading event only fires when the **complete** data for that event has been written to the asyncio transport. Any earlier will cause untold craziness.

```
"""
import asyncio
import importlib
import queue
import ssl
import sys
import threading

from h2.config import H2Configuration
from h2.connection import H2Connection
from h2.events import (
    DataReceived, RequestReceived, WindowUpdated, StreamEnded, StreamReset
)

# Used to signal that a request has completed.
#
# This is a convenient way to do "in-band" signaling of stream completion
# without doing anything so heavyweight as using a class. Essentially, we can
# test identity against this empty object. In fact, this is so convenient that
# we use this object for all streams, for data in both directions: in and out.
END_DATA_SENTINEL = object()

# The WSGI callable. Stored here so that the protocol instances can get hold
# of the data.
APPLICATION = None

class H2Protocol(asyncio.Protocol):
    def __init__(self):
        config = H2Configuration(client_side=False, header_encoding='utf-8')
```

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```

92     # Our server-side state machine.
93     self.conn = H2Connection(config=config)
94
95     # The backing transport.
96     self.transport = None
97
98     # A dictionary of ``Stream`` objects, keyed by their stream ID. This
99     # makes it easy to route data to the correct WSGI application instance.
100    self.streams = {}
101
102    # A queue of data emitted by WSGI applications that has not yet been
103    # sent. Each stream may only have one chunk of data in either this
104    # queue or the flow_controlled_data dictionary at any one time.
105    self._stream_data = asyncio.Queue()
106
107    # Data that has been pulled off the queue that is for a stream blocked
108    # behind flow control limitations. This is used to avoid spinning on
109    # _stream_data queue when a stream cannot have its data sent. Data that
110    # cannot be sent on the connection when it is popped off the queue gets
111    # placed here until the stream flow control window opens up again.
112    self._flow_controlled_data = {}
113
114    # A reference to the loop in which this protocol runs. This is needed
115    # to synchronise up with background threads.
116    self._loop = asyncio.get_event_loop()
117
118    # Any streams that have been remotely reset. We keep track of these to
119    # ensure that we don't emit data from a WSGI application whose stream
120    # has been cancelled.
121    self._reset_streams = set()
122
123    # Keep track of the loop sending task so we can kill it when the
124    # connection goes away.
125    self._send_loop_task = None
126
127    def connection_made(self, transport):
128        """
129        The connection has been made. Here we need to save off our transport,
130        do basic HTTP/2 connection setup, and then start our data writing
131        coroutine.
132        """
133        self.transport = transport
134        self.conn.initiate_connection()
135        self.transport.write(self.conn.data_to_send())
136        self._send_loop_task = self._loop.create_task(self.sending_loop())
137
138    def connection_lost(self, exc):
139        """
140        With the end of the connection, we just want to cancel our data sending
141        coroutine.
142        """
143        self._send_loop_task.cancel()
144
145    def data_received(self, data):
146        """
147        Process inbound data.
148        """

```

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```

149     events = self.conn.receive_data(data)
150
151     for event in events:
152         if isinstance(event, RequestReceived):
153             self.request_received(event)
154         elif isinstance(event, DataReceived):
155             self.data_frame_received(event)
156         elif isinstance(event, WindowUpdated):
157             self.window_opened(event)
158         elif isinstance(event, StreamEnded):
159             self.end_stream(event)
160         elif isinstance(event, StreamReset):
161             self.reset_stream(event)
162
163     outbound_data = self.conn.data_to_send()
164     if outbound_data:
165         self.transport.write(outbound_data)
166
167     def window_opened(self, event):
168         """
169         The flow control window got opened.
170
171         This is important because it's possible that we were unable to send
172         some WSGI data because the flow control window was too small. If that
173         happens, the sending_loop coroutine starts buffering data.
174
175         As the window gets opened, we need to unbuffer the data. We do that by
176         placing the data chunks back on the back of the send queue and letting
177         the sending loop take another shot at sending them.
178
179         This system only works because we require that each stream only have
180         *one* data chunk in the sending queue at any time. The threading events
181         force this invariant to remain true.
182         """
183         if event.stream_id:
184             # This is specific to a single stream.
185             if event.stream_id in self._flow_controlled_data:
186                 self._stream_data.put_nowait(
187                     self._flow_controlled_data.pop(event.stream_id)
188                 )
189             else:
190                 # This event is specific to the connection. Free up *all* the
191                 # streams. This is a bit tricky, but we *must not* yield the flow
192                 # of control here or it all goes wrong.
193                 for data in self._flow_controlled_data.values():
194                     self._stream_data.put_nowait(data)
195
196                 self._flow_controlled_data = {}
197
198     @asyncio.coroutine
199     def sending_loop(self):
200         """
201         A call that loops forever, attempting to send data. This sending loop
202         contains most of the flow-control smarts of this class: it pulls data
203         off of the asyncio queue and then attempts to send it.
204
205         The difficulties here are all around flow control. Specifically, a

```

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chunk of data may be too large to send. In this case, what will happen is that this coroutine will attempt to send what it can and will then store the unsent data locally. When a flow control event comes in that data will be freed up and placed back onto the asyncio queue, causing it to pop back up into the sending logic of this coroutine.

This method explicitly *does not* handle HTTP/2 priority. That adds an extra layer of complexity to what is already a fairly complex method, and we'll look at how to do it another time.

This coroutine explicitly *does not end*.

"""

while True:

 stream_id, data, event = **yield from** self._stream_data.get()

 # If this stream got reset, just drop the data on the floor. Note
 # that we need to reset the event here to make sure that
 # application doesn't lock up.

if stream_id **in** self._reset_streams:
 event.set()

 # Check if the body is done. If it is, this is really easy! Again,
 # we *must* set the event here or the application will lock up.

if data **is** END_DATA_SENTINEL:
 self.conn.end_stream(stream_id)
 self.transport.write(self.conn.data_to_send())
 event.set()
 continue

 # We need to send data, but not to exceed the flow control window.
 # For that reason, grab only the data that fits: we'll buffer the
 # rest.

 window_size = self.conn.local_flow_control_window(stream_id)
 chunk_size = min(window_size, len(data))
 data_to_send = data[:chunk_size]
 data_to_buffer = data[chunk_size:]

if data_to_send:
 # There's a maximum frame size we have to respect. Because we
 # aren't paying any attention to priority here, we can quite
 # safely just split this string up into chunks of max frame
 # size and blast them out.
 #
 # In a *real* application you'd want to consider priority here.
 max_size = self.conn.max_outbound_frame_size
 chunks = (
 data_to_send[x:x+max_size]
 for x **in** range(0, len(data_to_send), max_size)
)
 for chunk **in** chunks:
 self.conn.send_data(stream_id, chunk)
 self.transport.write(self.conn.data_to_send())

 # If there's data left to buffer, we should do that. Put it in a
 # dictionary and *don't* set the event*: the app must not generate
 # any more data until we got rid of all of this data.

if data_to_buffer:

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```

263         self._flow_controlled_data[stream_id] = (
264             stream_id, data_to_buffer, event
265         )
266     else:
267         # We sent everything. We can let the WSGI app progress.
268         event.set()
269
270     def request_received(self, event):
271         """
272         A HTTP/2 request has been received. We need to invoke the WSGI
273         application in a background thread to handle it.
274         """
275         # First, we are going to want an object to hold all the relevant state
276         # for this request/response. For that, we have a stream object. We
277         # need to store the stream object somewhere reachable for when data
278         # arrives later.
279         s = Stream(event.stream_id, self)
280         self.streams[event.stream_id] = s
281
282         # Next, we need to build the WSGI environ dictionary.
283         environ = _build_environ_dict(event.headers, s)
284
285         # Finally, we want to throw these arguments out to a threadpool and
286         # let it run.
287         self._loop.run_in_executor(
288             None,
289             s.run_in_threadpool,
290             APPLICATION,
291             environ,
292         )
293
294     def data_frame_received(self, event):
295         """
296         Data has been received by WSGI server and needs to be dispatched to a
297         running application.
298
299         Note that the flow control window is not modified here. That's
300         deliberate: see Stream.__next__ for a longer discussion of why.
301         """
302         # Grab the stream in question from our dictionary and pass it on.
303         stream = self.streams[event.stream_id]
304         stream.receive_data(event.data, event.flow_controlled_length)
305
306     def end_stream(self, event):
307         """
308         The stream data is complete.
309         """
310         stream = self.streams[event.stream_id]
311         stream.request_complete()
312
313     def reset_stream(self, event):
314         """
315         A stream got forcefully reset.
316
317         This is a tricky thing to deal with because WSGI doesn't really have a
318         good notion for it. Essentially, you have to let the application run
319         until completion, but not actually let it send any data.

```

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We do that by discarding any data we currently have for it, and then marking the stream as reset to allow us to spot when that stream is trying to send data and drop that data on the floor.

*We then *also* signal the WSGI application that no more data is incoming, to ensure that it does not attempt to do further reads of the data.*

"""

```
if event.stream_id in self._flow_controlled_data:
    del self._flow_controlled_data
```

```
self._reset_streams.add(event.stream_id)
self.end_stream(event)
```

```
def data_for_stream(self, stream_id, data):
```

"""

Thread-safe method called from outside the main asyncio thread in order to send data on behalf of a WSGI application.

Places data being written by a stream on an asyncio queue. Returns a threading event that will fire when that data is sent.

"""

```
event = threading.Event()
self._loop.call_soon_threadsafe(
    self._stream_data.put_nowait,
    (stream_id, data, event)
)
```

```
return event
```

```
def send_response(self, stream_id, headers):
```

"""

Thread-safe method called from outside the main asyncio thread in order to send the HTTP response headers on behalf of a WSGI application.

Returns a threading event that will fire when the headers have been emitted to the network.

"""

```
event = threading.Event()
```

```
def _inner_send(stream_id, headers, event):
```

```
    self.conn.send_headers(stream_id, headers, end_stream=False)
    self.transport.write(self.conn.data_to_send())
    event.set()
```

```
self._loop.call_soon_threadsafe(
    _inner_send,
    stream_id,
    headers,
    event
)
```

```
return event
```

```
def open_flow_control_window(self, stream_id, increment):
```

"""

Opens a flow control window for the given stream by the given amount. Called from a WSGI thread. Does not return an event because there's no

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```

377     need to block on this action, it may take place at any time.
378     """
379     def _inner_open(stream_id, increment):
380         self.conn.increment_flow_control_window(increment, stream_id)
381         self.conn.increment_flow_control_window(increment, None)
382         self.transport.write(self.conn.data_to_send())
383
384     self._loop.call_soon_threadsafe(
385         _inner_open,
386         stream_id,
387         increment,
388     )
389
390
391 class Stream:
392     """
393     This class holds all of the state for a single stream. It also provides
394     several of the callables used by the WSGI application. Finally, it provides
395     the logic for actually interfacing with the WSGI application.
396
397     For these reasons, the object has strict requirements on thread-safety.
398     While the object can be initialized in the main WSGI thread, the
399     ``run_in_threadpool`` method must be called from outside that thread. At
400     that point, the main WSGI thread may only call specific methods.
401     """
402     def __init__(self, stream_id, protocol):
403         self.stream_id = stream_id
404         self._protocol = protocol
405
406         # Queue for data that has been received from the network. This is a
407         # thread-safe queue, to allow both the WSGI application to block on
408         # receiving more data and to allow the asyncio server to keep sending
409         # more data.
410         #
411         # This queue is unbounded in size, but in practice it cannot contain
412         # too much data because the flow control window doesn't get adjusted
413         # unless data is removed from it.
414         self._received_data = queue.Queue()
415
416         # This buffer is used to hold partial chunks of data from
417         # _received_data that were not returned out of ``read`` and friends.
418         self._temp_buffer = b''
419
420         # Temporary variables that allow us to keep hold of the headers and
421         # response status until such time as the application needs us to send
422         # them.
423         self._response_status = b''
424         self._response_headers = []
425         self._headers_emitted = False
426
427         # Whether the application has received all the data from the network
428         # or not. This allows us to short-circuit some reads.
429         self._complete = False
430
431     def receive_data(self, data, flow_controlled_size):
432         """
433         Called by the H2Protocol when more data has been received from the

```

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```

434     network.
435
436     Places the data directly on the queue in a thread-safe manner without
437     blocking. Does not introspect or process the data.
438     """
439     self._received_data.put_nowait((data, flow_controlled_size))
440
441     def request_complete(self):
442         """
443         Called by the H2Protocol when all the request data has been received.
444
445         This works by placing the ``END_DATA_SENTINEL`` on the queue. The
446         reading code knows, when it sees the ``END_DATA_SENTINEL``, to expect
447         no more data from the network. This ensures that the state of the
448         application only changes when it has finished processing the data from
449         the network, even though the server may have long-since finished
450         receiving all the data for this request.
451         """
452         self._received_data.put_nowait((END_DATA_SENTINEL, None))
453
454     def run_in_threadpool(self, wsgi_application, environ):
455         """
456         This method should be invoked in a threadpool. At the point this method
457         is invoked, the only safe methods to call from the original thread are
458         ``receive_data`` and ``request_complete``: any other method is unsafe.
459
460         This method handles the WSGI logic. It invokes the application callable
461         in this thread, passing control over to the WSGI application. It then
462         ensures that the data makes it back to the HTTP/2 connection via
463         the thread-safe APIs provided below.
464         """
465         result = wsgi_application(environ, self.start_response)
466
467         try:
468             for data in result:
469                 self.write(data)
470         finally:
471             # This signals that we're done with data. The server will know that
472             # this allows it to clean up its state: we're done here.
473             self.write(END_DATA_SENTINEL)
474
475         # The next few methods are called by the WSGI application. Firstly, the
476         # three methods provided by the input stream.
477         def read(self, size=None):
478             """
479             Called by the WSGI application to read data.
480
481             This method is the one of two that explicitly pumps the input data
482             queue, which means it deals with the ``_complete`` flag and the
483             ``END_DATA_SENTINEL``.
484             """
485             # If we've already seen the END_DATA_SENTINEL, return immediately.
486             if self._complete:
487                 return b''
488
489             # If we've been asked to read everything, just iterate over ourselves.
490             if size is None:

```

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```

491         return b''.join(self)
492
493         # Otherwise, as long as we don't have enough data, spin looking for
494         # another data chunk.
495         data = b''
496         while len(data) < size:
497             try:
498                 chunk = next(self)
499             except StopIteration:
500                 break
501
502             # Concatenating strings this way is slow, but that's ok, this is
503             # just a demo.
504             data += chunk
505
506         # We have *at least* enough data to return, but we may have too much.
507         # If we do, throw it on a buffer: we'll use it later.
508         to_return = data[:size]
509         self._temp_buffer = data[size:]
510         return to_return
511
512     def readline(self, hint=None):
513         """
514         Called by the WSGI application to read a single line of data.
515
516         This method rigorously observes the ``hint`` parameter: it will only
517         ever read that much data. It then splits the data on a newline
518         character and throws everything it doesn't need into a buffer.
519         """
520         data = self.read(hint)
521         first_newline = data.find(b'\n')
522         if first_newline == -1:
523             # No newline, return all the data
524             return data
525
526         # We want to slice the data so that the head *includes* the first
527         # newline. Then, any data left in this line we don't care about should
528         # be prepended to the internal buffer.
529         head, tail = data[:first_newline + 1], data[first_newline + 1:]
530         self._temp_buffer = tail + self._temp_buffer
531
532         return head
533
534     def readlines(self, hint=None):
535         """
536         Called by the WSGI application to read several lines of data.
537
538         This method is really pretty stupid. It rigorously observes the
539         ``hint`` parameter, and quite happily returns the input split into
540         lines.
541         """
542         # This method is *crazy inefficient*, but it's also a pretty stupid
543         # method to call.
544         data = self.read(hint)
545         lines = data.split(b'\n')
546
547         # Split removes the newline character, but we want it, so put it back.

