The CRIME attack

HTTPS:// Secure HTTP

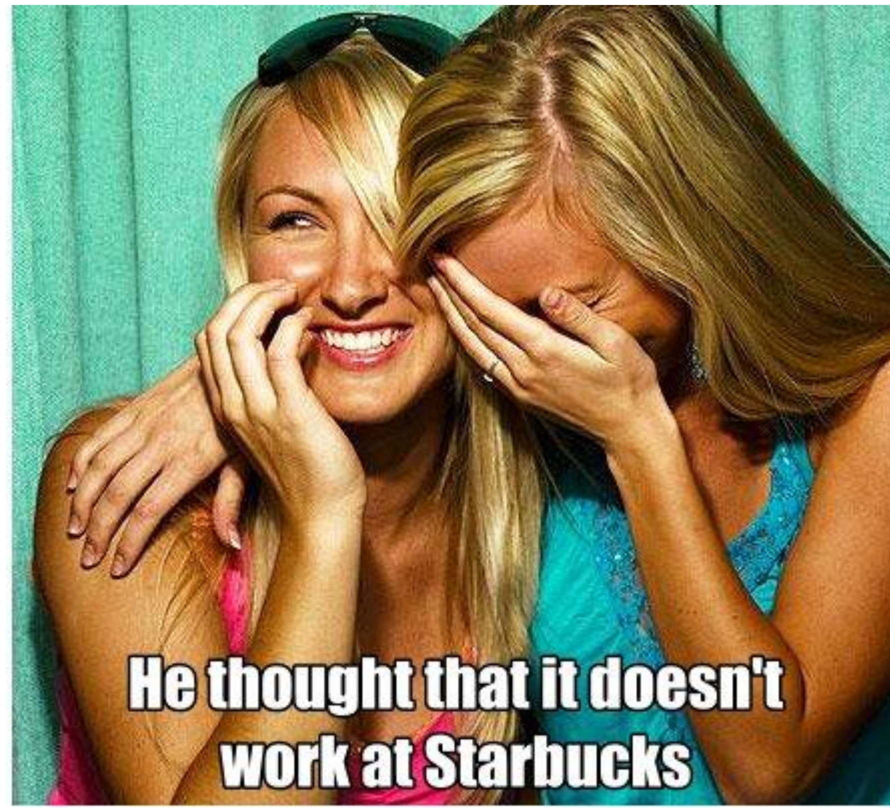
HTTPS provides:

- Confidentiality (Encryption),
- Integrity (Message Authentication Code),
- Authenticity (Certificates)

CRIME decrypts HTTPS traffic to steal cookies and hijack sessions.

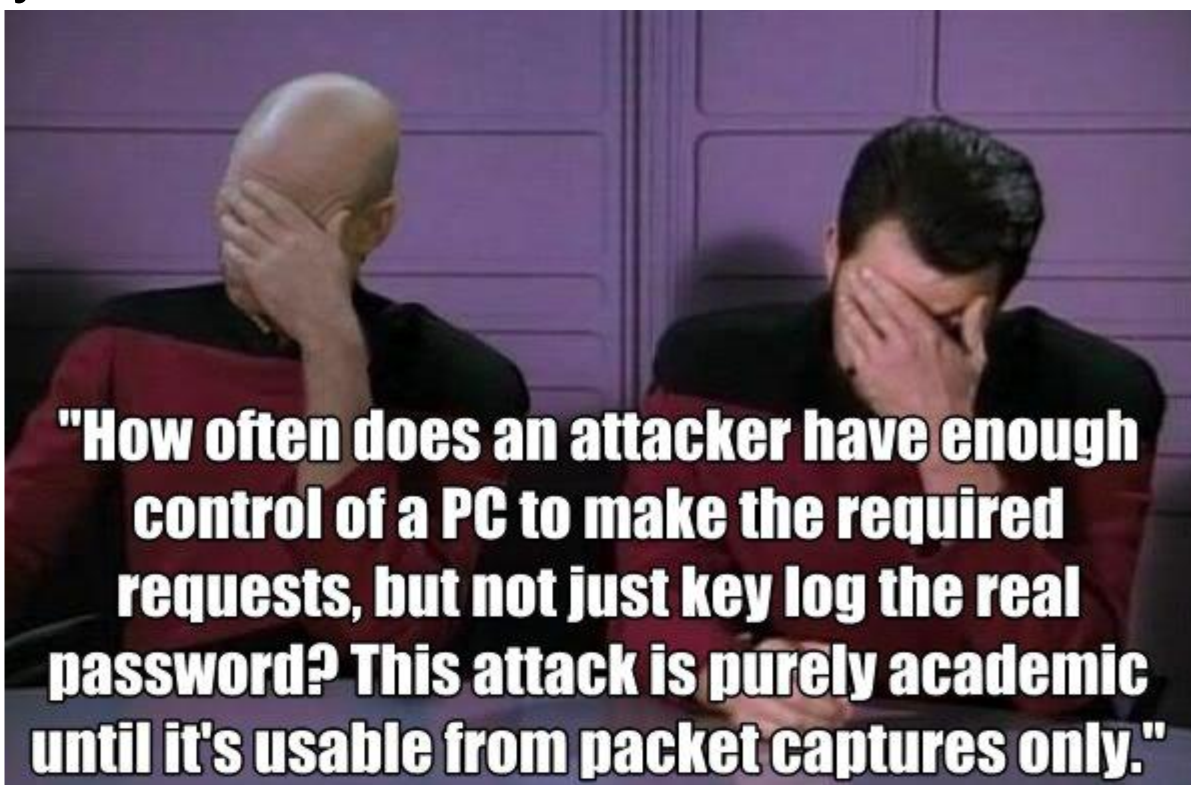
How can you become a victim of CRIME?

