The Security Impact of HTTPS Interception

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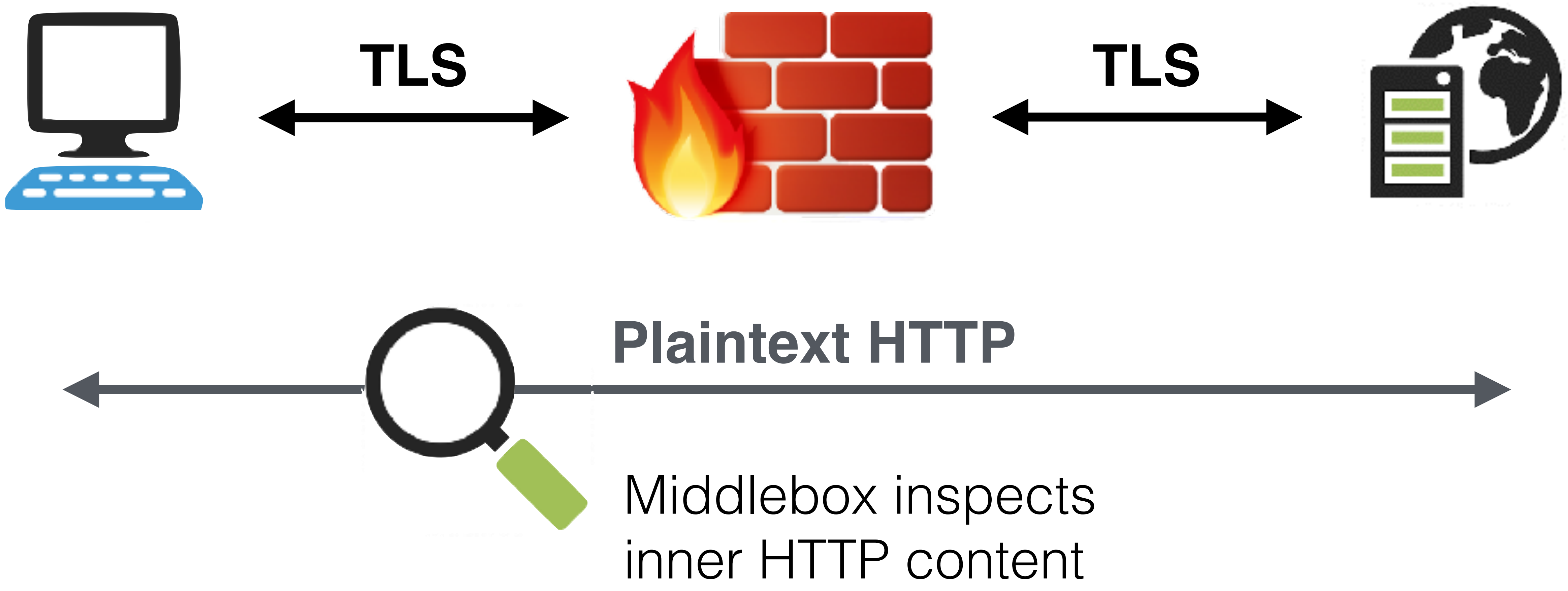
HTTPS Interception

Middle boxes and security software are increasingly intercepting HTTPS connections in order to inspect encrypted content.

