

Playing with HTTP/2 CONNECT

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Content

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In HTTP/1, the `CONNECT` method instructs a proxy to establish a TCP tunnel to a requested target. Once the tunnel is up, the proxy blindly forwards raw traffic in both directions. This mechanism is most commonly used to tunnel TLS traffic through forwarding proxies.

While digging through the HTTP/2 specification ([RFC 9113](#)), I noticed it also features the `CONNECT` method but with a slight twist. Unlike its predecessor, HTTP/2 `CONNECT` doesn't hijack the entire TCP connection, it operates on a single stream. This subtle difference piqued my curiosity.

A typical HTTP/1 `CONNECT` request is straightforward:

```
CONNECT google.de:443 HTTP/1.1
Host: google.de:443
User-Agent: curl/8.5.0
```

Once the server responds with `HTTP/1.1 200 OK`, the tunnel is ready. In essence, HTTP/1 `CONNECT` upgrades the entire TCP connection. Raw data is forwarded from that point on, making it seem as if the client is connected directly to the target.

HTTP/2, by contrast, is a binary protocol where the fundamental protocol unit is the frame. As shown below, every frame carries a stream identifier:

```
---
title: "HTTP/2 Frame"
---
packet
0-23: "Length (24)"
24-31: "Type (8)"
32-39: "Flags (8)"
40-40: "rsvd"
41-71: "Stream Identifier (31)"
```

This stream identifier is used to simulate the HTTP/1 request and response pattern by associating each interaction with a unique stream. Streams allow multiplexing which means a single HTTP/2 connection can host multiple, simultaneous `CONNECT` tunnels. The raw data for each tunnel is then encapsulated within `DATA` frames on its respective stream.

To experiment with this, I decided to build a scanner for misconfigured proxies that allow connections to internal targets, leveraging multiplexing to efficiently scan a range of internal ports over a single TCP connection.

Building a Scanner in Go

Go is currently my language of choice, and its standard library includes HTTP/2 support. While the high-level `net/http` client doesn't directly expose the `CONNECT` method for HTTP/2, the necessary building blocks are available in the `golang.org/x/net/http2` package.

First, we establish a raw TCP or TLS connection to the proxy. For TLS, we must negotiate HTTP/2 using ALPN by setting `NextProtos` to `h2`.

```
// Note: All code snippets omit error handling for brevity.
conn, _ := tls.Dial("tcp", url.Host, &tls.Config{
    InsecureSkipVerify: true,
    NextProtos:         []string{"h2"},
})
```

To initiate the HTTP/2 connection, the client must send the `connection preface` (`PRI * HTTP/2.0\r\n\r\nSM\r\n\r\n`) followed by a, potentially empty, `SETTINGS` frame. The server replies with its own `SETTINGS` frame. Once both sides have acknowledged each other's settings, the connection is ready.

```
conn.Write([]byte(http2.ClientPreface))
framer := http2.NewFramer(conn, conn)
framer.WriteSettings(http2.Setting{})
```

The `http2.Framer` handles the low-level work of parsing and serializing frames. Our main logic can be built around a loop that reads and processes incoming frames:

```
for {
    f, _ := framer.ReadFrame()
    switch f := f.(type) {
    case *http2.DataFrame:
        // Handle incoming data for a tunnel
    case *http2.MetaHeadersFrame:
        // Handle response headers for a CONNECT request
    case *http2.GoAwayFrame:
        log.Println("Received GoAway frame")
        return // Connection is closing
    case *http2.SettingsFrame:
        log.Printf("Received SETTINGS frame, ACK: %t\n", f.IsAck())
    case *http2.RSTStreamFrame:
        log.Printf("Received RST_STREAM frame for stream %d. Error: %s", f.StreamID, f.ErrCode)
    case *http2.PingFrame:
        log.Printf("Received frame: %v\n", f.FrameHeader.Type)
    case *http2.WindowUpdateFrame:
        log.Printf("Received frame: %v\n", f.FrameHeader.Type)
    default:
        log.Printf("Transport: unhandled response frame type %T", f)
    }
}
```