- 1st requirement: the attacker can sniff your network traffic.
  - You share a (W)LAN.
  - He's [hacked](#) your home router.
  - He's your network admin, ISP or government.

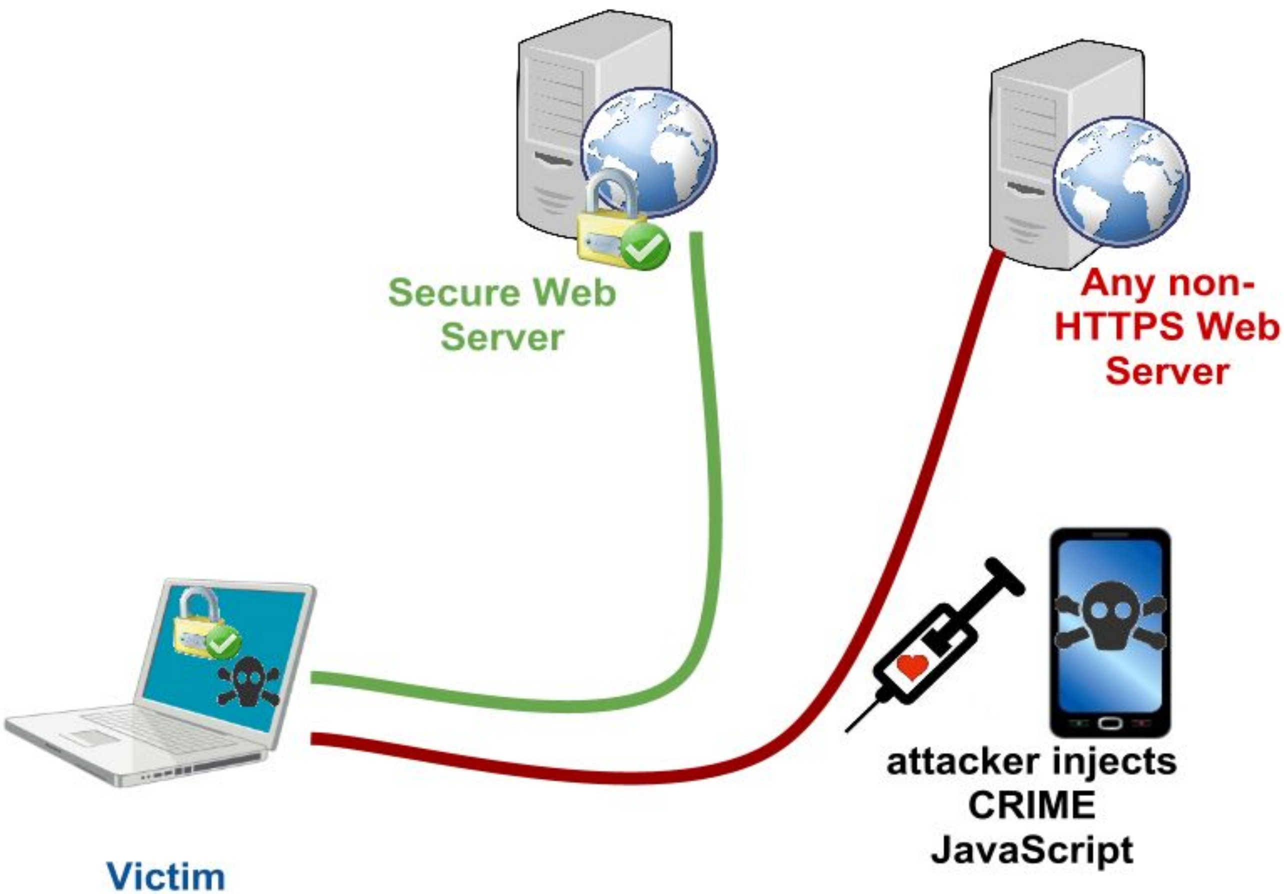


How can you become a victim of CRIME?

- 2nd requirement: you visit evil.com.
  - You click on a link.
  - Or you surf a non-HTTPS site.



CRIME injection



C in CRIME is compression

- Transmit or store the same amount of data in fewer bits.
- When you see compression in Internet protocols, it's probably DEFLATE.
- zlib and gzip are the two most popular DEFLATE wrappers.

Compression is everywhere

- TLS layer compression.

- Application layer compression
  - SPDY header compression,
  - HTTP response gzip compression,
  - Not so sure if exploitable: SSH, PPTP, OpenVPN, XMPP, IMAP, SMTP, etc.

- We will discuss TLS compression, SPDY and HTTP gzip.

DEFLATE