```

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```

548     lines = [line + b'\n' for line in lines]
549
550     # Except if the last character was a newline character we now have an
551     # extra line that is just a newline: pull that out.
552     if lines[-1] == b'\n':
553         lines = lines[:-1]
554     return lines
555
556 def start_response(self, status, response_headers, exc_info=None):
557     """
558     This is the PEP-3333 mandated start_response callable.
559
560     All it does is store the headers for later sending, and return our
561     ``write`` callable.
562     """
563     if self._headers_emitted and exc_info is not None:
564         raise exc_info[1].with_traceback(exc_info[2])
565
566     assert not self._response_status or exc_info is not None
567     self._response_status = status
568     self._response_headers = response_headers
569
570     return self.write
571
572 def write(self, data):
573     """
574     Provides some data to write.
575
576     This function *blocks* until such time as the data is allowed by
577     HTTP/2 flow control. This allows a client to slow or pause the response
578     as needed.
579
580     This function is not supposed to be used, according to PEP-3333, but
581     once we have it it becomes quite convenient to use it, so this app
582     actually runs all writes through this function.
583     """
584     if not self._headers_emitted:
585         self._emit_headers()
586     event = self._protocol.data_for_stream(self.stream_id, data)
587     event.wait()
588     return
589
590 def _emit_headers(self):
591     """
592     Sends the response headers.
593
594     This is only called from the write callable and should only ever be
595     called once. It does some minor processing (converts the status line
596     into a status code because reason phrases are evil) and then passes
597     the headers on to the server. This call explicitly blocks until the
598     server notifies us that the headers have reached the network.
599     """
600     assert self._response_status and self._response_headers
601     assert not self._headers_emitted
602     self._headers_emitted = True
603
604     # We only need the status code

```

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```

605     status = self._response_status.split(" ", 1)[0]
606     headers = [(":status", status)]
607     headers.extend(self._response_headers)
608     event = self._protocol.send_response(self.stream_id, headers)
609     event.wait()
610     return
611
612     # These two methods implement the iterator protocol. This allows a WSGI
613     # application to iterate over this Stream object to get the data.
614     def __iter__(self):
615         return self
616
617     def __next__(self):
618         # If the complete request has been read, abort immediately.
619         if self._complete:
620             raise StopIteration()
621
622         # If we have data stored in a temporary buffer for any reason, return
623         # that and clear the buffer.
624         #
625         # This can actually only happen when the application uses one of the
626         # read* callables, but that's fine.
627         if self._temp_buffer:
628             buffered_data = self._temp_buffer
629             self._temp_buffer = b''
630             return buffered_data
631
632         # Otherwise, pull data off the queue (blocking as needed). If this is
633         # the end of the request, we're done here: mark ourselves as complete
634         # and call it time. Otherwise, open the flow control window an
635         # appropriate amount and hand the chunk off.
636         chunk, chunk_size = self._received_data.get()
637         if chunk is END_DATA_SENTINEL:
638             self._complete = True
639             raise StopIteration()
640
641         # Let's talk a little bit about why we're opening the flow control
642         # window *here*, and not in the server thread.
643         #
644         # The purpose of HTTP/2 flow control is to allow for servers and
645         # clients to avoid needing to buffer data indefinitely because their
646         # peer is producing data faster than they can consume it. As a result,
647         # it's important that the flow control window be opened as late in the
648         # processing as possible. In this case, we open the flow control window
649         # exactly when the server hands the data to the application. This means
650         # that the flow control window essentially signals to the remote peer
651         # how much data hasn't even been *seen* by the application yet.
652         #
653         # If you wanted to be really clever you could consider not opening the
654         # flow control window until the application asks for the *next* chunk
655         # of data. That means that any buffers at the application level are now
656         # included in the flow control window processing. In my opinion, the
657         # advantage of that process does not outweigh the extra logical
658         # complexity involved in doing it, so we don't bother here.
659         #
660         # Another note: you'll notice that we don't include the _temp_buffer in
661         # our flow control considerations. This means you could in principle

```

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```

662         # lead us to buffer slightly more than one connection flow control
663         # window's worth of data. That risk is considered acceptable for the
664         # much simpler logic available here.
665         #
666         # Finally, this is a pretty dumb flow control window management scheme:
667         # it causes us to emit a *lot* of window updates. A smarter server
668         # would want to use the content-length header to determine whether
669         # flow control window updates need to be emitted at all, and then to be
670         # more efficient about emitting them to avoid firing them off really
671         # frequently. For an example like this, there's very little gained by
672         # worrying about that.
673         self._protocol.open_flow_control_window(self.stream_id, chunk_size)
674
675     return chunk
676
677
678 def _build_environ_dict(headers, stream):
679     """
680     Build the WSGI environ dictionary for a given request. To do that, we'll
681     temporarily create a dictionary for the headers. While this isn't actually
682     a valid way to represent headers, we know that the special headers we need
683     can only have one appearance in the block.
684
685     This code is arguably somewhat incautious: the conversion to dictionary
686     should only happen in a way that allows us to correctly join headers that
687     appear multiple times. That's acceptable in a demo app: in a productised
688     version you'd want to fix it.
689     """
690     header_dict = dict(headers)
691     path = header_dict.pop(u':path')
692     try:
693         path, query = path.split(u'?', 1)
694     except ValueError:
695         query = u""
696     server_name = header_dict.pop(u':authority')
697     try:
698         server_name, port = server_name.split(u':', 1)
699     except ValueError as e:
700         port = "8443"
701
702     environ = {
703         u'REQUEST_METHOD': header_dict.pop(u':method'),
704         u'SCRIPT_NAME': u'',
705         u'PATH_INFO': path,
706         u'QUERY_STRING': query,
707         u'SERVER_NAME': server_name,
708         u'SERVER_PORT': port,
709         u'SERVER_PROTOCOL': u'HTTP/2',
710         u'HTTPS': u"on",
711         u'SSL_PROTOCOL': u'TLSv1.2',
712         u'wsgi.version': (1, 0),
713         u'wsgi.url_scheme': header_dict.pop(u':scheme'),
714         u'wsgi.input': stream,
715         u'wsgi.errors': sys.stderr,
716         u'wsgi.multithread': True,
717         u'wsgi.multiprocess': False,
718         u'wsgi.run_once': False,

```

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```

719     }
720     if u'content-type' in header_dict:
721         environ[u'CONTENT_TYPE'] = header_dict[u'content-type']
722     if u'content-length' in header_dict:
723         environ[u'CONTENT_LENGTH'] = header_dict[u'content-length']
724     for name, value in header_dict.items():
725         environ[u'HTTP_' + name.upper()] = value
726     return environ
727
728
729 # Set up the WSGI app.
730 application_string = sys.argv[1]
731 path, func = application_string.split(':', 1)
732 module = importlib.import_module(path)
733 APPLICATION = getattr(module, func)
734
735 # Set up TLS
736 ssl_context = ssl.create_default_context(ssl.Purpose.CLIENT_AUTH)
737 ssl_context.options |= (
738     ssl.OP_NO_TLSv1 | ssl.OP_NO_TLSv1_1 | ssl.OP_NO_COMPRESSION
739 )
740 ssl_context.set_ciphers("ECDHE+AESGCM")
741 ssl_context.load_cert_chain(certfile="cert.crt", keyfile="cert.key")
742 ssl_context.set_alpn_protocols(["h2"])
743
744 # Do the asyncio bits
745 loop = asyncio.get_event_loop()
746 # Each client connection will create a new protocol instance
747 coro = loop.create_server(H2Protocol, '127.0.0.1', 8443, ssl=ssl_context)
748 server = loop.run_until_complete(coro)
749
750 # Serve requests until Ctrl+C is pressed
751 print('Serving on {}'.format(server.sockets[0].getsockname()))
752 try:
753     loop.run_forever()
754 except KeyboardInterrupt:
755     pass
756
757 # Close the server
758 server.close()
759 loop.run_until_complete(server.wait_closed())
760 loop.close()

```

1.4.2 Example Clients

Twisted Example Client: Head Requests

This example is a basic HTTP/2 client written for the `Twisted` asynchronous networking framework.

This client is fairly simple: it makes a hard-coded HEAD request to `nghttp2.org/httpbin/` and prints out the response data. Its purpose is to demonstrate how to write a very basic HTTP/2 client implementation.

```

1 # -*- coding: utf-8 -*-
2 """
3 head_request.py

```

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```

4  ~~~~~
5
6  A short example that demonstrates a client that makes HEAD requests to certain
7  websites.
8
9  This example is intended as a reproduction of nghttp2 issue 396, for the
10 purposes of compatibility testing.
11 """
12 from __future__ import print_function
13
14 from twisted.internet import reactor
15 from twisted.internet.endpoints import connectProtocol, SSL4ClientEndpoint
16 from twisted.internet.protocol import Protocol
17 from twisted.internet.ssl import optionsForClientTLS
18 from hyperframe.frame import SettingsFrame
19 from h2.connection import H2Connection
20 from h2.events import (
21     ResponseReceived, DataReceived, StreamEnded,
22     StreamReset, SettingsAcknowledged,
23 )
24
25
26 AUTHORITY = u'nghttp2.org'
27 PATH = '/httpbin/'
28 SIZE = 4096
29
30
31 class H2Protocol(Protocol):
32     def __init__(self):
33         self.conn = H2Connection()
34         self.known_proto = None
35         self.request_made = False
36
37     def connectionMade(self):
38         self.conn.initiate_connection()
39
40         # This reproduces the error in #396, by changing the header table size.
41         self.conn.update_settings({SettingsFrame.HEADER_TABLE_SIZE: SIZE})
42
43         self.transport.write(self.conn.data_to_send())
44
45     def dataReceived(self, data):
46         if not self.known_proto:
47             self.known_proto = self.transport.negotiatedProtocol
48             assert self.known_proto == b'h2'
49
50         events = self.conn.receive_data(data)
51
52         for event in events:
53             if isinstance(event, ResponseReceived):
54                 self.handleResponse(event.headers, event.stream_id)
55             elif isinstance(event, DataReceived):
56                 self.handleData(event.data, event.stream_id)
57             elif isinstance(event, StreamEnded):
58                 self.endStream(event.stream_id)
59             elif isinstance(event, SettingsAcknowledged):
60                 self.settingsAked(event)

```

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```

61         elif isinstance(event, StreamReset):
62             reactor.stop()
63             raise RuntimeError("Stream reset: %d" % event.error_code)
64         else:
65             print(event)
66
67         data = self.conn.data_to_send()
68         if data:
69             self.transport.write(data)
70
71     def settingsAcked(self, event):
72         # Having received the remote settings change, lets send our request.
73         if not self.request_made:
74             self.sendRequest()
75
76     def handleResponse(self, response_headers, stream_id):
77         for name, value in response_headers:
78             print("%s: %s" % (name.decode('utf-8'), value.decode('utf-8')))
79
80         print("")
81
82     def handleData(self, data, stream_id):
83         print(data, end='')
84
85     def endStream(self, stream_id):
86         self.conn.close_connection()
87         self.transport.write(self.conn.data_to_send())
88         self.transportloseConnection()
89         reactor.stop()
90
91     def sendRequest(self):
92         request_headers = [
93             (':method', 'HEAD'),
94             (':authority', AUTHORITY),
95             (':scheme', 'https'),
96             (':path', PATH),
97             ('user-agent', 'hyper-h2/1.0.0'),
98         ]
99         self.conn.send_headers(1, request_headers, end_stream=True)
100         self.request_made = True
101
102 options = optionsForClientTLS(
103     hostname=AUTHORITY,
104     acceptableProtocols=[b'h2'],
105 )
106
107 connectProtocol(
108     SSL4ClientEndpoint(reactor, AUTHORITY, 443, options),
109     H2Protocol()
110 )
111 reactor.run()

```

Twisted Example Client: Post Requests

This example is a basic HTTP/2 client written for the [Twisted](#) asynchronous networking framework.

This client is fairly simple: it makes a hard-coded POST request to `nghttp2.org/httpbin/post` and prints out the response data, sending a file that is provided on the command line or the script itself. Its purpose is to demonstrate how to write a HTTP/2 client implementation that handles flow control.

```

1  # -*- coding: utf-8 -*-
2  """
3  post_request.py
4  ~~~~~
5
6  A short example that demonstrates a client that makes POST requests to certain
7  websites.
8
9  This example is intended to demonstrate how to handle uploading request bodies.
10 In this instance, a file will be uploaded. In order to handle arbitrary files,
11 this example also demonstrates how to obey HTTP/2 flow control rules.
12
13 Takes one command-line argument: a path to a file in the filesystem to upload.
14 If none is present, uploads this file.
15 """
16 from __future__ import print_function
17
18 import mimetypes
19 import os
20 import sys
21
22 from twisted.internet import reactor, defer
23 from twisted.internet.endpoints import connectProtocol, SSL4ClientEndpoint
24 from twisted.internet.protocol import Protocol
25 from twisted.internet.ssl import optionsForClientTLS
26 from h2.connection import H2Connection
27 from h2.events import (
28     ResponseReceived, DataReceived, StreamEnded, StreamReset, WindowUpdated,
29     SettingsAcknowledged,
30 )
31
32
33 AUTHORITY = u'nghttp2.org'
34 PATH = '/httpbin/post'
35
36
37 class H2Protocol(Protocol):
38     def __init__(self, file_path):
39         self.conn = H2Connection()
40         self.known_proto = None
41         self.request_made = False
42         self.request_complete = False
43         self.file_path = file_path
44         self.flow_control_deferred = None
45         self.fileobj = None
46         self.file_size = None
47
48     def connectionMade(self):
49         """
50         Called by Twisted when the TCP connection is established. We can start
51         sending some data now: we should open with the connection preamble.
52         """
53         self.conn.initiate_connection()
54         self.transport.write(self.conn.data_to_send())

```

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```

55
56 def dataReceived(self, data):
57     """
58     Called by Twisted when data is received on the connection.
59
60     We need to check a few things here. Firstly, we want to validate that
61     we actually negotiated HTTP/2: if we didn't, we shouldn't proceed!
62
63     Then, we want to pass the data to the protocol stack and check what
64     events occurred.
65     """
66     if not self.known_proto:
67         self.known_proto = self.transport.negotiatedProtocol
68         assert self.known_proto == b'h2'
69
70     events = self.conn.receive_data(data)
71
72     for event in events:
73         if isinstance(event, ResponseReceived):
74             self.handleResponse(event.headers)
75         elif isinstance(event, DataReceived):
76             self.handleData(event.data)
77         elif isinstance(event, StreamEnded):
78             self.endStream()
79         elif isinstance(event, SettingsAcknowledged):
80             self.settingsAked(event)
81         elif isinstance(event, StreamReset):
82             reactor.stop()
83             raise RuntimeError("Stream reset: %d" % event.error_code)
84         elif isinstance(event, WindowUpdated):
85             self.windowUpdated(event)
86
87     data = self.conn.data_to_send()
88     if data:
89         self.transport.write(data)
90
91     def settingsAked(self, event):
92         """
93         Called when the remote party ACKs our settings. We send a SETTINGS
94         frame as part of the preamble, so if we want to be very polite we can
95         wait until the ACK for that frame comes before we start sending our
96         request.
97         """
98         if not self.request_made:
99             self.sendRequest()
100
101     def handleResponse(self, response_headers):
102         """
103         Handle the response by printing the response headers.
104         """
105         for name, value in response_headers:
106             print("%s: %s" % (name.decode('utf-8'), value.decode('utf-8')))
107
108         print("")
109
110     def handleData(self, data):
111         """

```

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```

112     We handle data that's received by just printing it.
113     """
114     print(data, end='')
115
116     def endStream(self):
117         """
118         We call this when the stream is cleanly ended by the remote peer. That
119         means that the response is complete.
120
121         Because this code only makes a single HTTP/2 request, once we receive
122         the complete response we can safely tear the connection down and stop
123         the reactor. We do that as cleanly as possible.
124         """
125         self.request_complete = True
126         self.conn.close_connection()
127         self.transport.write(self.conn.data_to_send())
128         self.transportloseConnection()
129
130     def windowUpdated(self, event):
131         """
132         We call this when the flow control window for the connection or the
133         stream has been widened. If there's a flow control deferred present
134         (that is, if we're blocked behind the flow control), we fire it.
135         Otherwise, we do nothing.
136         """
137         if self.flow_control_deferred is None:
138             return
139
140         # Make sure we remove the flow control deferred to avoid firing it
141         # more than once.
142         flow_control_deferred = self.flow_control_deferred
143         self.flow_control_deferred = None
144         flow_control_deferred.callback(None)
145
146     def connectionLost(self, reason=None):
147         """
148         Called by Twisted when the connection is gone. Regardless of whether
149         it was clean or not, we want to stop the reactor.
150         """
151         if self.fileobj is not None:
152             self.fileobj.close()
153
154         if reactor.running:
155             reactor.stop()
156
157     def sendRequest(self):
158         """
159         Send the POST request.
160
161         A POST request is made up of one headers frame, and then 0+ data
162         frames. This method begins by sending the headers, and then starts a
163         series of calls to send data.
164         """
165         # First, we need to work out how large the file is.
166         self.file_size = os.stat(self.file_path).st_size
167
168         # Next, we want to guess a content-type and content-encoding.