How HTTPS Interception Works



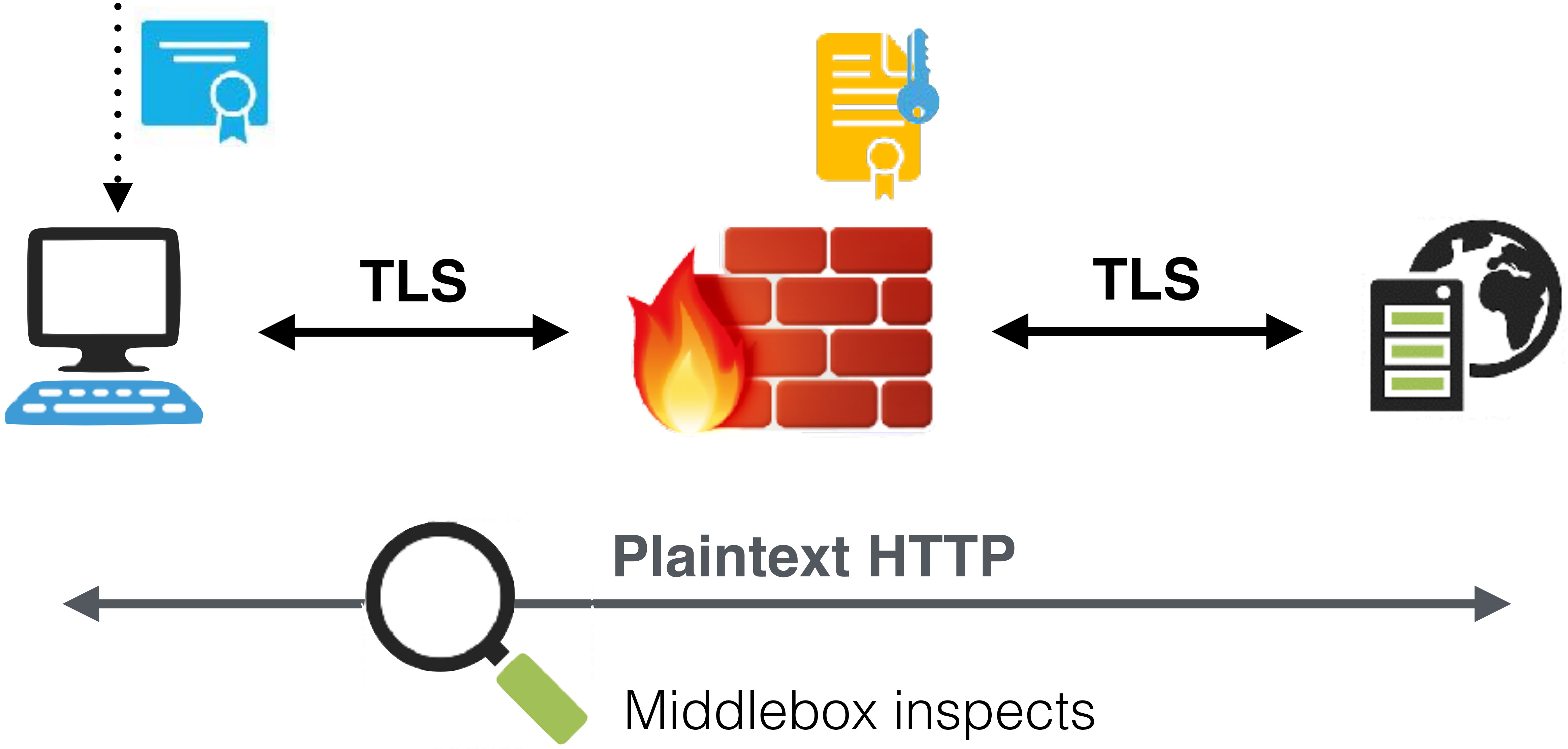
TLS

TLS

Plaintext HTTP

Middlebox inspects inner HTTP content

How HTTPS Interception Works



Administrator installs root certificate on client

