New HTTP Client Stack

iOS 18 / macOS Sequoia

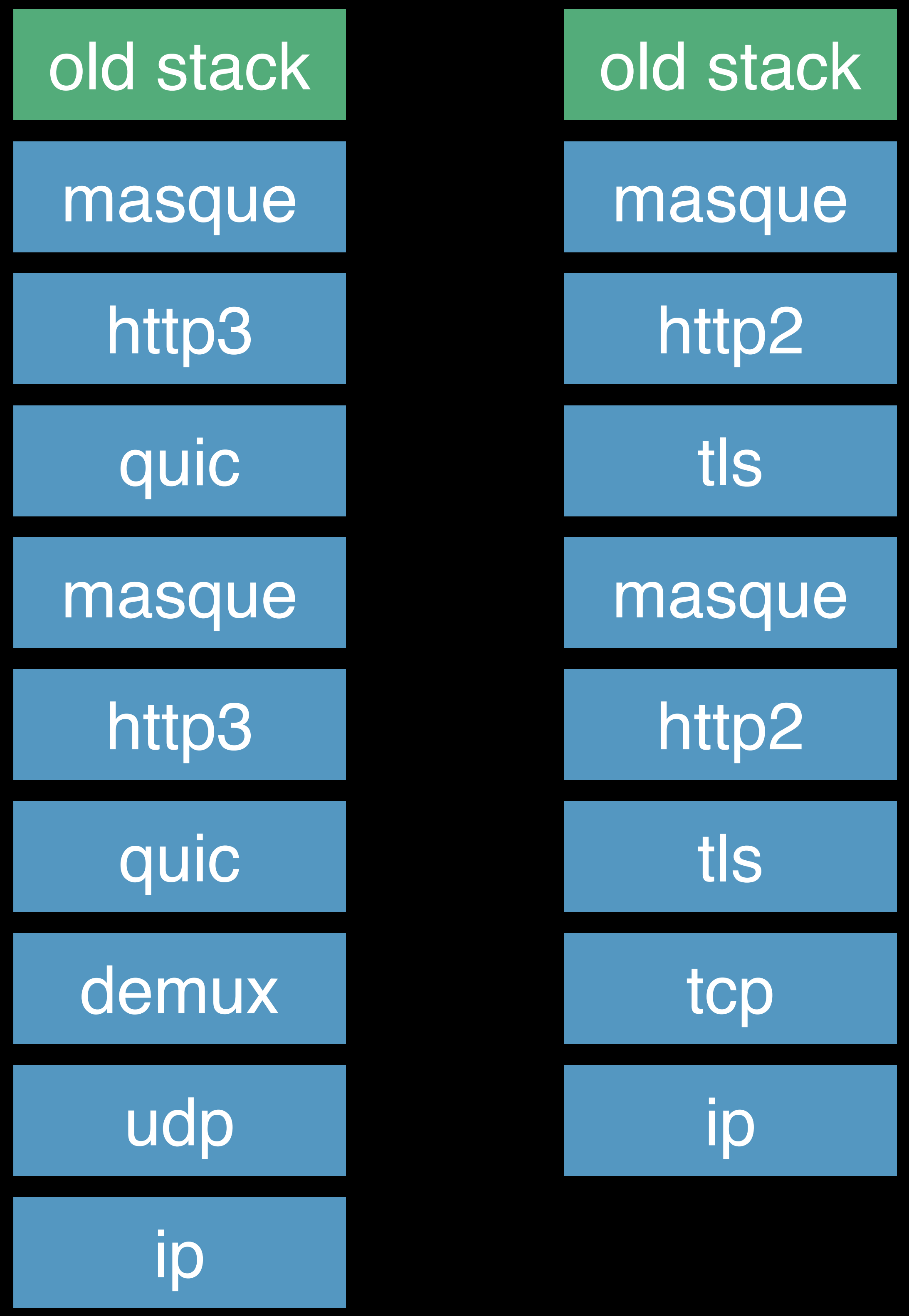
Guoye Zhang, Apple

Brief history

- Old HTTP stack
  - CFNetwork.framework
  - Started in 2000
  - Almost as old as Mac OS X
- New HTTP stack
  - Network.framework
  - Started in 2020

Why building a new HTTP stack?

iCloud Private Relay



old stack
masque
http3
quic
masque
http3
quic
demux
udp
ip

old stack
masque
http2
tls
masque
http2
tls
tcp
ip

Why building a new HTTP stack?

- Support iCloud Private Relay
- Composable
- Enable new features
  - 0-RTT early data

Can we use the new HTTP stack in Safari?

Yes!

(After thousands of changes and bug fixes)

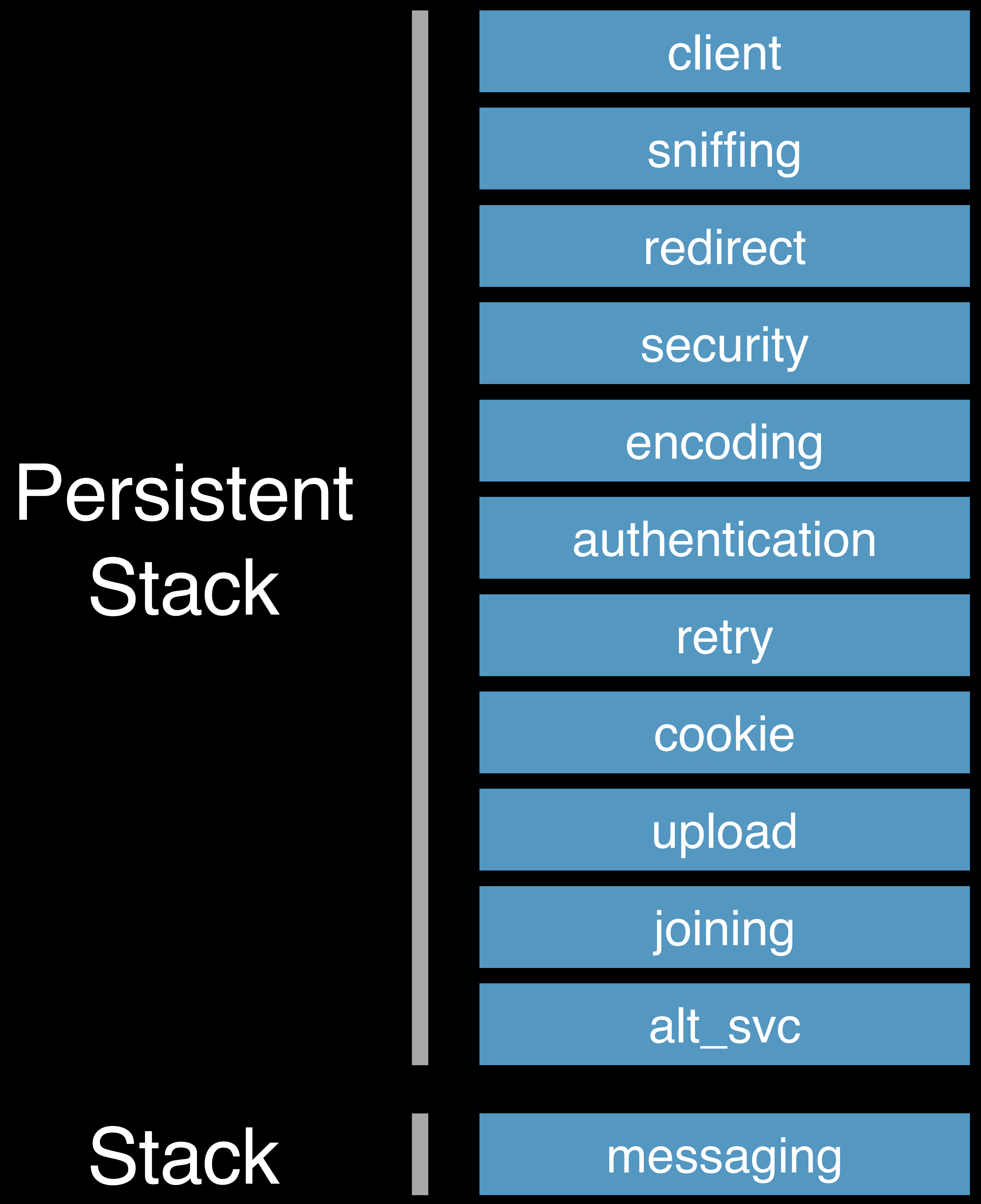
What was missing?

- HTTP Parsing
  - HTTP/1
  - ALPN version negotiation
- HTTP Semantics
  - Cookies
  - Authentication
  - Redirection

Old HTTP stack

- Monolithic HTTPProtocol object (~8000 LOC)
- Many layers of abstractions
- Version negotiation then send requests
- Other protocol like FTP

New HTTP stack



Persistent Stack

client

sniffing

redirect

security

encoding

authentication

retry

cookie

upload

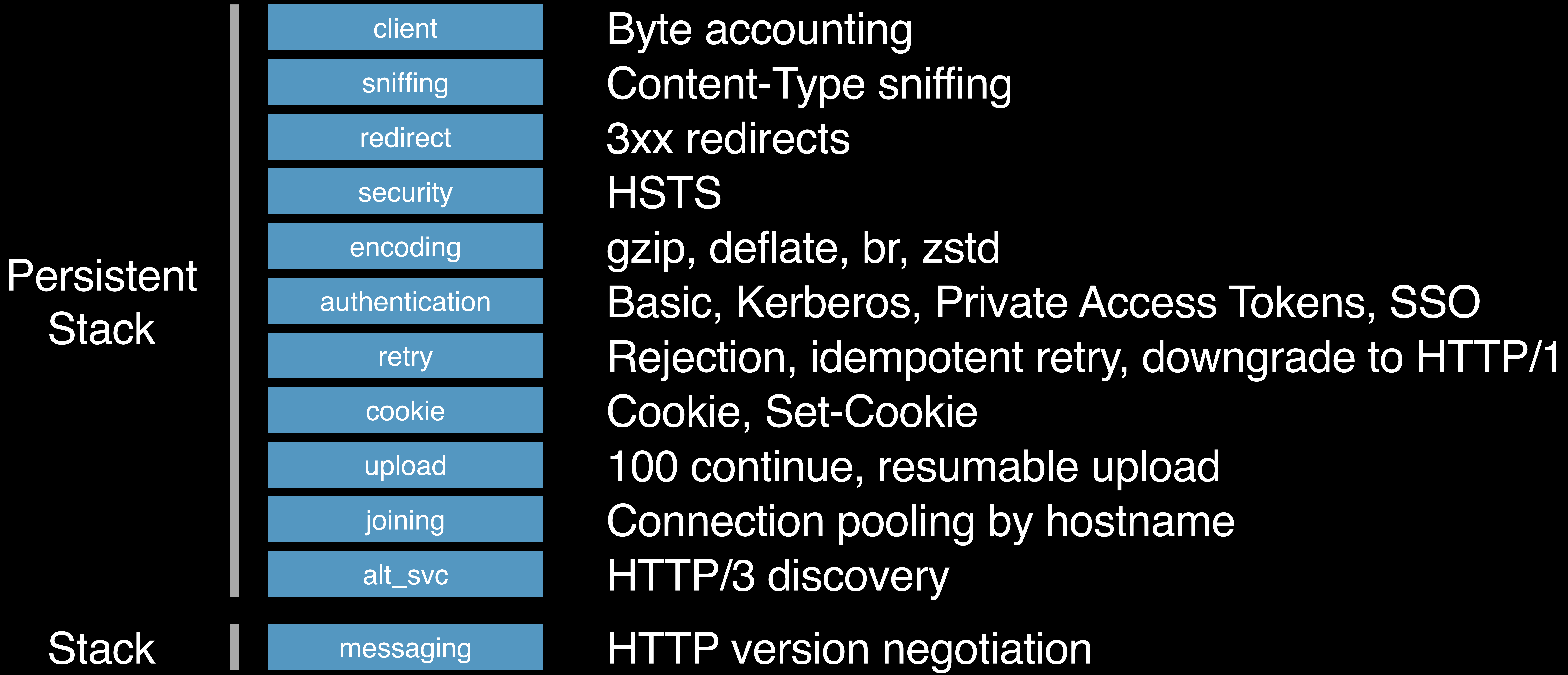
joining

alt_svc

Stack

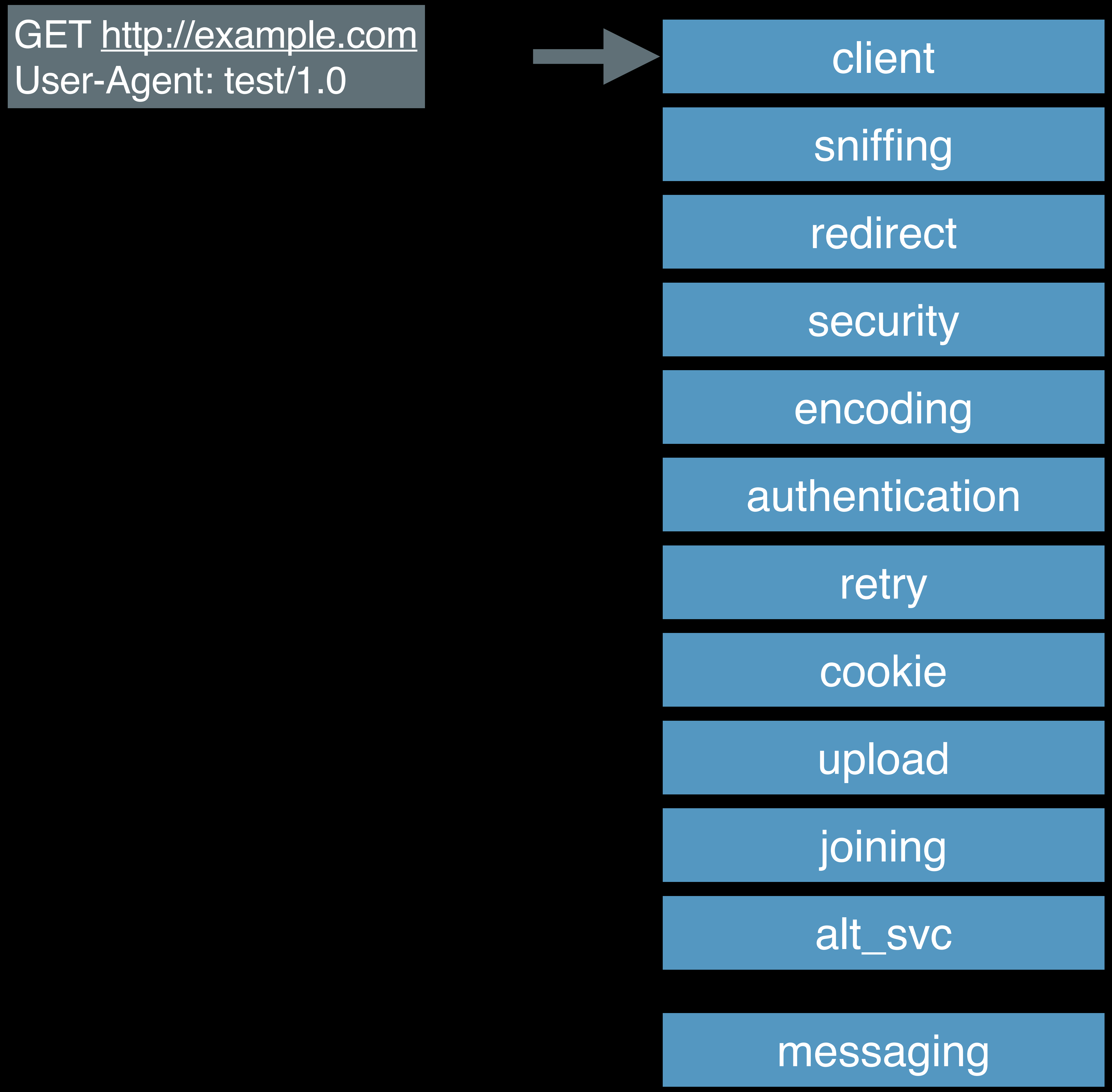
messaging

New HTTP stack



Persistent Stack	client	Byte accounting
	sniffing	Content-Type sniffing
	redirect	3xx redirects
	security	HSTS
	encoding	gzip, deflate, br, zstd
	authentication	Basic, Kerberos, Private Access Tokens, SSO
	retry	Rejection, idempotent retry, downgrade to HTTP/1
	cookie	Cookie, Set-Cookie
	upload	100 continue, resumable upload
	joining	Connection pooling by hostname
	alt_svc	HTTP/3 discovery
Stack	messaging	HTTP version negotiation