```

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```

169     content_type, content_encoding = mimetypes.guess_type(self.file_path)
170
171     # Now we can build a header block.
172     request_headers = [
173         (':method', 'POST'),
174         (':authority', AUTHORITY),
175         (':scheme', 'https'),
176         (':path', PATH),
177         ('user-agent', 'hyper-h2/1.0.0'),
178         ('content-length', str(self.file_size)),
179     ]
180
181     if content_type is not None:
182         request_headers.append(('content-type', content_type))
183
184         if content_encoding is not None:
185             request_headers.append(('content-encoding', content_encoding))
186
187     self.conn.send_headers(1, request_headers)
188     self.request_made = True
189
190     # We can now open the file.
191     self.fileobj = open(self.file_path, 'rb')
192
193     # We now need to send all the relevant data. We do this by checking
194     # what the acceptable amount of data is to send, and sending it. If we
195     # find ourselves blocked behind flow control, we then place a deferred
196     # and wait until that deferred fires.
197     self.sendFileData()
198
199     def sendFileData(self):
200         """
201         Send some file data on the connection.
202         """
203         # Firstly, check what the flow control window is for stream 1.
204         window_size = self.conn.local_flow_control_window(stream_id=1)
205
206         # Next, check what the maximum frame size is.
207         max_frame_size = self.conn.max_outbound_frame_size
208
209         # We will send no more than the window size or the remaining file size
210         # of data in this call, whichever is smaller.
211         bytes_to_send = min(window_size, self.file_size)
212
213         # We now need to send a number of data frames.
214         while bytes_to_send > 0:
215             chunk_size = min(bytes_to_send, max_frame_size)
216             data_chunk = self.fileobj.read(chunk_size)
217             self.conn.send_data(stream_id=1, data=data_chunk)
218
219             bytes_to_send -= chunk_size
220             self.file_size -= chunk_size
221
222         # We've prepared a whole chunk of data to send. If the file is fully
223         # sent, we also want to end the stream: we're done here.
224         if self.file_size == 0:
225             self.conn.end_stream(stream_id=1)