To create a tunnel, we send a `HEADERS` frame with the `CONNECT` method and set the `:authority` pseudo-header to our desired destination. Unlike HTTP/1's plaintext headers, HTTP/2 headers must be HPACK-encoded. This compression scheme saves bandwidth while also resisting compression oracle attacks like CRIME. HPACK uses a combination of a static table for common headers, a dynamic table that indexes repeated headers within the connection, and a static Huffman code for any remaining string literals. The initial static table and Huffman code are defined in the [specification](#).

```

var hpackBuf bytes.Buffer
hpackEncoder := hpack.NewEncoder(&hpackBuf)

// Client-initiated streams MUST use odd-numbered stream identifiers.
streamID := uint32(1)
targetAddress := "192.168.1.1:8080"

connectHeaders := []hpack.HeaderField{
    {Name: ":method", Value: "CONNECT"},
    {Name: ":authority", Value: targetAddress},
}

for _, hf := range connectHeaders {
    _ = hpackEncoder.WriteField(hf)
}

err := framer.WriteHeaders(http2.HeadersFrameParam{
    StreamID:    streamID,
    EndHeaders:  true,
    EndStream:   false, // Keep the stream open for data
    BlockFragment: hpackBuf.Bytes(),
})

```

If the proxy successfully establishes the tunnel, it will respond with a `HEADERS` frame containing a `:status 200`. From that point on, any `DATA` frames we send on that stream ID will be forwarded to the target, and any data from the target will be sent back to us in `DATA` frames on the same stream.

To make this stream usable in Go, we can wrap it in an object that satisfies the standard `net.Conn` interface. This allows us to treat our proxied tunnel just like any other network connection, such as one created with `net.Dial()`. The interface is defined as follows:

```

type Conn interface {
    Read(b []byte) (n int, err error)
    Write(b []byte) (n int, err error)
    Close() error
    LocalAddr() Addr
    RemoteAddr() Addr
    SetDeadline(t time.Time) error
    SetReadDeadline(t time.Time) error
    SetWriteDeadline(t time.Time) error
}

```

An example implementation for the `Read` and `Write` methods might look like this:

```

type tunnelConn struct {
    proxyConn *proxyConn
    streamID  uint32
    rxChan    chan []byte
    rxBuff    bytes.Buffer
}

func (t *tunnelConn) Write(b []byte) (n int, err error) {
    err = t.proxyConn.framer.WriteData(t.streamID, false, b)
    return len(b), err
}

func (t *tunnelConn) Read(b []byte) (n int, err error) {
    if t.rxBuff.Len() == 0 {
        data, ok := <-t.rxChan
        if !ok {
            return 0, io.EOF
        }
        t.rxBuff.Write(data)
    }
    return t.rxBuff.Read(b)
}

```

With this `net.Conn` implementation, we can easily layer other protocols on top. For instance, we could perform a TLS handshake and send an HTTP/1 request through the tunnel:

```

tunnel, _ := proxyConn.getTunnelConn(ports, resultChan, "example.com", rxChan)

tlsClient := tls.Client(tunnel, &tls.Config{
    ServerName:    "example.com",
    InsecureSkipVerify: true,
})

fmt.Fprintf(tlsClient, "GET / HTTP/1.1\r\nHost: %s\r\n\r\n", "example.com")

```

Here is an example of the tool connecting to `example.com` through an HTTP/2 proxy:

```
$ ./http2ConnTun -u example.com -p 443 -c -k
2025/09/10 07:02:20 INFO Connected to proxy
HTTP/1.1 200 OK
Content-Type: text/html
ETag: "84238dfc8092e5d9c0dac8ef93371a07:1736799080.121134"
Last-Modified: Mon, 13 Jan 2025 20:11:20 GMT
Cache-Control: max-age=86000
Date: Wed, 10 Sep 2025 05:02:21 GMT
Content-Length: 1256
Connection: keep-alive
Alt-Svc: h3=":443"; ma=93600

<!doctype html>
<html>
<head>
  <title>Example Domain</title>

  <meta charset="utf-8" />
  <meta http-equiv="Content-type" content="text/html; charset=utf-8" />
  <meta name="viewport" content="width=device-width, initial-scale=1" />
  <style type="text/css">
    body {
...