Middlebox generates new certificate for client

TLS

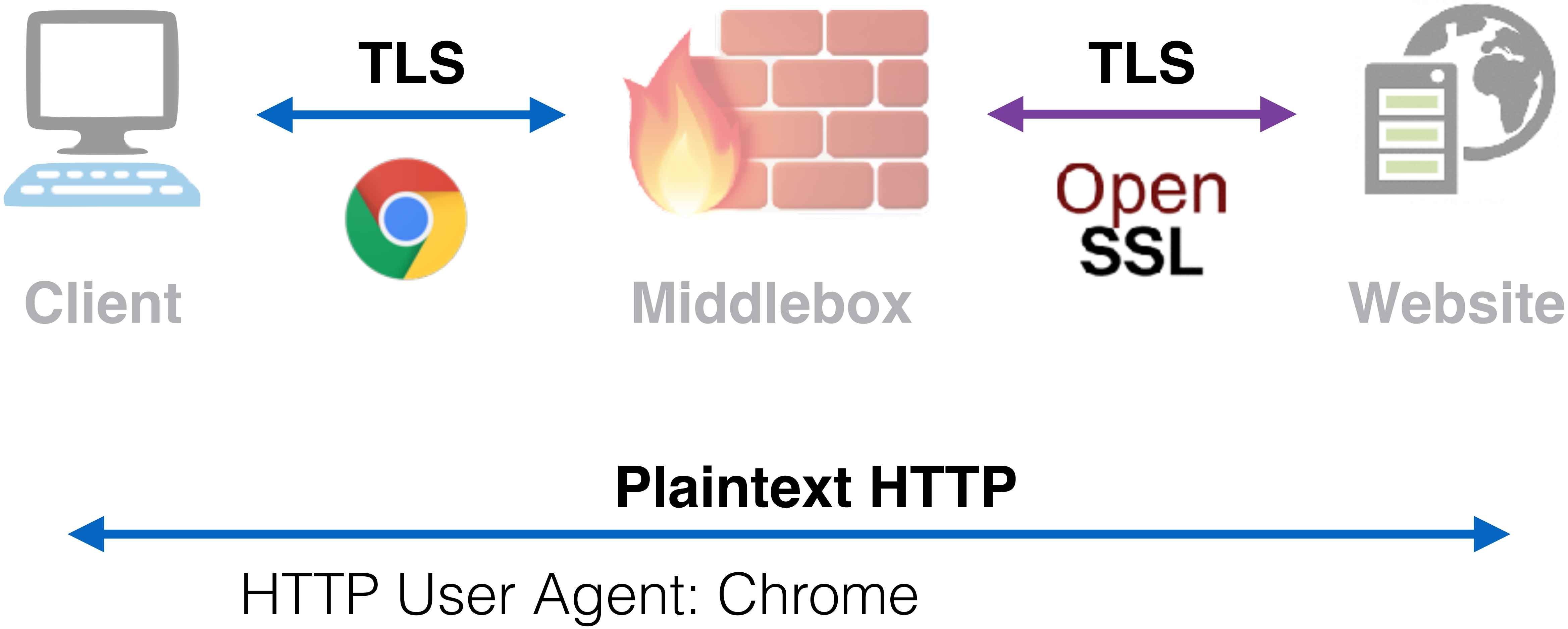
TLS

Plaintext HTTP

Middlebox inspects inner HTTP content

How do you measure the total amount of interception?