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```
226     else:
227         # We've still got data left to send but the window is closed. Save
228         # a Deferred that will call us when the window gets opened.
229         self.flow_control_deferred = defer.Deferred()
230         self.flow_control_deferred.addCallback(self.sendFileData)
231
232         self.transport.write(self.conn.data_to_send())
233
234
235     try:
236         filename = sys.argv[1]
237     except IndexError:
238         filename = __file__
239
240     options = optionsForClientTLS(
241         hostname=AUTHORITY,
242         acceptableProtocols=[b'h2'],
243     )
244
245     connectProtocol(
246         SSL4ClientEndpoint(reactor, AUTHORITY, 443, options),
247         H2Protocol(filename)
248     )
249     reactor.run()
```

1.5 Advanced Usage

1.5.1 Priority

New in version 2.0.0.

[RFC 7540](#) has a fairly substantial and complex section describing how to build a HTTP/2 priority tree, and the effect that should have on sending data from a server.

Hyper-h2 does not enforce any priority logic by default for servers. This is because scheduling data sends is outside the scope of this library, as it likely requires fairly substantial understanding of the scheduler being used.

However, for servers that *do* want to follow the priority recommendations given by clients, the Hyper project provides an [implementation](#) of the [RFC 7540](#) priority tree that will be useful to plug into a server. That, combined with the [PriorityUpdated](#) event from this library, can be used to build a server that conforms to RFC 7540's recommendations for priority handling.

1.5.2 Related Events

New in version 2.4.0.

In the 2.4.0 release hyper-h2 added support for signaling “related events”. These are a HTTP/2-only construct that exist because certain HTTP/2 events can occur simultaneously: that is, one HTTP/2 frame can cause multiple state transitions to occur at the same time. One example of this is a HEADERS frame that contains priority information and carries the END_STREAM flag: this would cause three events to fire (one of the various request/response received events, a [PriorityUpdated](#) event, and a [StreamEnded](#) event).

Ordinarily hyper-h2’s logic will emit those events to you one at a time. This means that you may attempt to process, for example, a *DataReceived* event, not knowing that the next event out will be a *StreamEnded* event. hyper-h2 *does* know this, however, and so will forbid you from taking certain actions that are a violation of the HTTP/2 protocol.

To avoid this asymmetry of information, events that can occur simultaneously now carry properties for their “related events”. These allow users to find the events that can have occurred simultaneously with each other before the event is emitted by hyper-h2. The following objects have “related events”:

- *RequestReceived*:
 - *stream_ended*: any *StreamEnded* event that occurred at the same time as receiving this request.
 - *priority_updated*: any *PriorityUpdated* event that occurred at the same time as receiving this request.
- *ResponseReceived*:
 - *stream_ended*: any *StreamEnded* event that occurred at the same time as receiving this response.
 - *priority_updated*: any *PriorityUpdated* event that occurred at the same time as receiving this response.
- *TrailersReceived*:
 - *stream_ended*: any *StreamEnded* event that occurred at the same time as receiving this set of trailers. This will **always** be present for trailers, as they must terminate streams.
 - *priority_updated*: any *PriorityUpdated* event that occurred at the same time as receiving this response.
- *InformationalResponseReceived*:
 - *priority_updated*: any *PriorityUpdated* event that occurred at the same time as receiving this informational response.
- *DataReceived*:
 - *stream_ended*: any *StreamEnded* event that occurred at the same time as receiving this data.

Warning: hyper-h2 does not know if you are looking for related events or expecting to find events in the event stream. Therefore, it will always emit “related events” in the event stream. If you are using the “related events” event pattern, you will want to be careful to avoid double-processing related events.

1.5.3 Connections: Advanced

Thread Safety

`H2Connection` objects are *not* thread-safe. They cannot safely be accessed from multiple threads at once. This is a deliberate design decision: it is not trivially possible to design the `H2Connection` object in a way that would be either lock-free or have the locks at a fine granularity.

Your implementations should bear this in mind, and handle it appropriately. It should be simple enough to use locking alongside the `H2Connection`: simply lock around the connection object itself. Because the `H2Connection` object does no I/O it should be entirely safe to do that. Alternatively, have a single thread take ownership of the `H2Connection` and use a message-passing interface to serialize access to the `H2Connection`.

If you are using a non-threaded concurrency approach (e.g. Twisted), this should not affect you.

Internal Buffers

In order to avoid doing I/O, the `H2Connection` employs an internal buffer. This buffer is *unbounded* in size: it can potentially grow infinitely. This means that, if you are not making sure to regularly empty it, you are at risk of exceeding the memory limit of a single process and finding your program crashes.

It is highly recommended that you send data at regular intervals, ideally as soon as possible.

Sending Data

When sending data on the network, it's important to remember that you may not be able to send an unbounded amount of data at once. Particularly when using TCP, it is often the case that there are limits on how much data may be in flight at any one time. These limits can be very low, and your operating system will only buffer so much data in memory before it starts to complain.

For this reason, it is possible to consume only a subset of the data available when you call `data_to_send`. However, once you have pulled the data out of the `H2Connection` internal buffer, it is *not* possible to put it back on again. For that reason, it is advisable that you confirm how much space is available in the OS buffer before sending.

Alternatively, use tools made available by your framework. For example, the Python standard library `socket` module provides a `sendall` method that will automatically block until all the data has been sent. This will enable you to always use the unbounded form of `data_to_send`, and will help you avoid subtle bugs.

When To Send

In addition to knowing how much data to send (see [Sending Data](#)) it is important to know when to send data. For hyper-h2, this amounts to knowing when to call `data_to_send`.

Hyper-h2 may write data into its send buffer at two times. The first is whenever `receive_data` is called. This data is sent in response to some control frames that require no user input: for example, responding to PING frames. The second time is in response to user action: whenever a user calls a method like `send_headers`, data may be written into the buffer.

In a standard design for a hyper-h2 consumer, then, that means there are two places where you'll potentially want to send data. The first is in your "receive data" loop. This is where you take the data you receive, pass it into `receive_data`, and then dispatch events. For this loop, it is usually best to save sending data until the loop is complete: that allows you to empty the buffer only once.

The other place you'll want to send the data is when initiating requests or taking any other active, unprompted action on the connection. In this instance, you'll want to make all the relevant `send_*` calls, and *then* call `data_to_send`.

1.5.4 Headers

HTTP/2 defines several "special header fields" which are used to encode data that was previously sent in either the request or status line of HTTP/1.1. These header fields are distinguished from ordinary header fields because their field name begins with a `:` character. The special header fields defined in [RFC 7540](#) are:

- `:status`
- `:path`
- `:method`
- `:scheme`
- `:authority`

RFC 7540 **mandates** that all of these header fields appear *first* in the header block, before the ordinary header fields. This could cause difficulty if the `send_headers` method accepted a plain dict for the `headers` argument, because dict objects are unordered. For this reason, we require that you provide a list of two-tuples.

1.5.5 Flow Control

HTTP/2 defines a complex flow control system that uses a sliding window of data on both a per-stream and per-connection basis. Essentially, each implementation allows its peer to send a specific amount of data at any time (the “flow control window”) before it must stop. Each stream has a separate window, and the connection as a whole has a window. Each window can be opened by an implementation by sending a `WINDOW_UPDATE` frame, either on a specific stream (causing the window for that stream to be opened), or on stream 0, which causes the window for the entire connection to be opened.

In HTTP/2, only data in `DATA` frames is flow controlled. All other frames are exempt from flow control. Each `DATA` frame consumes both stream and connection flow control window bytes. This means that the maximum amount of data that can be sent on any one stream before a `WINDOW_UPDATE` frame is received is the *lower* of the stream and connection windows. The maximum amount of data that can be sent on *all* streams before a `WINDOW_UPDATE` frame is received is the size of the connection flow control window.

Working With Flow Control

The amount of flow control window a `DATA` frame consumes is the sum of both its contained application data *and* the amount of padding used. `hyper-h2` shows this to the user in a `DataReceived` event by using the `flow_controlled_length` field. When working with flow control in `hyper-h2`, users *must* use this field: simply using `len(datareceived.data)` can eventually lead to deadlock.

When data has been received and given to the user in a `DataReceived`, it is the responsibility of the user to re-open the flow control window when the user is ready for more data. `hyper-h2` does not do this automatically to avoid flooding the user with data: if we did, the remote peer could send unbounded amounts of data that the user would need to buffer before processing.

To re-open the flow control window, then, the user must call `increment_flow_control_window` with the `flow_controlled_length` of the received data. `hyper-h2` requires that you manage both the connection and the stream flow control windows separately, so you may need to increment both the stream the data was received on and stream 0.

When sending data, a HTTP/2 implementation must not send more than flow control window available for that stream. As noted above, the maximum amount of data that can be sent on the stream is the minimum of the stream and the connection flow control windows. You can find out how much data you can send on a given stream by using the `local_flow_control_window` method, which will do all of these calculations for you. If you attempt to send more than this amount of data on a stream, `hyper-h2` will throw a `ProtocolError` and refuse to send the data.

In `hyper-h2`, receiving a `WINDOW_UPDATE` frame causes a `WindowUpdated` event to fire. This will notify you that there is potentially more room in a flow control window. Note that, just because an increment of a given size was received *does not* mean that that much more data can be sent: remember that both the connection and stream flow control windows constrain how much data can be sent.

As a result, when a `WindowUpdated` event fires with a non-zero stream ID, and the user has more data to send on that stream, the user should call `local_flow_control_window` to check if there really is more room to send data on that stream.

When a `WindowUpdated` event fires with a stream ID of 0, that may have unblocked *all* streams that are currently blocked. The user should use `local_flow_control_window` to check all blocked streams to see if more data is available.

Auto Flow Control

New in version 2.5.0.

In most cases, there is no advantage for users in managing their own flow control strategies. While particular high performance or specific-use-case applications may gain value from directly controlling the emission of `WINDOW_UPDATE` frames, the average application can use a lowest-common-denominator strategy to emit those frames. As of version 2.5.0, hyper-h2 now provides this automatic strategy for users, if they want to use it.

This automatic strategy is built around a single method: `acknowledge_received_data`. This method flags to the connection object that your application has dealt with a certain number of flow controlled bytes, and that the window should be incremented in some way. Whenever your application has “processed” some received bytes, this method should be called to signal that they have been processed.

The key difference between this method and `increment_flow_control_window` is that the method `acknowledge_received_data` does not guarantee that it will emit a `WINDOW_UPDATE` frame, and if it does it will not necessarily emit them for *only* the stream or *only* the frame. Instead, the `WINDOW_UPDATE` frames will be *coalesced*: they will be emitted only when a certain number of bytes have been freed up.

For most applications, this method should be preferred to the manual flow control mechanism.

1.6 Low-Level Details

Warning: This section of the documentation covers low-level implementation details of hyper-h2. This is most likely to be of use to hyper-h2 developers and to other HTTP/2 implementers, though it could well be of general interest. Feel free to peruse it, but if you’re looking for information about how to *use* hyper-h2 you should consider looking elsewhere.

1.6.1 State Machines

hyper-h2 is fundamentally built on top of a pair of interacting Finite State Machines. One of these FSMs manages per-connection state, and another manages per-stream state. Almost without exception (see *Priority* for more details) every single frame is unconditionally translated into events for both state machines and those state machines are turned.

The advantages of a system such as this is that the finite state machines can very densely encode the kinds of things that are allowed at any particular moment in a HTTP/2 connection. However, most importantly, almost all protocols are defined *in terms* of finite state machines: that is, protocol descriptions can be reduced to a number of states and inputs. That makes FSMs a very natural tool for implementing protocol stacks.

Indeed, most protocol implementations that do not explicitly encode a finite state machine almost always *implicitly* encode a finite state machine, by using classes with a bunch of variables that amount to state-tracking variables, or by using the call-stack as an implicit state tracking mechanism. While these methods are not immediately problematic, they tend to lack *explicitness*, and can lead to subtle bugs of the form “protocol action X is incorrectly allowed in state Y”.

For these reasons, we have implemented two *explicit* finite state machines. These machines aim to encode most of the protocol-specific state, in particular regarding what frame is allowed at what time. This target goal is sometimes not achieved: in particular, as of this writing the *stream* FSM contains a number of other state variables that really ought to be rolled into the state machine itself in the form of new states, or in the form of a transformation of the FSM to use state *vectors* instead of state *scalars*.

The following sections contain some implementers notes on these FSMs.

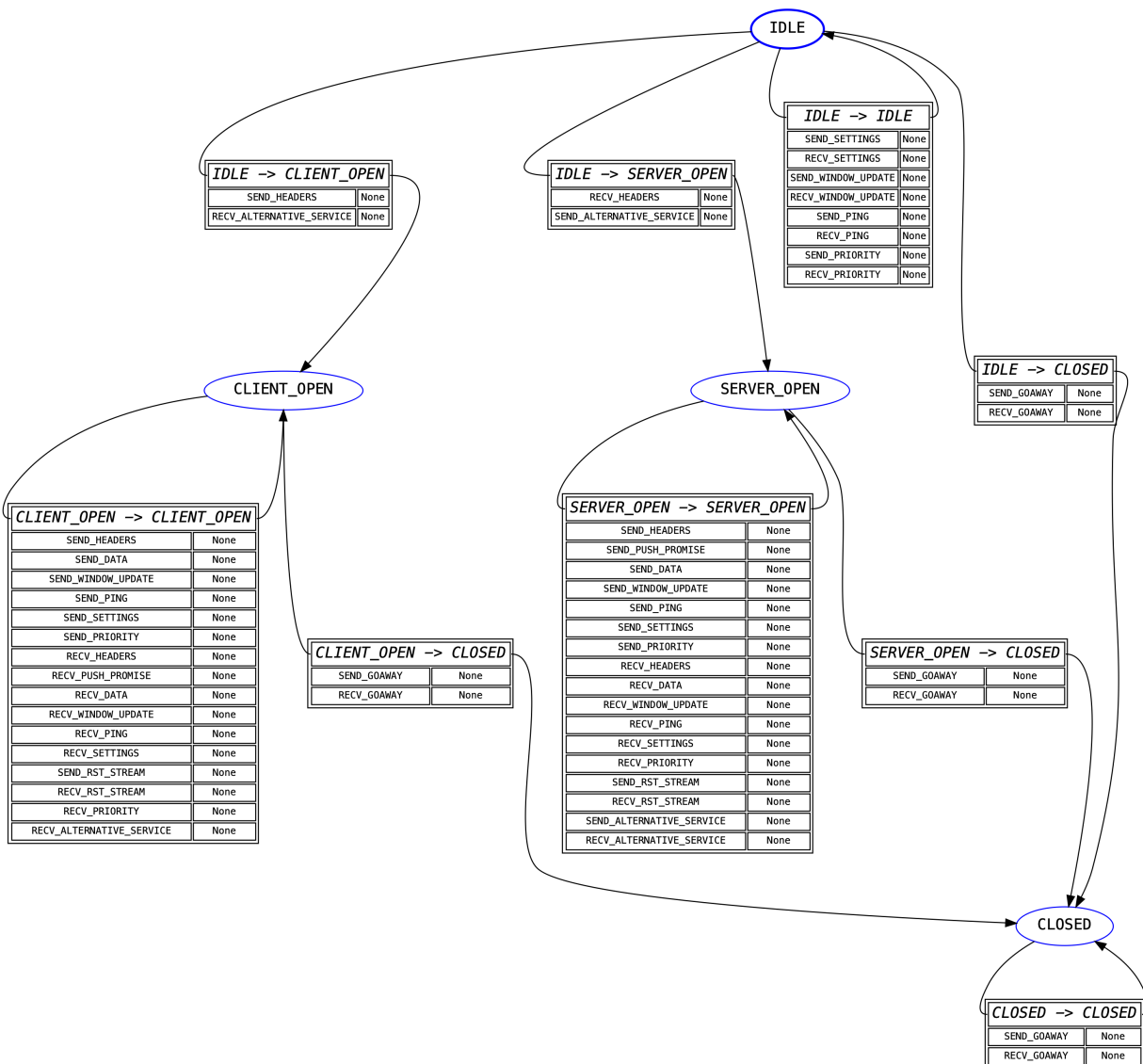
Connection State Machine

The “outer” state machine, the first one that is encountered when sending or receiving data, is the connection state machine. This state machine tracks whole-connection state.

This state machine is primarily intended to forbid certain actions on the basis of whether the implementation is acting as a client or a server. For example, clients are not permitted to send `PUSH_PROMISE` frames: this state machine forbids that by refusing to define a valid transition from the `CLIENT_OPEN` state for the `SEND_PUSH_PROMISE` event.

Otherwise, this particular state machine triggers no side-effects. It has a very coarse, high-level, functionality.

A visual representation of this FSM is shown below:



Stream State Machine

Once the connection state machine has been spun, any frame that belongs to a stream is passed to the stream state machine for its given stream. Each stream has its own instance of the state machine, but all of them share the transition

table: this is because the table itself is sufficiently large that having it be per-instance would be a ridiculous memory overhead.

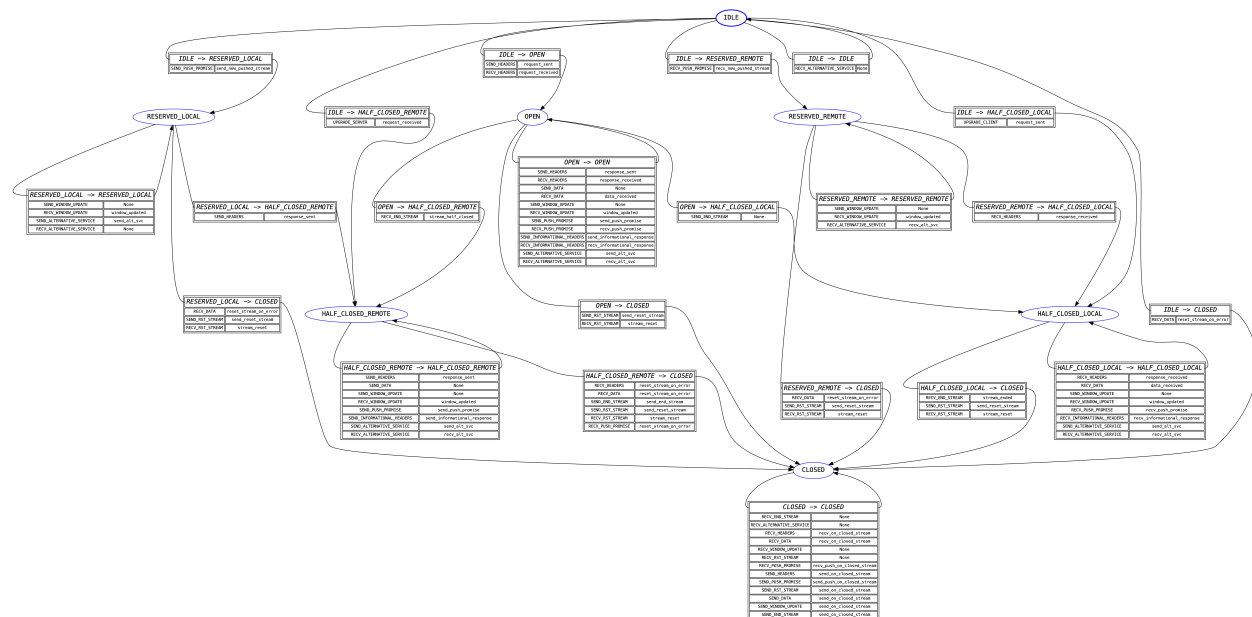
Unlike the connection state machine, the stream state machine is quite complex. This is because it frequently needs to encode some side-effects. The most common side-effect is emitting a `RST_STREAM` frame when an error is encountered: the need to do this means that far more transitions need to be encoded than for the connection state machine.

Many of the side-effect functions in this state machine also raise `ProtocolError` exceptions. This is almost always done on the basis of an extra state variable, which is an annoying code smell: it should always be possible for the state machine itself to police these using explicit state management. A future refactor will hopefully address this problem by making these additional state variables part of the state definitions in the FSM, which will lead to an expansion of the number of states but a greater degree of simplicity in understanding and tracking what is going on in the state machine.

The other action taken by the side-effect functions defined here is returning *events*. Most of these events are returned directly to the user, and reflect the specific state transition that has taken place, but some of the events are purely *internal*: they are used to signal to other parts of the hyper-h2 codebase what action has been taken.

The major use of the internal events functionality at this time is for validating header blocks: there are different rules for request headers than there are for response headers, and different rules again for trailers. The internal events are used to determine *exactly* what kind of data the user is attempting to send, and using that information to do the correct kind of validation. This approach ensures that the final source of truth about what’s happening at the protocol level lives inside the FSM, which is an extremely important design principle we want to continue to enshrine in hyper-h2.

A visual representation of this FSM is shown below:



Priority

In the *Stream State Machine* section we said that any frame that belongs to a stream is passed to the stream state machine. This turns out to be not quite true.

Specifically, while `PRIORITY` frames are technically sent on a given stream (that is, [RFC 7540 Section 6.3](#) defines them as “always identifying a stream” and forbids the use of stream ID 0 for them), in practice they are almost completely exempt from the usual stream FSM behaviour. Specifically, the RFC has this to say:

The `PRIORITY` frame can be sent on a stream in any state, though it cannot be sent between consecutive frames that comprise a single header block (Section 4.3).

Given that the consecutive header block requirement is handled outside of the FSMs, this section of the RFC essentially means that there is *never* a situation where it is invalid to receive a `PRIORITY` frame. This means that including it in the stream FSM would require that we allow `SEND_PRIORITY` and `RECV_PRIORITY` in all states.