Example HTTP load



```
GET http://example.com
User-Agent: test/1.0
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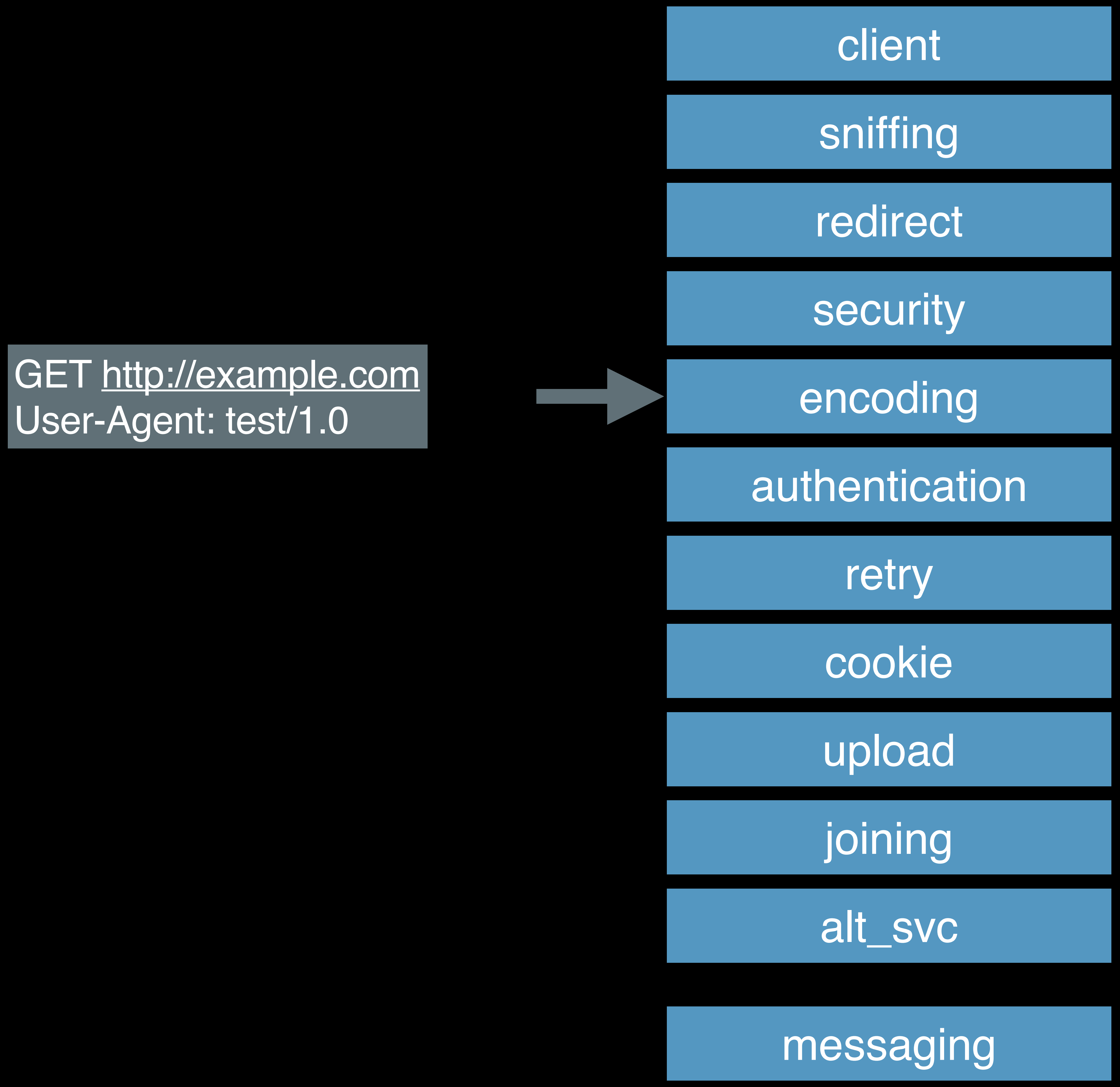

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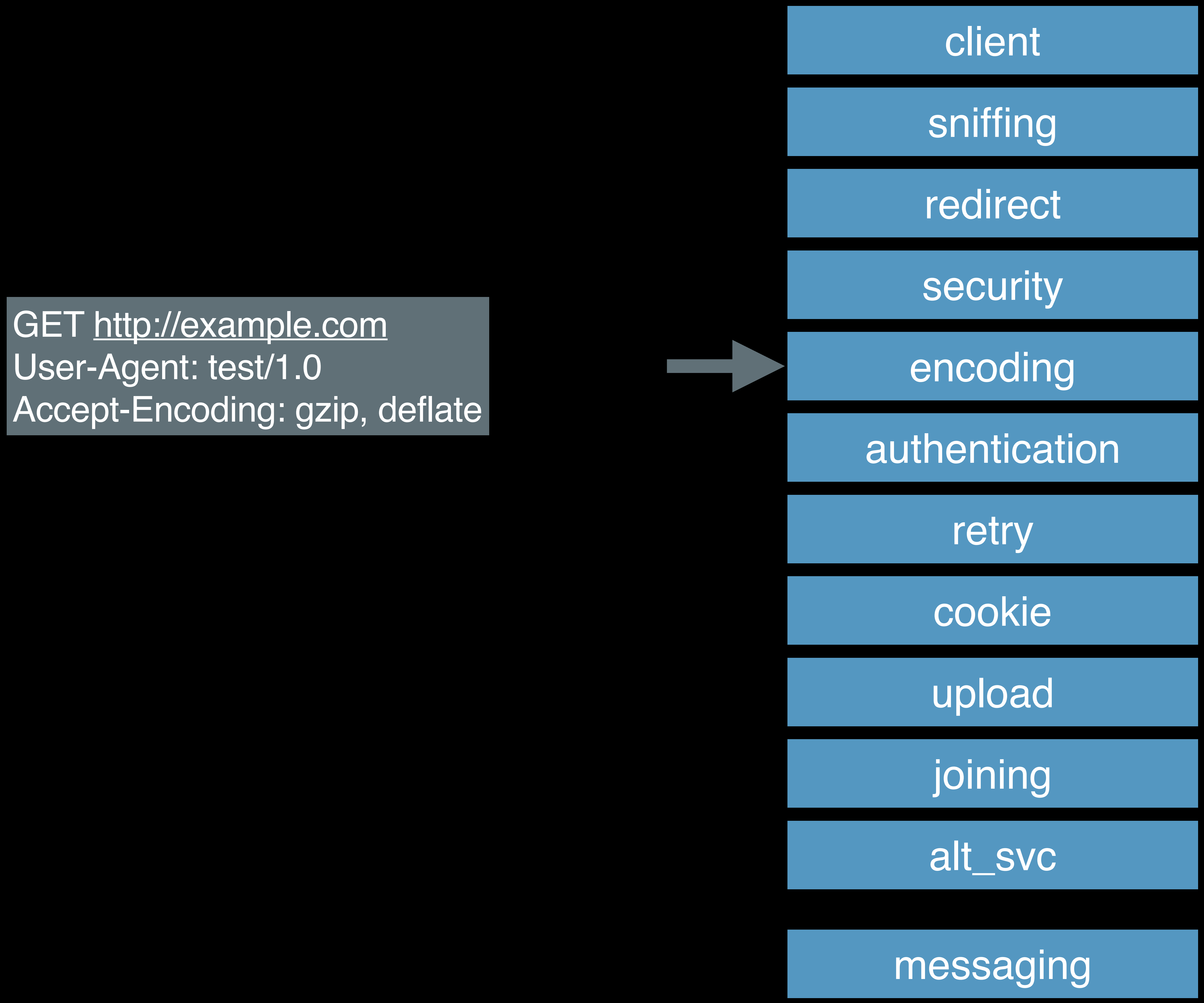

```
GET http://example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate
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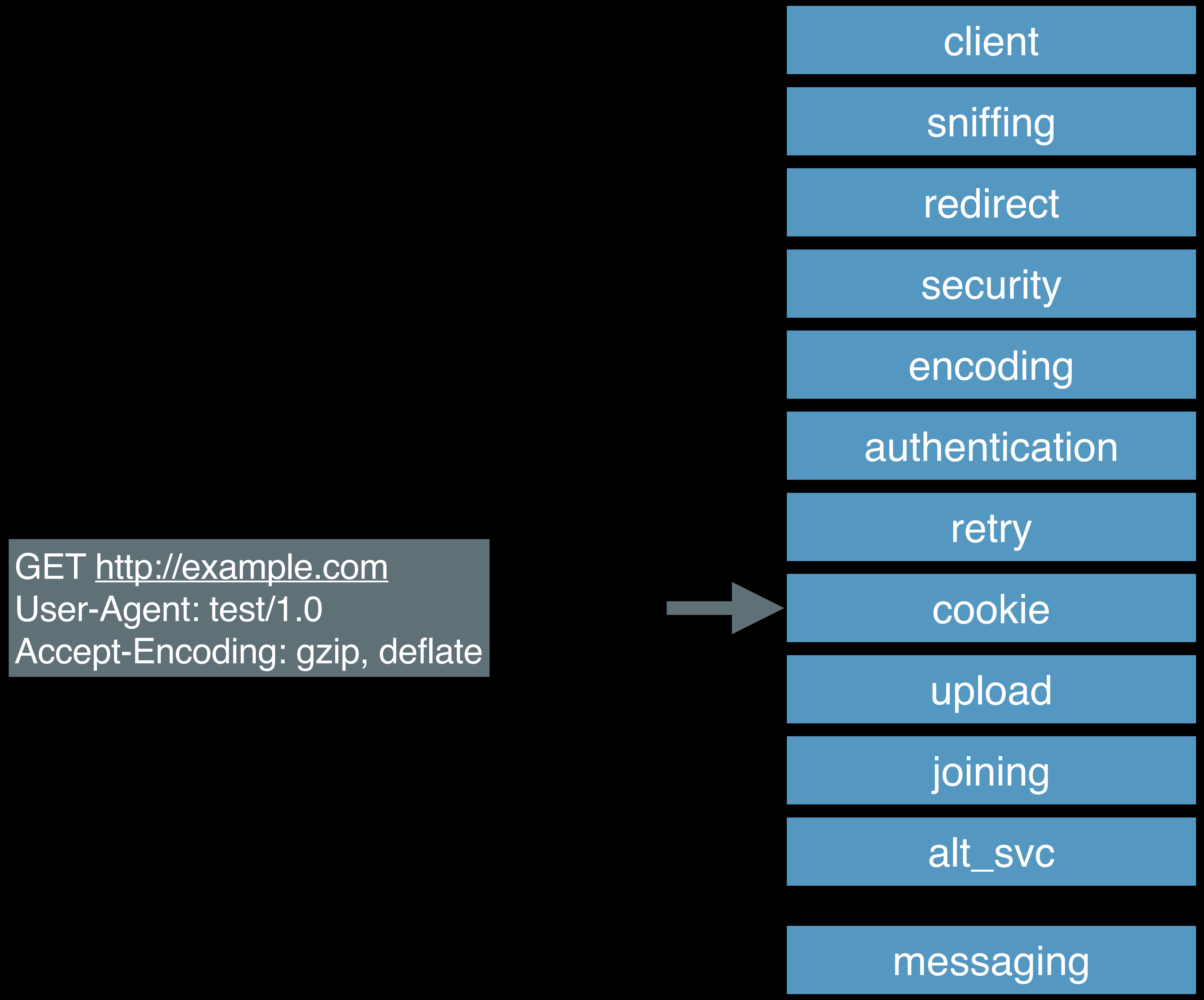
Example HTTP load



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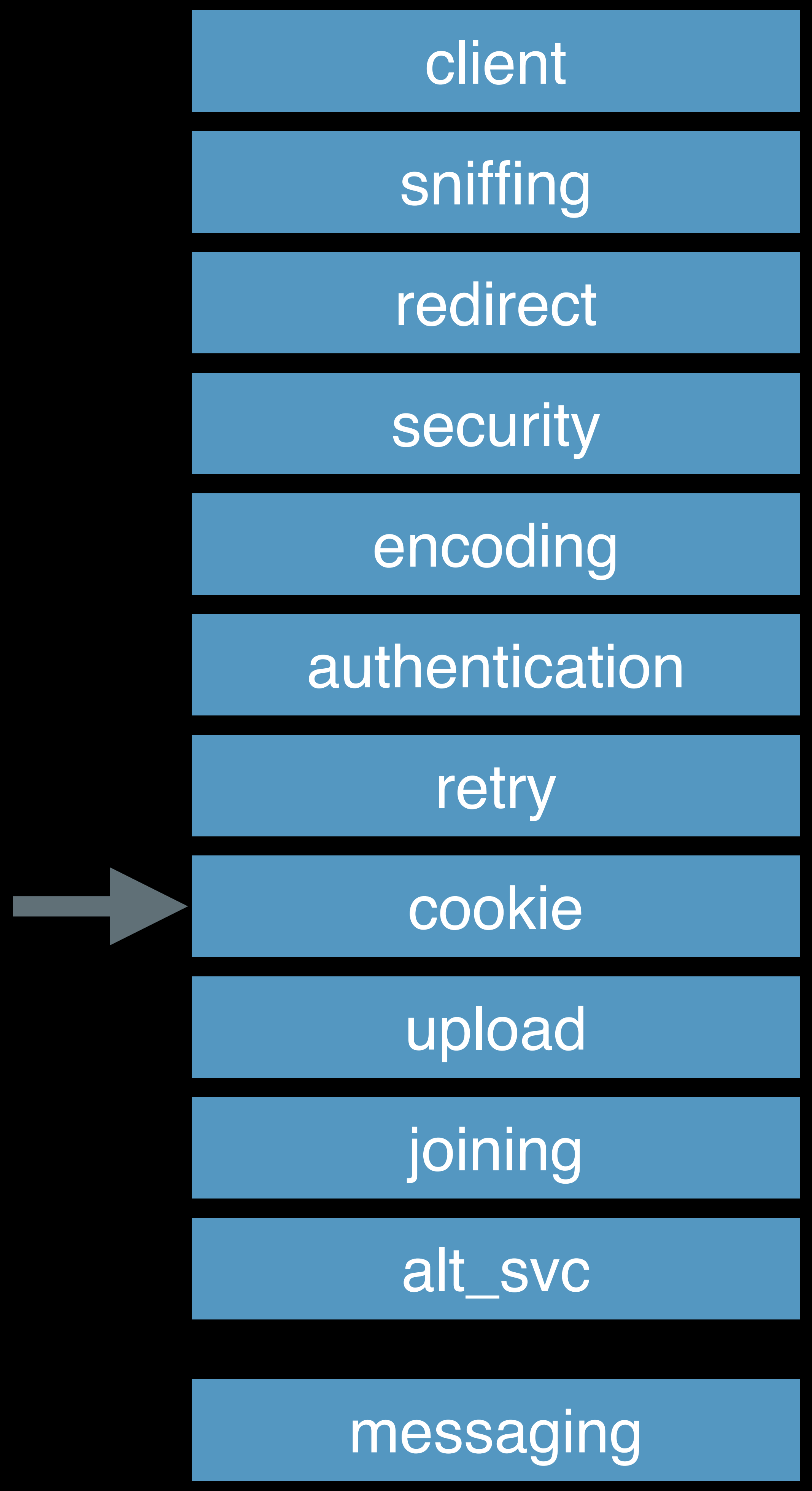
Example HTTP load

```
GET http://example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate
Cookie: foo=bar
```



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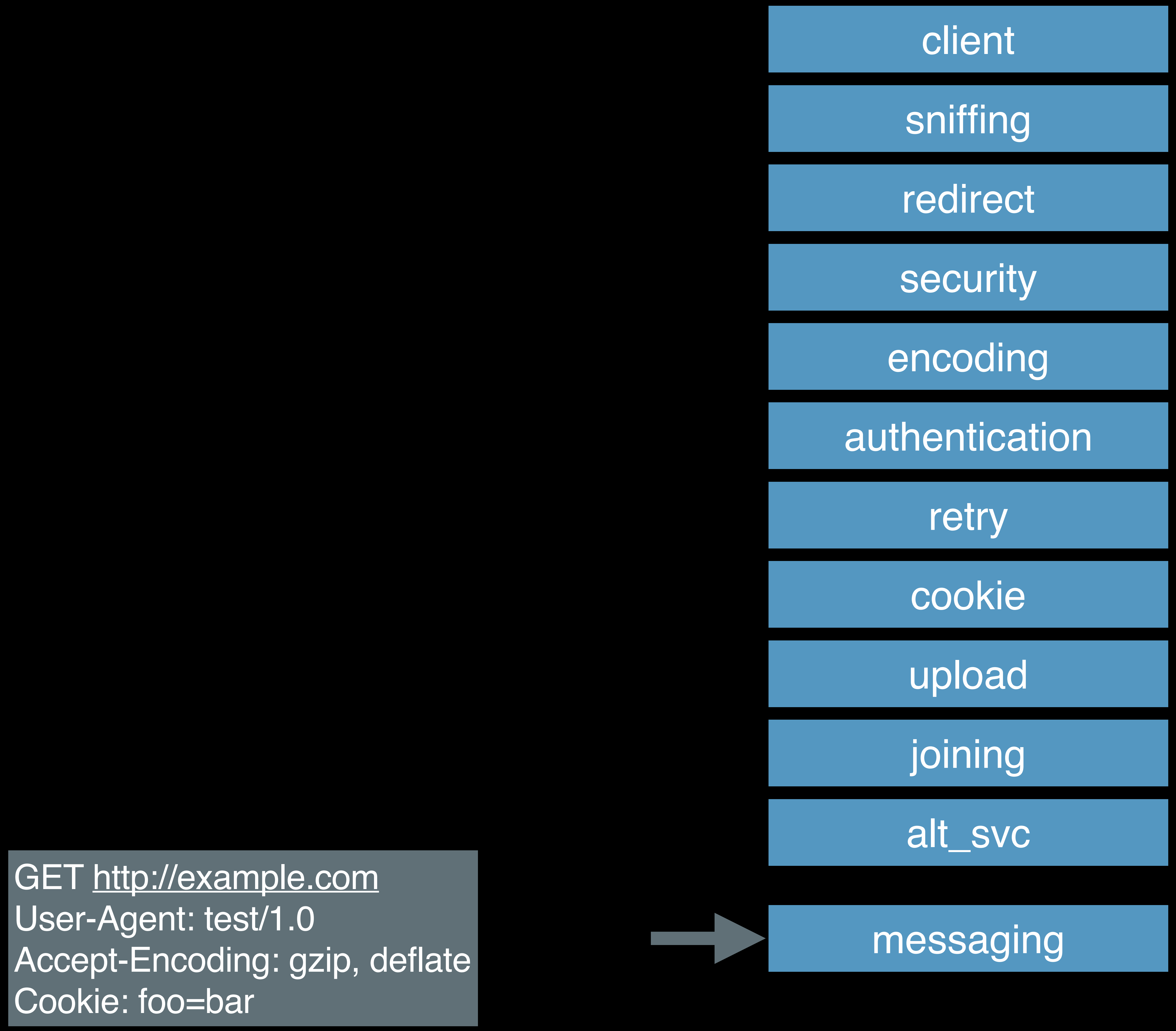

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GET http://example.com
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Cookie: foo=bar
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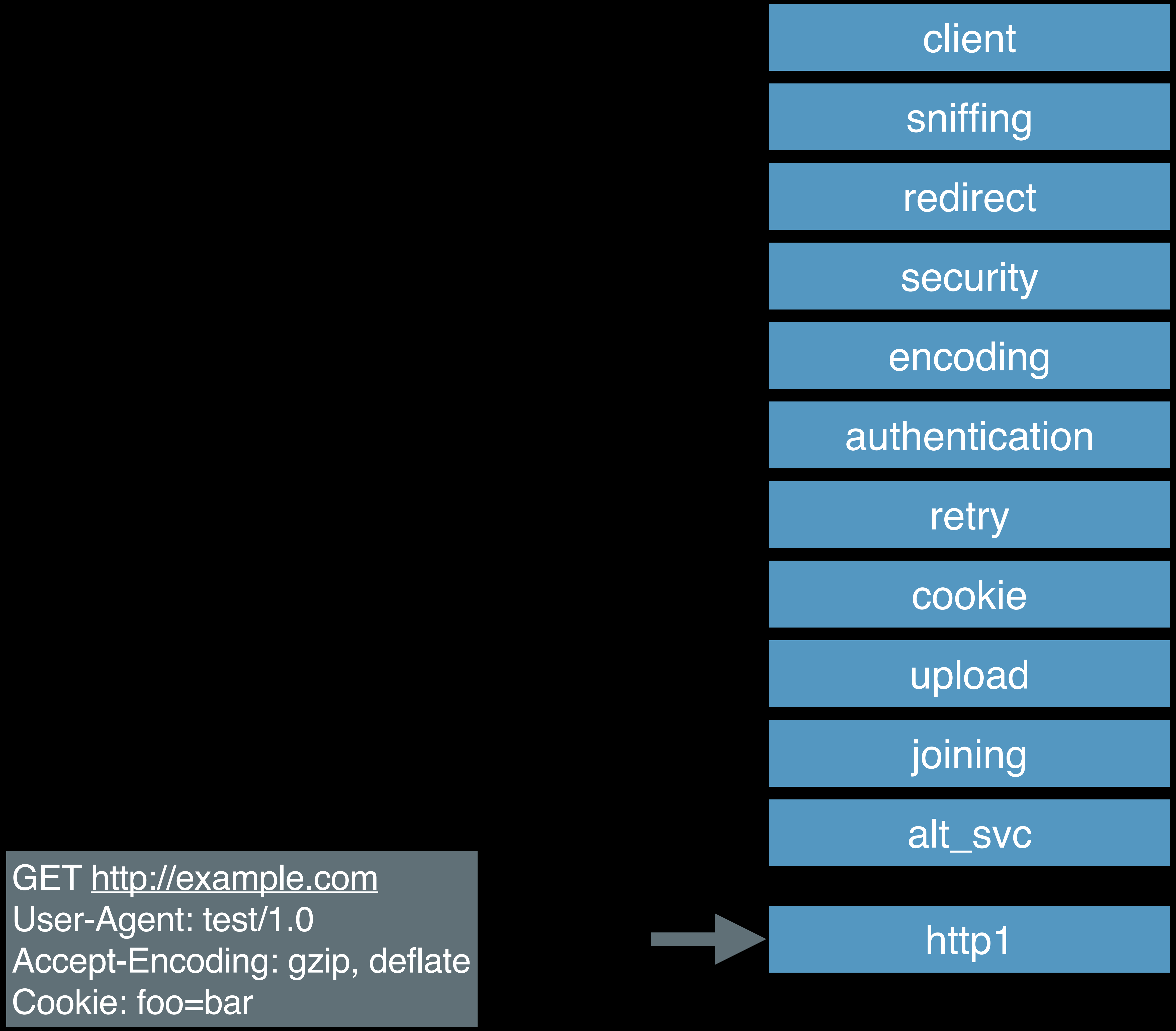