Change in TLS Library



TLS

TLS

Client

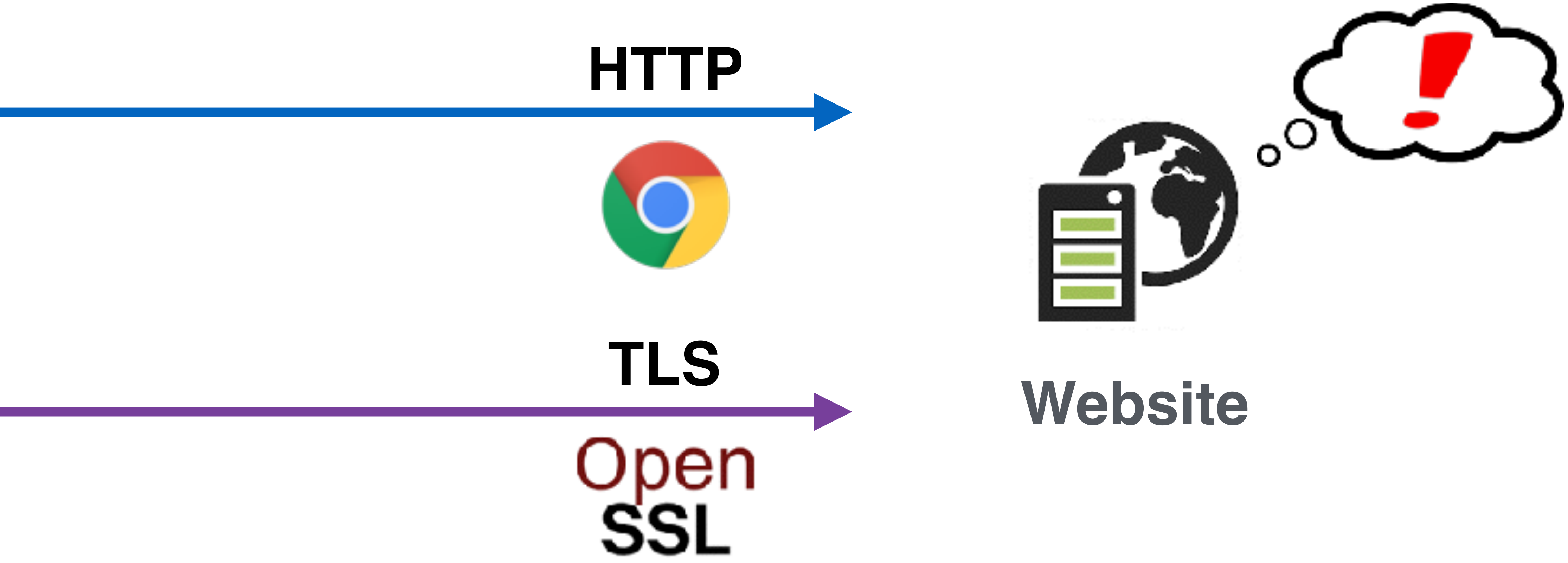
Middlebox

Website

Plaintext HTTP

HTTP User Agent: Chrome

Measuring Interception



Websites can potentially detect interception by identifying a *mismatch* between network layers

Identifying Network Layers

HTTP

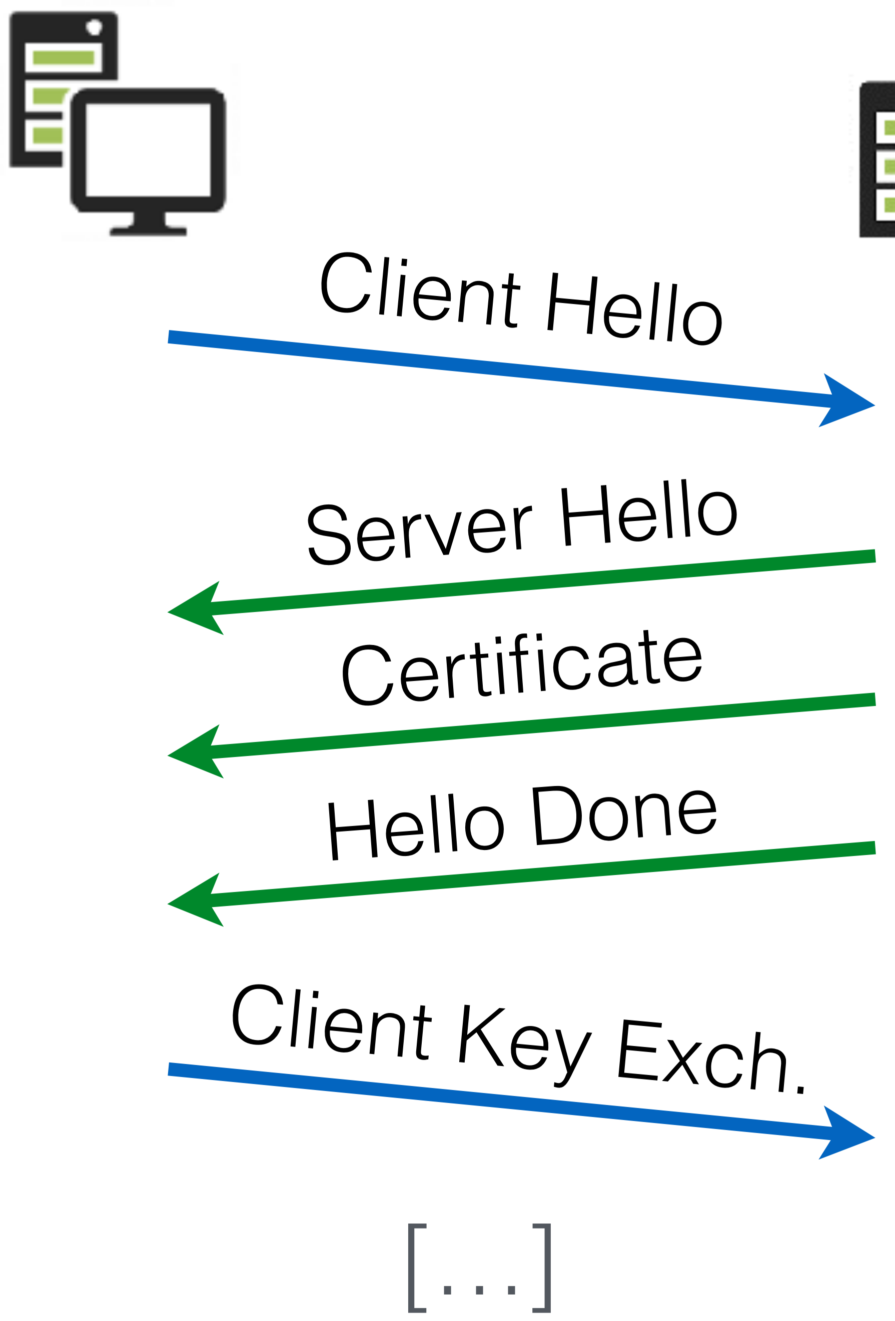
Parse HTTP User Agent Header:

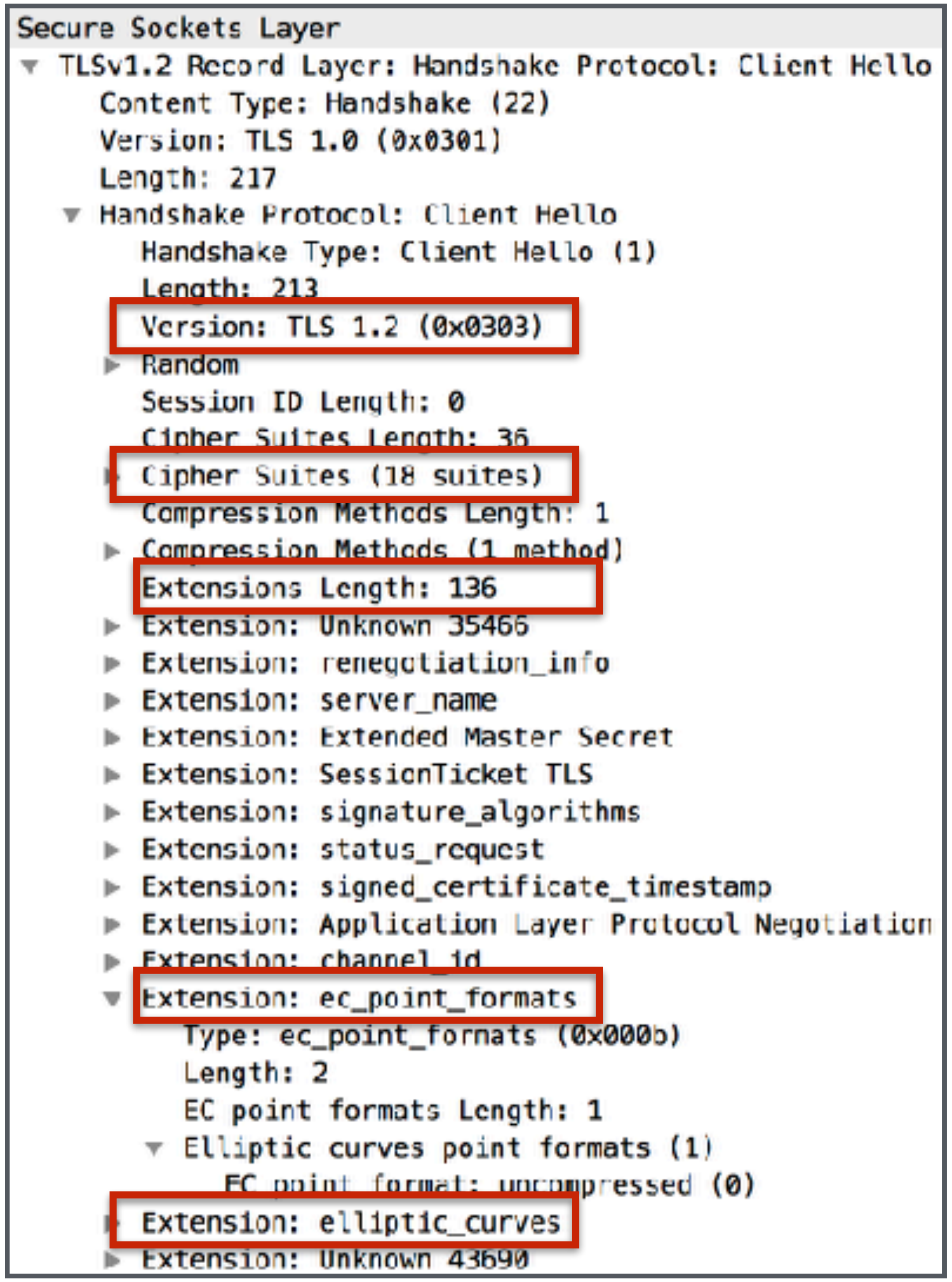
```
Mozilla/5.0 (Macintosh; Intel Mac OS X 10_12_2) AppleWebKit/
537.36 (KHTML, like Gecko) Chrome/55.0.2883.95 Safari/537.36
```