This is not a totally onerous task: however, another key note is that hyper-h2 uses the *absence* of a stream state machine to flag a closed stream. This is primarily for memory conservation reasons: if we needed to keep around an FSM for every stream we've ever seen, that would cause long-lived HTTP/2 connections to consume increasingly large amounts of memory. On top of this, it would require us to create a stream FSM each time we received a `PRIORITY` frame for a given stream, giving a malicious peer an easy route to force a hyper-h2 user to allocate nearly unbounded amounts of memory.

For this reason, hyper-h2 circumvents the stream FSM entirely for `PRIORITY` frames. Instead, these frames are treated as being connection-level frames that *just happen* to identify a specific stream. They do not bring streams into being, or in any sense interact with hyper-h2's view of streams. Their stream details are treated as strictly metadata that hyper-h2 is not interested in beyond being able to parse it out.

1.7 Hyper-h2 API

This document details the API of Hyper-h2.

1.7.1 Semantic Versioning

Hyper-h2 follows semantic versioning for its public API. Please note that the guarantees of semantic versioning apply only to the API that is *documented here*. Simply because a method or data field is not prefaced by an underscore does not make it part of Hyper-h2's public API. Anything not documented here is subject to change at any time.

1.7.2 Connection

class `h2.connection.H2Connection` (*config=None*)

A low-level HTTP/2 connection object. This handles building and receiving frames and maintains both connection and per-stream state for all streams on this connection.

This wraps a HTTP/2 Connection state machine implementation, ensuring that frames can only be sent/received when the connection is in a valid state. It also builds stream state machines on demand to ensure that the constraints of those state machines are met as well. Attempts to create frames that cannot be sent will raise a `ProtocolError`.

Changed in version 2.3.0: Added the `header_encoding` keyword argument.

Changed in version 2.5.0: Added the `config` keyword argument. Deprecated the `client_side` and `header_encoding` parameters.

Changed in version 3.0.0: Removed deprecated parameters and properties.

Parameters `config` (*H2Configuration*) – The configuration for the HTTP/2 connection.

New in version 2.5.0.

acknowledge_received_data (*acknowledged_size, stream_id*)

Inform the *H2Connection* that a certain number of flow-controlled bytes have been processed, and that the space should be handed back to the remote peer at an opportune time.

New in version 2.5.0.

Parameters

- **acknowledged_size** (int) – The total *flow-controlled size* of the data that has been processed. Note that this must include the amount of padding that was sent with that data.
- **stream_id** (int) – The ID of the stream on which this data was received.

Returns Nothing

Return type None

advertise_alternative_service (*field_value*, *origin=None*, *stream_id=None*)

Notify a client about an available Alternative Service.

An Alternative Service is defined in [RFC 7838](#). An Alternative Service notification informs a client that a given origin is also available elsewhere.

Alternative Services can be advertised in two ways. Firstly, they can be advertised explicitly: that is, a server can say “origin X is also available at Y”. To advertise like this, set the `origin` argument and not the `stream_id` argument. Alternatively, they can be advertised implicitly: that is, a server can say “the origin you’re contacting on stream X is also available at Y”. To advertise like this, set the `stream_id` argument and not the `origin` argument.

The explicit method of advertising can be done as long as the connection is active. The implicit method can only be done after the client has sent the request headers and before the server has sent the response headers: outside of those points, Hyper-h2 will forbid sending the Alternative Service advertisement by raising a `ProtocolError`.

The `field_value` parameter is specified in RFC 7838. Hyper-h2 does not validate or introspect this argument: the user is required to ensure that it’s well-formed. `field_value` corresponds to RFC 7838’s “Alternative Service Field Value”.

Note: It is strongly preferred to use the explicit method of advertising Alternative Services. The implicit method of advertising Alternative Services has a number of subtleties and can lead to inconsistencies between the server and client. Hyper-h2 allows both mechanisms, but caution is strongly advised.

New in version 2.3.0.

Parameters

- **field_value** (bytes) – The RFC 7838 Alternative Service Field Value. This argument is not introspected by Hyper-h2: the user is responsible for ensuring that it is well-formed.
- **origin** (bytes or None) – The origin/authority to which the Alternative Service being advertised applies. Must not be provided at the same time as `stream_id`.
- **stream_id** (int or None) – The ID of the stream which was sent to the authority for which this Alternative Service advertisement applies. Must not be provided at the same time as `origin`.

Returns Nothing.

clear_outbound_data_buffer ()

Clears the outbound data buffer, such that if this call was immediately followed by a call to `data_to_send`, that call would return no data.

This method should not normally be used, but is made available to avoid exposing implementation details.

close_connection (*error_code=0*, *additional_data=None*, *last_stream_id=None*)

Close a connection, emitting a GOAWAY frame.

Changed in version 2.4.0: Added `additional_data` and `last_stream_id` arguments.

Parameters

- **error_code** – (optional) The error code to send in the GOAWAY frame.
- **additional_data** – (optional) Additional debug data indicating a reason for closing the connection. Must be a bytestring.
- **last_stream_id** – (optional) The last stream which was processed by the sender. Defaults to `highest_inbound_stream_id`.

Returns Nothing

config = `None`

The configuration for this HTTP/2 connection object.

New in version 2.5.0.

data_to_send (*amount=None*)

Returns some data for sending out of the internal data buffer.

This method is analogous to `read` on a file-like object, but it doesn't block. Instead, it returns as much data as the user asks for, or less if that much data is not available. It does not perform any I/O, and so uses a different name.

Parameters **amount** (`int`) – (optional) The maximum amount of data to return. If not set, or set to `None`, will return as much data as possible.

Returns A bytestring containing the data to send on the wire.

Return type `bytes`

end_stream (*stream_id*)

Cleanly end a given stream.

This method ends a stream by sending an empty DATA frame on that stream with the `END_STREAM` flag set.

Parameters **stream_id** (`int`) – The ID of the stream to end.

Returns Nothing

get_next_available_stream_id ()

Returns an integer suitable for use as the stream ID for the next stream created by this endpoint. For server endpoints, this stream ID will be even. For client endpoints, this stream ID will be odd. If no stream IDs are available, raises `NoAvailableStreamIDError`.

Warning: The return value from this function does not change until the stream ID has actually been used by sending or pushing headers on that stream. For that reason, it should be called as close as possible to the actual use of the stream ID.

New in version 2.0.0.

Raises `NoAvailableStreamIDError`

Returns The next free stream ID this peer can use to initiate a stream.

Return type `int`

increment_flow_control_window (*increment, stream_id=None*)

Increment a flow control window, optionally for a single stream. Allows the remote peer to send more data.

Changed in version 2.0.0: Rejects attempts to increment the flow control window by out of range values with a `ValueError`.

Parameters

- **increment** (`int`) – The amount to increment the flow control window by.
- **stream_id** (`int` or `None`) – (optional) The ID of the stream that should have its flow control window opened. If not present or `None`, the connection flow control window will be opened instead.

Returns Nothing

Raises `ValueError`

initiate_connection()

Provides any data that needs to be sent at the start of the connection. Must be called for both clients and servers.

initiate_upgrade_connection(settings_header=None)

Call to initialise the connection object for use with an upgraded HTTP/2 connection (i.e. a connection negotiated using the `Upgrade: h2c` HTTP header).

This method differs from `initiate_connection` in several ways. Firstly, it handles the additional SETTINGS frame that is sent in the HTTP2-Settings header field. When called on a client connection, this method will return a bytestring that the caller can put in the HTTP2-Settings field they send on their initial request. When called on a server connection, the user **must** provide the value they received from the client in the HTTP2-Settings header field to the `settings_header` argument, which will be used appropriately.

Additionally, this method sets up stream 1 in a half-closed state appropriate for this side of the connection, to reflect the fact that the request is already complete.

Finally, this method also prepares the appropriate preamble to be sent after the upgrade.

New in version 2.3.0.

Parameters settings_header (`bytes`) – (optional, server-only): The value of the HTTP2-Settings header field received from the client.

Returns For clients, a bytestring to put in the HTTP2-Settings. For servers, returns nothing.

Return type `bytes` or `None`

local_flow_control_window(stream_id)

Returns the maximum amount of data that can be sent on stream `stream_id`.

This value will never be larger than the total data that can be sent on the connection: even if the given stream allows more data, the connection window provides a logical maximum to the amount of data that can be sent.

The maximum data that can be sent in a single data frame on a stream is either this value, or the maximum frame size, whichever is *smaller*.

Parameters stream_id (`int`) – The ID of the stream whose flow control window is being queried.

Returns The amount of data in bytes that can be sent on the stream before the flow control window is exhausted.

Return type `int`

max_inbound_frame_size = None

The maximum size of a frame that can be received by this peer, in bytes.

max_outbound_frame_size = None

The maximum size of a frame that can be emitted by this peer, in bytes.

open_inbound_streams

The current number of open inbound streams.

open_outbound_streams

The current number of open outbound streams.

ping (*opaque_data*)

Send a PING frame.

Parameters *opaque_data* – A bytestring of length 8 that will be sent in the PING frame.

Returns Nothing

prioritize (*stream_id*, *weight=None*, *depends_on=None*, *exclusive=None*)

Notify a server about the priority of a stream.

Stream priorities are a form of guidance to a remote server: they inform the server about how important a given response is, so that the server may allocate its resources (e.g. bandwidth, CPU time, etc.) accordingly. This exists to allow clients to ensure that the most important data arrives earlier, while less important data does not starve out the more important data.

Stream priorities are explained in depth in [RFC 7540 Section 5.3](#).

This method updates the priority information of a single stream. It may be called well before a stream is actively in use, or well after a stream is closed.

Warning: RFC 7540 allows for servers to change the priority of streams. However, hyper-h2 **does not** allow server stacks to do this. This is because most clients do not adequately know how to respond when provided conflicting priority information, and relatively little utility is provided by making that functionality available.

Note: hyper-h2 **does not** maintain any information about the RFC 7540 priority tree. That means that hyper-h2 does not prevent incautious users from creating invalid priority trees, particularly by creating priority loops. While some basic error checking is provided by hyper-h2, users are strongly recommended to understand their prioritisation strategies before using the priority tools here.

Note: Priority information is strictly advisory. Servers are allowed to disregard it entirely. Avoid relying on the idea that your priority signaling will definitely be obeyed.

New in version 2.4.0.

Parameters

- **stream_id** (*int*) – The ID of the stream to prioritize.
- **weight** (*int*) – The weight to give the stream. Defaults to 16, the default weight of any stream. May be any value between 1 and 256 inclusive. The relative weight of a stream indicates what proportion of available resources will be allocated to that stream.
- **depends_on** (*int*) – The ID of the stream on which this stream depends. This stream will only be progressed if it is impossible to progress the parent stream (the one on which this one depends). Passing the value 0 means that this stream does not depend on any other. Defaults to 0.

- **exclusive** (`bool`) – Whether this stream is an exclusive dependency of its “parent” stream (i.e. the stream given by `depends_on`). If a stream is an exclusive dependency of another, that means that all previously-set children of the parent are moved to become children of the new exclusively-dependent stream. Defaults to `False`.

push_stream (*stream_id*, *promised_stream_id*, *request_headers*)

Push a response to the client by sending a PUSH_PROMISE frame.

If it is important to send HPACK “never indexed” header fields (as defined in [RFC 7451 Section 7.1.3](#)), the user may instead provide headers using the HPACK library’s `HeaderTuple` and `NeverIndexedHeaderTuple` objects.

Parameters

- **stream_id** (`int`) – The ID of the stream that this push is a response to.
- **promised_stream_id** (`int`) – The ID of the stream that the pushed response will be sent on.
- **request_headers** (An iterable of two tuples of bytestrings or `HeaderTuple` objects.) – The headers of the request that the pushed response will be responding to.

Returns Nothing

receive_data (*data*)

Pass some received HTTP/2 data to the connection for handling.

Parameters **data** (`bytes`) – The data received from the remote peer on the network.

Returns A list of events that the remote peer triggered by sending this data.

remote_flow_control_window (*stream_id*)

Returns the maximum amount of data the remote peer can send on stream `stream_id`.

This value will never be larger than the total data that can be sent on the connection: even if the given stream allows more data, the connection window provides a logical maximum to the amount of data that can be sent.

The maximum data that can be sent in a single data frame on a stream is either this value, or the maximum frame size, whichever is *smaller*.

Parameters **stream_id** (`int`) – The ID of the stream whose flow control window is being queried.

Returns The amount of data in bytes that can be received on the stream before the flow control window is exhausted.

Return type `int`

reset_stream (*stream_id*, *error_code=0*)

Reset a stream.

This method forcibly closes a stream by sending a RST_STREAM frame for a given stream. This is not a graceful closure. To gracefully end a stream, try the `end_stream` method.

Parameters

- **stream_id** (`int`) – The ID of the stream to reset.
- **error_code** (`int`) – (optional) The error code to use to reset the stream. Defaults to `ErrorCodes.NO_ERROR`.

Returns Nothing

send_data (*stream_id*, *data*, *end_stream=False*, *pad_length=None*)

Send data on a given stream.

This method does no breaking up of data: if the data is larger than the value returned by *local_flow_control_window* for this stream then a *FlowControlError* will be raised. If the data is larger than *max_outbound_frame_size* then a *FrameTooLargeError* will be raised.

Hyper-h2 does this to avoid buffering the data internally. If the user has more data to send than hyper-h2 will allow, consider breaking it up and buffering it externally.

Parameters

- **stream_id** (int) – The ID of the stream on which to send the data.
- **data** (bytes) – The data to send on the stream.
- **end_stream** (bool) – (optional) Whether this is the last data to be sent on the stream. Defaults to *False*.
- **pad_length** (int) – (optional) Length of the padding to apply to the data frame. Defaults to *None* for no use of padding. Note that a value of 0 results in padding of length 0 (with the “padding” flag set on the frame).

New in version 2.6.0.

Returns

Nothing

send_headers (*stream_id*, *headers*, *end_stream=False*, *priority_weight=None*, *priority_depends_on=None*, *priority_exclusive=None*)

Send headers on a given stream.

This function can be used to send request or response headers: the kind that are sent depends on whether this connection has been opened as a client or server connection, and whether the stream was opened by the remote peer or not.

If this is a client connection, calling *send_headers* will send the headers as a request. It will also implicitly open the stream being used. If this is a client connection and *send_headers* has *already* been called, this will send trailers instead.

If this is a server connection, calling *send_headers* will send the headers as a response. It is a protocol error for a server to open a stream by sending headers. If this is a server connection and *send_headers* has *already* been called, this will send trailers instead.

When acting as a server, you may call *send_headers* any number of times allowed by the following rules, in this order:

- zero or more times with (':status', '1XX') (where 1XX is a placeholder for any 100-level status code).
- once with any other status header.
- zero or one time for trailers.

That is, you are allowed to send as many informational responses as you like, followed by one complete response and zero or one HTTP trailer blocks.

Clients may send one or two header blocks: one request block, and optionally one trailer block.

If it is important to send HPACK “never indexed” header fields (as defined in [RFC 7451 Section 7.1.3](#)), the user may instead provide headers using the HPACK library’s *HeaderTuple* and *NeverIndexedHeaderTuple* objects.

This method also allows users to prioritize the stream immediately, by sending priority information on the HEADERS frame directly. To do this, any one of *priority_weight*, *priority_depends_on*, or

`priority_exclusive` must be set to a value that is not `None`. For more information on the priority fields, see [prioritize](#).

Warning: In HTTP/2, it is mandatory that all the HTTP/2 special headers (that is, ones whose header keys begin with :) appear at the start of the header block, before any normal headers.

Changed in version 2.3.0: Added support for using `HeaderTuple` objects to store headers.

Changed in version 2.4.0: Added the ability to provide priority keyword arguments: `priority_weight`, `priority_depends_on`, and `priority_exclusive`.

Parameters

- **`stream_id`** (`int`) – The stream ID to send the headers on. If this stream does not currently exist, it will be created.
- **`headers`** (An iterable of two tuples of bytestrings or `HeaderTuple` objects.) – The request/response headers to send.
- **`end_stream`** (`bool`) – Whether this headers frame should end the stream immediately (that is, whether no more data will be sent after this frame). Defaults to `False`.
- **`priority_weight`** (`int` or `None`) – Sets the priority weight of the stream. See [prioritize](#) for more about how this field works. Defaults to `None`, which means that no priority information will be sent.
- **`priority_depends_on`** (`bool` or `None`) – Sets which stream this one depends on for priority purposes. See [prioritize](#) for more about how this field works. Defaults to `None`, which means that no priority information will be sent.
- **`priority_exclusive`** – Sets whether this stream exclusively depends on the stream given in `priority_depends_on` for priority purposes. See [prioritize](#) for more about how this field works. Defaults to `None`, which means that no priority information will be sent.

Returns Nothing

`update_settings` (*`new_settings`*)

Update the local settings. This will prepare and emit the appropriate SETTINGS frame.

Parameters *`new_settings`* – A dictionary of {setting: new value}

1.7.3 Configuration