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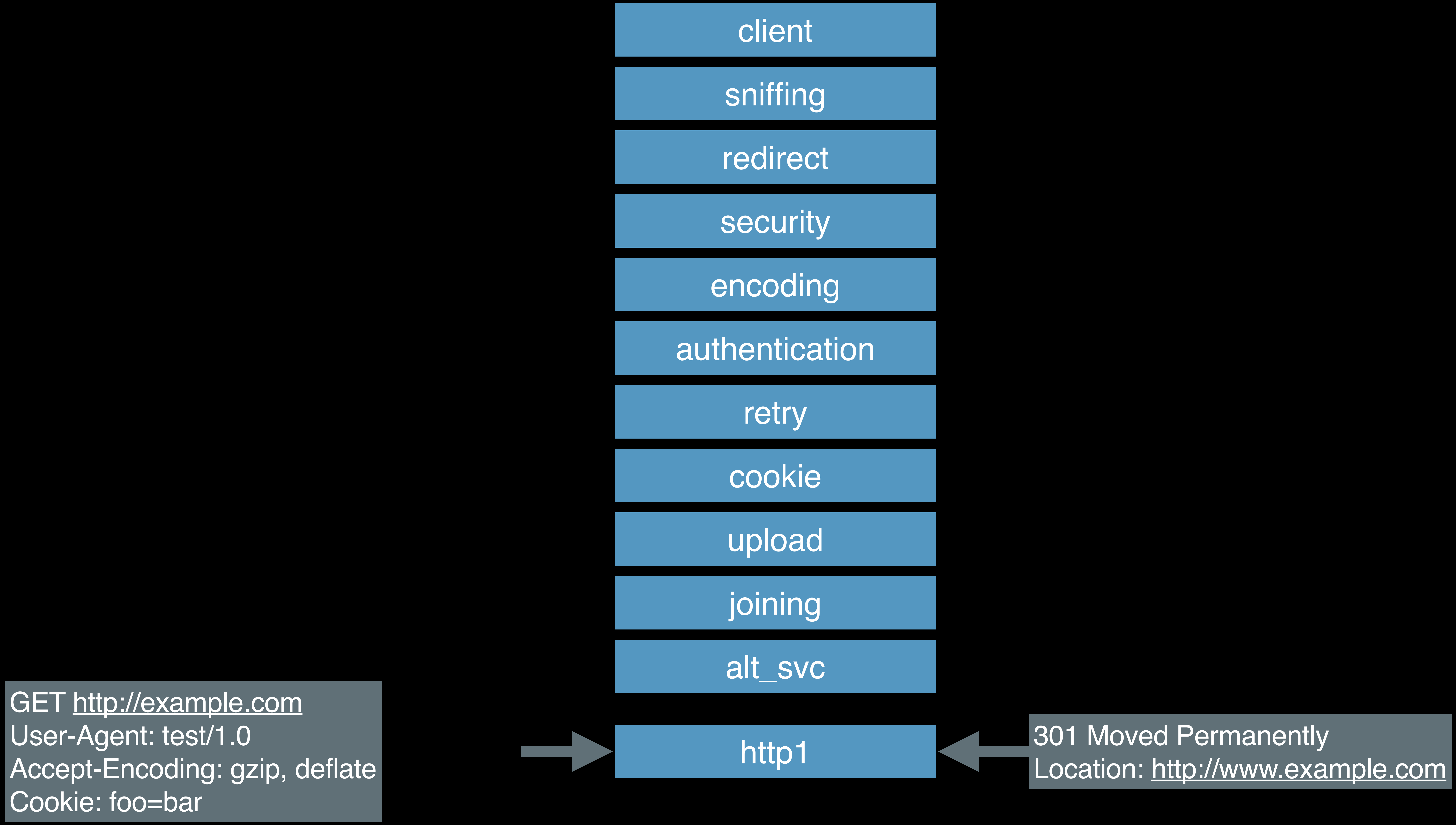

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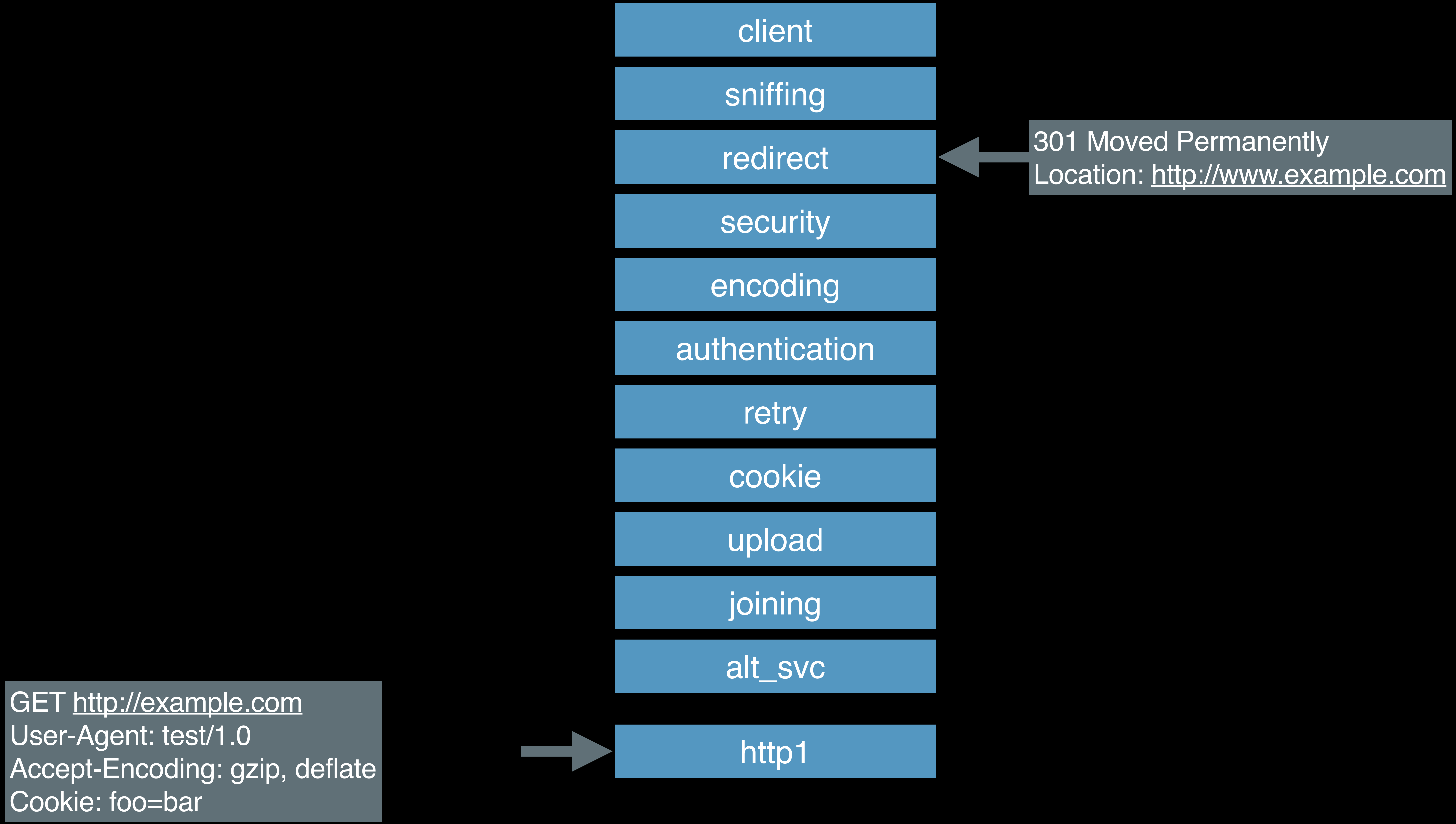
http1

GET http://example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate
Cookie: foo=bar

301 Moved Permanently
Location: http://www.example.com

Example HTTP load



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Location: http://www.example.com
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GET http://example.com
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Cookie: foo=bar
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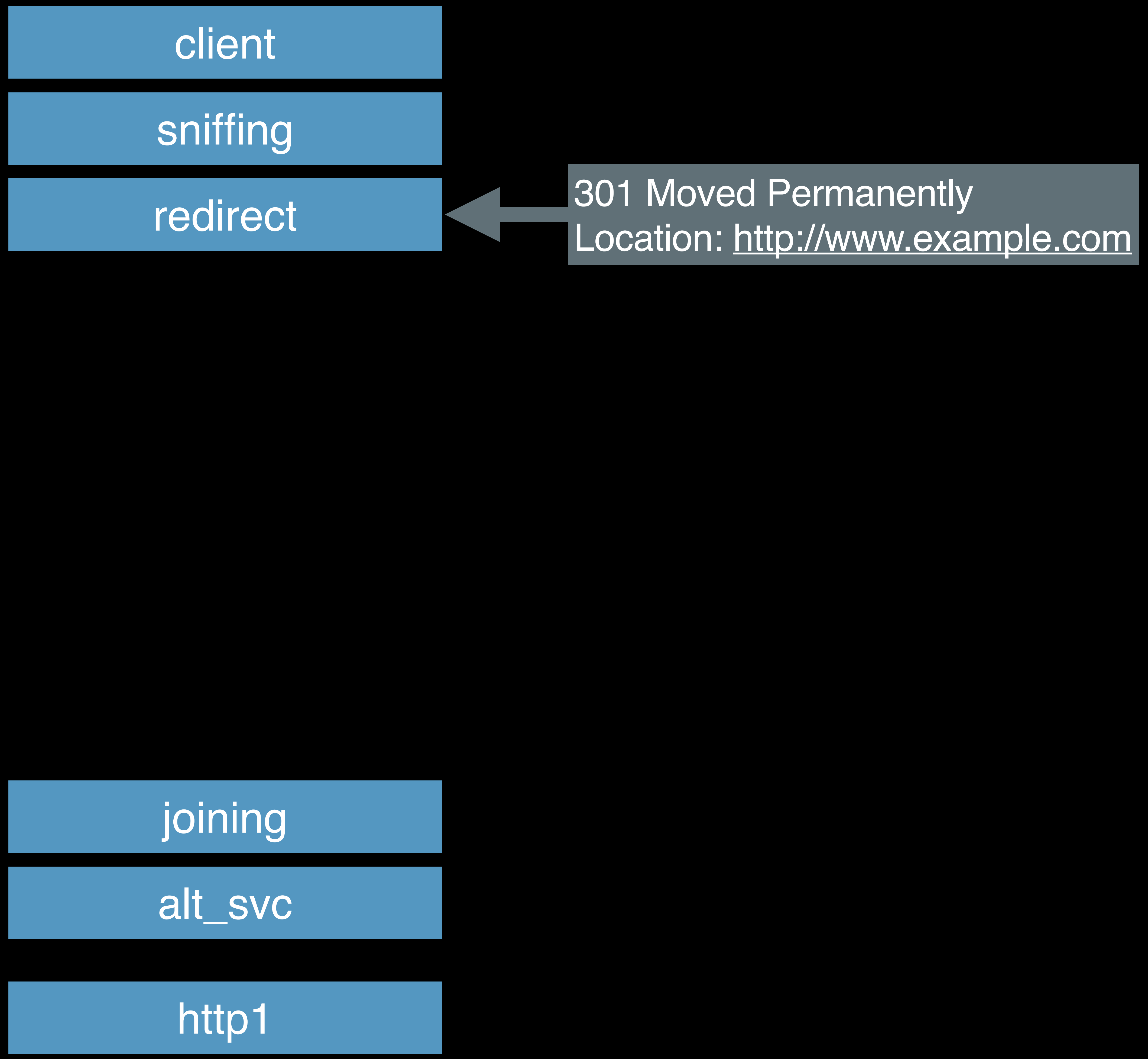
Example HTTP load



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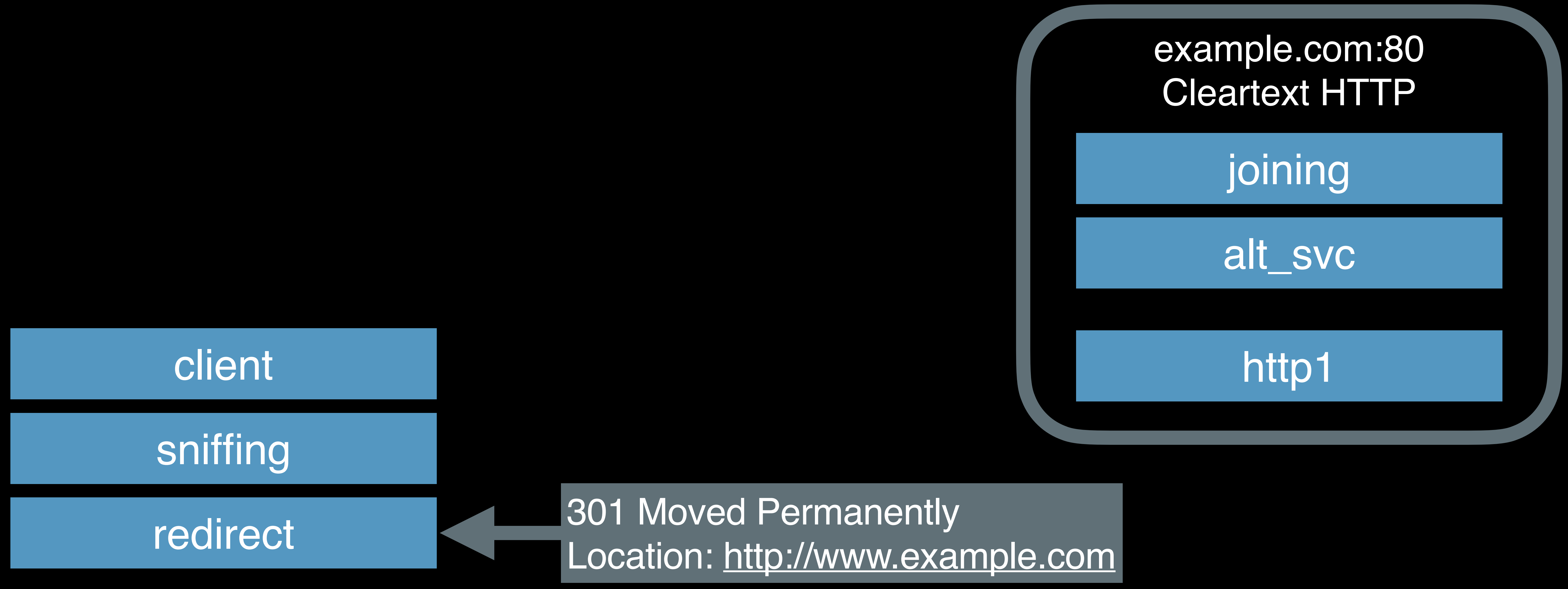

example.com:80
Cleartext HTTP

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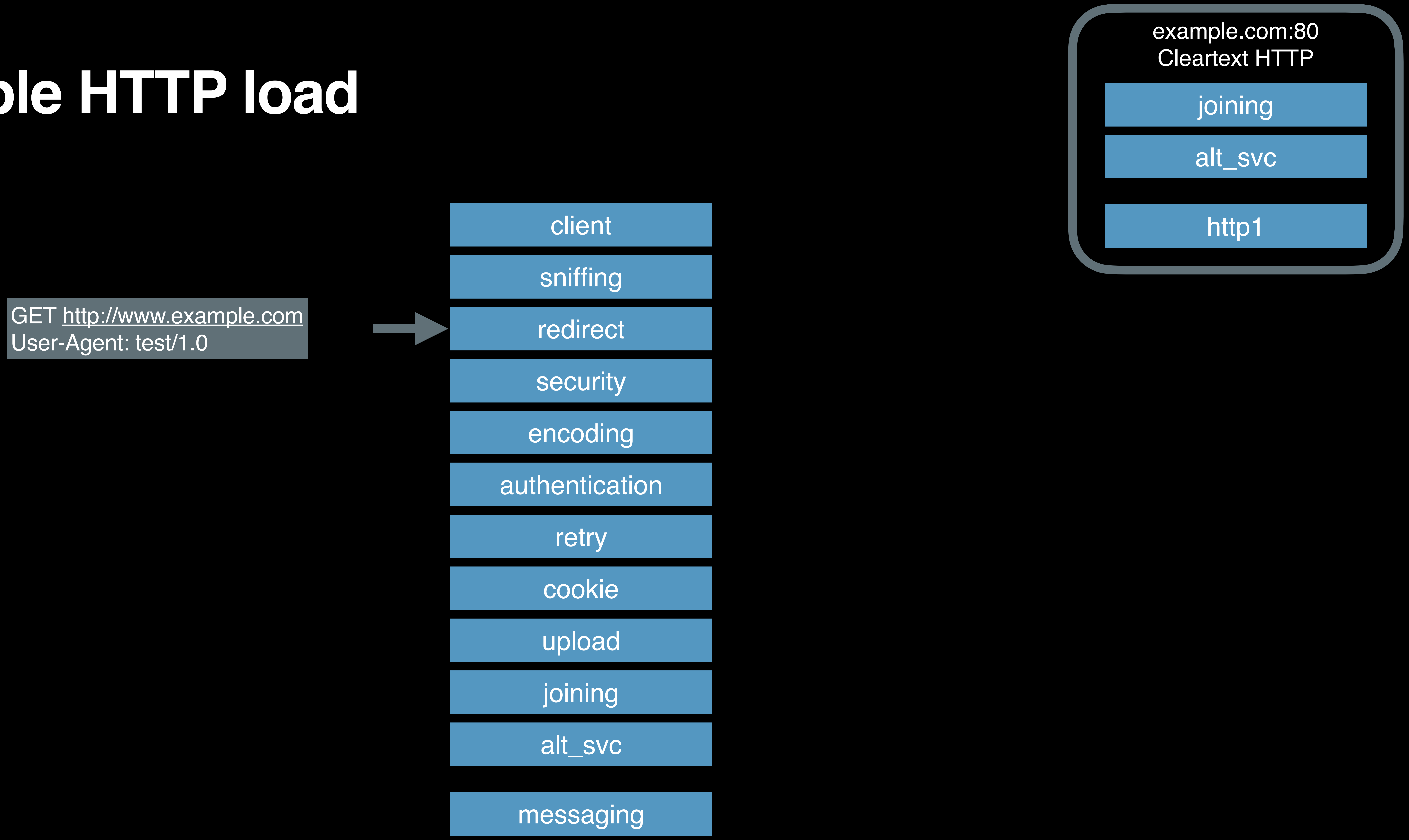

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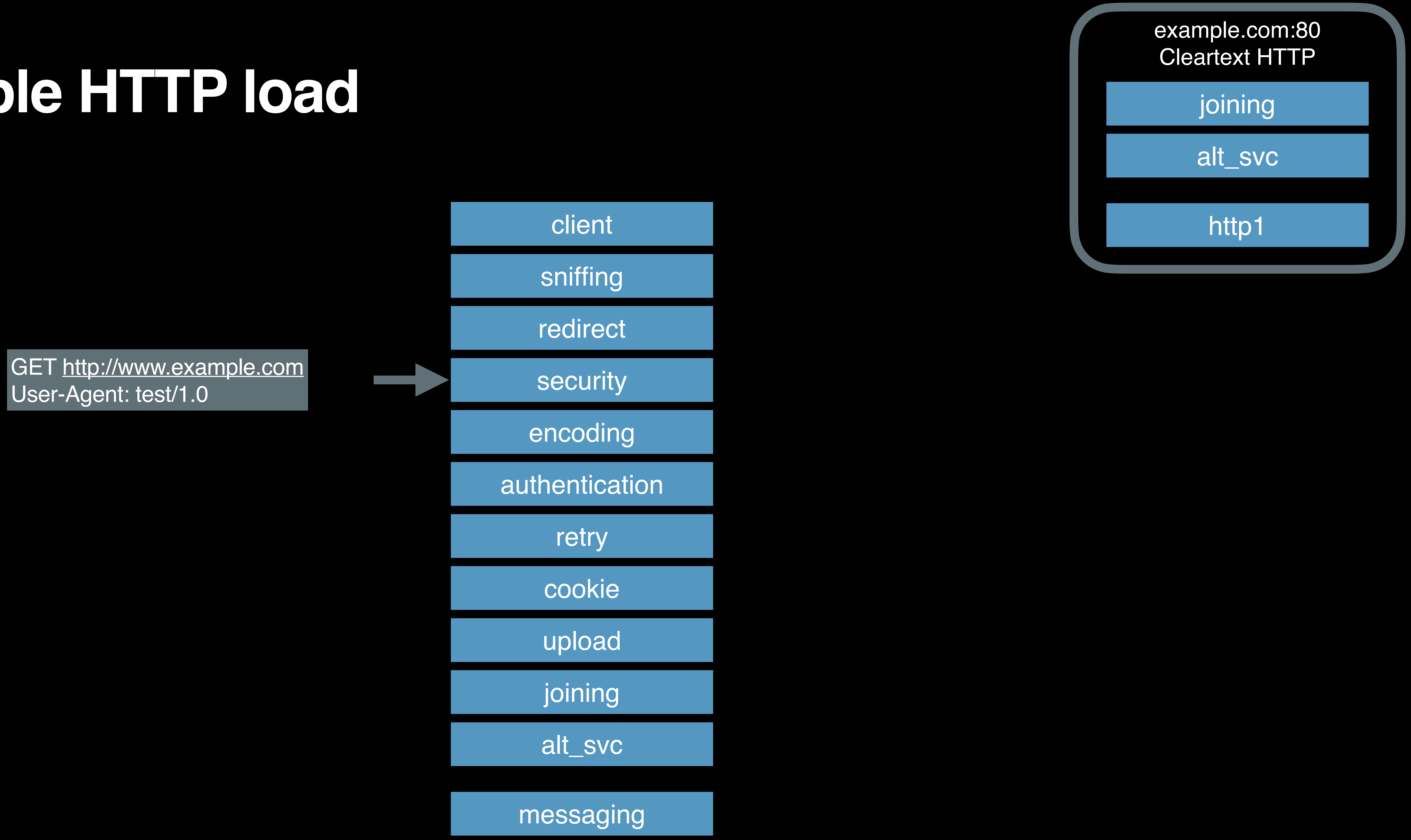

