Protecting the Data That Drives Business

A Perfect CRIME? TIME Will Tell

Tal Be’ery, Web research TL

Agenda

- BEAST
  - Modes of operation
- CRIME
  - Gzip compression
  - Compression + encryption leak data
- TIME
  - Timing + compression leak data
- Attacking responses

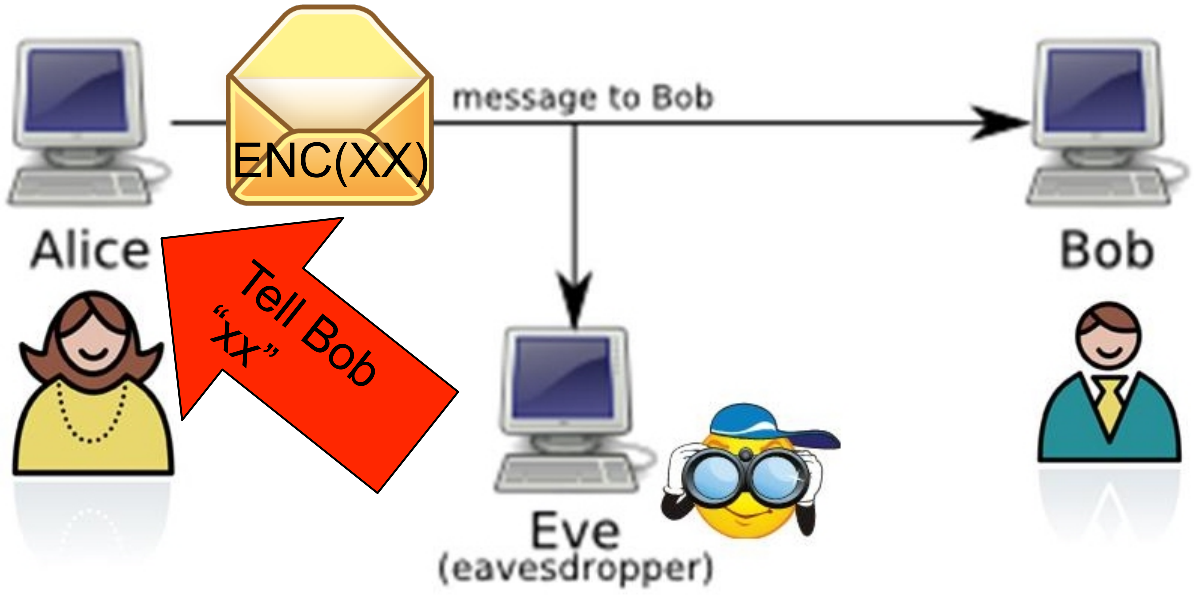
BEAST

BEAST

- Rizzo and Duong - 2011
- Browser Exploit Against SSL/TLS (BEAST)
- Chosen Plaintext Attack
- Targets deterministic Initialization Vectors of Cipher-Block Chaining (CBC)

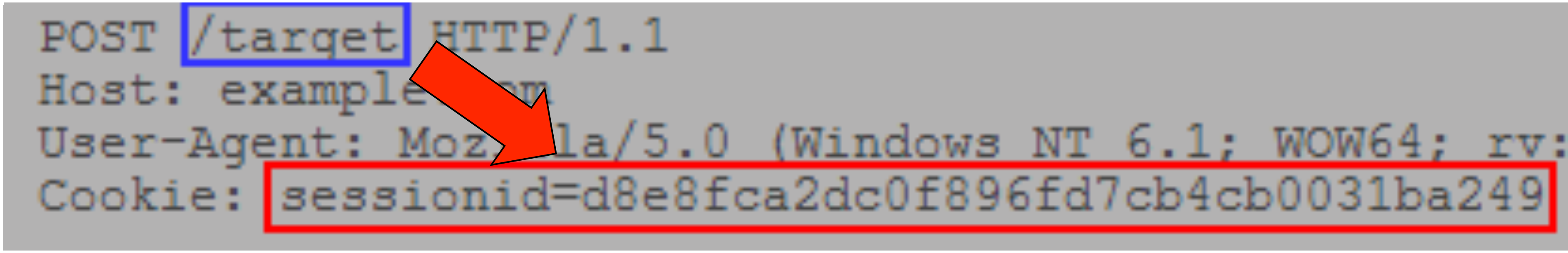
Chosen Plaintext Attack Model

- **A chosen-plaintext attack (CPA)** is an attack model for cryptanalysis which presumes that the attacker has the capability to choose arbitrary plaintexts to be encrypted and obtain the corresponding ciphertexts.