TLS

No identifying field. Instead, we built a set heuristics that identify whether a TLS handshake is consistent with a browser.

Typical TLS Handshake





```
Secure Sockets Layer
▼ TLSv1.2 Record Layer: Handshake Protocol: Client Hello
    Content Type: Handshake (22)
    Version: TLS 1.0 (0x0301)
    Length: 217
  ▼ Handshake Protocol: Client Hello
      Handshake Type: Client Hello (1)
      Length: 213
      Version: TLS 1.2 (0x0303)
    ▶ Random
      Session ID Length: 0
      Cipher Suites Length: 36
    ▶ Cipher Suites (18 suites)
      Compression Methods Length: 1
    ▶ Compression Methods (1 method)
      Extensions Length: 136
    ▶ Extension: Unknown 35466
    ▶ Extension: renegotiation_info
    ▶ Extension: server_name
    ▶ Extension: Extended Master Secret
    ▶ Extension: SessionTicket TLS
    ▶ Extension: signature_algorithms
    ▶ Extension: status_request
    ▶ Extension: signed_certificate_timestamp
    ▶ Extension: Application Layer Protocol Negotiation
    ▶ Extension: channel_id
    ▼ Extension: ec_point_formats
        Type: ec_point_formats (0x000b)
        Length: 2
        EC point formats Length: 1
      ▼ Elliptic curves point formats (1)
          EC point format: uncompressed (0)
    ▶ Extension: elliptic_curves
    ▶ Extension: Unknown 43690
```

(Client Hello)

Investigating Common Products

We analyzed the TLS Client Hello messages from popular browsers browsers, middle boxes, client security software, and malware

Every product we investigated produced a unique TLS Client Hello message

Not always possible to identify product based on the handshake, but possible to detect whether a handshake is incompatible with a given browser

Firefox vs. GnuTLS Client Hellos

Extensions
Server Name (SNI)
Extended Master Secret
Renegotiation Info
Elliptic Curves
[…]

Ciphers
ECDHE_ECDSA_AES128_GCM_SHA256
ECDHE_RSA_AES128_GCM_SHA256
ECDHE_RSA_CHACHA20_SHA2156
ECDHE_ECDSA_AES256_GCM_SHA384
[…]

Curves
secp256r1
secp384r1
secp521r1

Extensions
Extended Master Secret
Encrypt then MAC
OCSP Status Request
Server Name (SNI)
[…]

Ciphers
ECDHE_ECDSA_AES128_GCM_SHA256
ECDHE_ECDSA_AES128_GCM_SHA386
ECDSA_CAMELLIA_128_GCM_SHA256
ECDSA_CAMELLIA_128_GCM_SHA384
[…]

Curves
secp256r1
secp384r1
secp521r1
secp224r1
secp192r1

Deploying Heuristics

We deployed our heuristics for one week at three large service providers:

- Mozilla Firefox Update Servers
- Cloudflare CDN
- Popular E-commerce Site

Overall Interception Rates

We find a varying amount of interception between vantage points:

	No Interception	Likely Interception	Confirmed Interception
Cloudflare	88.6%	0.5%	10.9%
Firefox	96.0%	0.0%	4.0%
E-Commerce	92.9%	0.9%	6.2%