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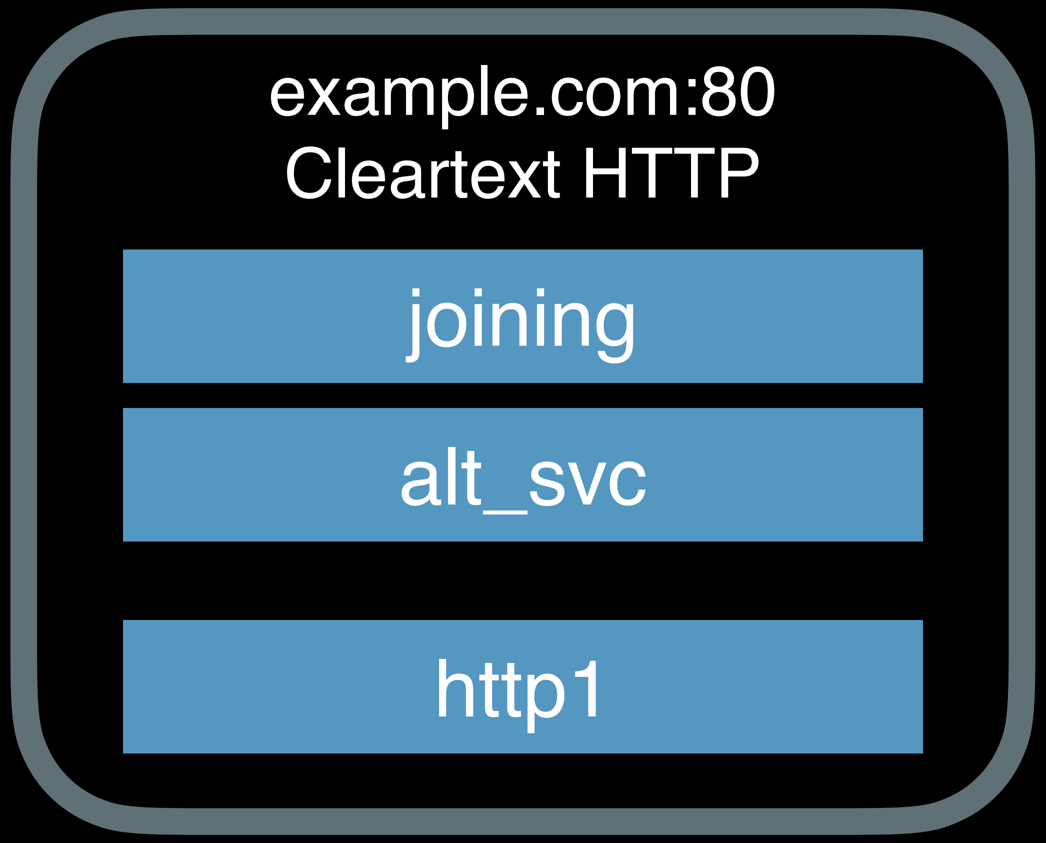

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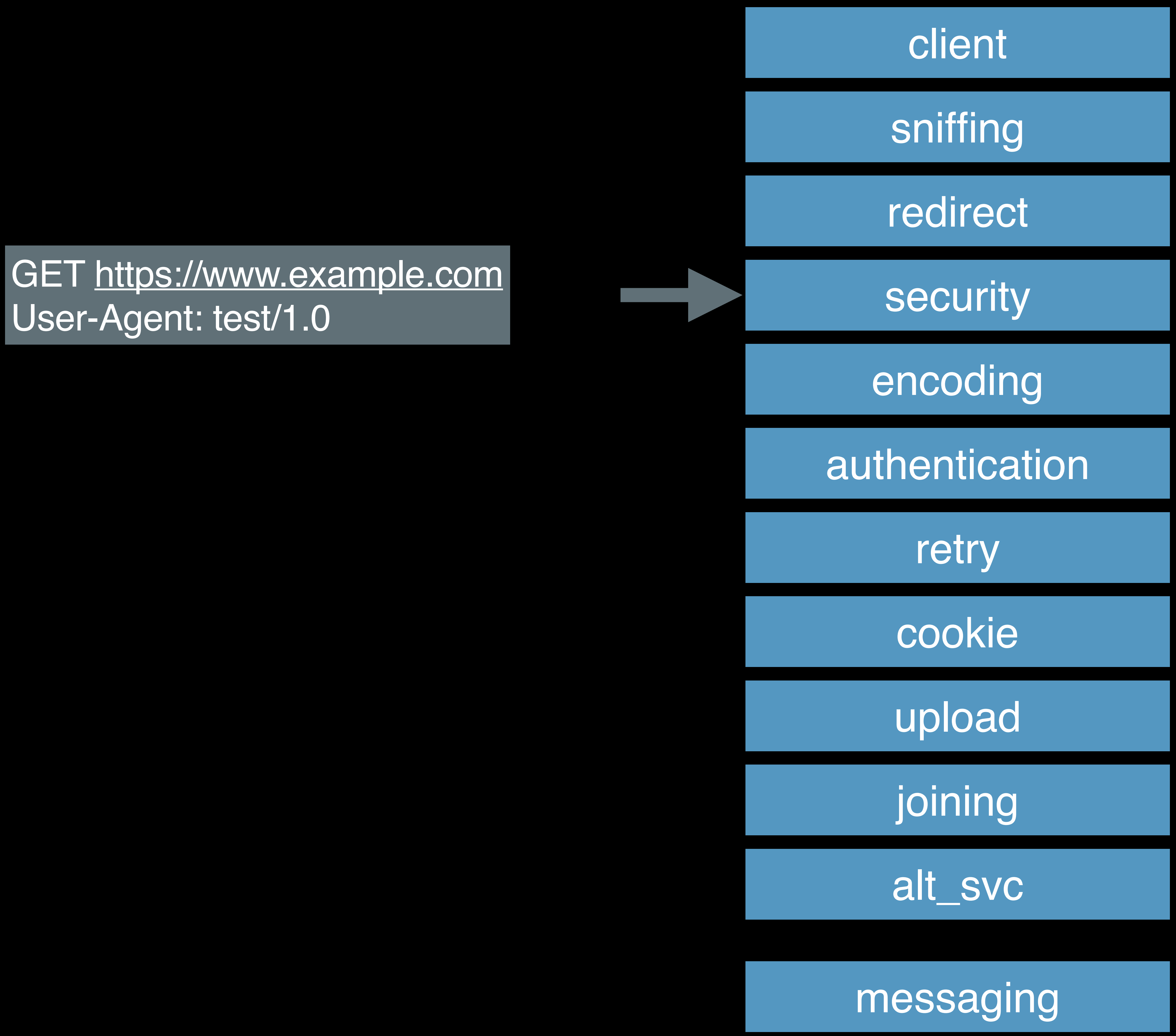

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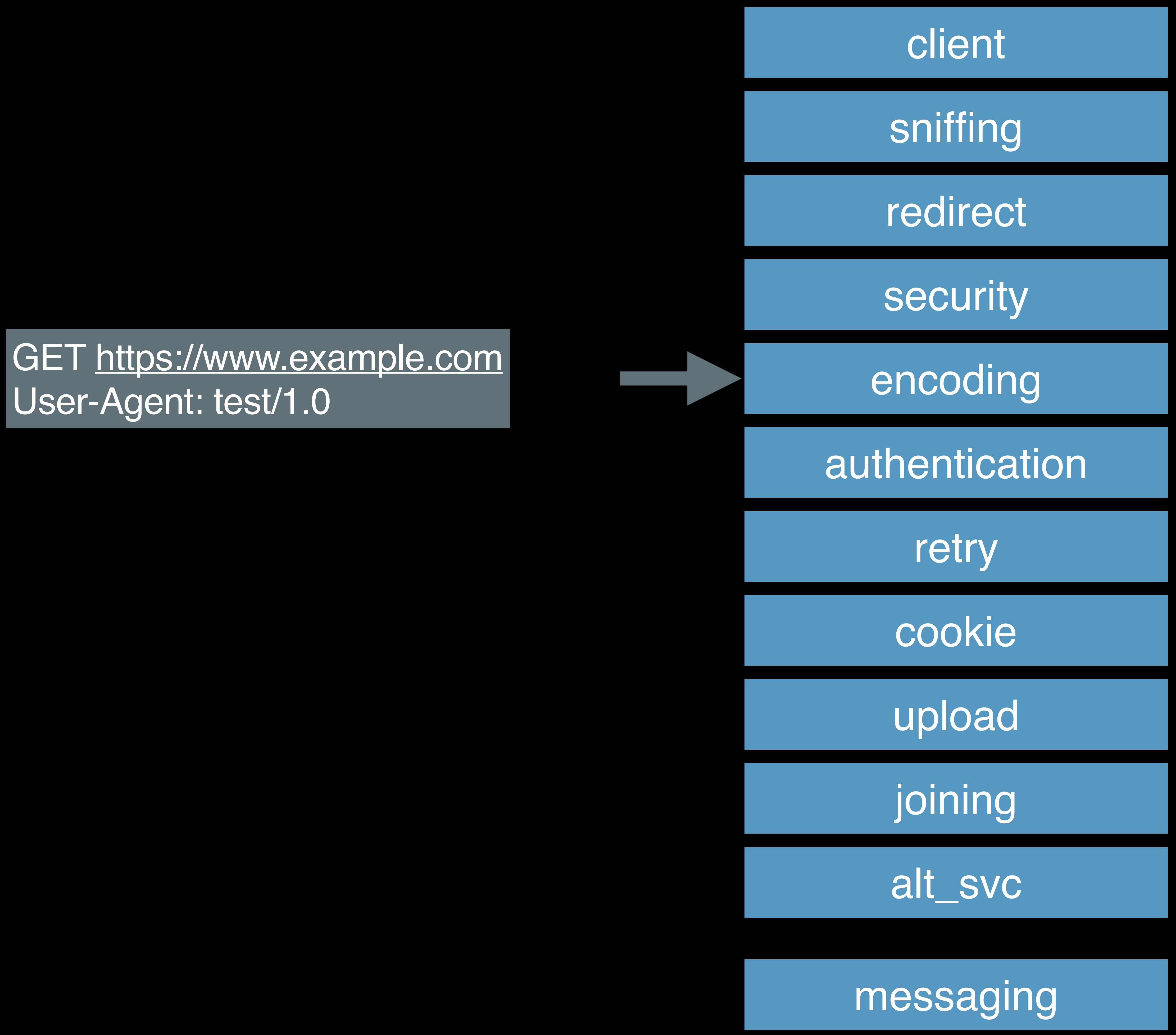

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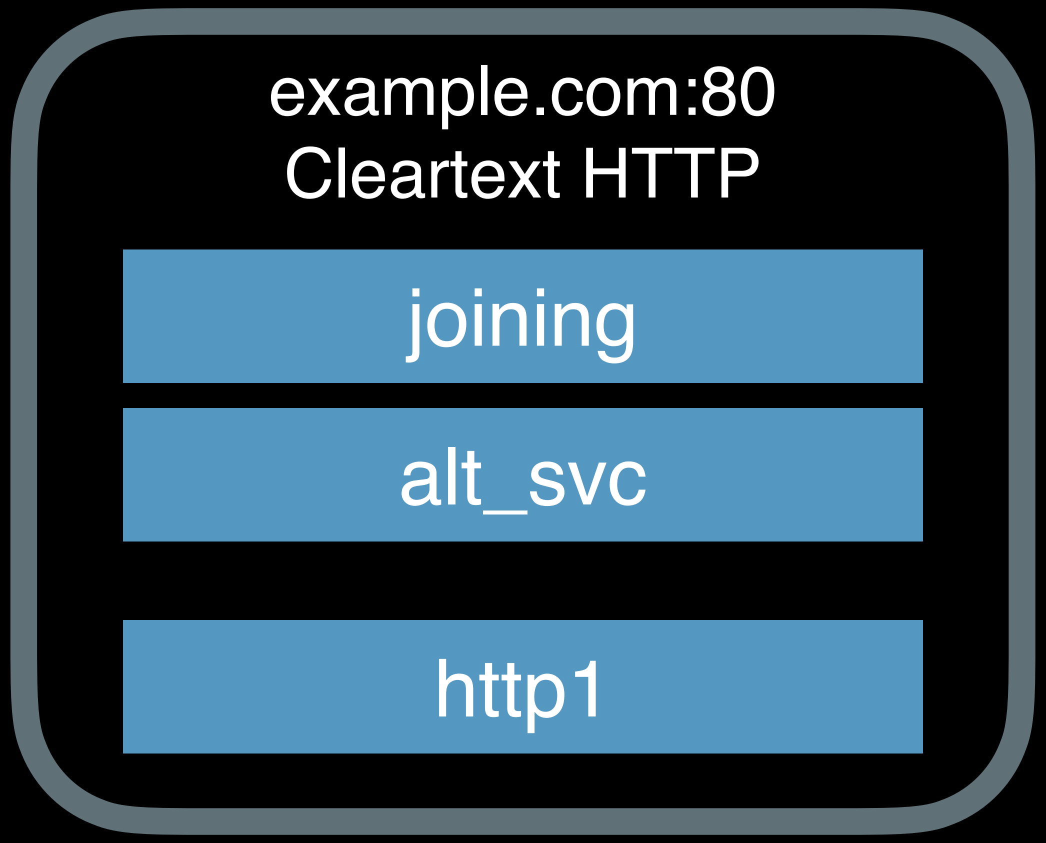

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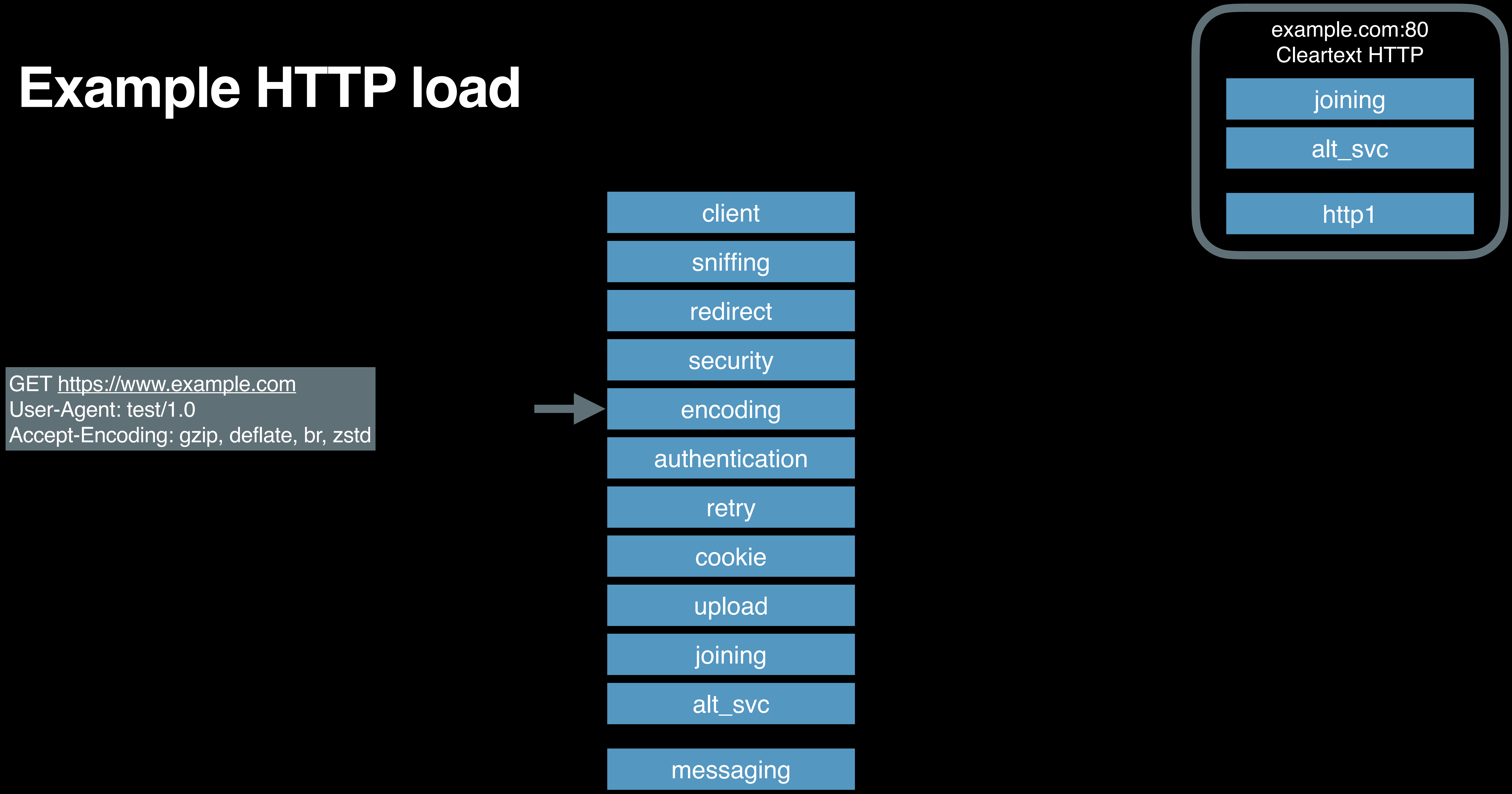

GET https://www.example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate, br, zstd