```
class h2.config.H2Configuration(client_side=True, header_encoding=None,
                                validate_outbound_headers=True, nor-
                                malize_outbound_headers=True, vali-
                                date_inbound_headers=True, normal-
                                ize_inbound_headers=True, logger=None)
```

An object that controls the way a single HTTP/2 connection behaves.

This object allows the users to customize behaviour. In particular, it allows users to enable or disable optional features, or to otherwise handle various unusual behaviours.

This object has very little behaviour of its own: it mostly just ensures that configuration is self-consistent.

Parameters

- **client_side** (`bool`) – Whether this object is to be used on the client side of a connection, or on the server side. Affects the logic used by the state machine, the default settings values, the allowable stream IDs, and several other properties. Defaults to `True`.
- **header_encoding** (`str`, `False`, or `None`) – Controls whether the headers emitted by this object in events are transparently decoded to `unicode` strings, and what encoding is used to do that decoding. This defaults to `None`, meaning that headers will be returned as bytes. To automatically decode headers (that is, to return them as `unicode` strings), this can be set to the string name of any encoding, e.g. `'utf-8'`.

Changed in version 3.0.0: Changed default value from `'utf-8'` to `None`

- **validate_outbound_headers** (`bool`) – Controls whether the headers emitted by this object are validated against the rules in RFC 7540. Disabling this setting will cause outbound header validation to be skipped, and allow the object to emit headers that may be illegal according to RFC 7540. Defaults to `True`.
- **normalize_outbound_headers** (`bool`) – Controls whether the headers emitted by this object are normalized before sending. Disabling this setting will cause outbound header normalization to be skipped, and allow the object to emit headers that may be illegal according to RFC 7540. Defaults to `True`.
- **validate_inbound_headers** (`bool`) – Controls whether the headers received by this object are validated against the rules in RFC 7540. Disabling this setting will cause inbound header validation to be skipped, and allow the object to receive headers that may be illegal according to RFC 7540. Defaults to `True`.
- **normalize_inbound_headers** (`bool`) – Controls whether the headers received by this object are normalized according to the rules of RFC 7540. Disabling this setting may lead to hyper-h2 emitting header blocks that some RFCs forbid, e.g. with multiple cookie fields.

New in version 3.0.0.

- **logger** (`logging.Logger`) – A logger that conforms to the requirements for this module, those being no I/O and no context switches, which is needed in order to run in asynchronous operation.

New in version 2.6.0.

header_encoding

Controls whether the headers emitted by this object in events are transparently decoded to `unicode` strings, and what encoding is used to do that decoding. This defaults to `None`, meaning that headers will be returned as bytes. To automatically decode headers (that is, to return them as `unicode` strings), this can be set to the string name of any encoding, e.g. `'utf-8'`.

1.7.4 Events

class `h2.events.RequestReceived`

The `RequestReceived` event is fired whenever request headers are received. This event carries the HTTP headers for the given request and the stream ID of the new stream.

Changed in version 2.3.0: Changed the type of headers to `HeaderTuple`. This has no effect on current users.

Changed in version 2.4.0: Added `stream_ended` and `priority_updated` properties.

headers = None

The request headers.

priority_updated = None

If this request also had associated priority information, the associated *PriorityUpdated* event will be available here.

New in version 2.4.0.

stream_ended = None

If this request also ended the stream, the associated *StreamEnded* event will be available here.

New in version 2.4.0.

stream_id = None

The Stream ID for the stream this request was made on.

class h2.events.ResponseReceived

The ResponseReceived event is fired whenever response headers are received. This event carries the HTTP headers for the given response and the stream ID of the new stream.

Changed in version 2.3.0: Changed the type of headers to *HeaderTuple*. This has no effect on current users.

Changed in version 2.4.0: Added *stream_ended* and *priority_updated* properties.

headers = None

The response headers.

priority_updated = None

If this response also had associated priority information, the associated *PriorityUpdated* event will be available here.

New in version 2.4.0.

stream_ended = None

If this response also ended the stream, the associated *StreamEnded* event will be available here.

New in version 2.4.0.

stream_id = None

The Stream ID for the stream this response was made on.

class h2.events.TrailersReceived

The TrailersReceived event is fired whenever trailers are received on a stream. Trailers are a set of headers sent after the body of the request/response, and are used to provide information that wasn't known ahead of time (e.g. content-length). This event carries the HTTP header fields that form the trailers and the stream ID of the stream on which they were received.

Changed in version 2.3.0: Changed the type of headers to *HeaderTuple*. This has no effect on current users.

Changed in version 2.4.0: Added *stream_ended* and *priority_updated* properties.

headers = None

The trailers themselves.

priority_updated = None

If the trailers also set associated priority information, the associated *PriorityUpdated* event will be available here.

New in version 2.4.0.

stream_ended = None

Trailers always end streams. This property has the associated *StreamEnded* in it.

New in version 2.4.0.

stream_id = None

The Stream ID for the stream on which these trailers were received.

class h2.events.InformationalResponseReceived

The InformationalResponseReceived event is fired when an informational response (that is, one whose status code is a 1XX code) is received from the remote peer.

The remote peer may send any number of these, from zero upwards. These responses are most commonly sent in response to requests that have the `expect: 100-continue` header field present. Most users can safely ignore this event unless you are intending to use the `expect: 100-continue` flow, or are for any reason expecting a different 1XX status code.

New in version 2.2.0.

Changed in version 2.3.0: Changed the type of `headers` to `HeaderTuple`. This has no effect on current users.

Changed in version 2.4.0: Added `priority_updated` property.

headers = None

The headers for this informational response.

priority_updated = None

If this response also had associated priority information, the associated `PriorityUpdated` event will be available here.

New in version 2.4.0.

stream_id = None

The Stream ID for the stream this informational response was made on.

class h2.events.DataReceived

The DataReceived event is fired whenever data is received on a stream from the remote peer. The event carries the data itself, and the stream ID on which the data was received.

Changed in version 2.4.0: Added `stream_ended` property.

data = None

The data itself.

flow_controlled_length = None

The amount of data received that counts against the flow control window. Note that padding counts against the flow control window, so when adjusting flow control you should always use this field rather than `len(data)`.

stream_ended = None

If this data chunk also completed the stream, the associated `StreamEnded` event will be available here.

New in version 2.4.0.

stream_id = None

The Stream ID for the stream this data was received on.

class h2.events.WindowUpdated

The WindowUpdated event is fired whenever a flow control window changes size. HTTP/2 defines flow control windows for connections and streams: this event fires for both connections and streams. The event carries the ID of the stream to which it applies (set to zero if the window update applies to the connection), and the delta in the window size.

delta = None

The window delta.

stream_id = None

The Stream ID of the stream whose flow control window was changed. May be 0 if the connection window was changed.

class `h2.events.RemoteSettingsChanged`

The RemoteSettingsChanged event is fired whenever the remote peer changes its settings. It contains a complete inventory of changed settings, including their previous values.

In HTTP/2, settings changes need to be acknowledged. hyper-h2 automatically acknowledges settings changes for efficiency. However, it is possible that the caller may not be happy with the changed setting.

When this event is received, the caller should confirm that the new settings are acceptable. If they are not acceptable, the user should close the connection with the error code `PROTOCOL_ERROR`.

Changed in version 2.0.0: Prior to this version the user needed to acknowledge settings changes. This is no longer the case: hyper-h2 now automatically acknowledges them.

changed_settings = None

A dictionary of setting byte to *ChangedSetting*, representing the changed settings.

classmethod `from_settings(old_settings, new_settings)`

Build a RemoteSettingsChanged event from a set of changed settings.

Parameters

- **old_settings** – A complete collection of old settings, in the form of a dictionary of {setting: value}.
- **new_settings** – All the changed settings and their new values, in the form of a dictionary of {setting: value}.

class `h2.events.PingReceived`

The PingReceived event is fired whenever a PING is received. It contains the ‘opaque data’ of the PING frame. A ping acknowledgment with the same ‘opaque data’ is automatically emitted after receiving a ping.

New in version 3.1.0.

ping_data = None

The data included on the ping.

class `h2.events.PingAckReceived`

The PingAckReceived event is fired whenever a PING acknowledgment is received. It contains the ‘opaque data’ of the PING+ACK frame, allowing the user to correlate PINGs and calculate RTT.

New in version 3.1.0.

Changed in version 4.0.0: Removed deprecated but equivalent PingAcknowledged.

ping_data = None

The data included on the ping.

class `h2.events.StreamEnded`

The StreamEnded event is fired whenever a stream is ended by a remote party. The stream may not be fully closed if it has not been closed locally, but no further data or headers should be expected on that stream.

stream_id = None

The Stream ID of the stream that was closed.

class `h2.events.StreamReset`

The StreamReset event is fired in two situations. The first is when the remote party forcefully resets the stream. The second is when the remote party has made a protocol error which only affects a single stream. In this case, Hyper-h2 will terminate the stream early and return this event.

Changed in version 2.0.0: This event is now fired when Hyper-h2 automatically resets a stream.

error_code = None

The error code given. Either one of *ErrorCodes* or int

remote_reset = None

Whether the remote peer sent a RST_STREAM or we did.

stream_id = None

The Stream ID of the stream that was reset.

class h2.events.PushedStreamReceived

The PushedStreamReceived event is fired whenever a pushed stream has been received from a remote peer. The event carries on it the new stream ID, the ID of the parent stream, and the request headers pushed by the remote peer.

headers = None

The request headers, sent by the remote party in the push.

parent_stream_id = None

The Stream ID of the stream that the push is related to.

pushed_stream_id = None

The Stream ID of the stream created by the push.

class h2.events.SettingsAcknowledged

The SettingsAcknowledged event is fired whenever a settings ACK is received from the remote peer. The event carries on it the settings that were acknowledged, in the same format as *h2.events.RemoteSettingsChanged*.

changed_settings = None

A dictionary of setting byte to *ChangedSetting*, representing the changed settings.

class h2.events.PriorityUpdated

The PriorityUpdated event is fired whenever a stream sends updated priority information. This can occur when the stream is opened, or at any time during the stream lifetime.

This event is purely advisory, and does not need to be acted on.

New in version 2.0.0.

depends_on = None

The stream ID this stream now depends on. May be 0.

exclusive = None

Whether the stream *exclusively* depends on the parent stream. If it does, this stream should inherit the current children of its new parent.

stream_id = None

The ID of the stream whose priority information is being updated.

weight = None

The new stream weight. May be the same as the original stream weight. An integer between 1 and 256.

class h2.events.ConnectionTerminated

The ConnectionTerminated event is fired when a connection is torn down by the remote peer using a GOAWAY frame. Once received, no further action may be taken on the connection: a new connection must be established.

additional_data = None

Additional debug data that can be appended to GOAWAY frame.

error_code = None

The error code cited when tearing down the connection. Should be one of *ErrorCodes*, but may not be if unknown HTTP/2 extensions are being used.

last_stream_id = None

The stream ID of the last stream the remote peer saw. This can provide an indication of what data, if any, never reached the remote peer and so can safely be resent.

class `h2.events.AlternativeServiceAvailable`

The `AlternativeServiceAvailable` event is fired when the remote peer advertises an [RFC 7838](#) Alternative Service using an ALTSVC frame.

This event always carries the origin to which the ALTSVC information applies. That origin is either supplied by the server directly, or inferred by hyper-h2 from the `:authority` pseudo-header field that was sent by the user when initiating a given stream.

This event also carries what RFC 7838 calls the “Alternative Service Field Value”, which is formatted like a HTTP header field and contains the relevant alternative service information. Hyper-h2 does not parse or in any way modify that information: the user is required to do that.

This event can only be fired on the client end of a connection.

New in version 2.3.0.

field_value = None

The ALTSVC field value. This contains information about the HTTP alternative service being advertised by the server. Hyper-h2 does not parse this field: it is left exactly as sent by the server. The structure of the data in this field is given by [RFC 7838 Section 3](#).

origin = None

The origin to which the alternative service field value applies. This field is either supplied by the server directly, or inferred by hyper-h2 from the `:authority` pseudo-header field that was sent by the user when initiating the stream on which the frame was received.

class `h2.events.UnknownFrameReceived`

The `UnknownFrameReceived` event is fired when the remote peer sends a frame that hyper-h2 does not understand. This occurs primarily when the remote peer is employing HTTP/2 extensions that hyper-h2 doesn’t know anything about.

RFC 7540 requires that HTTP/2 implementations ignore these frames. hyper-h2 does so. However, this event is fired to allow implementations to perform special processing on those frames if needed (e.g. if the implementation is capable of handling the frame itself).

New in version 2.7.0.

frame = None

The `hyperframe.Frame` object that encapsulates the received frame.

1.7.5 Exceptions

class `h2.exceptions.H2Error`

The base class for all exceptions for the HTTP/2 module.

class `h2.exceptions.NoSuchStreamError` (*stream_id*)

Bases: `h2.exceptions.ProtocolError`

A stream-specific action referenced a stream that does not exist.

Changed in version 2.0.0: Became a subclass of `ProtocolError`

stream_id = None

The stream ID corresponds to the non-existent stream.

class `h2.exceptions.StreamClosedError` (*stream_id*)

Bases: `h2.exceptions.NoSuchStreamError`

A more specific form of *NoSuchStreamError*. Indicates that the stream has since been closed, and that all state relating to that stream has been removed.

stream_id = None

The stream ID corresponds to the nonexistent stream.

class `h2.exceptions.RFC1122Error`

Bases: `h2.exceptions.H2Error`

Emitted when users attempt to do something that is literally allowed by the relevant RFC, but is sufficiently ill-defined that it's unwise to allow users to actually do it.

While there is some disagreement about whether or not we should be liberal in what accept, it is a truth universally acknowledged that we should be conservative in what emit.

New in version 2.4.0.

Protocol Errors

class `h2.exceptions.ProtocolError`

Bases: `h2.exceptions.H2Error`

An action was attempted in violation of the HTTP/2 protocol.

error_code = 1

The error code corresponds to this kind of Protocol Error.

class `h2.exceptions.FrameTooLargeError`

Bases: `h2.exceptions.ProtocolError`

The frame that we tried to send or that we received was too large.

error_code = 6

The error code corresponds to this kind of Protocol Error.

class `h2.exceptions.FrameDataMissingError`

Bases: `h2.exceptions.ProtocolError`

The frame that we received is missing some data.

New in version 2.0.0.

error_code = 6

The error code corresponds to this kind of Protocol Error.

class `h2.exceptions.TooManyStreamsError`

Bases: `h2.exceptions.ProtocolError`

An attempt was made to open a stream that would lead to too many concurrent streams.

class `h2.exceptions.FlowControlError`

Bases: `h2.exceptions.ProtocolError`

An attempted action violates flow control constraints.

error_code = 3

The error code corresponds to this kind of Protocol Error.

class `h2.exceptions.StreamIDTooLowError` (*stream_id*, *max_stream_id*)

Bases: `h2.exceptions.ProtocolError`

An attempt was made to open a stream that had an ID that is lower than the highest ID we have seen on this connection.

max_stream_id = None

The current highest-seen stream ID.

stream_id = None

The ID of the stream that we attempted to open.

class `h2.exceptions.InvalidSettingsValueError` (*msg, error_code*)

An attempt was made to set an invalid Settings value.

New in version 2.0.0.

class `h2.exceptions.NoAvailableStreamIDError`

Bases: `h2.exceptions.ProtocolError`

There are no available stream IDs left to the connection. All stream IDs have been exhausted.

New in version 2.0.0.

class `h2.exceptions.InvalidBodyLengthError` (*expected, actual*)

Bases: `h2.exceptions.ProtocolError`

The remote peer sent more or less data than the Content-Length header indicated.

New in version 2.0.0.

class `h2.exceptions.UnsupportedFrameError`

The remote peer sent a frame that is unsupported in this context.

New in version 2.1.0.

Changed in version 4.0.0: Removed deprecated `KeyError` parent class.

class `h2.exceptions.DenialOfServiceError`

Bases: `h2.exceptions.ProtocolError`

Emitted when the remote peer exhibits a behaviour that is likely to be an attempt to perform a Denial of Service attack on the implementation. This is a form of `ProtocolError` that carries a different error code, and allows more easy detection of this kind of behaviour.

New in version 2.5.0.

error_code = 11

The error code corresponds to this kind of `ProtocolError`

1.7.6 HTTP/2 Error Codes

h2/errors

Global error code registry containing the established HTTP/2 error codes.

The current registry is available at: <https://tools.ietf.org/html/rfc7540#section-11.4>

class `h2.errors.ErrorCodes`

All known HTTP/2 error codes.

New in version 2.5.0.

CANCEL = 8

Stream cancelled.

COMPRESSION_ERROR = 9

Compression state not updated.

CONNECT_ERROR = 10
TCP connection error for CONNECT method.

ENHANCE_YOUR_CALM = 11