Overall Interception Rates

We find a varying amount of interception between

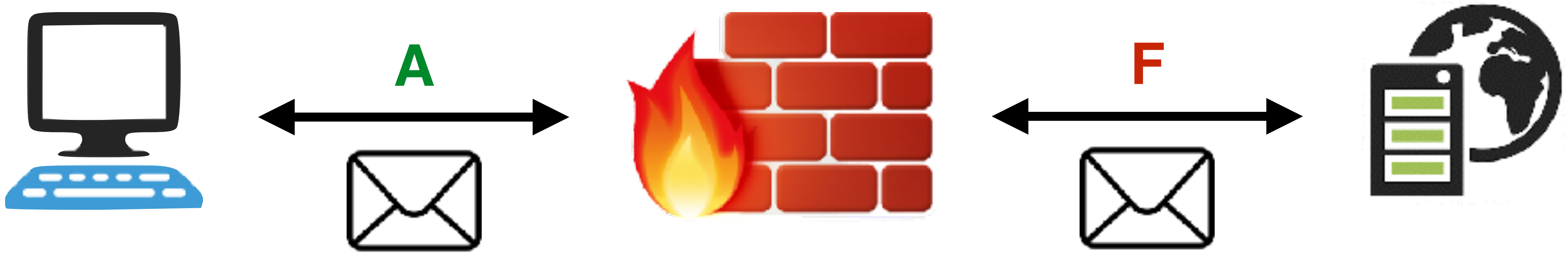
We estimate that 5-10% of all HTTPS connections are intercepted.

Firefox	96.0%	0.0%	4.0%
E-Commerce	92.9%	0.9%	6.2%

Measuring Security Impact

If interception products are performing high quality handshakes, there isn't an inherent security risk

We measured the security impact of interception by grading the security features advertised by the intercepted connection and the original browser