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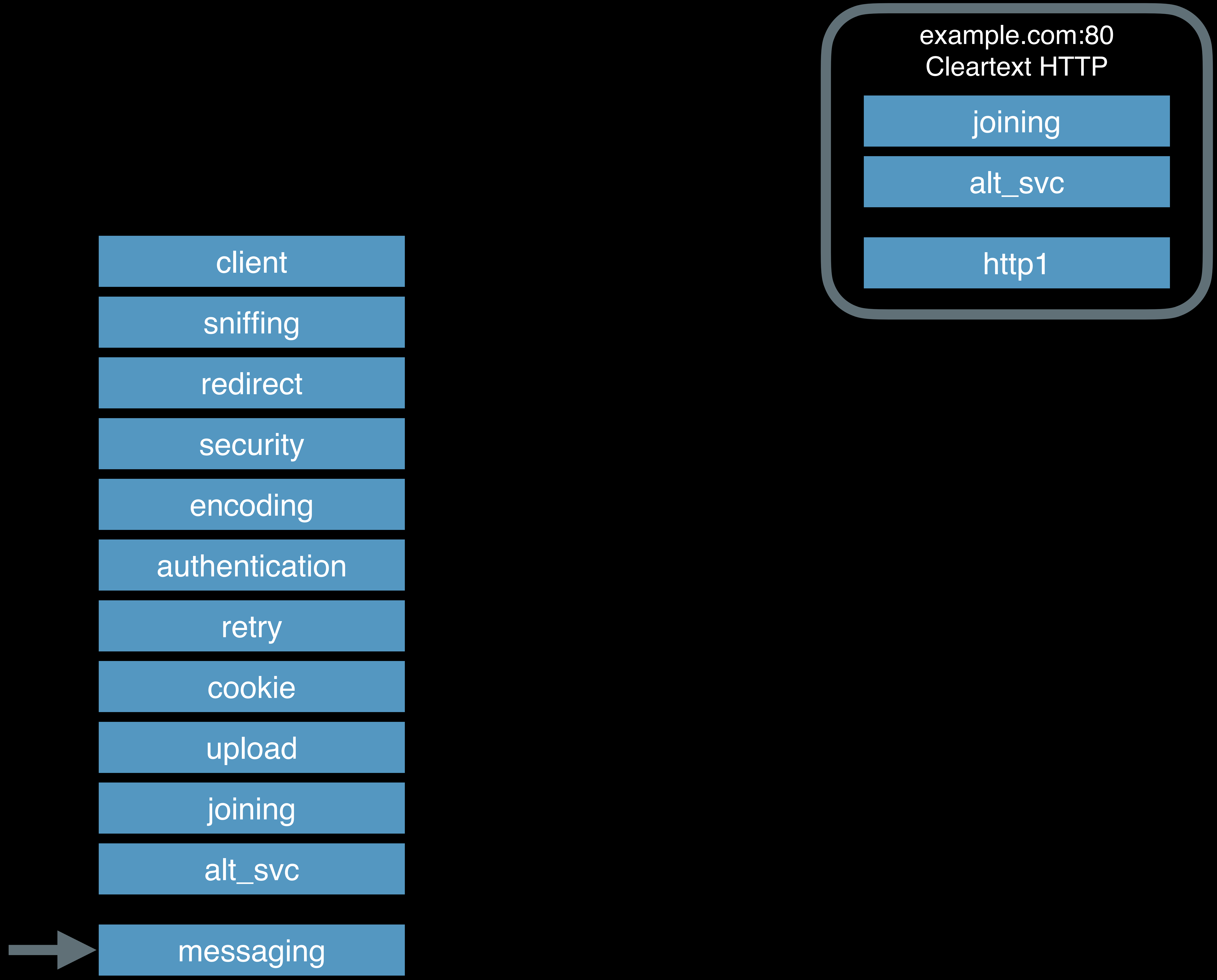
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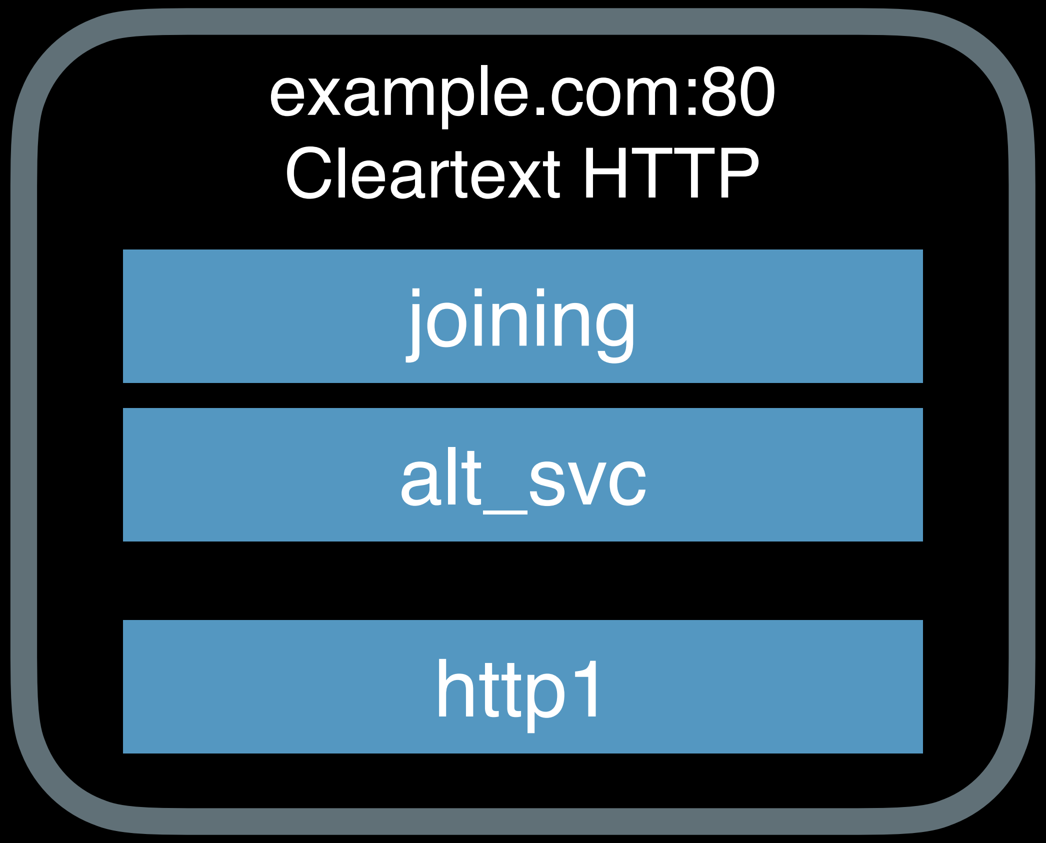

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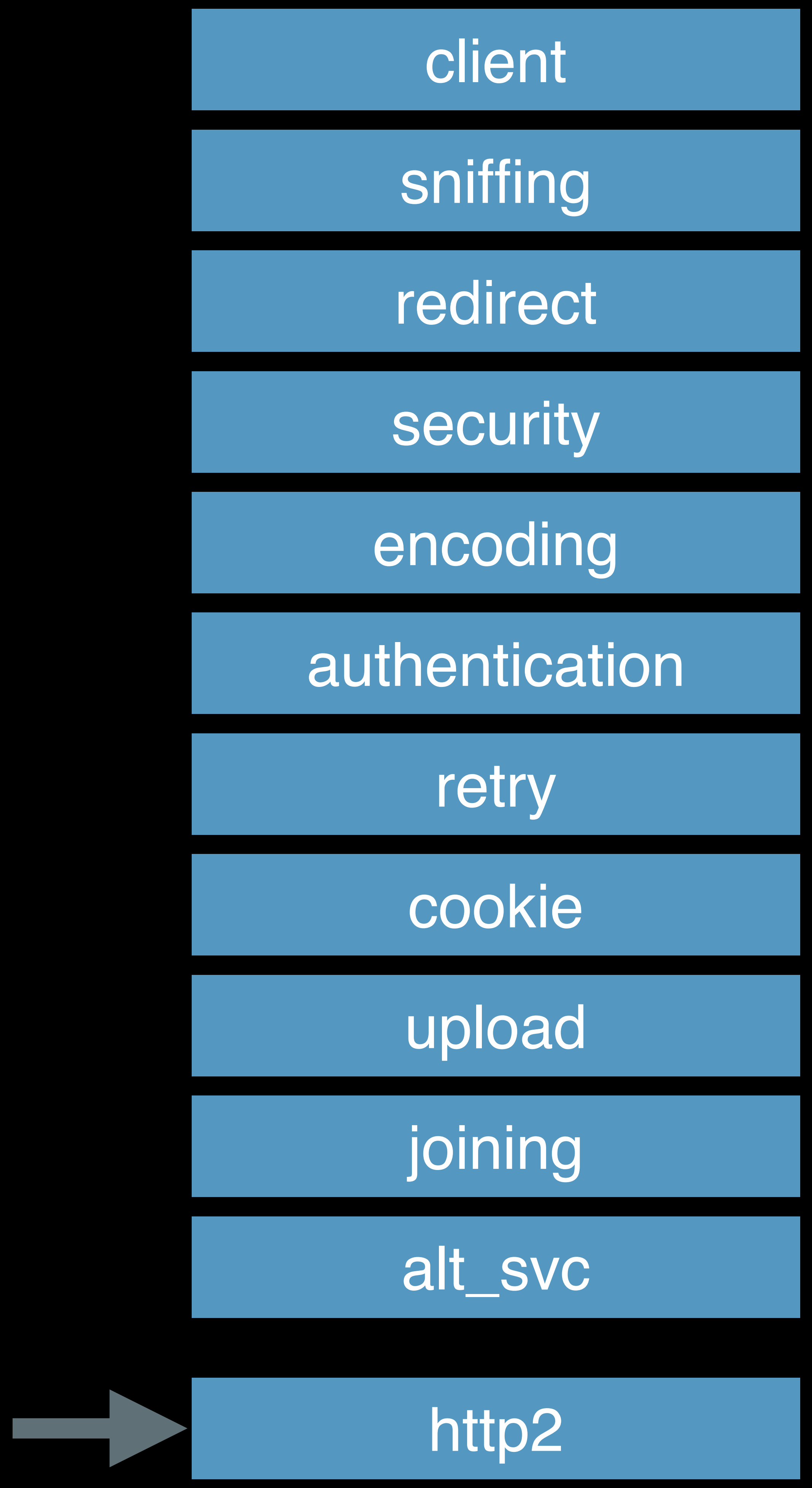

client

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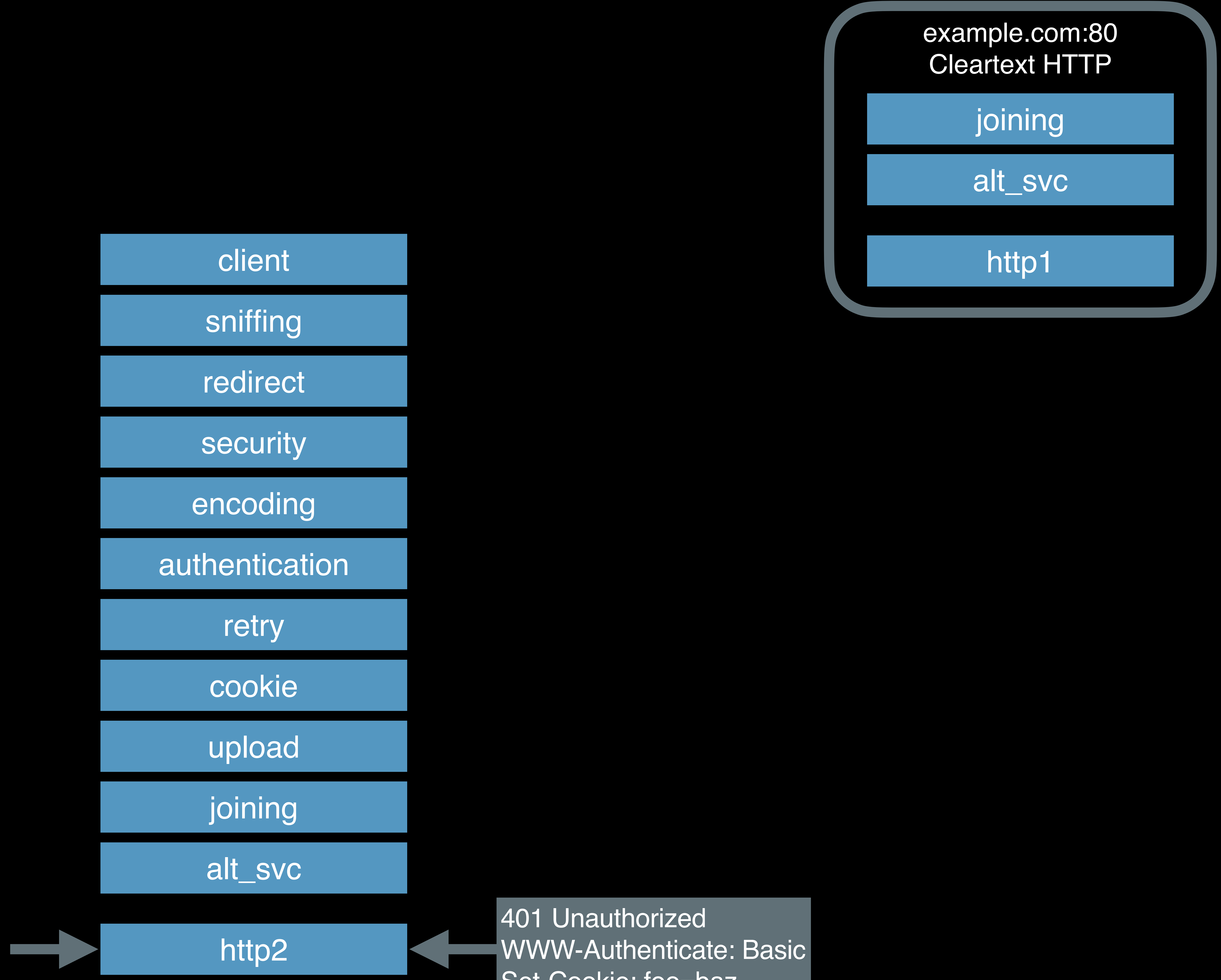
GET https://www.example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate, br, zstd

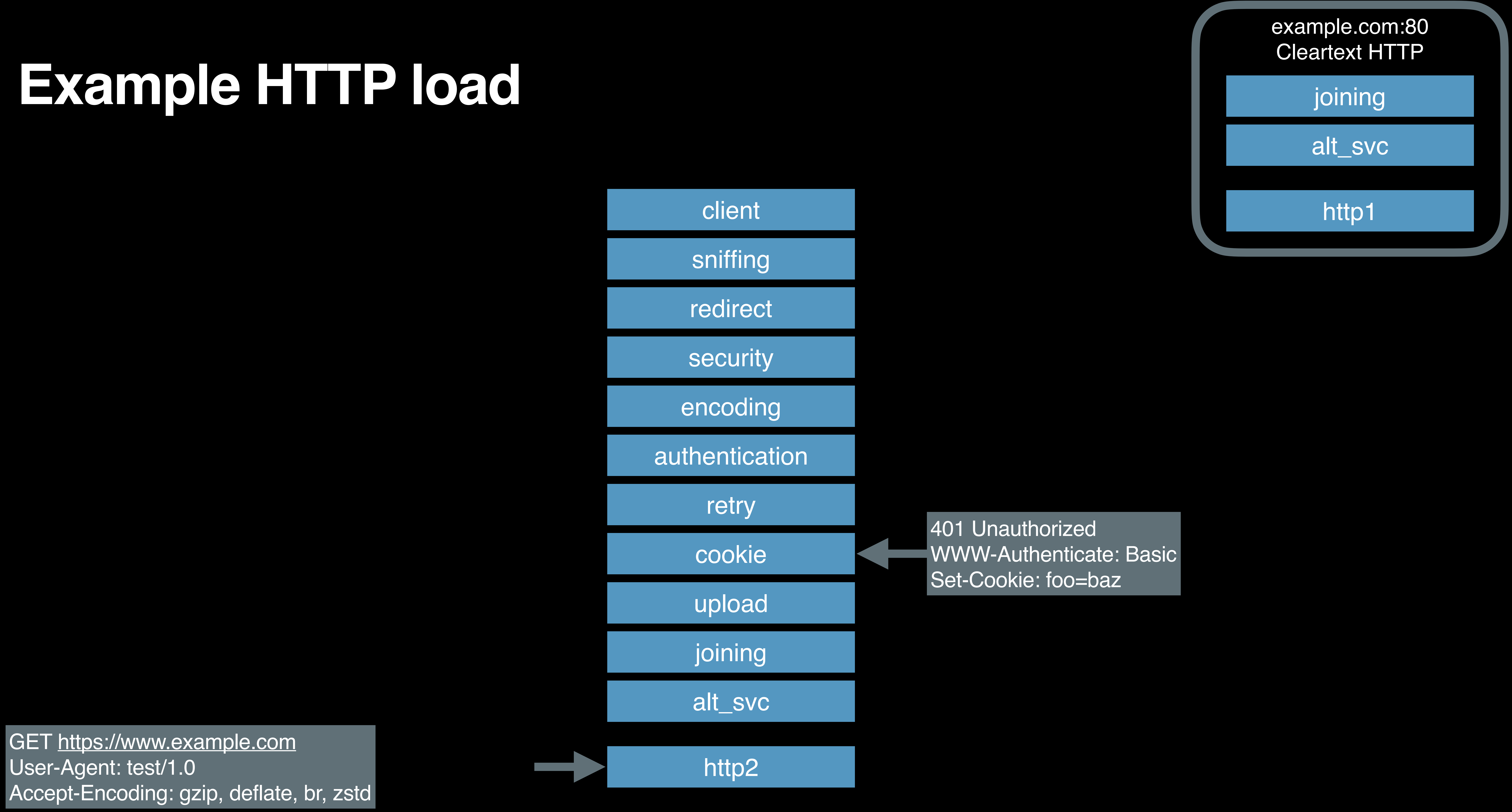
Example HTTP load



GET https://www.example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate, br, zstd

401 Unauthorized
WWW-Authenticate: Basic
Set-Cookie: foo=baz

Example HTTP load



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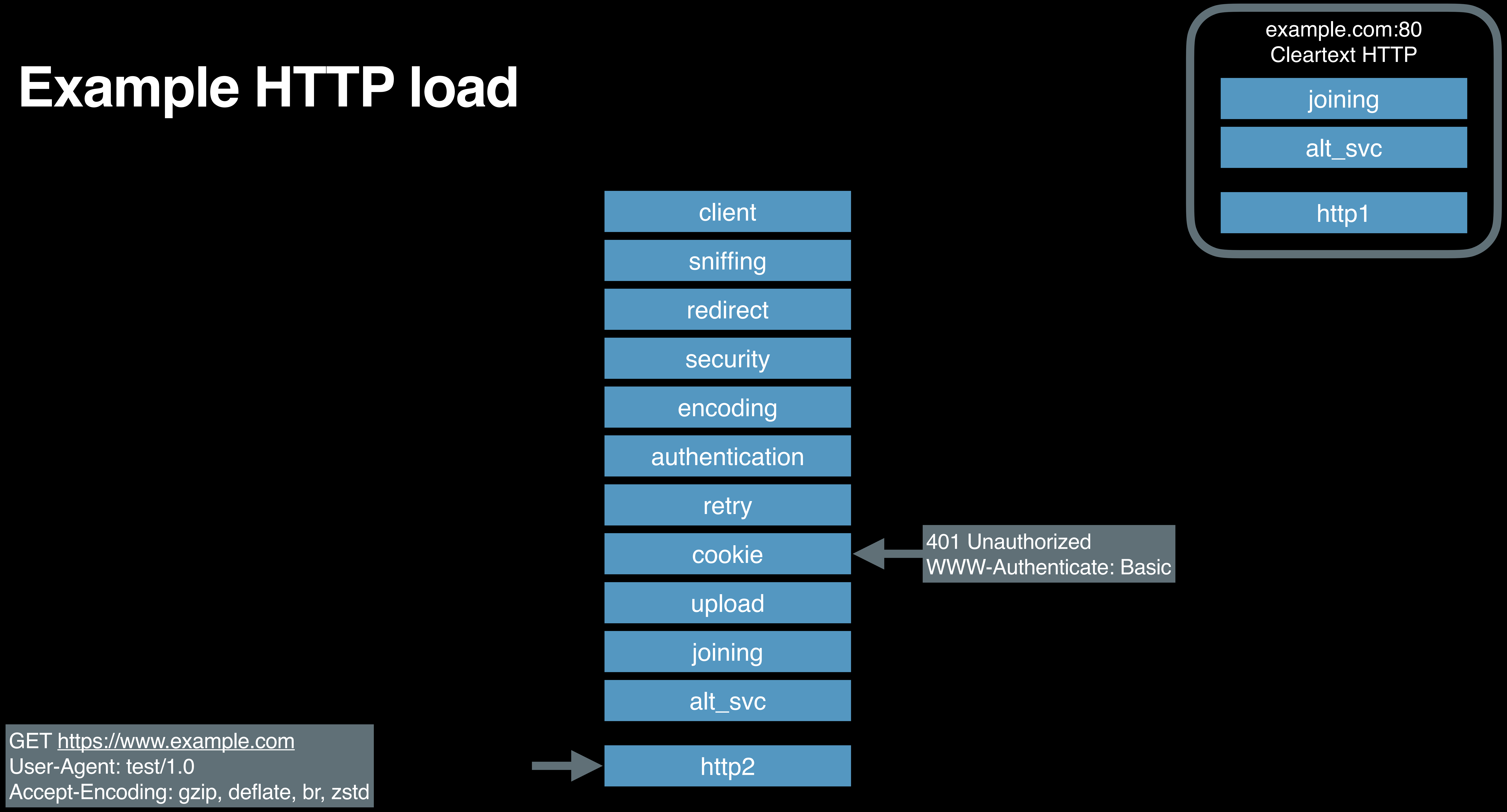
Example HTTP load