Processing capacity exceeded.

FLOW_CONTROL_ERROR = 3
Flow-control limits exceeded.

FRAME_SIZE_ERROR = 6
Frame size incorrect.

HTTP_1_1_REQUIRED = 13
Use HTTP/1.1 for the request.

INADEQUATE_SECURITY = 12
Negotiated TLS parameters not acceptable.

INTERNAL_ERROR = 2
Implementation fault.

NO_ERROR = 0
Graceful shutdown.

PROTOCOL_ERROR = 1
Protocol error detected.

REFUSED_STREAM = 7
Stream not processed.

SETTINGS_TIMEOUT = 4
Settings not acknowledged.

STREAM_CLOSED = 5
Frame received for closed stream.

1.7.7 Settings

class `h2.settings.SettingCodes`

All known HTTP/2 setting codes.

New in version 2.6.0.

ENABLE_CONNECT_PROTOCOL = 8

This setting can be used to enable the connect protocol. To enable on a client set this to 1.

ENABLE_PUSH = 2

This setting can be used to disable server push. To disable server push on a client, set this to 0.

HEADER_TABLE_SIZE = 1

Allows the sender to inform the remote endpoint of the maximum size of the header compression table used to decode header blocks, in octets.

INITIAL_WINDOW_SIZE = 4

Indicates the sender's initial window size (in octets) for stream-level flow control.

MAX_CONCURRENT_STREAMS = 3

Indicates the maximum number of concurrent streams that the sender will allow.

MAX_FRAME_SIZE = 5

Indicates the size of the largest frame payload that the sender is willing to receive, in octets.

MAX_HEADER_LIST_SIZE = 6

This advisory setting informs a peer of the maximum size of header list that the sender is prepared to accept, in octets. The value is based on the uncompressed size of header fields, including the length of the name and value in octets plus an overhead of 32 octets for each header field.

class `h2.settings.Settings` (*client=True, initial_values=None*)

An object that encapsulates HTTP/2 settings state.

HTTP/2 Settings are a complex beast. Each party, remote and local, has its own settings and a view of the other party's settings. When a settings frame is emitted by a peer it cannot assume that the new settings values are in place until the remote peer acknowledges the setting. In principle, multiple settings changes can be “in flight” at the same time, all with different values.

This object encapsulates this mess. It provides a dict-like interface to settings, which return the *current* values of the settings in question. Additionally, it keeps track of the stack of proposed values: each time an acknowledgement is sent/received, it updates the current values with the stack of proposed values. On top of all that, it validates the values to make sure they're allowed, and raises *InvalidSettingsValueError* if they are not.

Finally, this object understands what the default values of the HTTP/2 settings are, and sets those defaults appropriately.

Changed in version 2.2.0: Added the `initial_values` parameter.

Changed in version 2.5.0: Added the `max_header_list_size` property.

Parameters

- **client** (`bool`) – (optional) Whether these settings should be defaulted for a client implementation or a server implementation. Defaults to `True`.
- **initial_values** – (optional) Any initial values the user would like set, rather than RFC 7540's defaults.

acknowledge()

The settings have been acknowledged, either by the user (remote settings) or by the remote peer (local settings).

Returns A dict of {setting: ChangedSetting} that were applied.

clear() → `None`. Remove all items from D.

enable_connect_protocol

The current value of the `ENABLE_CONNECT_PROTOCOL` setting.

enable_push

The current value of the `ENABLE_PUSH` setting.

get(*k*, *d*) → `D[k]` if *k* in *D*, else *d*. *d* defaults to `None`.

header_table_size

The current value of the `HEADER_TABLE_SIZE` setting.

initial_window_size

The current value of the `INITIAL_WINDOW_SIZE` setting.

items() → a set-like object providing a view on D's items

keys() → a set-like object providing a view on D's keys

max_concurrent_streams

The current value of the `MAX_CONCURRENT_STREAMS` setting.

max_frame_size

The current value of the `MAX_FRAME_SIZE` setting.

max_header_list_size

The current value of the `MAX_HEADER_LIST_SIZE` setting. If not set, returns `None`, which means unlimited.

New in version 2.5.0.

pop ($k[, d]$) $\rightarrow v$, remove specified key and return the corresponding value.

If key is not found, `d` is returned if given, otherwise `KeyError` is raised.

popitem () $\rightarrow (k, v)$, remove and return some (key, value) pair

as a 2-tuple; but raise `KeyError` if `D` is empty.

setdefault ($k[, d]$) $\rightarrow D.get(k, d)$, also set `D[k]=d` if `k` not in `D`

update ($[E], **F$) $\rightarrow None$. Update `D` from mapping/iterable `E` and `F`.

If `E` present and has a `.keys()` method, does: for `k` in `E`: `D[k] = E[k]` If `E` present and lacks `.keys()` method, does: for `(k, v)` in `E`: `D[k] = v` In either case, this is followed by: for `k, v` in `F.items()`: `D[k] = v`

values () \rightarrow an object providing a view on `D`'s values

class `h2.settings.ChangedSetting` (*setting, original_value, new_value*)

new_value = None

The new value after being changed.

original_value = None

The original value before being changed.

setting = None

The setting code given. Either one of `SettingCodes` or `int`

Changed in version 2.6.0.

1.8 Testimonials

1.8.1 Glyph Lefkowitz

Frankly, Hyper-h2 is almost SURREAL in how well-factored and decoupled the implementation is from I/O. If libraries in the Python ecosystem looked like this generally, Twisted would be a much better platform than it is. (Frankly, most of Twisted's `_own_` protocol implementations should aspire to such cleanliness.)

(Source)

1.9 Release Process

Because of Hyper-h2's place at the bottom of the dependency tree, it is extremely important that the project maintains a diligent release schedule. This document outlines our process for managing releases.

1.9.1 Versioning

Hyper-h2 follows [semantic versioning](#) of its public API when it comes to numbering releases. The public API of Hyper-h2 is strictly limited to the entities listed in the [Hyper-h2 API](#) documentation: anything not mentioned in that

document is not considered part of the public API and is not covered by the versioning guarantees given by semantic versioning.

1.9.2 Maintenance

Hyper-h2 has the notion of a “release series”, given by a major and minor version number: for example, there is the 2.1 release series. When each minor release is made and a release series is born, a branch is made off the release tag: for example, for the 2.1 release series, the 2.1.X branch.

All changes merged into the master branch will be evaluated for whether they can be considered ‘bugfixes’ only (that is, they do not affect the public API). If they can, they will also be cherry-picked back to all active maintenance branches that require the bugfix. If the bugfix is not necessary, because the branch in question is unaffected by that bug, the bugfix will not be backported.

1.9.3 Supported Release Series’

The developers of Hyper-h2 commit to supporting the following release series:

- The most recent, as identified by the first two numbers in the highest version currently released.
- The immediately prior release series.

The only exception to this policy is that no release series earlier than the 2.1 series will be supported. In this context, “supported” means that they will continue to receive bugfix releases.

For releases other than the ones identified above, no support is guaranteed. The developers may *choose* to support such a release series, but they do not promise to.

The exception here is for security vulnerabilities. If a security vulnerability is identified in an out-of-support release series, the developers will do their best to patch it and issue an emergency release. For more information, see [our security documentation](#).

1.10 Release Notes

This document contains release notes for Hyper-h2. In addition to the [Release History](#) found at the bottom of this document, this document also includes a high-level prose overview of each major release after 1.0.0.

1.10.1 High Level Notes

3.0.0: 24 March 2017

The Hyper-h2 team and the Hyper project are delighted to announce the release of Hyper-h2 version 3.0.0! Unlike the really notable 2.0.0 release, this release is proportionally quite small: however, it has the effect of removing a lot of cruft and complexity that has built up in the codebase over the lifetime of the v2 release series.

This release was motivated primarily by discovering that applications that attempted to use both HTTP/1.1 and HTTP/2 using hyper-h2 would encounter problems with cookies, because hyper-h2 did not join together cookie headers as required by RFC 7540. Normally adding such behaviour would be a non-breaking change, but we previously had no flags to prevent normalization of received HTTP headers.

Because it makes no sense for the cookie to be split *by default*, we needed to add a controlling flag and set it to true. The breaking nature of this change is very subtle, and it’s possible most users would never notice, but nevertheless it *is* a breaking change and we need to treat it as such.

Happily, we can take this opportunity to finalise a bunch of deprecations we'd made over the past year. The v2 release series was long-lived and successful, having had a series of releases across the past year-and-a-bit, and the Hyper team are very proud of it. However, it's time to open a new chapter, and remove the deprecated code.

The past year has been enormously productive for the Hyper team. A total of 30 v2 releases were made, an enormous amount of work. A good number of people have made their first contribution in this time, more than I can thank reasonably without taking up an unreasonable amount of space in this document, so instead I invite you to check out [our awesome contributor list](#).

We're looking forward to the next chapter in hyper-h2: it's been a fun ride so far, and we hope even more of you come along and join in the fun over the next year!

2.0.0: 25 January 2016

The Hyper-h2 team and the Hyper project are delighted to announce the release of Hyper-h2 version 2.0.0! This is an enormous release that contains a gigantic collection of new features and fixes, with the goal of making it easier than ever to use Hyper-h2 to build a compliant HTTP/2 server or client.

An enormous chunk of this work has been focused on tighter enforcement of restrictions in RFC 7540, ensuring that we correctly police the actions of remote peers, and error appropriately when those peers violate the specification. Several of these constitute breaking changes, because data that was previously received and handled without obvious error now raises `ProtocolError` exceptions and causes the connection to be terminated.

Additionally, the public API was cleaned up and had several helper methods that had been inadvertently exposed removed from the public API. The team wants to stress that while Hyper-h2 follows semantic versioning, the guarantees of semver apply only to the public API as documented in [Hyper-h2 API](#). Reducing the surface area of these APIs makes it easier for us to continue to ensure that the guarantees of semver are respected on our public API.

We also attempted to clear up some of the warts that had appeared in the API, and add features that are helpful for implementing HTTP/2 endpoints. For example, the `H2Connection` object now exposes a method for generating the next stream ID that your client or server can use to initiate a connection (`get_next_available_stream_id`). We also removed some needless return values that were guaranteed to return empty lists, which were an attempt to make a forward-looking guarantee that was entirely unneeded.

Altogether, this has been an extremely productive period for Hyper-h2, and a lot of great work has been done by the community. To that end, we'd also like to extend a great thankyou to those contributors who made their first contribution to the project between release 1.0.0 and 2.0.0. Many thanks to: [Thomas Kriebbaum](#), [Alex Chan](#), [Maximilian Hils](#), and [Glyph](#). For a full historical list of contributors, see [contributors](#).

We're looking forward to the next few months of Python HTTP/2 work, and hoping that you'll find lots of excellent HTTP/2 applications to build with Hyper-h2!

1.11 Release History

1.11.1 4.0.0 (2020-09-19)

API Changes (Backward-Incompatible)

- Support for Python 2.7 has been removed.
- Support for Python 3.4 has been removed.
- Support for Python 3.5 has been removed.
- Support for PyPy (Python 2.7 compatible) has been removed.
- Support for Python 3.8 has been added.

- Receiving DATA before HEADERS now raises a `ProtocolError` (see <https://tools.ietf.org/html/rfc7540#section-8.1>)

1.11.2 3.2.0 (2020-02-08)

Bugfixes

- Receiving DATA frames on closed (or reset) streams now properly emit a `WINDOW_UPDATE` to keep the connection flow window topped up.

API Changes (Backward-Incompatible)

- `h2.config.logger` now uses a `trace(...)` function, in addition to `debug(...)`. If you defined a custom logger object, you need to handle these new function calls.

1.11.3 3.1.1 (2019-08-02)

Bugfixes

- Ignore `WINDOW_UPDATE` and `RST_STREAM` frames received after stream closure.

1.11.4 3.1.0 (2019-01-22)

API Changes (Backward-Incompatible)

- `h2.connection.H2Connection.data_to_send` first and only argument `amt` was renamed to `amount`.
- Support for Python 3.3 has been removed.

API Changes (Backward-Compatible)

- `h2.connection.H2Connection.send_data` now supports `data` parameter being a `memoryview` object.
- Refactor ping-related events: a `h2.events.PingReceived` event is fired when a PING frame is received and a `h2.events.PingAckReceived` event is fired when a PING frame with an ACK flag is received. `h2.events.PingAcknowledged` is deprecated in favour of the identical `h2.events.PingAckReceived`.
- Added `ENABLE_CONNECT_PROTOCOL` to `h2.settings.SettingCodes`.
- Support `CONNECT` requests with a `:protocol` pseudo header thereby supporting RFC 8441.
- A limit to the number of closed streams kept in memory by the connection is applied. It can be configured by `h2.connection.H2Connection.MAX_CLOSED_STREAMS`.

Bugfixes

- Debug logging when `stream_id` is `None` is now fixed and no longer errors.

1.11.5 3.0.1 (2017-04-03)

Bugfixes

- CONTINUATION frames sent on closed streams previously caused stream errors of type `STREAM_CLOSED`. RFC 7540 § 6.10 requires that these be connection errors of type `PROTOCOL_ERROR`, and so this release changes to match that behaviour.
- Remote peers incrementing their inbound connection window beyond the maximum allowed value now cause stream-level errors, rather than connection-level errors, allowing connections to stay up longer.
- h2 now rejects receiving and sending request header blocks that are missing any of the mandatory pseudo-header fields (`:path`, `:scheme`, and `:method`).
- h2 now rejects receiving and sending request header blocks that have an empty `:path` pseudo-header value.
- h2 now rejects receiving and sending request header blocks that contain response-only pseudo-headers, and vice versa.
- h2 now correct respects user-initiated changes to the `HEADER_TABLE_SIZE` local setting, and ensures that if users shrink or increase the header table size it is policed appropriately.

1.11.6 2.6.2 (2017-04-03)

Bugfixes

- CONTINUATION frames sent on closed streams previously caused stream errors of type `STREAM_CLOSED`. RFC 7540 § 6.10 requires that these be connection errors of type `PROTOCOL_ERROR`, and so this release changes to match that behaviour.
- Remote peers incrementing their inbound connection window beyond the maximum allowed value now cause stream-level errors, rather than connection-level errors, allowing connections to stay up longer.
- h2 now rejects receiving and sending request header blocks that are missing any of the mandatory pseudo-header fields (`:path`, `:scheme`, and `:method`).
- h2 now rejects receiving and sending request header blocks that have an empty `:path` pseudo-header value.
- h2 now rejects receiving and sending request header blocks that contain response-only pseudo-headers, and vice versa.
- h2 now correct respects user-initiated changes to the `HEADER_TABLE_SIZE` local setting, and ensures that if users shrink or increase the header table size it is policed appropriately.

1.11.7 2.5.4 (2017-04-03)

Bugfixes

- CONTINUATION frames sent on closed streams previously caused stream errors of type `STREAM_CLOSED`. RFC 7540 § 6.10 requires that these be connection errors of type `PROTOCOL_ERROR`, and so this release changes to match that behaviour.
- Remote peers incrementing their inbound connection window beyond the maximum allowed value now cause stream-level errors, rather than connection-level errors, allowing connections to stay up longer.
- h2 now correct respects user-initiated changes to the `HEADER_TABLE_SIZE` local setting, and ensures that if users shrink or increase the header table size it is policed appropriately.

1.11.8 3.0.0 (2017-03-24)

API Changes (Backward-Incompatible)

- By default, hyper-h2 now joins together received cookie header fields, per RFC 7540 Section 8.1.2.5.
- Added a `normalize_inbound_headers` flag to the `H2Configuration` object that defaults to `True`. Setting this to `False` changes the behaviour from the previous point back to the v2 behaviour.
- Removed deprecated fields from `h2.errors` module.
- Removed deprecated fields from `h2.settings` module.
- Removed deprecated `client_side` and `header_encoding` arguments from `H2Connection`.
- Removed deprecated `client_side` and `header_encoding` properties from `H2Connection`.
- `dict` objects are no longer allowed for user-supplied headers.
- The default header encoding is now `None`, not `utf-8`: this means that all events that carry headers now return those headers as byte strings by default. The header encoding can be set back to `utf-8` to restore the old behaviour.

API Changes (Backward-Compatible)

- Added new `UnknownFrameReceived` event that fires when unknown extension frames have been received. This only fires when using hyperframe 5.0 or later: earlier versions of hyperframe cause us to silently ignore extension frames.

Bugfixes

None

1.11.9 2.6.1 (2017-03-16)

Bugfixes

- Allowed hyperframe v5 support while continuing to ignore unexpected frames.

1.11.10 2.5.3 (2017-03-16)

Bugfixes

- Allowed hyperframe v5 support while continuing to ignore unexpected frames.

1.11.11 2.4.4 (2017-03-16)

Bugfixes

- Allowed hyperframe v5 support while continuing to ignore unexpected frames.

1.11.12 2.6.0 (2017-02-28)

API Changes (Backward-Compatible)

- Added a new `h2.events.Event` class that acts as a base class for all events.
- Rather than reject outbound Connection-specific headers, h2 will now normalize the header block by removing them.
- Implement equality for the `h2.settings.Settings` class.
- Added `h2.settings.SettingCodes`, an enum that is used to store all the HTTP/2 setting codes. This allows us to use a better printed representation of the setting code in most places that it is used.
- The `setting` field in `ChangedSetting` for the `RemoteSettingsChanged` and `SettingsAcknowledged` events has been updated to be instances of `SettingCodes` whenever they correspond to a known setting code. When they are an unknown setting code, they are instead `int`. As `SettingCodes` is a subclass of `int`, this is non-breaking.
- Deprecated the other fields in `h2.settings`. These will be removed in 3.0.0.
- Added an optional `pad_length` parameter to `H2Connection.send_data` to allow the user to include padding on a data frame.
- Added a new parameter to the `h2.config.H2Configuration` initializer which takes a logger. This allows us to log by providing a logger that conforms to the requirements of this module so that it can be used in different environments.