CPA and the web

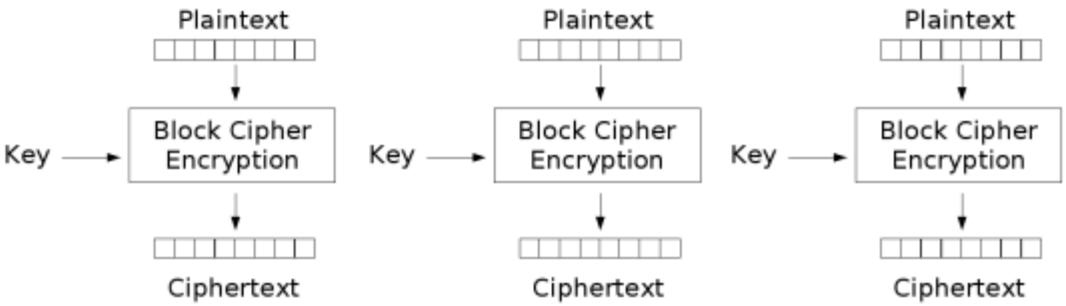
- Attacker is Eavesdropper – can see ciphered text
- Attacker creates HTTP request interactively (via script)
  - Full control (almost): URL
  - Can predict: Most headers
  - Does not control or see: cookies
    - Encrypted on wire
    - Not accessible from script
      - Same Origin Policy
      - "HTTP only"



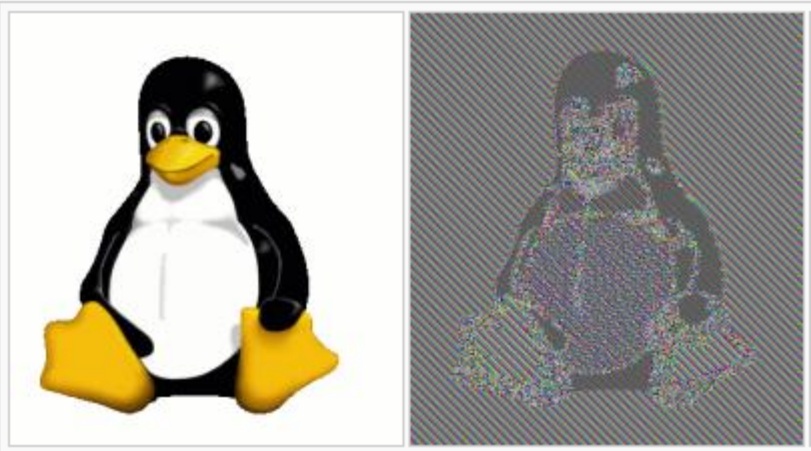
```
POST /target HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249
```

Modes of operation

- procedure of enabling the repeated and secure use of a block cipher under a single key



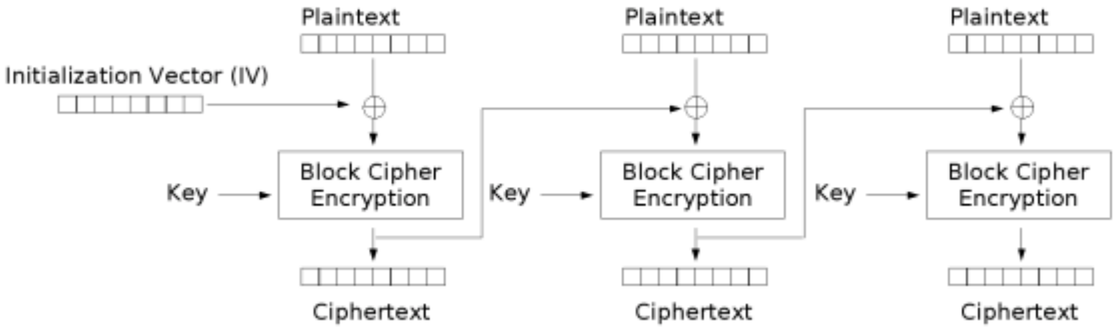
Electronic Codebook (ECB) mode encryption