- Lossless compression reducing bits by removing redundancy.

- Best way to learn: RFC 1951 and puff.c.

- DEFLATE consists of two sub algorithms:
    a. LZ77, and
    b. Huffman coding.

DEFLATE: LZ77

- Google is so googley -> Google is so g(-13, 5)y
- It scans input, looks for repeated strings and replaces them with back-references to last occurrence as (distance, length).
- Most important parameter: window size.
    - How far does it go back to search for repetition?
    - Also called dictionary size.

DEFLATE: Huffman coding

- Replace common bytes with shorter codes.

- Build a table that maps each byte with a unique code.
  - Dynamic table: built based on the input, codes can be as short as 1 or 2 bits.
  - Fixed table: specified in the RFC, longer codes (7-9 bits), good for English or short input.

R in CRIME is ratio

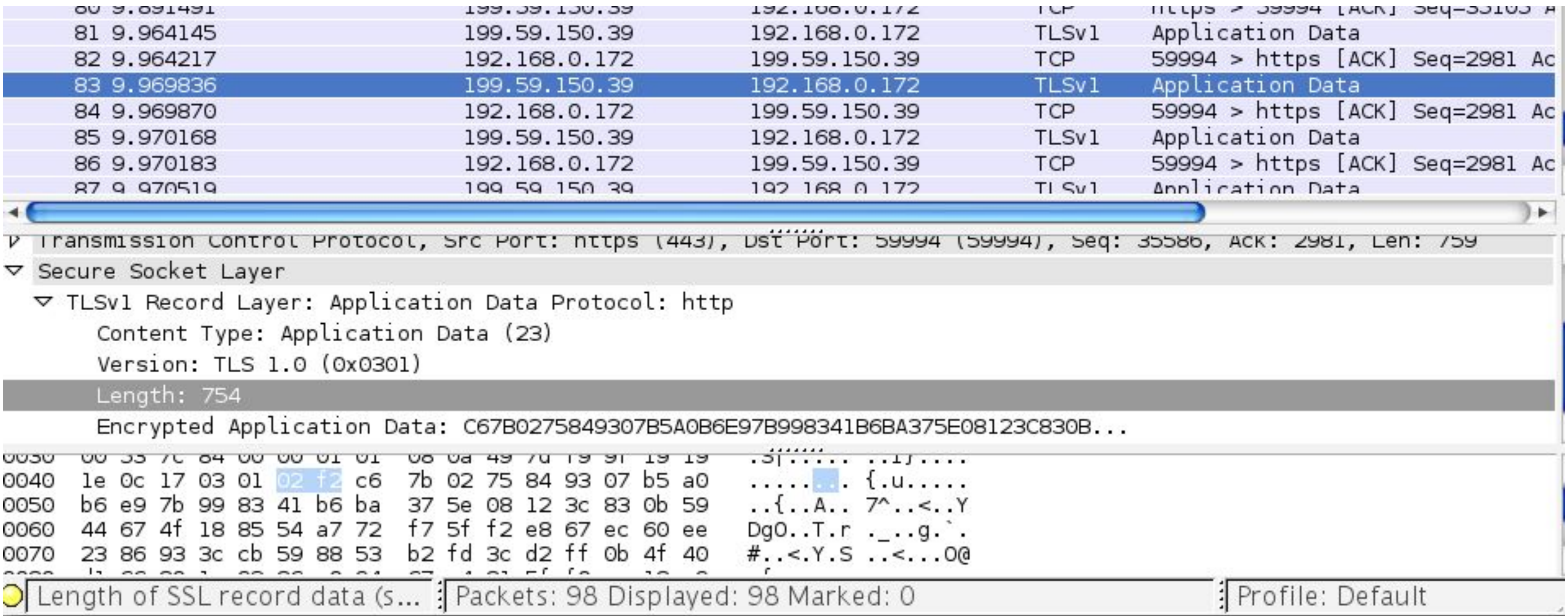
- How much redundancy the message has.