Bugfixes

- Correctly reject pushed request header blocks whenever they have malformed request header blocks.
- Correctly normalize pushed request header blocks whenever they have normalizable header fields.
- Remote peers are now allowed to send zero or any positive number as a value for `SETTINGS_MAX_HEADER_LIST_SIZE`, where previously sending zero would raise a `InvalidSettingsValueError`.
- Resolved issue where the HTTP2-Settings header value for plaintext upgrade that was emitted by `initiate_upgrade_connection` included the *entire* SETTINGS frame, instead of just the payload.
- Resolved issue where the HTTP2-Settings header value sent by a client for plaintext upgrade would be ignored by `initiate_upgrade_connection`, rather than have those settings applied appropriately.
- Resolved an issue whereby certain frames received from a peer in the CLOSED state would trigger connection errors when RFC 7540 says they should have triggered stream errors instead. Added more detailed stream closure tracking to ensure we don't throw away connections unnecessarily.

1.11.13 2.5.2 (2017-01-27)

- Resolved issue where the HTTP2-Settings header value for plaintext upgrade that was emitted by `initiate_upgrade_connection` included the *entire* SETTINGS frame, instead of just the payload.
- Resolved issue where the HTTP2-Settings header value sent by a client for plaintext upgrade would be ignored by `initiate_upgrade_connection`, rather than have those settings applied appropriately.

1.11.14 2.4.3 (2017-01-27)

- Resolved issue where the HTTP2-Settings header value for plaintext upgrade that was emitted by `initiate_upgrade_connection` included the *entire* SETTINGS frame, instead of just the payload.
- Resolved issue where the HTTP2-Settings header value sent by a client for plaintext upgrade would be ignored by `initiate_upgrade_connection`, rather than have those settings applied appropriately.

1.11.15 2.3.4 (2017-01-27)

- Resolved issue where the HTTP2-Settings header value for plaintext upgrade that was emitted by `initiate_upgrade_connection` included the *entire* SETTINGS frame, instead of just the payload.
- Resolved issue where the HTTP2-Settings header value sent by a client for plaintext upgrade would be ignored by `initiate_upgrade_connection`, rather than have those settings applied appropriately.

1.11.16 2.5.1 (2016-12-17)

Bugfixes

- Remote peers are now allowed to send zero or any positive number as a value for `SETTINGS_MAX_HEADER_LIST_SIZE`, where previously sending zero would raise a `InvalidSettingsValueError`.

1.11.17 2.5.0 (2016-10-25)

API Changes (Backward-Compatible)

- Added a new `H2Configuration` object that allows rich configuration of a `H2Connection`. This object supersedes the prior keyword arguments to the `H2Connection` object, which are now deprecated and will be removed in 3.0.
- Added support for automated window management via the `acknowledge_received_data` method. See the documentation for more details.
- Added a `DenialOfServiceError` that is raised whenever a behaviour that looks like a DoS attempt is encountered: for example, an overly large decompressed header list. This is a subclass of `ProtocolError`.
- Added support for setting and managing `SETTINGS_MAX_HEADER_LIST_SIZE`. This setting is now defaulted to 64kB.
- Added `h2.errors.ErrorCodes`, an enum that is used to store all the HTTP/2 error codes. This allows us to use a better printed representation of the error code in most places that it is used.
- The `error_code` fields on `ConnectionTerminated` and `StreamReset` events have been updated to be instances of `ErrorCodes` whenever they correspond to a known error code. When they are an unknown error code, they are instead `int`. As `ErrorCodes` is a subclass of `int`, this is non-breaking.
- Deprecated the other fields in `h2.errors`. These will be removed in 3.0.0.

Bugfixes

- Correctly reject request header blocks with neither `:authority` nor `Host` headers, or header blocks which contain mismatched `:authority` and `Host` headers, per RFC 7540 Section 8.1.2.3.

- Correctly expect that responses to HEAD requests will have no body regardless of the value of the Content-Length header, and reject those that do.
- Correctly refuse to send header blocks that contain neither :authority nor Host headers, or header blocks which contain mismatched :authority and Host headers, per RFC 7540 Section 8.1.2.3.
- Hyper-h2 will now reject header field names and values that contain leading or trailing whitespace.
- Correctly strip leading/trailing whitespace from header field names and values.
- Correctly refuse to send header blocks with a TE header whose value is not `trailers`, per RFC 7540 Section 8.1.2.2.
- Correctly refuse to send header blocks with connection-specific headers, per RFC 7540 Section 8.1.2.2.
- Correctly refuse to send header blocks that contain duplicate pseudo-header fields, or with pseudo-header fields that appear after ordinary header fields, per RFC 7540 Section 8.1.2.1.

This may cause passing a dictionary as the header block to `send_headers` to throw a `ProtocolError`, because dictionaries are unordered and so they may trip this check. Passing dictionaries here is deprecated, and callers should change to using a sequence of 2-tuples as their header blocks.

- Correctly reject trailers that contain HTTP/2 pseudo-header fields, per RFC 7540 Section 8.1.2.1.
- Correctly refuse to send trailers that contain HTTP/2 pseudo-header fields, per RFC 7540 Section 8.1.2.1.
- Correctly reject responses that do not contain the `:status` header field, per RFC 7540 Section 8.1.2.4.
- Correctly refuse to send responses that do not contain the `:status` header field, per RFC 7540 Section 8.1.2.4.
- Correctly update the maximum frame size when the user updates the value of that setting. Prior to this release, if the user updated the maximum frame size hyper-h2 would ignore the update, preventing the remote peer from using the higher frame sizes.

1.11.18 2.4.2 (2016-10-25)

Bugfixes

- Correctly update the maximum frame size when the user updates the value of that setting. Prior to this release, if the user updated the maximum frame size hyper-h2 would ignore the update, preventing the remote peer from using the higher frame sizes.

1.11.19 2.3.3 (2016-10-25)

Bugfixes

- Correctly update the maximum frame size when the user updates the value of that setting. Prior to this release, if the user updated the maximum frame size hyper-h2 would ignore the update, preventing the remote peer from using the higher frame sizes.

1.11.20 2.2.7 (2016-10-25)

Final 2.2.X release

Bugfixes

- Correctly update the maximum frame size when the user updates the value of that setting. Prior to this release, if the user updated the maximum frame size hyper-h2 would ignore the update, preventing the remote peer from using the higher frame sizes.

1.11.21 2.4.1 (2016-08-23)

Bugfixes

- Correctly expect that responses to HEAD requests will have no body regardless of the value of the Content-Length header, and reject those that do.

1.11.22 2.3.2 (2016-08-23)

Bugfixes

- Correctly expect that responses to HEAD requests will have no body regardless of the value of the Content-Length header, and reject those that do.

1.11.23 2.4.0 (2016-07-01)

API Changes (Backward-Compatible)

- Adds `additional_data` to `H2Connection.close_connection`, allowing the user to send additional debug data on the GOAWAY frame.
- Adds `last_stream_id` to `H2Connection.close_connection`, allowing the user to manually control what the reported last stream ID is.
- Add new method: `prioritize`.
- Add support for emitting stream priority information when sending headers frames using three new keyword arguments: `priority_weight`, `priority_depends_on`, and `priority_exclusive`.
- Add support for “related events”: events that fire simultaneously on a single frame.

1.11.24 2.3.1 (2016-05-12)

Bugfixes

- Resolved `AttributeError` encountered when receiving more than one sequence of CONTINUATION frames on a given connection.

1.11.25 2.2.5 (2016-05-12)

Bugfixes

- Resolved `AttributeError` encountered when receiving more than one sequence of CONTINUATION frames on a given connection.

1.11.26 2.3.0 (2016-04-26)

API Changes (Backward-Compatible)

- Added a new flag to the `H2Connection` constructor: `header_encoding`, that controls what encoding is used (if any) to decode the headers from bytes to unicode. This defaults to UTF-8 for backward compatibility. To disable the decode and use bytes exclusively, set the field to `False`, `None`, or the empty string. This affects all headers, including those pushed by servers.
- Bumped the minimum version of HPACK allowed from 2.0 to 2.2.
- Added support for advertising RFC 7838 Alternative services.
- Allowed users to provide `hpack.HeaderTuple` and `hpack.NeverIndexedHeaderTuple` objects to all methods that send headers.
- Changed all events that carry headers to emit `hpack.HeaderTuple` and `hpack.NeverIndexedHeaderTuple` instead of plain tuples. This allows users to maintain header indexing state.
- Added support for plaintext upgrade with the `initiate_upgrade_connection` method.

Bugfixes

- Automatically ensure that all `Authorization` and `Proxy-Authorization` headers, as well as short `Cookie` headers, are prevented from being added to encoding contexts.

1.11.27 2.2.4 (2016-04-25)

Bugfixes

- Correctly forbid pseudo-headers that were not defined in RFC 7540.
- Ignore `AltSvc` frames, rather than exploding when receiving them.

1.11.28 2.1.5 (2016-04-25)

Final 2.1.X release

Bugfixes

- Correctly forbid pseudo-headers that were not defined in RFC 7540.
- Ignore `AltSvc` frames, rather than exploding when receiving them.

1.11.29 2.2.3 (2016-04-13)

Bugfixes

- Allowed the 4.X series of hyperframe releases as dependencies.

1.11.30 2.1.4 (2016-04-13)

Bugfixes

- Allowed the 4.X series of hyperframe releases as dependencies.

1.11.31 2.2.2 (2016-04-05)

Bugfixes

- Fixed issue where informational responses were erroneously not allowed to be sent in the `HALF_CLOSED_REMOTE` state.
- Fixed issue where informational responses were erroneously not allowed to be received in the `HALF_CLOSED_LOCAL` state.
- Fixed issue where we allowed information responses to be sent or received after final responses.

1.11.32 2.2.1 (2016-03-23)

Bugfixes

- Fixed issue where users using locales that did not default to UTF-8 were unable to install source distributions of the package.

1.11.33 2.2.0 (2016-03-23)

API Changes (Backward-Compatible)

- Added support for sending informational responses (responses with 1XX status) codes as part of the standard flow. HTTP/2 allows zero or more informational responses with no upper limit: hyper-h2 does too.
- Added support for receiving informational responses (responses with 1XX status) codes as part of the standard flow. HTTP/2 allows zero or more informational responses with no upper limit: hyper-h2 does too.
- Added a new event: `ReceivedInformationalResponse`. This response is fired when informational responses (those with 1XX status codes).
- Added an `additional_data` field to the `ConnectionTerminated` event that carries any additional data sent on the GOAWAY frame. May be `None` if no such data was sent.
- Added the `initial_values` optional argument to the `Settings` object.

Bugfixes

- Correctly reject all of the connection-specific headers mentioned in RFC 7540 § 8.1.2.2, not just the `Connection:` header.
- Defaulted the value of `SETTINGS_MAX_CONCURRENT_STREAMS` to 100, unless explicitly overridden. This is a safe defensive initial value for this setting.

1.11.34 2.1.3 (2016-03-16)

Deprecations

- Passing dictionaries to `send_headers` as the header block is deprecated, and will be removed in 3.0.

1.11.35 2.1.2 (2016-02-17)

Bugfixes

- Reject attempts to push streams on streams that were themselves pushed: streams can only be pushed on streams that were initiated by the client.
- Correctly allow CONTINUATION frames to extend the header block started by a PUSH_PROMISE frame.
- Changed our handling of frames received on streams that were reset by the user.

Previously these would, at best, cause `ProtocolErrors` to be raised and the connection to be torn down (rather defeating the point of resetting streams at all) and, at worst, would cause subtle inconsistencies in state between hyper-h2 and the remote peer that could lead to header block decoding errors or flow control blockages.

Now when the user resets a stream all further frames received on that stream are ignored except where they affect some form of connection-level state, where they have their effect and are then ignored.

- Fixed a bug whereby receiving a PUSH_PROMISE frame on a stream that was closed would cause a RST_STREAM frame to be emitted on the closed-stream, but not the newly-pushed one. Now this causes a `ProtocolError`.

1.11.36 2.1.1 (2016-02-05)

Bugfixes

- Added debug representations for all events.
- Fixed problems with `setup.py` that caused trouble on older `setuptools`/`pip` installs.

1.11.37 2.1.0 (2016-02-02)

API Changes (Backward-Compatible)

- Added new field to `DataReceived`: `flow_controlled_length`. This is the length of the frame including padded data, allowing users to correctly track changes to the flow control window.
- Defined new `UnsupportedFrameError`, thrown when frames that are known to hyperframe but not supported by hyper-h2 are received. For backward-compatibility reasons, this is a `ProtocolError` *and* a `KeyError`.

Bugfixes

- Hyper-h2 now correctly accounts for padding when maintaining flow control windows.
- Resolved a bug where hyper-h2 would mistakenly apply `SETTINGS_INITIAL_WINDOW_SIZE` to the connection flow control window in addition to the stream-level flow control windows.

- Invalid Content-Length headers now throw `ProtocolError` exceptions and correctly tear the connection down, instead of leaving the connection in an indeterminate state.
- Invalid header blocks now throw `ProtocolError`, rather than a grab bag of possible other exceptions.

1.11.38 2.0.0 (2016-01-25)

API Changes (Breaking)

- Attempts to open streams with invalid stream IDs, either by the remote peer or by the user, are now rejected as a `ProtocolError`. Previously these were allowed, and would cause remote peers to error.
- Receiving frames that have invalid padding now causes the connection to be terminated with a `ProtocolError` being raised. Previously these passed undetected.
- Settings values set by both the user and the remote peer are now validated when they're set. If they're invalid, a new `InvalidSettingsValueError` is raised and, if set by the remote peer, a connection error is signaled. Previously, it was possible to set invalid values. These would either be caught when building frames, or would be allowed to stand.
- Settings changes no longer require user action to be acknowledged: `hyper-h2` acknowledges them automatically. This moves the location where some exceptions may be thrown, and also causes the `acknowledge_settings` method to be removed from the public API.
- Removed a number of methods on the `H2Connection` object from the public, semantically versioned API, by renaming them to have leading underscores. Specifically, removed:
 - `get_stream_by_id`
 - `get_or_create_stream`
 - `begin_new_stream`
 - `receive_frame`
 - `acknowledge_settings`
- Added full support for receiving CONTINUATION frames, including policing logic about when and how they are received. Previously, receiving CONTINUATION frames was not supported and would throw exceptions.
- All public API functions on `H2Connection` except for `receive_data` no longer return lists of events, because these lists were always empty. Events are now only raised by `receive_data`.
- Calls to `increment_flow_control_window` with out of range values now raise `ValueError` exceptions. Previously they would be allowed, or would cause errors when serializing frames.

API Changes (Backward-Compatible)

- Added `PriorityUpdated` event for signaling priority changes.
- Added `get_next_available_stream_id` function.
- Receiving DATA frames on streams not in the OPEN or HALF_CLOSED_LOCAL states now causes a stream reset, rather than a connection reset. The error is now also classified as a `StreamClosedError`, rather than a more generic `ProtocolError`.
- Receiving HEADERS or PUSH_PROMISE frames in the HALF_CLOSED_REMOTE state now causes a stream reset, rather than a connection reset.

- Receiving frames that violate the max frame size now causes connection errors with error code `FRAME_SIZE_ERROR`, not a generic `PROTOCOL_ERROR`. This condition now also raises a `FrameTooLargeError`, a new subclass of `ProtocolError`.
- Made `NoSuchStreamError` a subclass of `ProtocolError`.
- The `StreamReset` event is now also fired whenever a protocol error from the remote peer forces a stream to close early. This is only fired once.
- The `StreamReset` event now carries a flag, `remote_reset`, that is set to `True` in all cases where `StreamReset` would previously have fired (e.g. when the remote peer sent a `RST_STREAM`), and is set to `False` when it fires because the remote peer made a protocol error.
- Hyper-h2 now rejects attempts by peers to increment a flow control window by zero bytes.
- Hyper-h2 now rejects peers sending header blocks that are ill-formed for a number of reasons as set out in RFC 7540 Section 8.1.2.
- Attempting to send non-PRIORITY frames on closed streams now raises `StreamClosedError`.
- Remote peers attempting to increase the flow control window beyond $2^{31} - 1$, either by window increment or by settings frame, are now rejected as `ProtocolError`.
- Local attempts to increase the flow control window beyond $2^{31} - 1$ by window increment are now rejected as `ProtocolError`.
- The bytes that represent individual settings are now available in `h2.settings`, instead of needing users to import them from `hyperframe`.

Bugfixes

- RFC 7540 requires that a separate minimum stream ID be used for inbound and outbound streams. Hyper-h2 now obeys this requirement.
- Hyper-h2 now does a better job of reporting the last stream ID it has partially handled when terminating connections.
- Fixed an error in the arguments of `StreamIDTooLowError`.
- Prevent `ValueError` leaking from `Hyperframe`.
- Prevent `struct.error` and `InvalidFrameError` leaking from `Hyperframe`.

1.11.39 1.1.1 (2015-11-17)

Bugfixes

- Forcibly lowercase all header names to improve compatibility with implementations that demand lower-case header names.

1.11.40 1.1.0 (2015-10-28)

API Changes (Backward-Compatible)

- Added a new `ConnectionTerminated` event, which fires when GOAWAY frames are received.
- Added a subclass of `NoSuchStreamError`, called `StreamClosedError`, that fires when actions are taken on a stream that is closed and has had its state flushed from the system.

- Added `StreamIDTooLowError`, raised when the user or the remote peer attempts to create a stream with an ID lower than one previously used in the dialog. Inherits from `ValueError` for backward-compatibility reasons.

Bugfixes

- Do not throw `ProtocolError` when attempting to send multiple GOAWAY frames on one connection.
- We no longer forcefully change the decoder table size when settings changes are ACKed, instead waiting for remote acknowledgement of the change.
- Improve the performance of checking whether a stream is open.
- We now attempt to lazily garbage collect closed streams, to avoid having the state hang around indefinitely, leaking memory.
- Avoid further per-stream allocations, leading to substantial performance improvements when many short-lived streams are used.

1.11.41 1.0.0 (2015-10-15)

- First production release!

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