Original image

Encrypted using ECB mode

Modes of operation - CBC

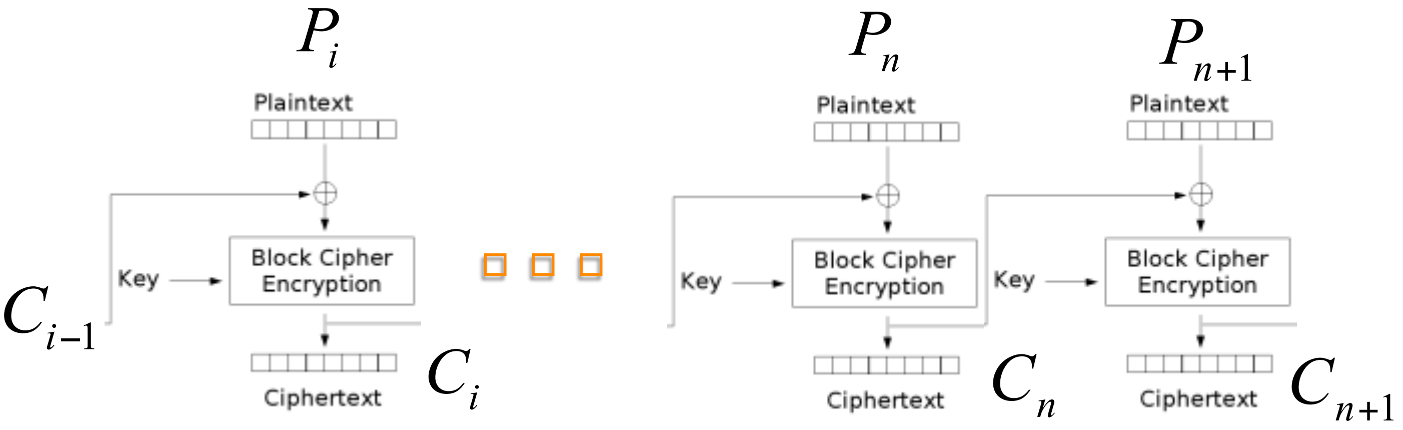


Cipher Block Chaining (CBC) mode encryption

- Previous block encryption result is fed as an IV to the next block
- Encryption becomes "Stateful"

CBC Oracle

- Attacker can verify a guess of any plaintext block



$$P_{n+1} = C_n \oplus C_{i-1} \oplus \tilde{P}_i$$

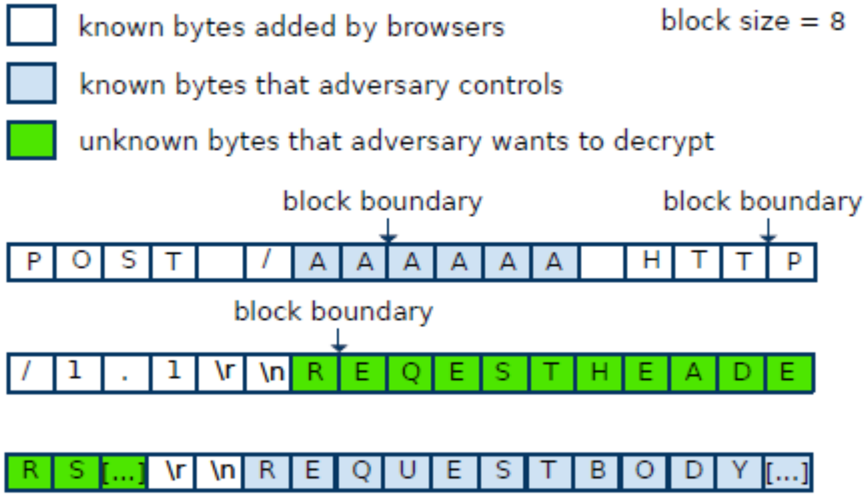
$$C_{n+1} = Enc(P_{n+1} \oplus C_n) = Enc(C_n \oplus C_{i-1} \oplus \tilde{P}_i \oplus C_n) = Enc(C_{i-1} \oplus \tilde{P}_i)$$