- More redundancy -> better compression ratio -> smaller request length.

- len(compress(input + secret))
  - input is attacker-controlled.
  - If it has some redundancy with secret, length will be smaller.
  - Idea: change input and measure length to guess secret.

I in CRIME is info-leak

- SSL/TLS doesn't hide request/response length.

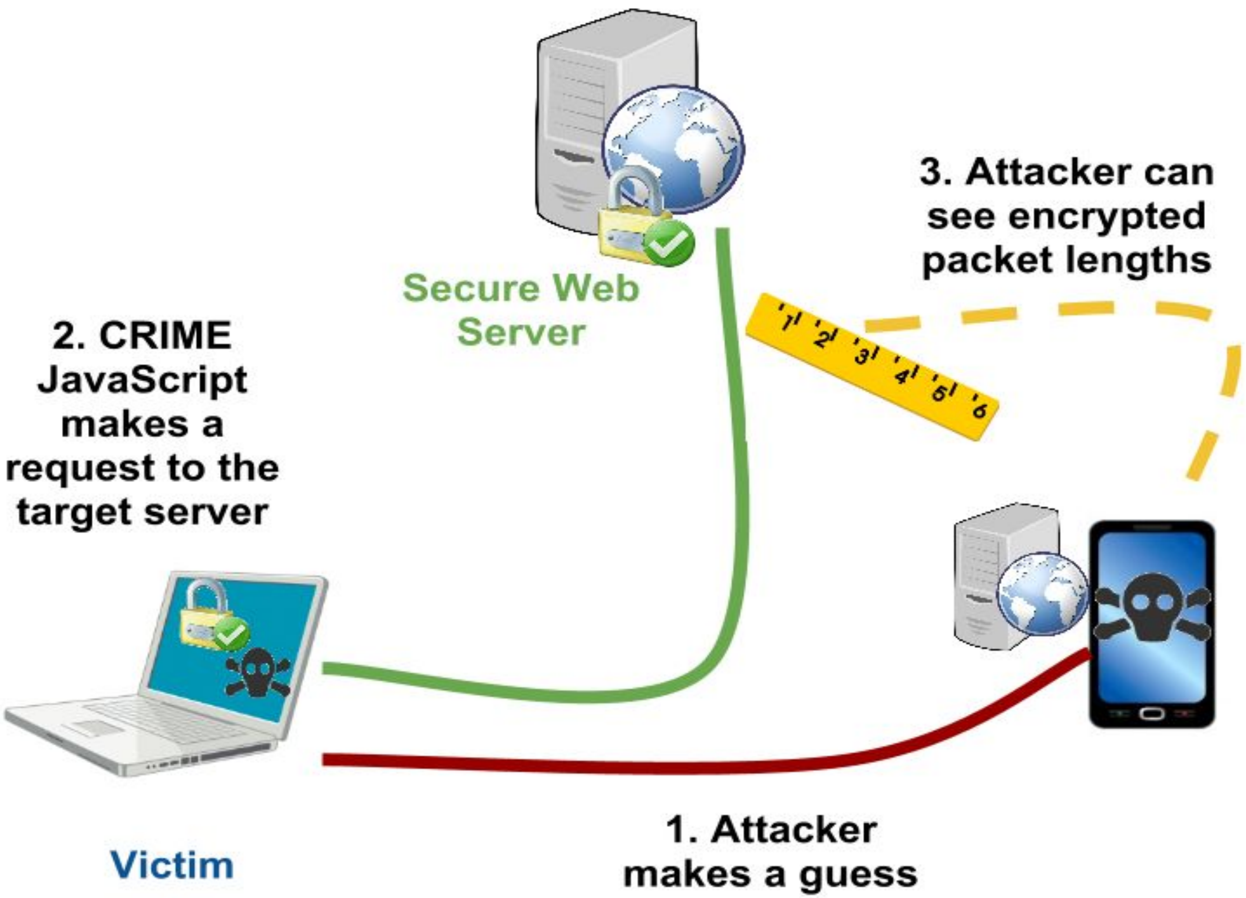


CRIME algorithm

- len(encrypt(compress(input + public + secret)) is *leaked*
  - input: URL path
  - public: known headers
  - secret: cookie
- Algorithm:
  - Make a guess, ask browser to send a request with path as guess.
  - Observe length of the request that was sent.
  - Correct guess is when length is *different* than usual.

```
GET /twid=a
Host: twitter.com
User-Agent: Chrome
Cookie: twid=secret
...
GET /twid=s
Host: twitter.com
User-Agent: Chrome
Cookie: twid=secret
```

CRIME in a slide



ME in CRIME is mass exploitation

- Worked for 45% of browsers: Chrome and Firefox.
- Worked for all SPDY servers: Gmail, Twitter, etc.
- Worked for 40% of SSL/TLS servers: Dropbox, GitHub, etc.

ME in CRIME is also made easy

- JavaScript is optional.

- Fast Hollywood-style decryption. The best algorithm requires on average 6 requests to decrypt 1 cookie byte.

- Worked for all TLS versions and all ciphersuites (AES and RC4).

- Work even if HSTS is active and preloaded.