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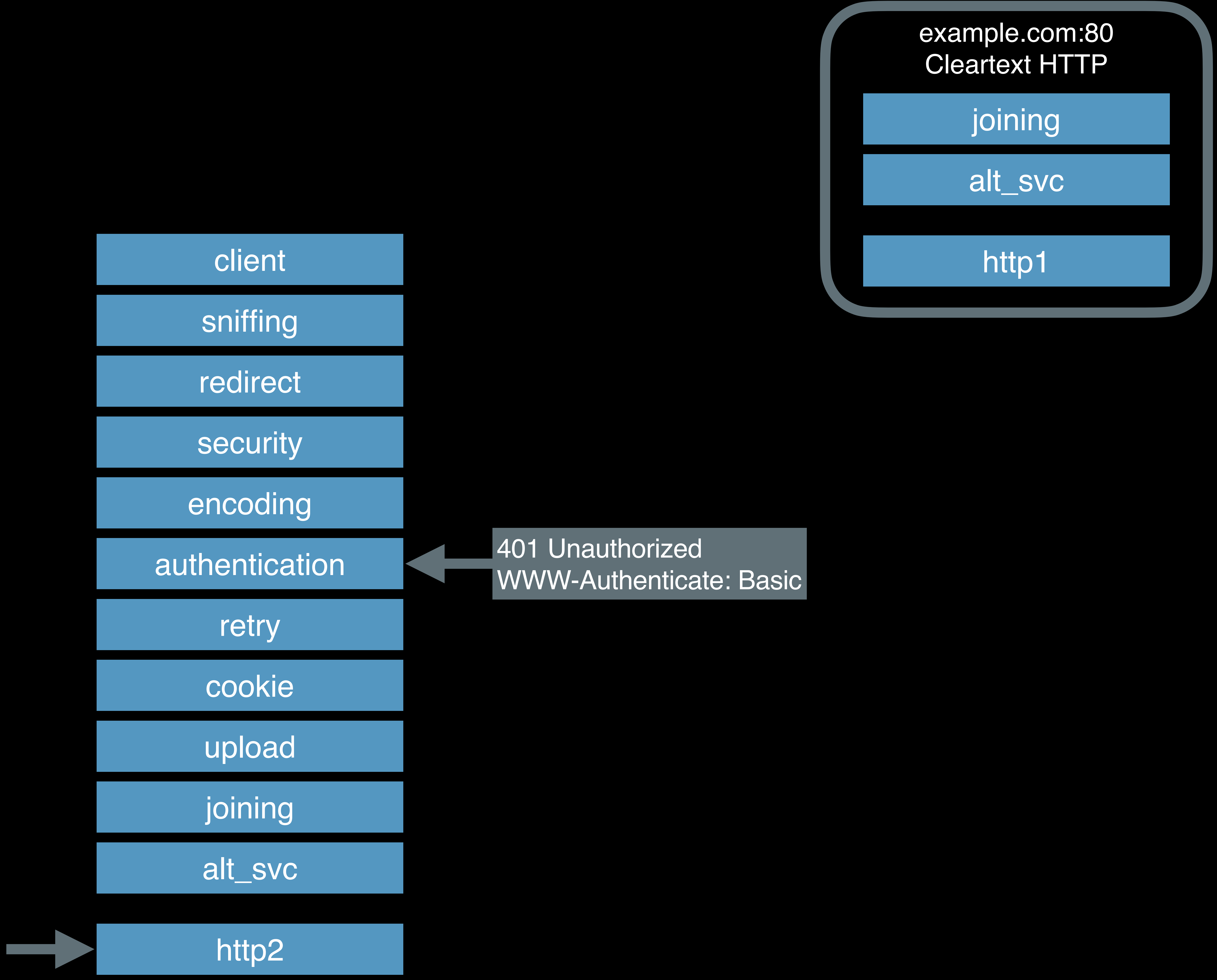

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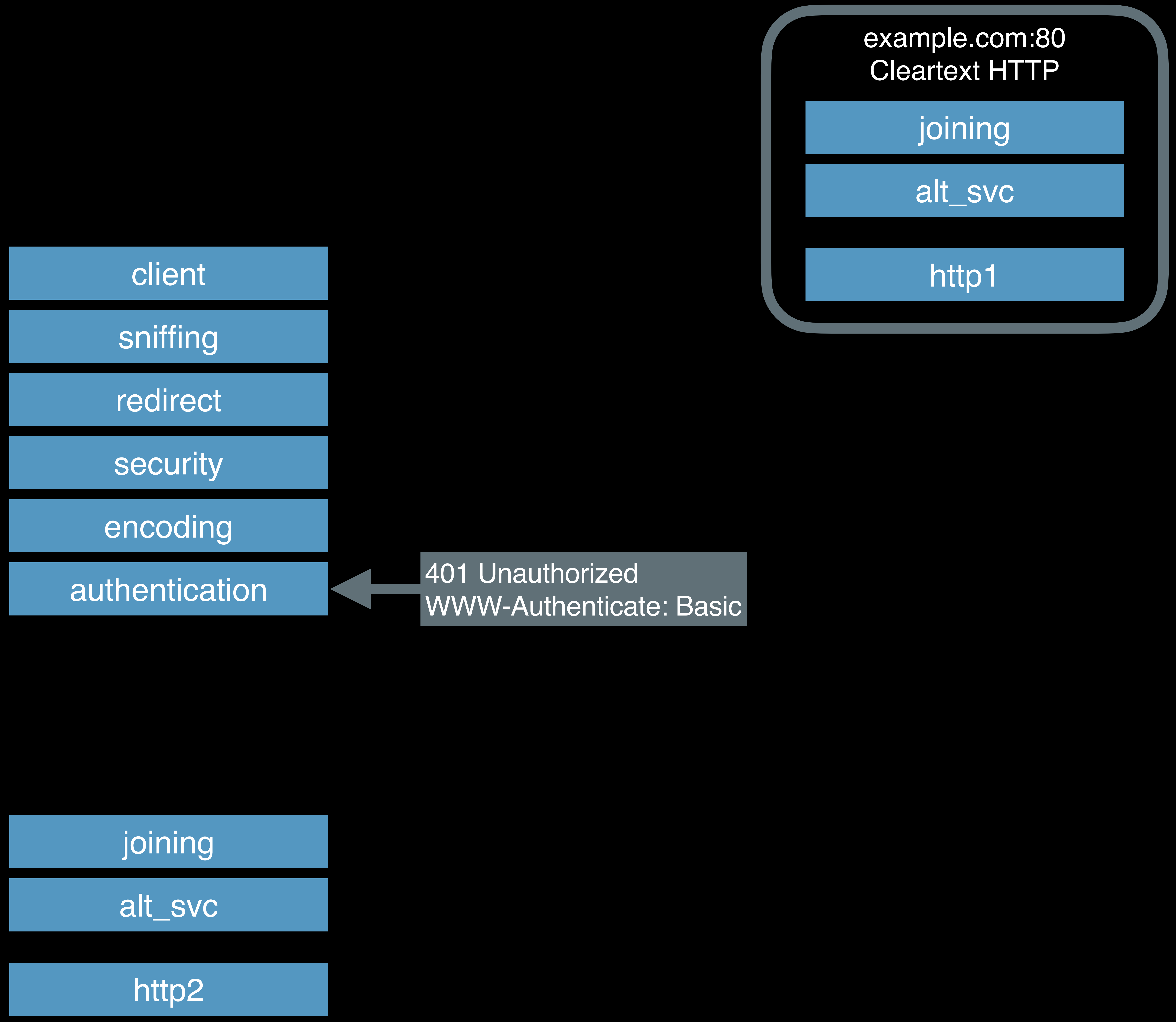

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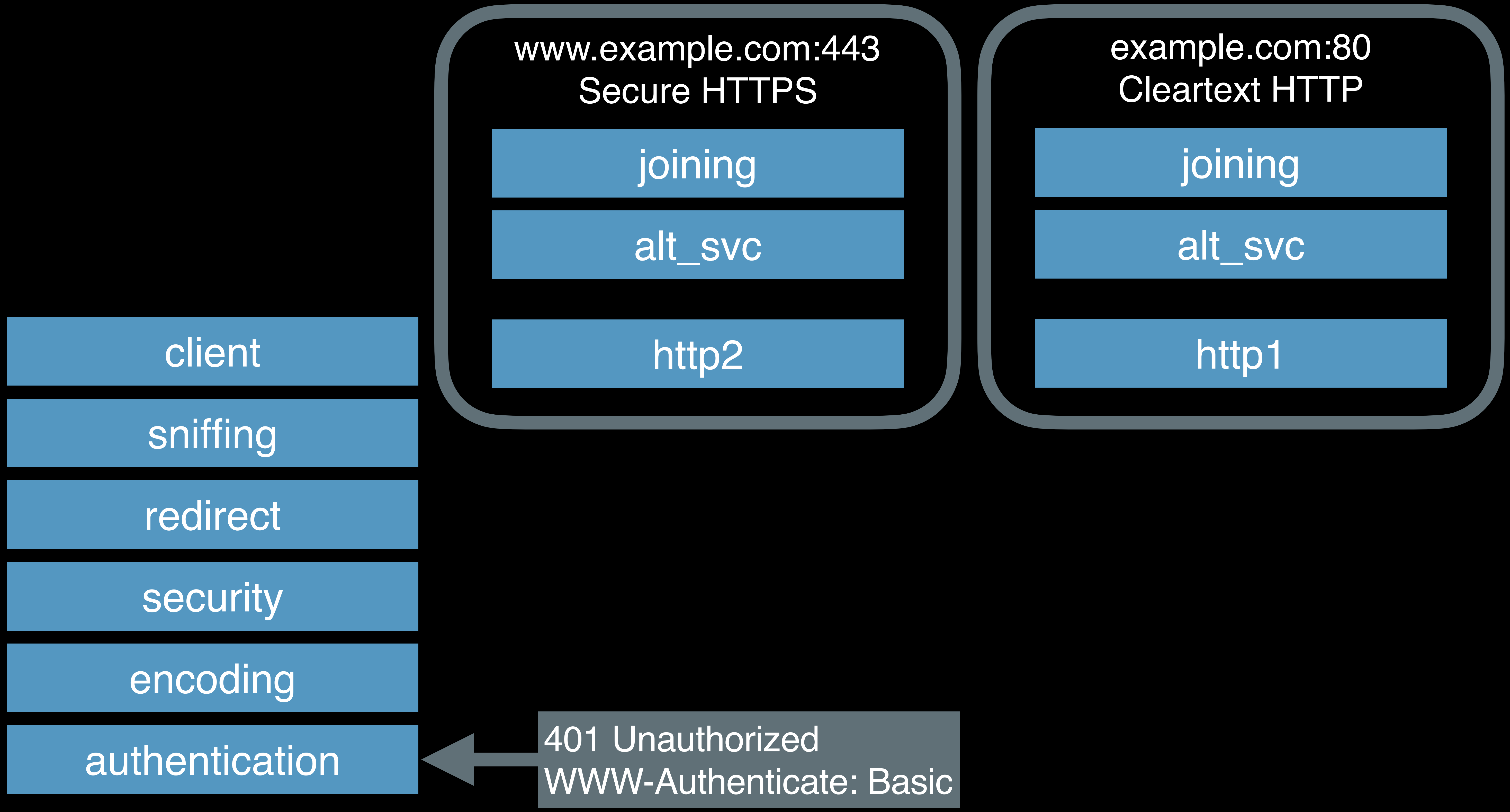

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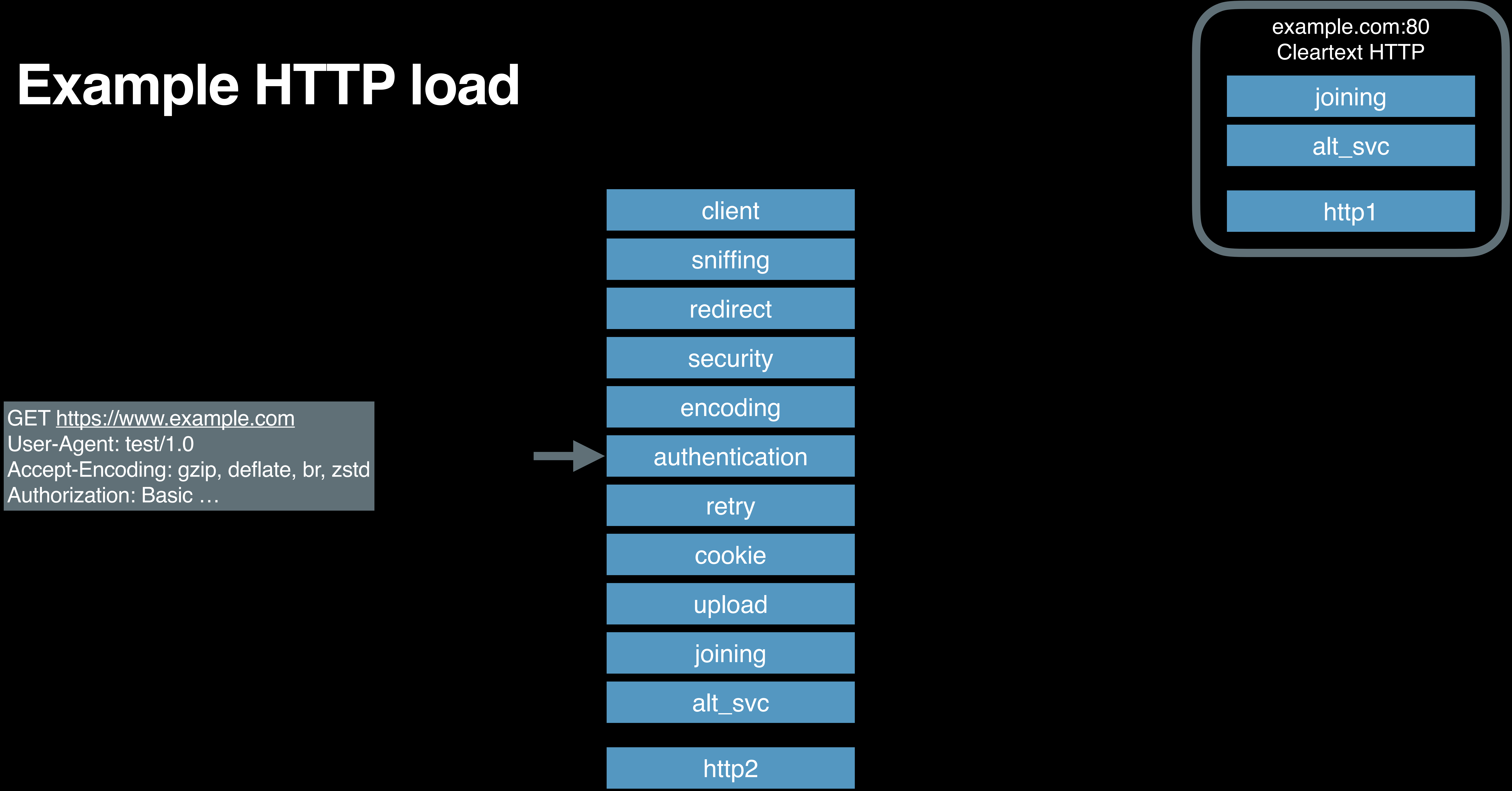

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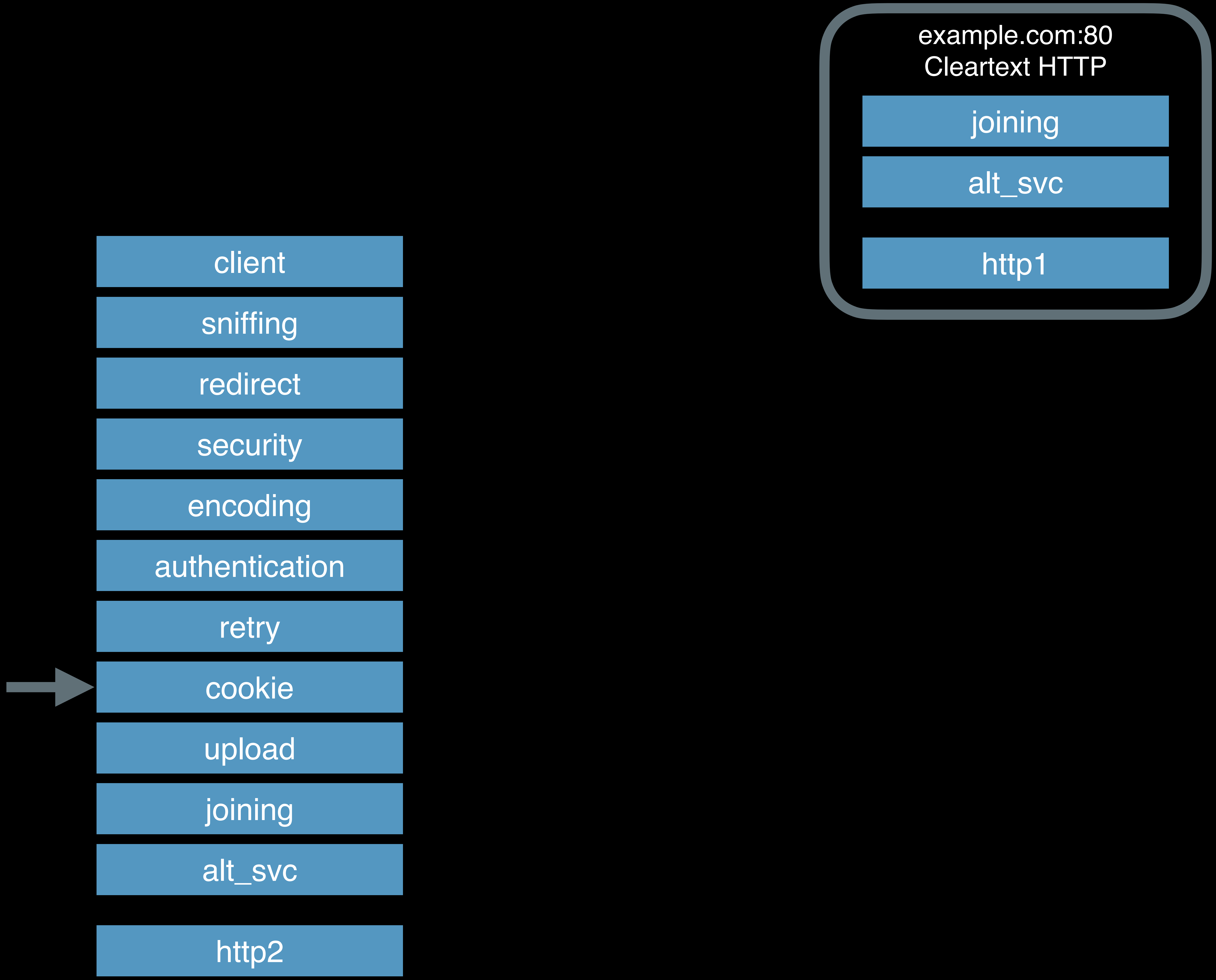