$$\tilde{P}_i = P_i \Rightarrow C_{n+1} = Enc(C_{i-1} \oplus P_i) = C_i$$

$$\tilde{P}_i \neq P_i \Rightarrow C_{n+1} \neq C_i$$

Using the CBC oracle to decrypt the Cookie

- Attacker knows in which block the cookie resides
- Attacker controls the block contents so she can guess only one byte at a time and verify with the oracle
  - 256 guesses on worst case
- Repeat the process to discover all bytes in Cookie



□ known bytes added by browsers

block size = 8

▨ known bytes that adversary controls

🟩 unknown bytes that adversary wants to decrypt

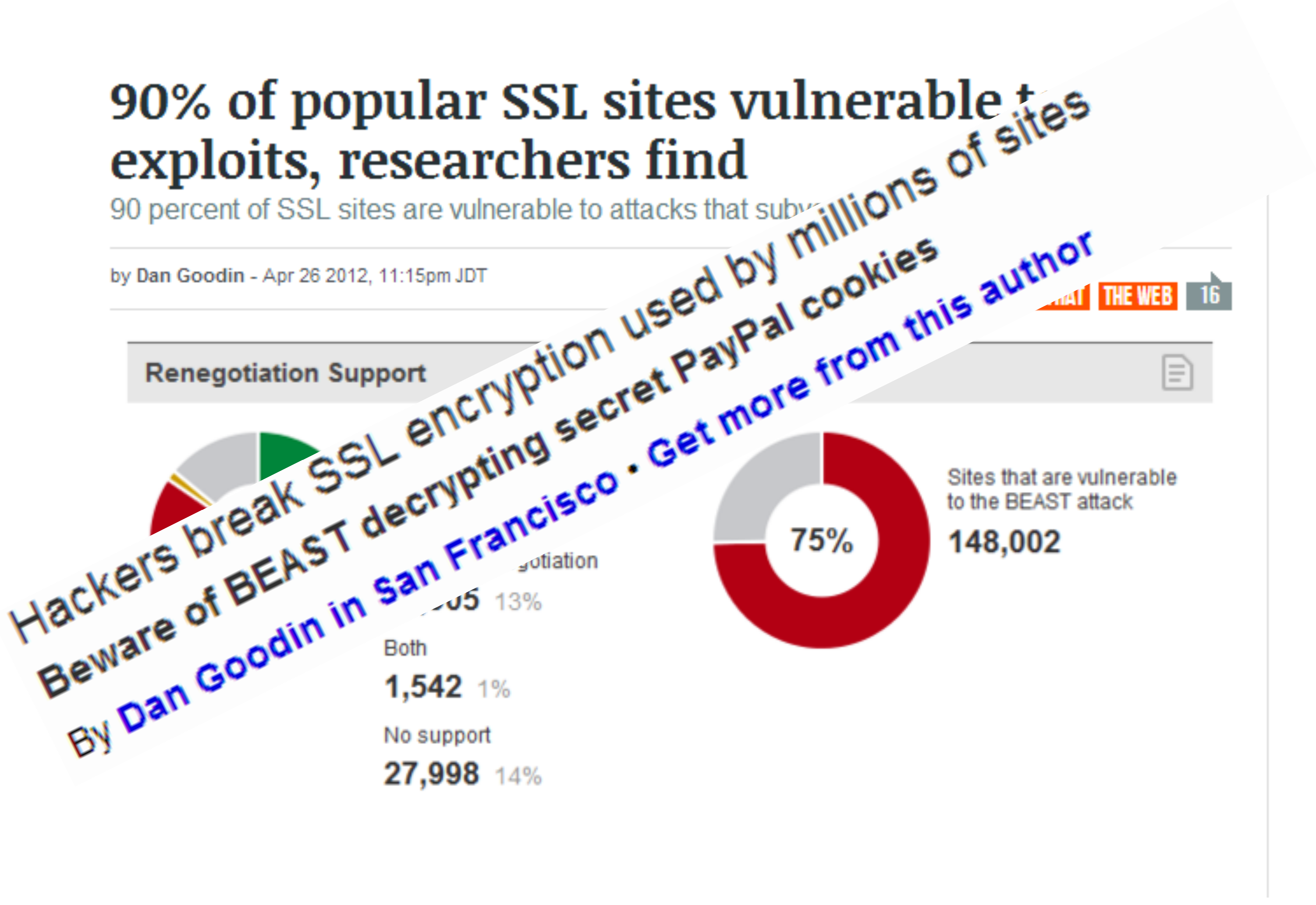
block boundary
block boundary
P O S T / A A A A A A H T T P
block boundary
/ 1 . 1 \r \n R E Q E S T H E A D E
R S [...] \r \n R E Q U E S T B O D Y [...]