PFS
Modern ciphers

Known broken ciphers

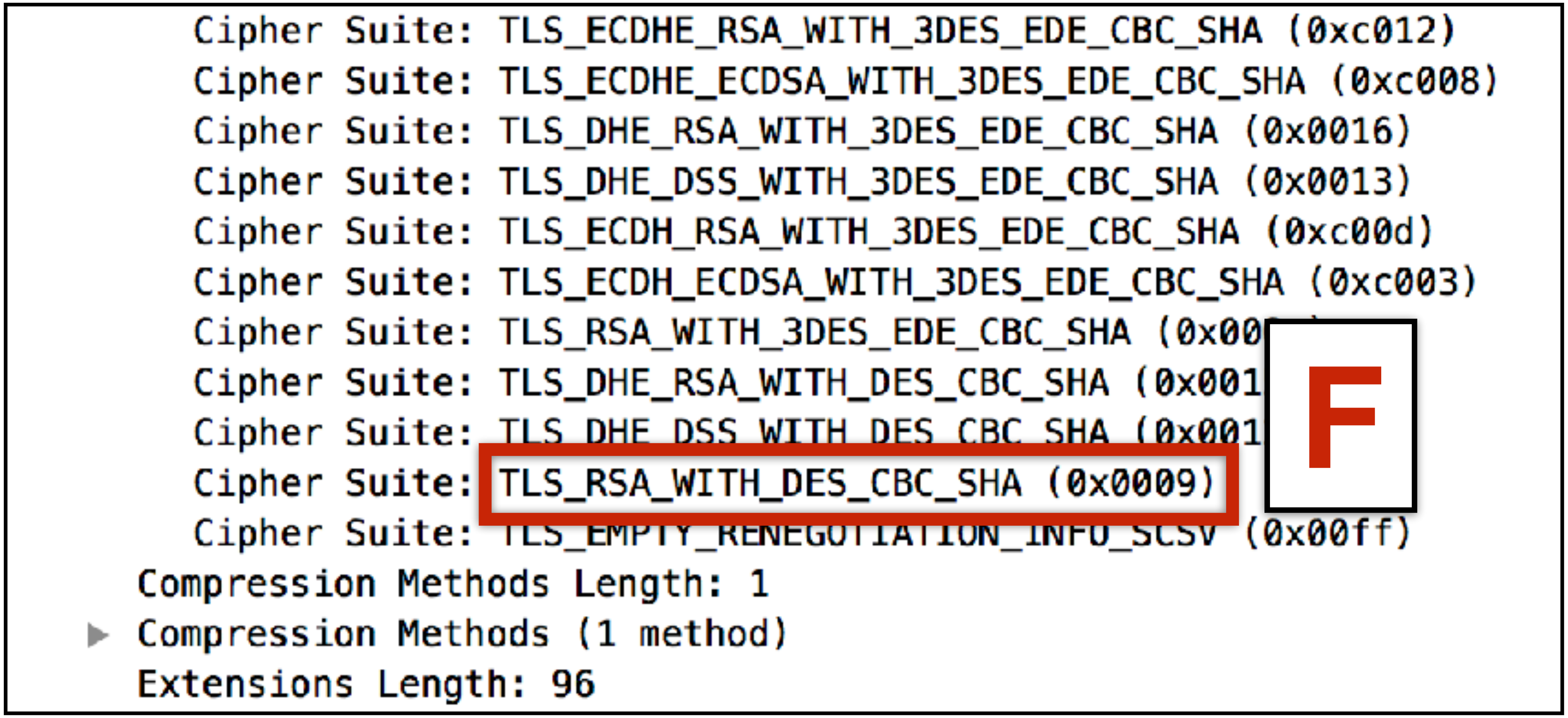
Quantifying Security Impact

We defined a security grading scale base on parameters advertised in Client Hello

Applied to original browsers and the connections we observed in the wild

Grading Scale	
A	**Optimal.** Equivalent to a modern web browser
B	**Suboptimal.** Non-ideal but not vulnerable to attacks
C	**Known Attack.** Vulnerable to known attack (e.g., RC4)
F	**Severely Broken.** An attacker could easily intercept connection

Security Grade Example



```
        Cipher Suite: TLS_ECDHE_RSA_WITH_3DES_EDE_CBC_SHA (0xc012)
        Cipher Suite: TLS_ECDHE_ECDSA_WITH_3DES_EDE_CBC_SHA (0xc008)
        Cipher Suite: TLS_DHE_RSA_WITH_3DES_EDE_CBC_SHA (0x0016)
        Cipher Suite: TLS_DHE_DSS_WITH_3DES_EDE_CBC_SHA (0x0013)
        Cipher Suite: TLS_ECDH_RSA_WITH_3DES_EDE_CBC_SHA (0xc00d)
        Cipher Suite: TLS_ECDH_ECDSA_WITH_3DES_EDE_CBC_SHA (0xc003)
        Cipher Suite: TLS_RSA_WITH_3DES_EDE_CBC_SHA (0x00
        Cipher Suite: TLS_DHE_RSA_WITH_DES_CBC_SHA (0x001
        Cipher Suite: TLS_DHE_DSS_WITH_DES_CBC_SHA (0x001
        Cipher Suite: TLS_RSA_WITH_DES_CBC_SHA (0x0009)
        Cipher Suite: TLS_EMPTY_RENEGOTIATION_INFO_SCSV (0x00ff)
      Compression Methods Length: 1
    ▶ Compression Methods (1 method)
      Extensions Length: 96
```

Security Impact of Interception

	Increased Security	Decreased Security	Severely Broken
E-Commerce	4%	27%	18%
Cloudflare	14%	45%	16%
Firefox Updates	0%	66%	37%

Middlebox Security

Network Middleboxes have a worse security profile than client-side software

62% of connections are less secure

58% are severely broken

```
x-forwarded-for:
192.168.15.56

x-bluecoat-via:
abce6cd5a6733123
```

Why is Security Suffering?

We investigated the default configurations of popular interception products:

- Popular middleboxes that intercept TLS connections (e.g., A10, Bluecoat, Cisco, Fortinet)
- Common antivirus software (e.g., Avast, AVG, Kaspersky)

We ran a series of automated tests to see with website configurations sites products would negotiate

Security Profile of Interception Products

TLS Security	Increased Security	Same Security	Decreased Security	Severely Broken
Client Security Products	0/20	2/20	18/20	10/20
Middleboxes	0/12	1/12	6/12	5/12

No products implemented new HTTPS features beyond the TLS specification (e.g., HPKP)

Moving Forward

We need community consensus on whether interception is acceptable

We need to reconsider implementing extended validation as browsers features instead of TLS

We should investigate extending the TLS protocol to allow middle boxes to communicate session information to browsers

Conclusion

We showed that web servers can detect interception by detecting a behavior mismatch between network layers

We estimate that 5-10% of HTTPS connections are intercepted

As a class, interception products severely reduce the security of HTTPS connections