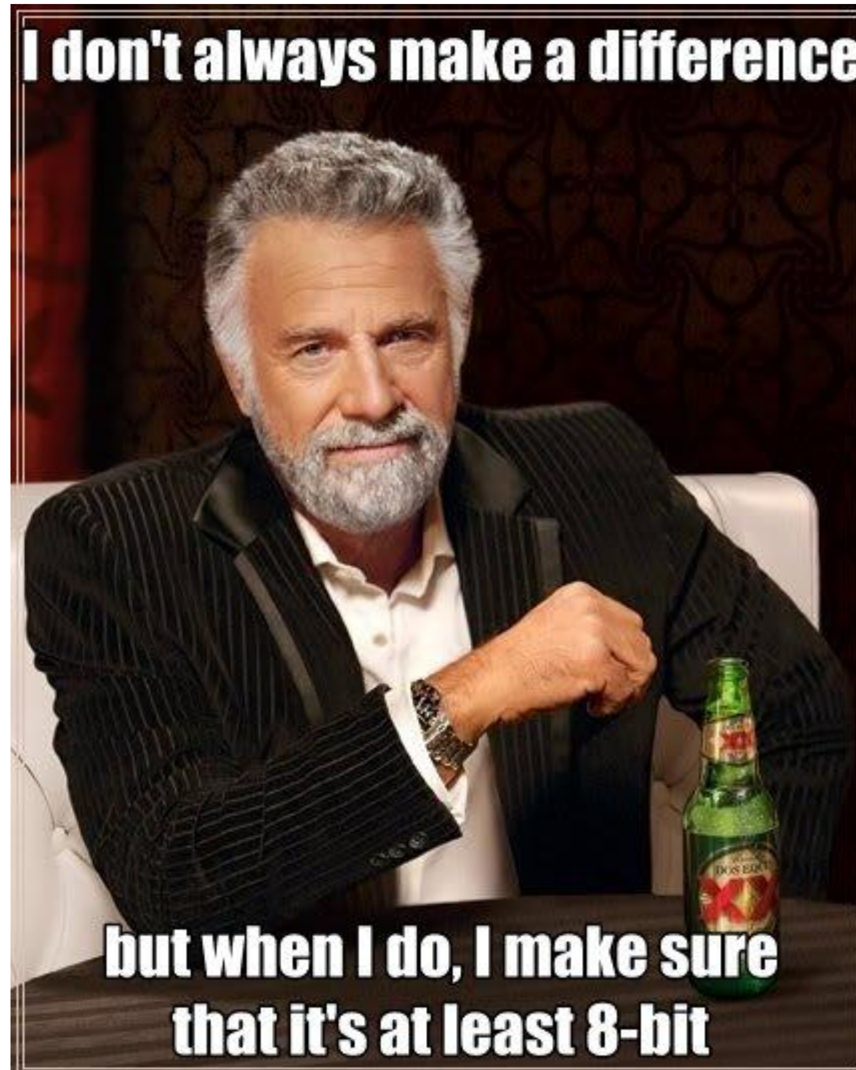
CRIME is the new BEAST

- BEAST opened the path to CRIME
  - Easy to perform chosen-plaintext attack against HTTPS.
  - Use URL path to decrypt cookie.
  - Move data across layer boundary.

- What's new?
  - SSL compressed record length info-leak, instead of CBC mode with chained IVs vulnerability.
  - New boundaries: compressor window size and TLS record size, instead of block cipher's block size.

So length is leaked

- Length is the number of bytes, but DEFLATE outputs bits.
- Length of request with a match must have a difference of at least 8 bits.
    - A 63-bit request looks exactly the same as a 59-bit on the wire.



First attack: Two Tries

- Recall window size: if the distance from the current string to the previous occurrence is greater than window size, it won't be replaced.

- Window size is essentially a data boundary. Let's move thing across it!

- For each guess, send two requests (hence Two Tries)
    - req1 with the guess inside the window of the cookie.
    - req2 is a permutation of req1, with the guess outside.

Two Tries: length difference

- If guess is incorrect:
  - guess won't be replaced by a reference to cookie in neither req1 nor req2.
  - hence, len(req1) == len(req2).

- If guess is correct:
  - guess will be replaced by a reference to cookie in req1.
  - guess *won't* be replaced in req2, because it's *outside* the window.
  - hence, len(req1) != len(req2).

Two Tries

- Oracle:
  - If len(req1) != len(req2), then the guess is correct;
  - It's incorrect otherwise.

GET /ABCDEFtwid=s<padding>Cookie: twid=secret

GET /twid=sABCDEF<padding>Cookie: twid=secret

Two Tries

- Pros:
  - Work for TLS compression, SPDY and HTTP gzip as well.
  - False positive free with a few tricks.

- Cons
  - Require O(W) requests, where W is cookie charset.
  - May fail when cookie contains repeated strings.
  - Depend on deep understanding of DEFLATE and zlib's deflate.c to create a 8-bit difference.

SPDY

- A new open networking protocol for transporting web content.

- Similar to HTTP, with particular goals to reduce web page load latency and improve web security.

- SPDY achieves reduced latency through *compression*, multiplexing, and prioritization.

SPDY

- Standardized: selected by IETF as the starting point for HTTP 2.0.

- Servers: Google, Twitter, Wordpress, F5 Networks, Cloudflare, Apache httpd, nginx, etc.

- Clients: Chrome, Firefox, Opera (beta), etc.

Compression in SPDY

- DEFLATE is used to compress headers.

- SPDY uses the same compression context for all requests in one direction on a connection.
  - repeated strings in new requests can be replaced by references to old requests.

CRIME for SPDY

- The shared compression context is a two-edged sword
  - Better compression.
  - Subsequent compressed headers are so small that zlib decides to use *fixed* Huffman table.

- Recall that fixed Huffman table uses 7-9 bit codes. Hence, it's easier to have a difference of 8 bits.