Practical issues

- HTTP requests ar ide for BEAST:
  - New request on
  - First bytes GET /POST /, e
  - URL can Only some cha are allowed
- The attac eeds i-directiona ection
  - Web sc Java, Silv
  - All of th chnologies re e
- So to expl ra vulnerbali
  - SOP bug i ementation
  - XSS in victim

NOT PRACTICAL

And yet...



90% of popular SSL sites vulnerable t
exploits, researchers find

90 percent of SSL sites are vulnerable to attacks that sub

by Dan Goodin - Apr 26 2012, 11:15pm JDT

Renegotiation Support

gotiation
05 13%

Both
1,542 1%

No support
27,998 14%

75%

Sites that are vulnerable to the BEAST attack
148,002

Hackers break SSL encryption used by millions of sites

Beware of BEAST decrypting secret PayPal cookies

By Dan Goodin in San Francisco • Get more from this author

Mitigations

- TLS 1.1 mitigates
  - Explicit IV
  - Not widely adopted
- Some advise to switch to SSL with stream ciphers
  - RC4

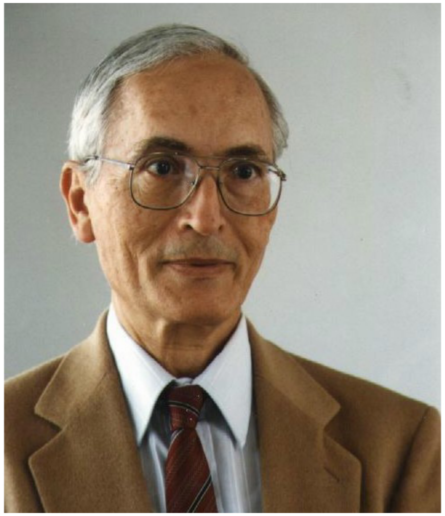
CRIME

CRIME

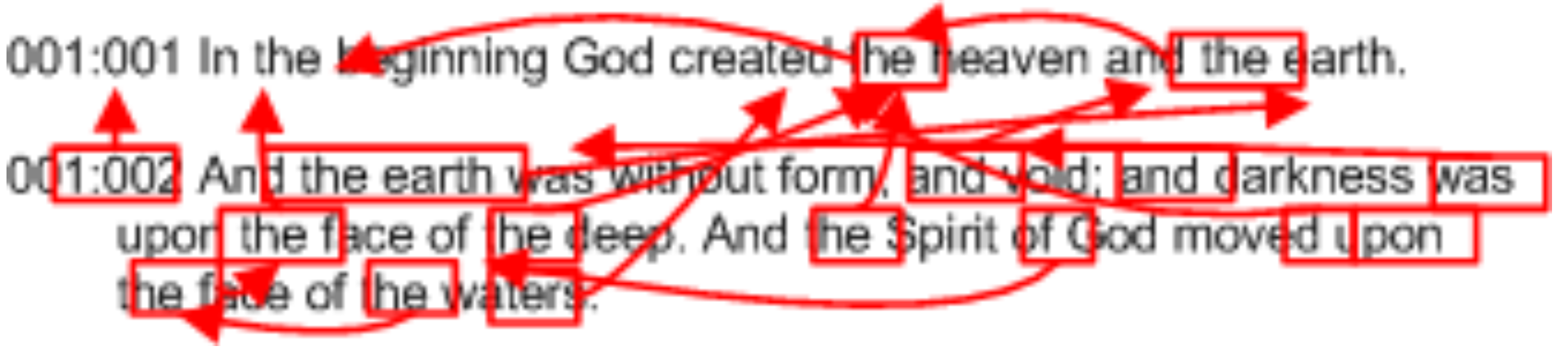
- Rizzo and Duong – 2012
- Compression Ratio Info-leak Made Easy (CRIME)
- Chosen Plaintext Attack
- Targets compression information leakage