```

4	0.000093410	172.17.0.1	172.17.0.2	HTTP2	78 Magic
5	0.000996748	172.17.0.2	172.17.0.1	TCP	54 10001 → 36646 [ACK] Seq=1 Ack=25 Win=64256 Len=0
6	0.000131383	172.17.0.1	172.17.0.2	HTTP2	69 SETTINGS[0]
7	0.000133937	172.17.0.2	172.17.0.1	TCP	54 10001 → 36646 [ACK] Seq=1 Ack=40 Win=64256 Len=0
8	0.000664385	172.17.0.2	172.17.0.1	HTTP2	109 SETTINGS[0], WINDOW_UPDATE[0], SETTINGS[0]
9	0.000996745	172.17.0.1	172.17.0.2	TCP	54 36646 → 10001 [ACK] Seq=40 Ack=56 Win=64256 Len=0
10	0.000910918	172.17.0.1	172.17.0.2	HTTP2	63 SETTINGS[0]
11	0.001017657	172.17.0.1	172.17.0.2	HTTP2	84 HEADERS[1]
12	0.001059178	172.17.0.2	172.17.0.1	TCP	54 10001 → 36646 [ACK] Seq=56 Ack=79 Win=64256 Len=0
13	0.183606872	172.17.0.2	172.17.0.1	HTTP2	94 HEADERS[1]: 200 OK
14	0.184138138	172.17.0.1	172.17.0.2	HTTP2	103 DATA[1]
15	0.224372160	172.17.0.2	172.17.0.1	TCP	54 10001 → 36646 [ACK] Seq=96 Ack=128 Win=64256 Len=0
16	0.373739003	172.17.0.2	172.17.0.1	HTTP2	1582 DATA[1]

Frame 16: 1582 bytes on wire (12656 bits), 1582 bytes captured (12656 bits) on interface eth0
Ethernet II, Src: fa:cd:82:19:6a:94 (fa:cd:82:19:6a:94), Dst: c6:5c:e6:1f:43:a8 (c6:5c:e6:1f:43:a8)
Internet Protocol Version 4, Src: 172.17.0.2, Dst: 172.17.0.1
Transmission Control Protocol, Src Port: 10001, Dst Port: 36646, Seq: 96, Ack: 128, Window: 64256
Hypertext Transfer Protocol 2

- Stream: DATA, Stream ID: 1, Length 1519 (partial entity body) (tunneled data)
- Length: 1519
- Type: DATA (0)
- Flags: 0x00
- 0... = Reserved: 0x0
- = Stream Identifier: 1
- [Pad Length: 0]

Data: 48545450f312e3120323030204f4b0d0a436f6e74656e742d54790653a20746578742

- The flow begins with the client preface, which Wireshark labels `Magic`.
- We see the initial `SETTINGS` frames from the client and server, followed by `SETTINGS` frames with the `ACK` flag set, confirming receipt.
- The client sends a `HEADERS` frame with the `CONNECT` method, and the server replies with a `HEADERS` frame indicating the result.

- Finally, two **DATA** frames contain the plaintext HTTP/1 request and response sent through the established tunnel.

The full source code is available at <https://github.com/fl0mb/HTTP2-CONNECT-Tunnel>.

Application: Efficient Port Scanning

With the underlying mechanics in place, building a port scanner is straightforward. Send out `CONNECT` requests for various `ip:port` combinations, each on a new stream ID. We don't even need to send `DATA` frames; we only need to monitor the response headers to determine if a port is open.

A successful connection yields a `HEADERS` frame with a `:status 200`.

As observed with Envoy and Apache httpd, a failed connection will typically result in:

- A `HEADERS` frame with a `:status 503`.
- A `DATA` frame from the proxy itself containing an error message.
- A `RST_STREAM` frame with an error like `CONNECT_ERROR` (Envoy) or `NO_ERROR` (Apache). This is the most reliable indicator of failure.

```
4 0.000120005 172.17.0.1 172.17.0.2 78 Magic
5 0.000131872 172.17.0.2 172.17.0.1 TCP 54 10001 .. 34304 [ACK] Seq=1 Ack=25 Win=64256 Len=0
6 0.000187557 172.17.0.1 172.17.0.2 HTTP2 69 SETTINGS[0]
7 0.000194747 172.17.0.2 172.17.0.1 TCP 54 10001 .. 34304 [ACK] Seq=1 Ack=40 Win=64256 Len=0
8 0.000448215 172.17.0.2 172.17.0.1 HTTP2 109 SETTINGS[0], WINDOW_UPDATE[0], SETTINGS[0]
9 0.000473530 172.17.0.1 172.17.0.2 TCP 54 34304 .. 10001 [ACK] Seq=40 Ack=56 Win=64256 Len=0
10 0.000676997 172.17.0.1 172.17.0.2 HTTP2 63 SETTINGS[0]
11 0.000881595 172.17.0.2 172.17.0.1 TCP 83 HEADERS[1]
12 0.000991638 172.17.0.2 172.17.0.1 TCP 54 10001 .. 34304 [ACK] Seq=56 Ack=78 Win=64256 Len=0
13 0.001794635 172.17.0.2 172.17.0.1 HTTP2 301 HEADERS[1]: 503 Service Unavailable, DATA[1], RST_STREAM[1]
14 0.002384182 172.17.0.1 172.17.0.2 TCP 54 34304 .. 10001 [FIN, ACK] Seq=78 Ack=303 Win=64128 Len=0
15 0.002613954 172.17.0.2 172.17.0.1 TCP 54 10001 .. 34304 [FIN, ACK] Seq=303 Ack=79 Win=64256 Len=0
16 0.002643980 172.17.0.1 172.17.0.2 TCP 54 34304 .. 10001 [ACK] Seq=79 Ack=304 Win=64128 Len=0

Frame 13: 301 bytes on wire (2408 bits), 301 bytes captured (2408 bits) on interface docker0, id 0
Ethernet II, Src: fa:cd:82:19:6a:94 (fa:cd:82:19:6a:94), Dst: c6:5c:e6:1f:43:a8 (c6:5c:e6:1f:43:a8)
Internet Protocol Version 4, Src: 172.17.0.2, Dst: 172.17.0.1
Transmission Control Protocol, Src Port: 10001, Dst Port: 34304, Seq: 56, Ack: 78, Len: 247
Hypertext Transfer Protocol 2
  Stream: HEADERS, Stream ID: 1, Length 49, 503 Service Unavailable
    Length: 49
    Type: HEADERS (1)
    Flags: 0x04, End Headers
    0 ..... = Reserved: 0x0
    000 0000 0000 0000 0000 0000 0000 0001 = Stream Identifier: 1
    [Pad Length: 0]
    Header Block Fragment: 0003530335c033136375f87497ca58ae819aa619c361be940894dc5ad41004da8166e0..
    [Header Length: 133]
    [Header Count: 5]
    Header: :status: 503 Service Unavailable
    Header: content-length: 167
    Header: content-type: text/plain
    Header: date: Fri, 12 Sep 2025 13:20:12 GMT
    Header: server: envoy
Hypertext Transfer Protocol 2
  Stream: DATA, Stream ID: 1, Length 167 (tunneled data)
    Length: 167
    Type: DATA (0)
    Flags: 0x01, End Stream
    0 ..... = Reserved: 0x0
    000 0000 0000 0000 0000 0000 0000 0001 = Stream Identifier: 1
    [Pad Length: 0]
    Data: 75f973747205616d20636f6e6e656374206572726f72206f7220646973636f6e6e656374..
Hypertext Transfer Protocol 2
  Stream: RST_STREAM, Stream ID: 1, Length 4
    Length: 4
    Type: RST_STREAM (3)
    Flags: 0x00
    0 ..... = Reserved: 0x0
    000 0000 0000 0000 0000 0000 0000 0001 = Stream Identifier: 1
    Error: CONNECT ERROR (10)
```

By tracking the responses for each stream ID, we can map out open ports on an internal network, all multiplexed over a single HTTP/2 connection. This technique may also bypass network security monitoring that isn't equipped to inspect multiplexed HTTP/2 traffic.

Setting Up a Test Environment

Support for HTTP/2 CONNECT tunneling is not yet widespread. I found reliable implementations in Envoy and Apache httpd.