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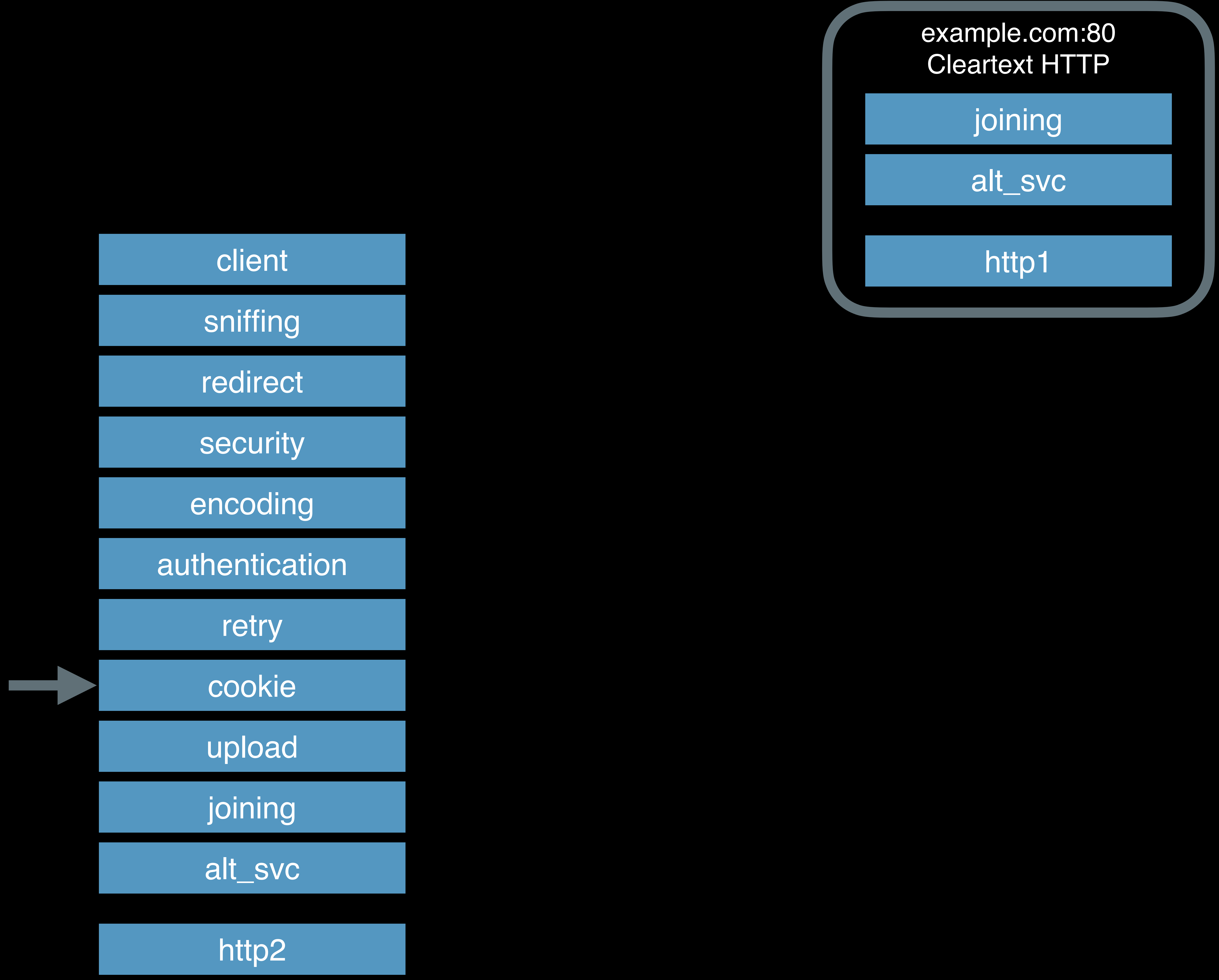
Cookie: foo=baz



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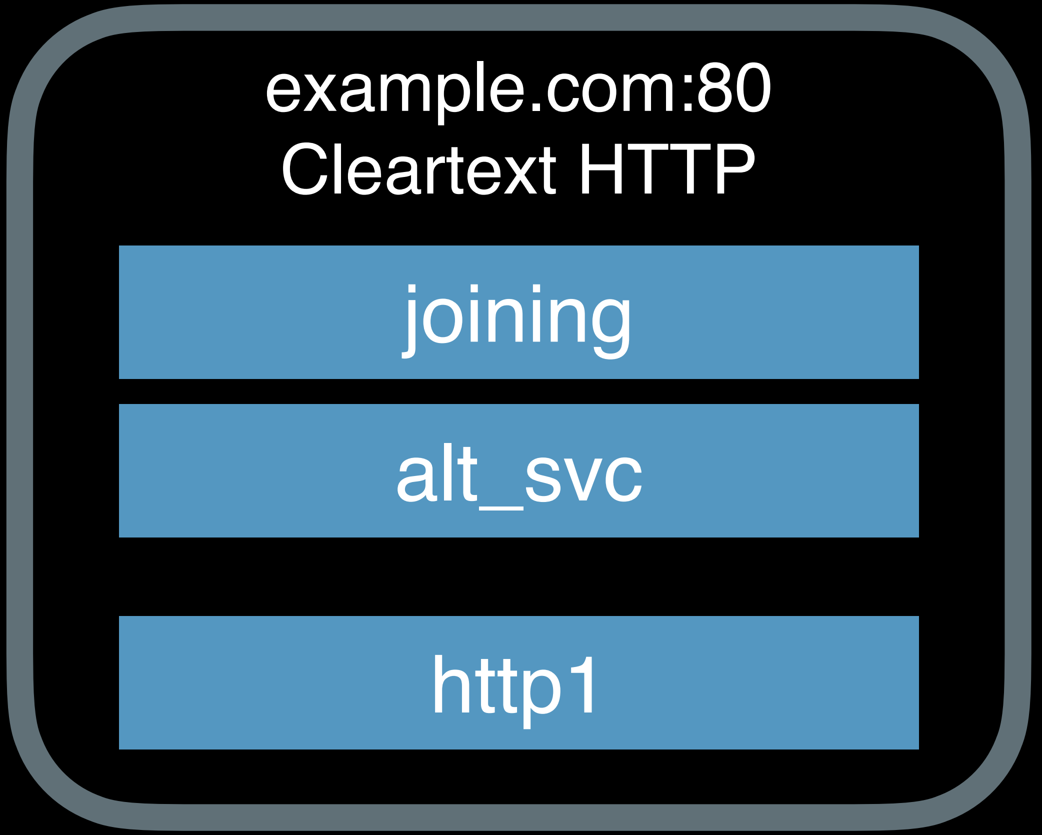

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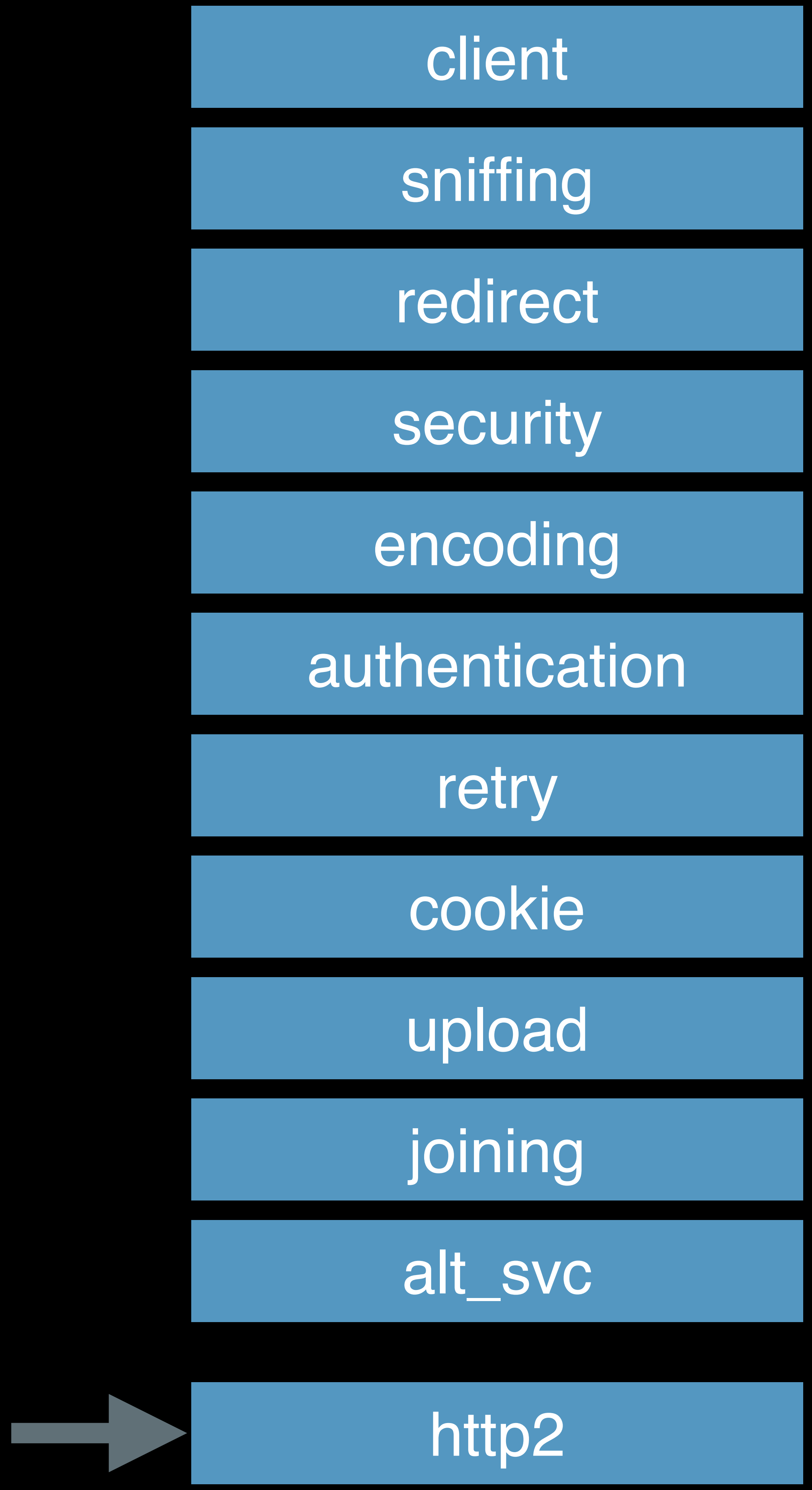

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GET https://www.example.com
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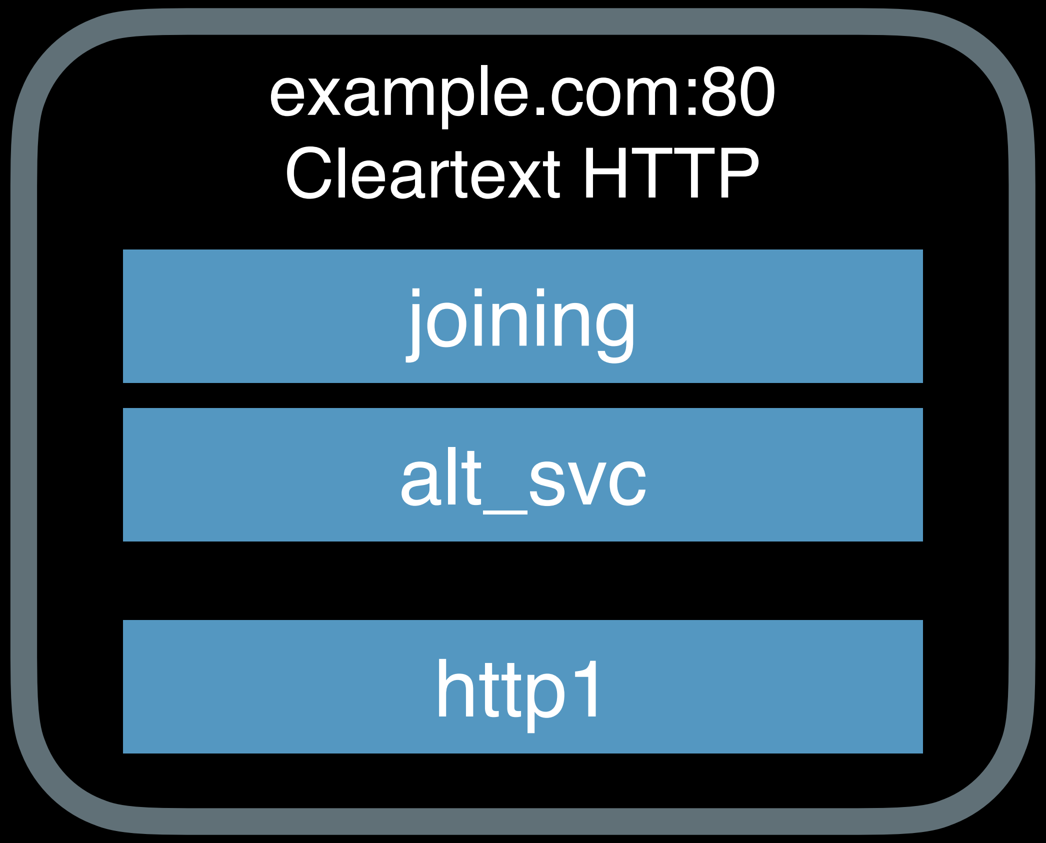

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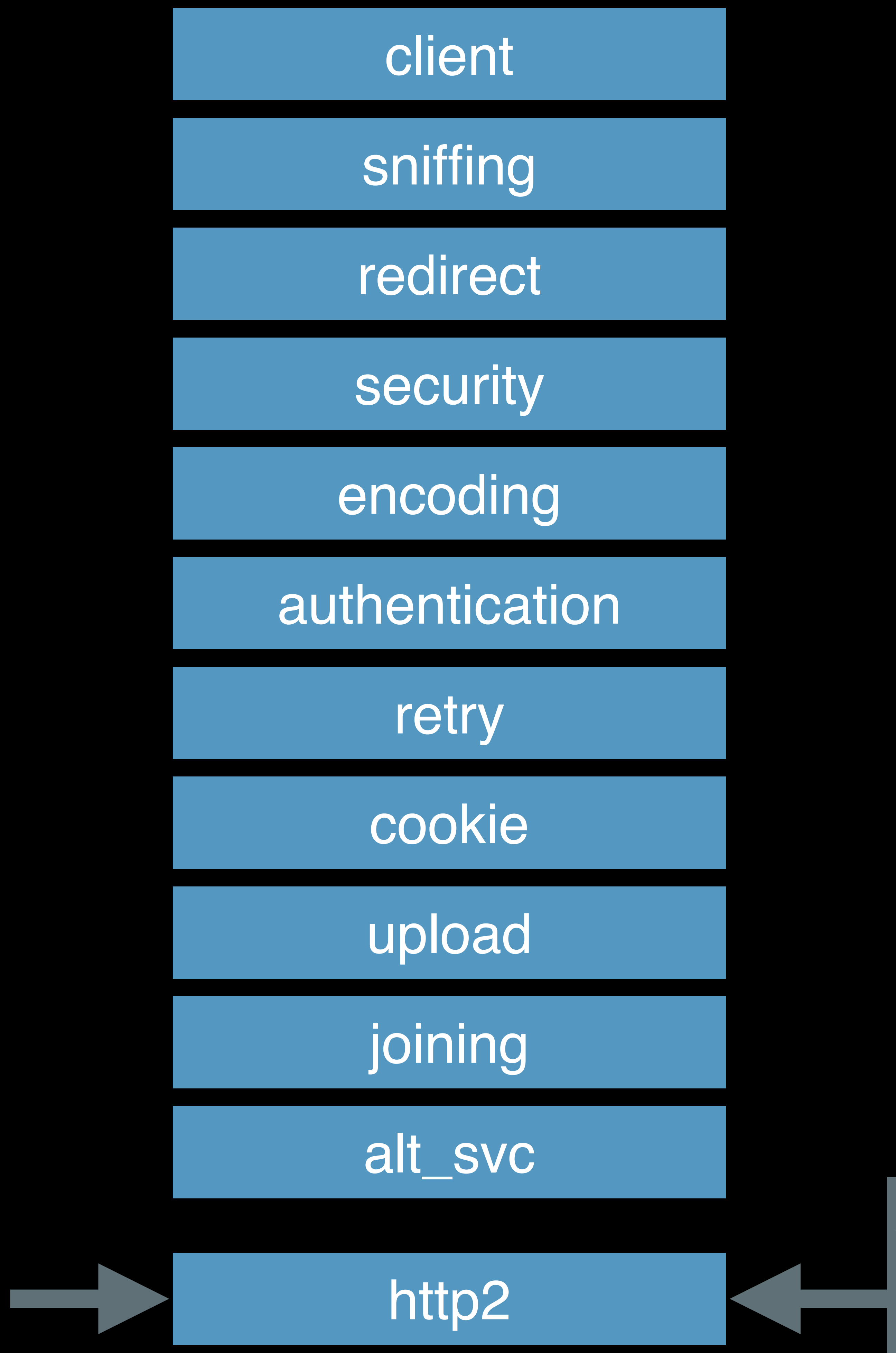

client

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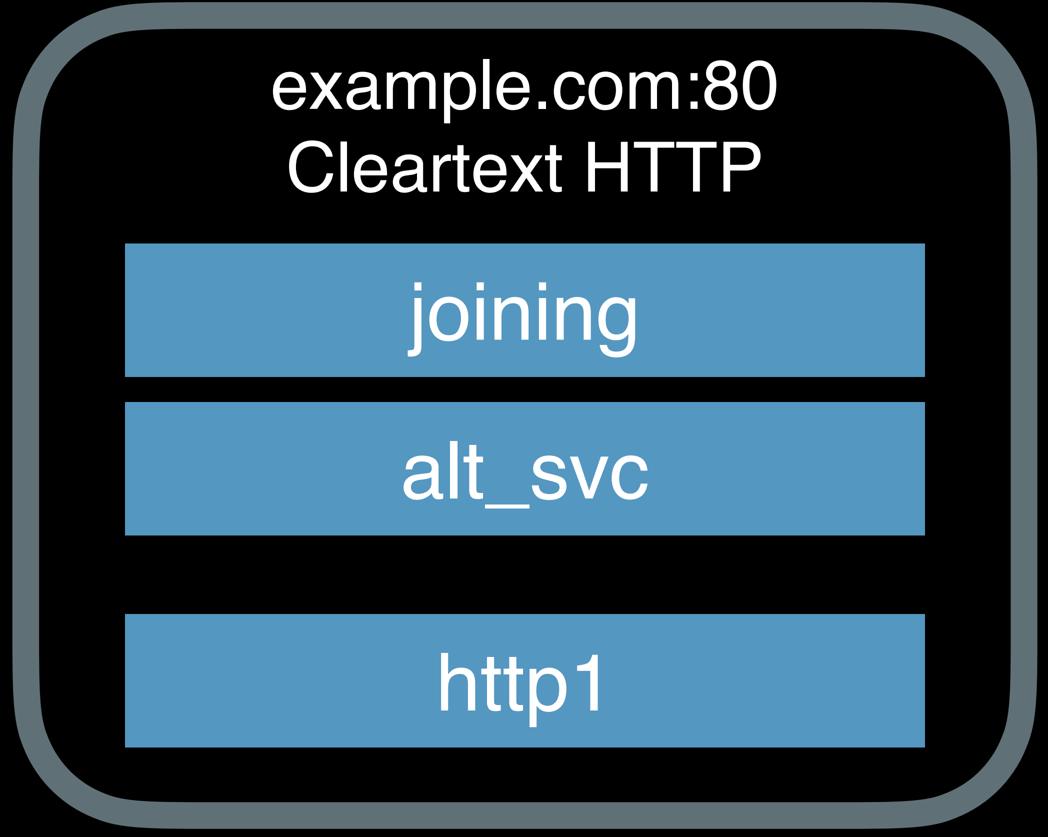
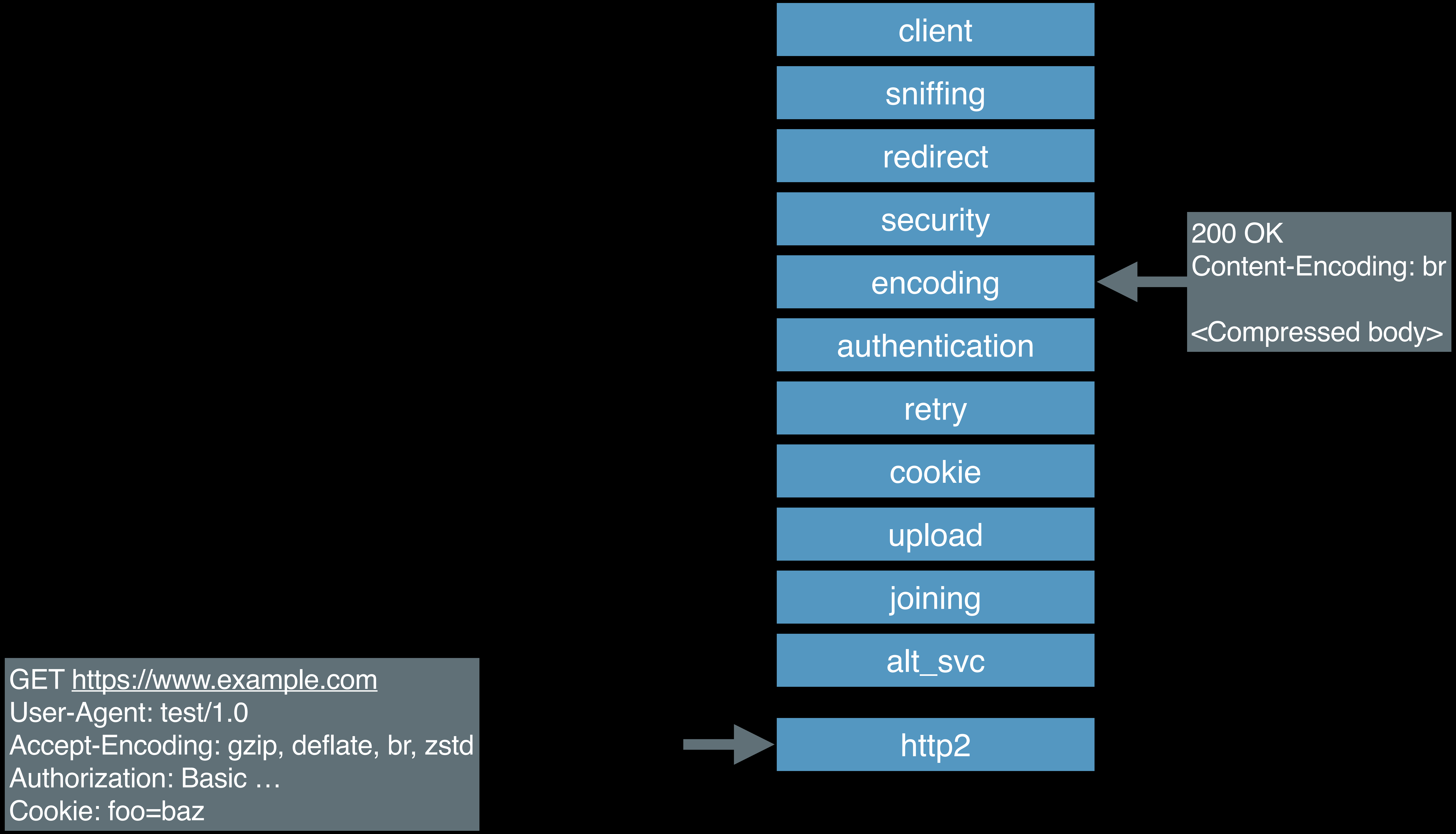
GET https://www.example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate, br, zstd
Authorization: Basic …
Cookie: foo=baz