Compression – LZ algorithms

- Lempel Ziv, late 70s
- Compress repeating strings
  - + Lossless
  - + Asymptotically optimal
  - + No overhead (No extra dictionary)



LZ Compression – Example



001:001 In the beginning God created the heaven and the earth.

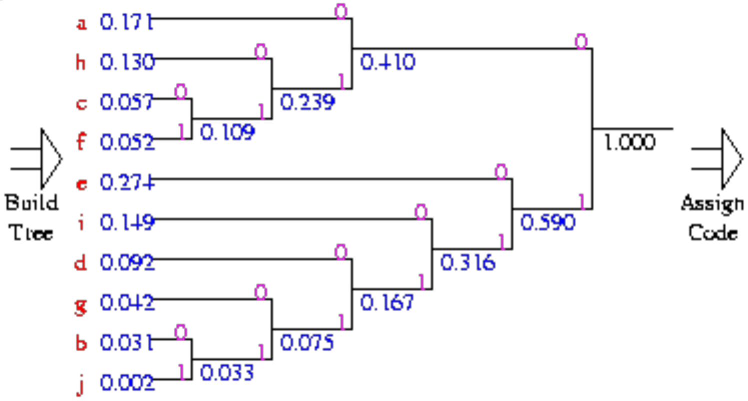
001:002 And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters.

- 001:001 In the beginning God created<25, 5>heaven an<14, 6>earth. 0<63, 5>2 A<23, 12> was without form,<55, 5>void;<9, 5>darkness<40, 4> <0, 7>upo<132, 6>face of<11, 5>deep.<93, 9>Spirit<27, 4><158, 4>mov<156, 3><54, 4><67, 9><62, 16>w<191, 3>rs

Huffman code

- David Huffman - 1952
- Assign shorter codes (in bits) for frequent letters
- Note - Prefix code is a must!
  - Since we cannot rely on length to parse

X	p(X)
a	0.171
b	0.031
c	0.057
d	0.092
e	0.274
f	0.052
g	0.042
h	0.130
i	0.149
j	0.002



X	Code
a	0 0
b	1 1 1 1 1 0
c	0 1 1 0
d	1 1 1 0
e	1 0
f	0 1 1 1
g	1 1 1 1 0
h	0 1 0
i	1 1 0
j	1 1 1 1 1 1