To run a test instance of Envoy, use the following Docker command:

```
docker run --rm -v ./envoy.yaml:/envoy.yaml:ro envoyproxy/envoy:distroless-v1.35-latest -c /envoy.yaml
```

envoy.yaml :

```
static_resources:
  listeners:
  - name: listener_0
    address:
      socket_address:
        protocol: TCP
        address: 0.0.0.0
        port_value: 10001
    filter_chains:
    - filters:
      - name: envoy.filters.network.http_connection_manager
        typed_config:
          "@type": type.googleapis.com/envoy.extensions.filters.network.http_connection_manager.v3.HttpConnectionManager
          stat_prefix: ingress_http
          codec_type: HTTP2
          route_config:
            name: local_route
            virtual_hosts:
            - name: local_service
              domains:
              - "*"
              routes:
              - match:
                  connect_matcher:
                    {}
                route:
                  cluster: dynamic_forward_proxy_cluster
                  upgrade_configs:
                  - upgrade_type: CONNECT
                    connect_config:
                      {}
          http_filters:
          - name: envoy.filters.http.dynamic_forward_proxy
            typed_config:
              '@type': type.googleapis.com/envoy.extensions.filters.http.dynamic_forward_proxy.v3.FilterConfig
              dns_cache_config:
                name: dynamic_forward_proxy_cache_config
                dns_lookup_family: V4_ONLY
          http_filters:
          - name: envoy.filters.http.router
            typed_config:
              "@type": type.googleapis.com/envoy.extensions.filters.http.router.v3.Router
          http2_protocol_options:
            allow_connect: true
```

```
clusters:
- name: dynamic_forward_proxy_cluster
  lb_policy: CLUSTER_PROVIDED
  cluster_type:
    name: envoy.clusters.dynamic_forward_proxy
  typed_config:
    '@type': type.googleapis.com/envoy.extensions.clusters.dynamic_forward_proxy.v3.ClusterConfig
  dns_cache_config:
    name: dynamic_forward_proxy_cache_config
    dns_lookup_family: V4_ONLY
```

To run a test instance of Apache httpd:

```
docker run --rm -p 8080:8080 -v ./httpd.conf:/usr/local/apache2/conf/httpd.conf httpd:2.4.65
```

httpd.conf :

```
ServerRoot "/usr/local/apache2"
Listen 8080

LoadModule mpm_event_module modules/mod_mpm_event.so
LoadModule http2_module modules/mod_http2.so
LoadModule proxy_module modules/mod_proxy.so
LoadModule proxy_connect_module modules/mod_proxy_connect.so
LoadModule proxy_http_module modules/mod_proxy_http.so
LoadModule authz_core_module modules/mod_authz_core.so
LoadModule log_config_module modules/mod_log_config.so
LoadModule unixd_module modules/mod_unixd.so

<IfModule unixd_module>
User daemon
Group daemon
</IfModule>

ErrorLog /dev/stderr
TransferLog /dev/stdout
ServerName localhost

<VirtualHost *:8080>
  ProxyRequests on
  Protocols h2c
  AllowCONNECT 443 80 8888
</VirtualHost>
```

Conclusion

HTTP/2's `CONNECT` method transforms a single connection into a conduit for multiple, independent tunnels. This offers a highly efficient way to multiplex connections, enabling applications like the port scanner demonstrated here. Because this traffic is encapsulated within a standard HTTP/2 stream, it may also bypass traditional network inspection tools.

While this post focused on TCP tunneling for port scanning, the `CONNECT` mechanism is being extended to support other protocols, opening up further possibilities.

- WebSockets: [RFC 8441](#) (Extended `CONNECT`) upgrades a stream to a WebSocket connection, bypassing the HTTP/1 `Connection: Upgrade` header, which is forbidden in HTTP/2. Example:

```
:method: CONNECT
:authority: 172.17.0.1:8888
:protocol: websocket
:scheme: http
:path: /ws
sec-websocket-version: 13
```

- UDP: [RFC 9298](#) defines a method for proxying UDP datagrams.
- IP: [RFC 9484](#) specifies a way to proxy raw IP packets.

HTTP/2 does not appear to be widely known in the security community and I am looking forward to more interesting and creative applications.

For a more thorough introduction of HTTP/2, I recommend the series of blog posts on <https://galbarahum.com/>.