200 OK
Content-Encoding: br

<Compressed body>

Example HTTP load



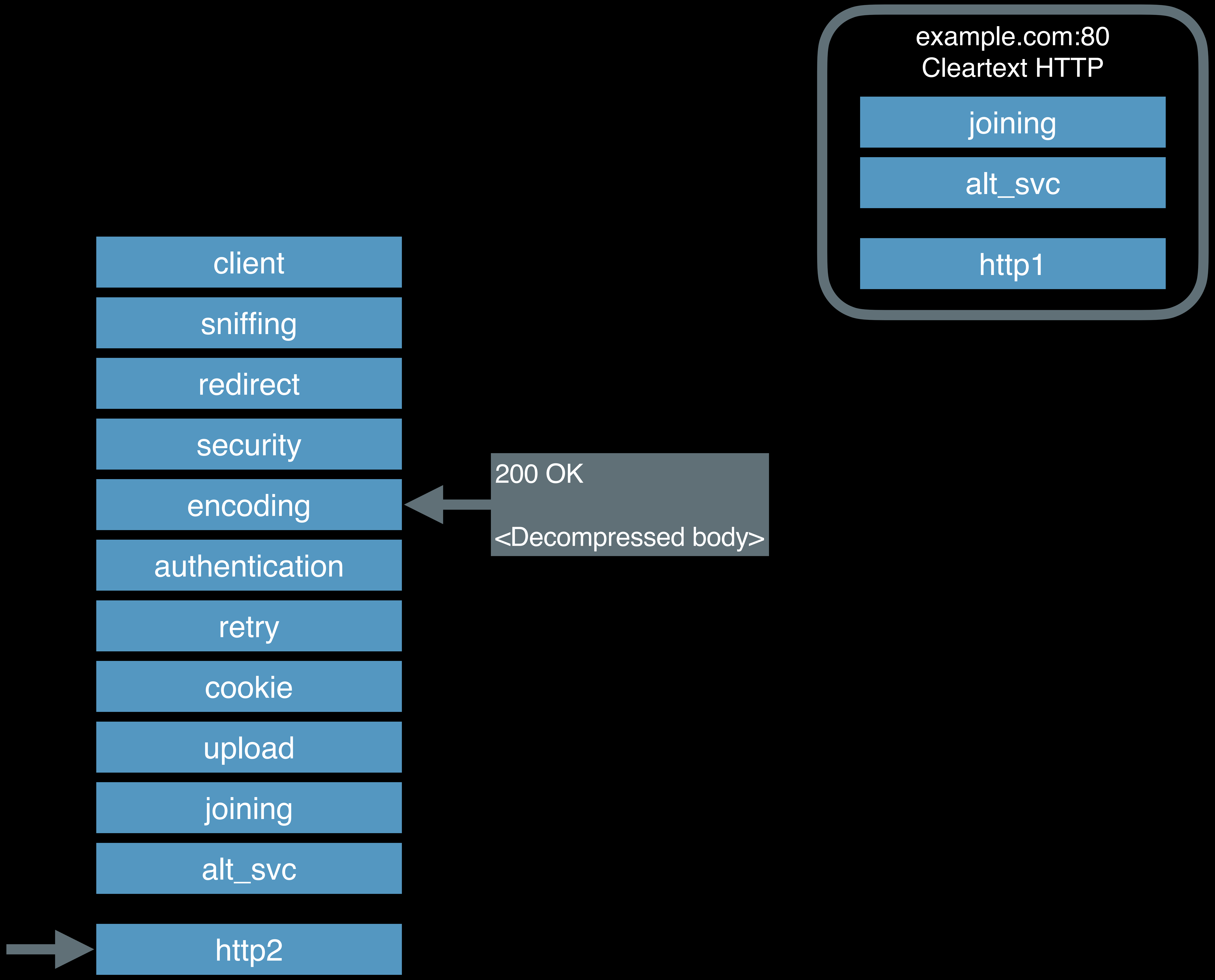


200 OK
Content-Encoding: br

<Compressed body>

GET https://www.example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate, br, zstd
Authorization: Basic …
Cookie: foo=baz

Example HTTP load

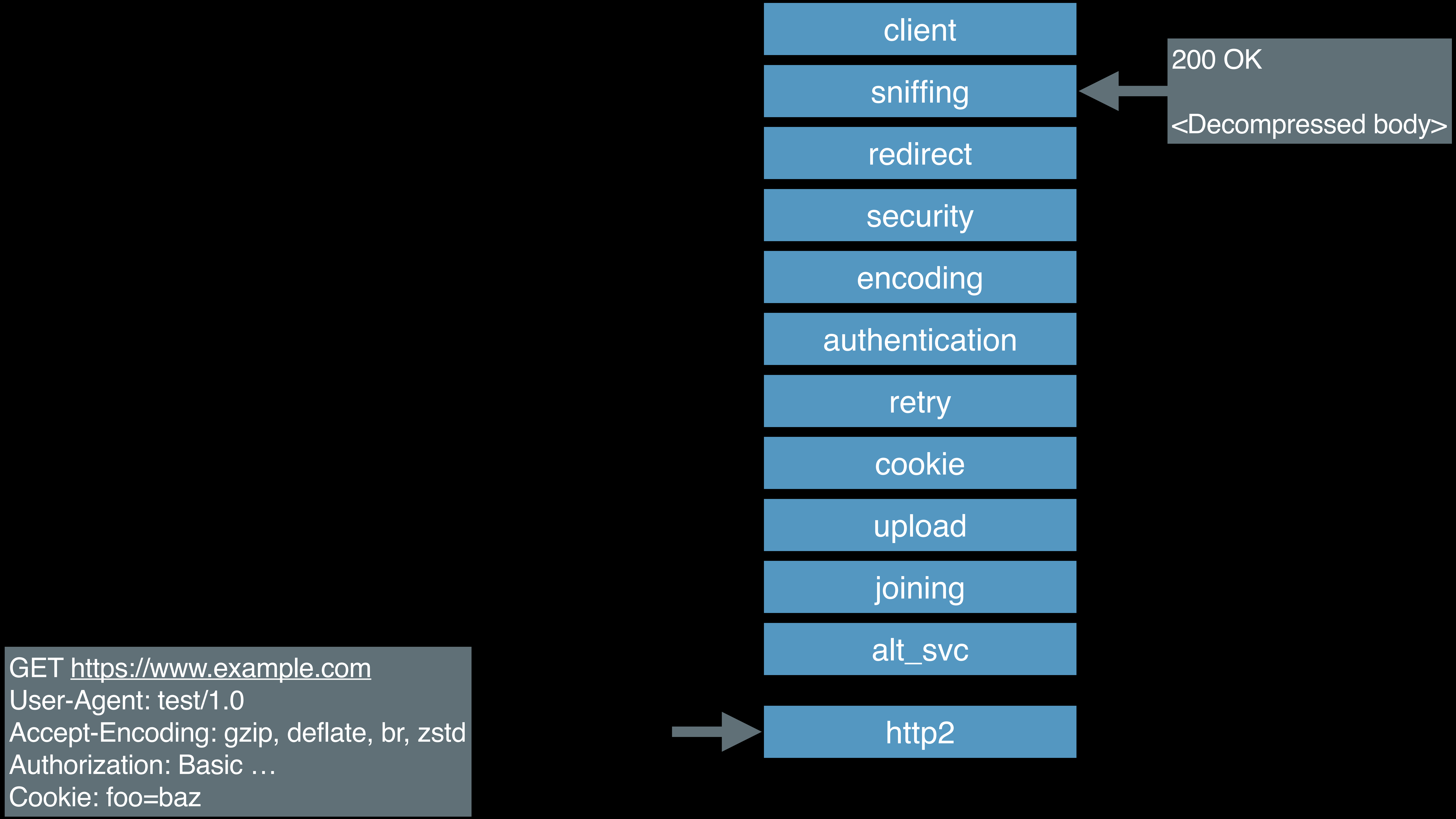


200 OK

<Decompressed body>

GET https://www.example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate, br, zstd
Authorization: Basic …
Cookie: foo=baz

Example HTTP load



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```
200 OK

<Decompressed body>
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User-Agent: test/1.0
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Cookie: foo=baz
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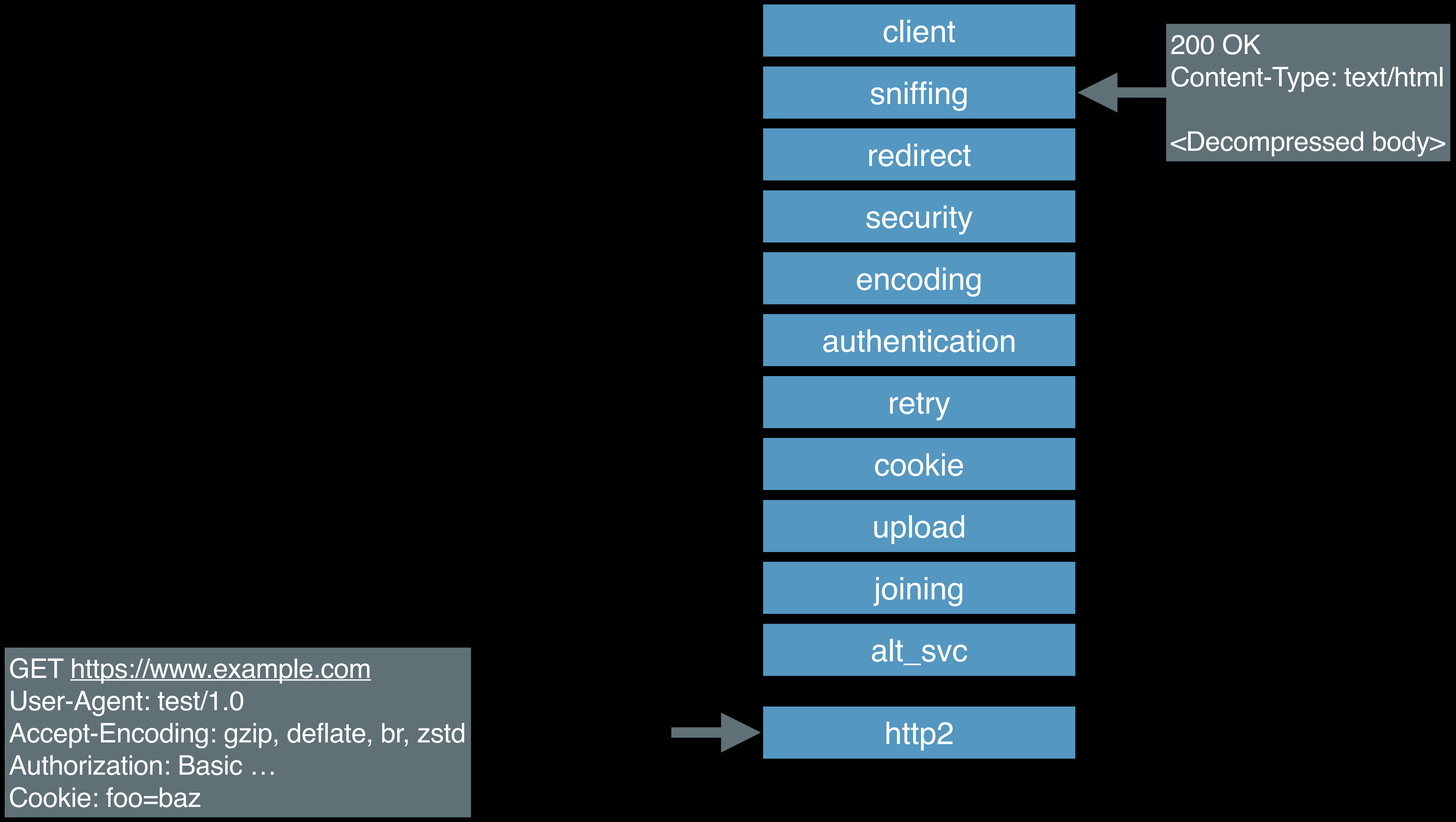
Example HTTP load



```
200 OK
Content-Type: text/html

<Decompressed body>
```

```
GET https://www.example.com
User-Agent: test/1.0
Accept-Encoding: gzip, deflate, br, zstd
Authorization: Basic …
Cookie: foo=baz
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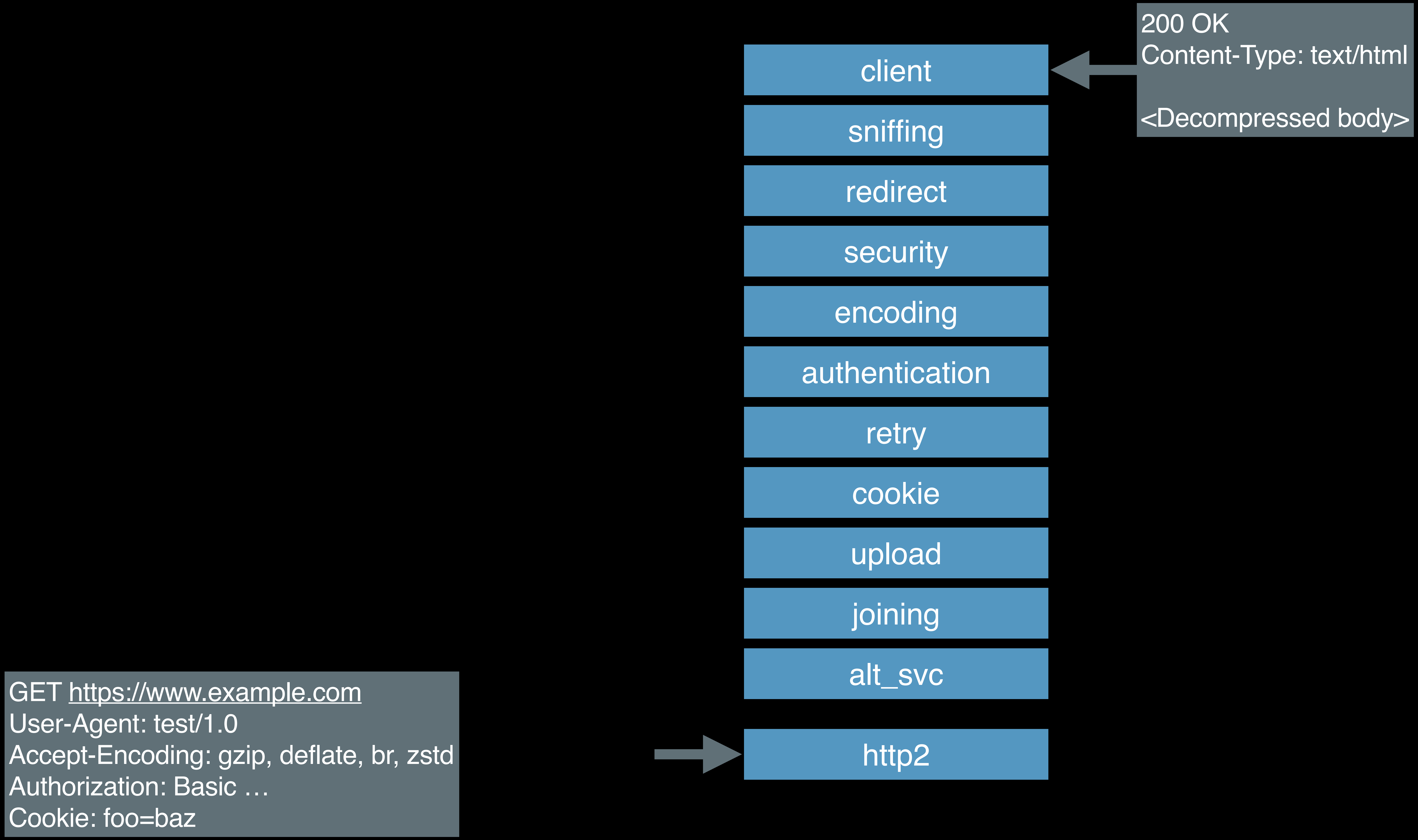
Example HTTP load



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Authorization: Basic …
Cookie: foo=baz

Benefits of micro-protocols

- Composable
  - State isolation
  - Stricter interaction model
- Easier to understand
- Unit testing individual pieces

Learnings

Ordering matters

- Sniffing above encoding
- Redirect / authentication above cookie
- Joining is a boundary

Learnings

Spec vs reality

- Content-Encoding
  - Deflate
  - Content-Length
  - x-gzip
  - Incomplete archives
- Location
  - Percent-encode invalid characters
- HTTP/1 parsing

Discussion

New HTTP stack

Persistent Stack	client	Byte accounting
	sniffing	Content-Type sniffing
	redirect	3xx redirects
	security	HSTS
	encoding	gzip, deflate, br, zstd
	authentication	Basic, Kerberos, Private Access Tokens, SSO
	retry	Rejection, idempotent retry, downgrade to HTTP/1
	cookie	Cookie, Set-Cookie
	upload	100 continue, resumable upload
	joining	Connection pooling by hostname
	alt_svc	HTTP/3 discovery
Stack	messaging	HTTP version negotiation