Compression & Encryption

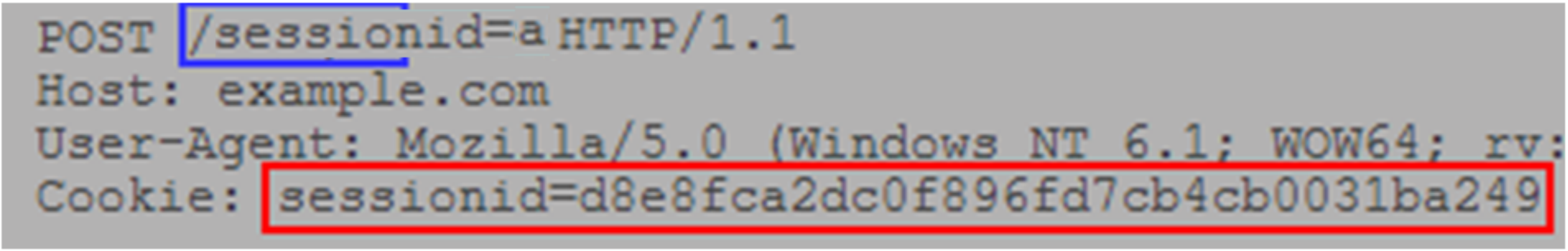
Compression & Encryption

Compression on the web

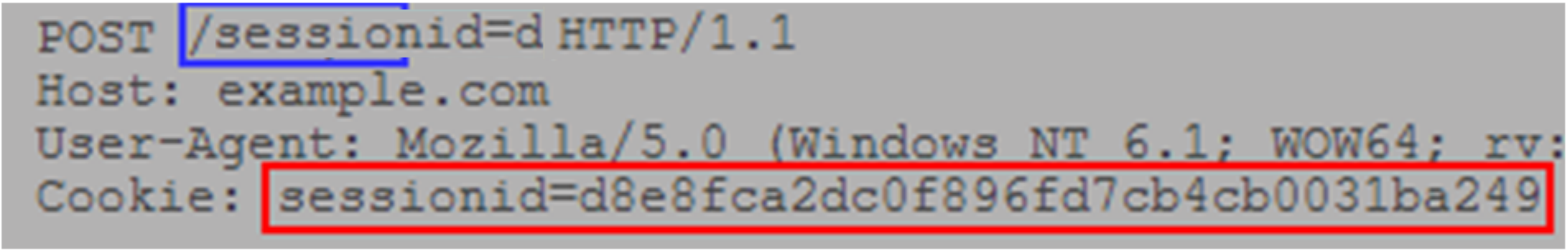
- Content compression
  - GZIP on response
  - On request body (Uncommon)
- Header compression
  - SSL/TLS Compression
    - Servers: Open SSL, others
    - Clients: Chrome
  - SPDY
    - Servers: Apache MOD_SSL, others
    - Clients: All but IE

Compression leaks data

- Again
  - Use the URL attacker controls
  - Guess byte by byte
  - Verify with an oracle
    - If we had guessed correctly then packet size will be shorter

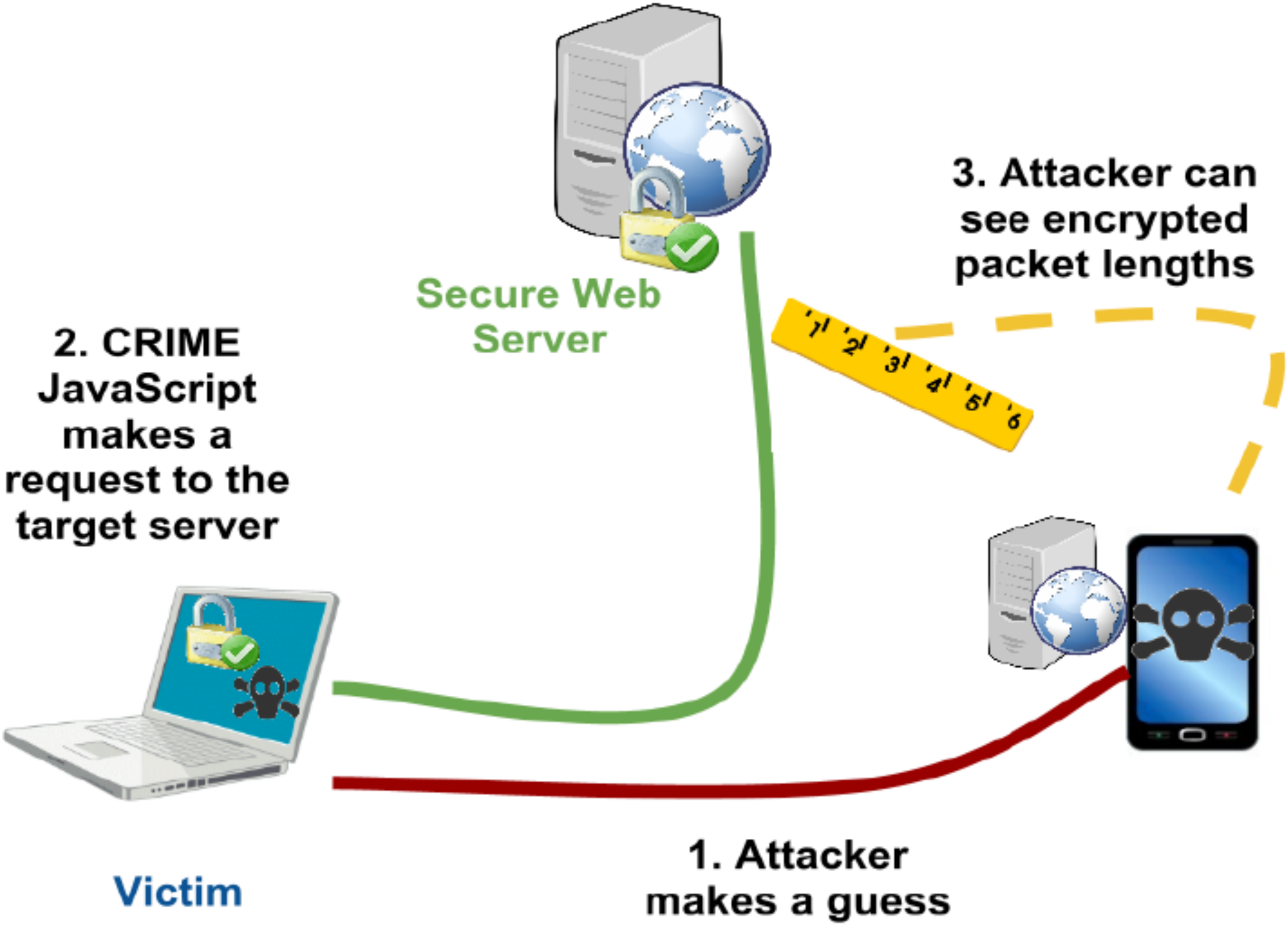


```
POST /sessionid=a HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249
```



```
POST /sessionid=d HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249
```