CRIME for SPDY

1. Send a request to "reset" the compression context (i.e., prepare the dictionary).

2. Send another request with a wrong guess to get the base length.

3. For each guess, send a request. Use the base length to spot possible correct guesses.

CRIME for SPDY

GET /aatwid=a HTTP/1.1\r\n (-84, 5)aa(-20, 5)a(-84, 71)
Host: twitter.com\r\n
User-Agent: Chrome\r\n
Cookie: twid=secret\r\n

GET /bbtwid=b HTTP/1.1\r\n (-84, 5)bb(-20, 5)b(-84, 71)
Host: twitter.com\r\n
User-Agent: Chrome\r\n
Cookie: twid=secret\r\n

CRIME for SPDY

GET /rrtwid=r HTTP/1.1\r\n (-84, 5)rr(-20, 5)r(-84, 71)
Host: twitter.com\r\n
User-Agent: Chrome\r\n
Cookie: twid=secret\r\n

GET /sstwid=s HTTP/1.1\r\n (-84, 5)ss(-20, 6)(-84, 71)
Host: twitter.com\r\n
User-Agent: Chrome\r\n
Cookie: twid=secret\r\n

CRIME for SPDY

- Pros
  - Still O(W), but with a smaller constant than Two Tries.
  - Very fast, thanks to SPDY.
  - Also false positive free.

- Cons
  - Can't send many requests at a time if server sets a maximum limit.
  - Different browsers have different implementations of SPDY header compression.

CRIME for SPDY

- Workaround
  - Chrome and Firefox have disabled header compression in their SPDY implementations.

- SPDY/4 will make CRIME irrelevant (hopefully).

Compression in TLS

- Specified in RFC 3749 (DEFLATE) and RFC 3943 (LZS).
- Chrome (NSS), OpenSSL, GnuTLS, etc. implement DEFLATE.
- If data is larger than maximum record size (16K), it split-then-compress each record independently (in a separate zlib context).

CRIME for TLS Compression: 16K-1

- 16K is essentially another boundary. BEAST's chosen-boundary attack strikes again!

- Make a request so big that it will be split into two records such that:
  - 1st record: GET /<padding>Cookie: twid=s
  - 2nd record: ecret

- Simulate the compression of the 1st record for every candidate.

- Send the request, obtain the compressed length of its 1st record. Use it to select possible correct bytes.

16K-1

16K

```
GET /AAAAAFILLTHERECORDAAAAA HTTP/1.1\r\n
Host: twitter.com\r\n
Cookie: twid=S
```

I'm so lonely :(

16K

```
ecret\r\n
```

16K-1 POC

```
def next_byte(cookie, known, alphabet=BASE64):
    candidates = list(alphabet)
    while len(candidates) != 1:
        url = random_16K_url(known)
        record_lens = query(url)
        length = record_lens[0]
        record = "GET /%s%s%s" (url, REQ, known)
        good = []
        for c in candidates:
            if len(compress(record + c)) == length:
                good.append(c)
        candidates = good
    return candidates[0]
```

CRIME for TLS Compression

- Pros
  - Require only O(logW) requests. Can choose between longer offline compression or larger number of online requests.
  - False positive free.
  - Compression algorithm independent.

- Cons
  - While server-side deployment is 40%, Chrome was the only browser that supported TLS compression.
  - zlib versions on victim and attacker should be the same.

CRIME for TLS Compression

- Workaround
  - Chrome has disabled compression in its ClientHello.

HTTP response gzip compression

- The most popular compression on the Internet.

- Just a wrapper on top of DEFLATE.

- CRIME works like a charm.

CRIME for HTTP gzip

- Requirement: server echoes back some client input in the response (e.g., /search?q=crimeN0tF0uddd).

- Use the echoed input to extract PII or XSRF token embedded in the response.

- Two Tries may work, but we haven't tested it yet.

"We believe"

- TLS compression may resurrect in the near future
  - "Browsers are not the only TLS clients!"
- HTTP gzip may be a bigger problem than both SPDY and TLS compression
  - If you control the network, then a XSRF token is as good as, if not better, a session cookie.
- Remember: compression is *everywhere*.

Thanks

- Google, Mozilla, and Dropbox.
- Dan Boneh, Agustin Gianni, Kenny Paterson, Marsh Ray, Eduardo Vela and many other friends.
- EKOPARTY xD xD xD!!

Related work

- *John Kelsey*, Compression and Information Leakage of Plaintext.

- *Adam Langley*, post to SPDY mailing list.

Questions?

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