CRIME in a slide



Secure Web Server
3. Attacker can see encrypted packet lengths
'1' '2' '3' '4' '5' '6
2. CRIME JavaScript makes a request to the target server
Victim
1. Attacker makes a guess

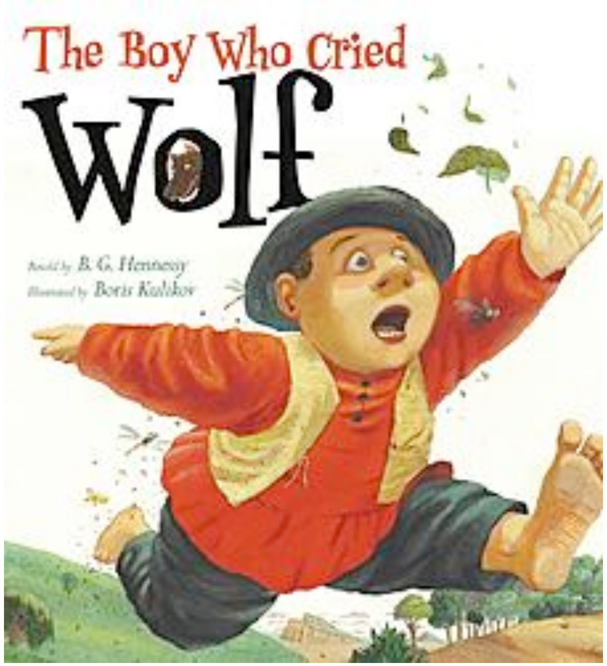
oung & Rizzo original presentation
https://docs.google.com/presentation/d/11eBmGiHbYcHR9gL5nDyZChu_-lCa2GizeuOfaLU2HOU/present#slide=id.g1d134dff_1_157

Practical issues

- HTTP requests are a good vehicle for CRIME:
  - New requests over SPDY use the same SSL connection and compression context
  - The controlled part is “location tolerant”
  - The controlled part can express needed alphabet
- Some issues with Huffman coding
  - Some chars representation < 1 byte
  - Good guess might get unnoticed
- Solutions
  - Mostly tricks to make GZIP compress with not so aggressive Huffman coding

Impact

- Actual impact
  - SPDY implementations cancel/modify header compression
  - Chrome disabled SSL compression
- PR Impact
  - Much less than BEAST
  - The boy who cried BEAST syndrome



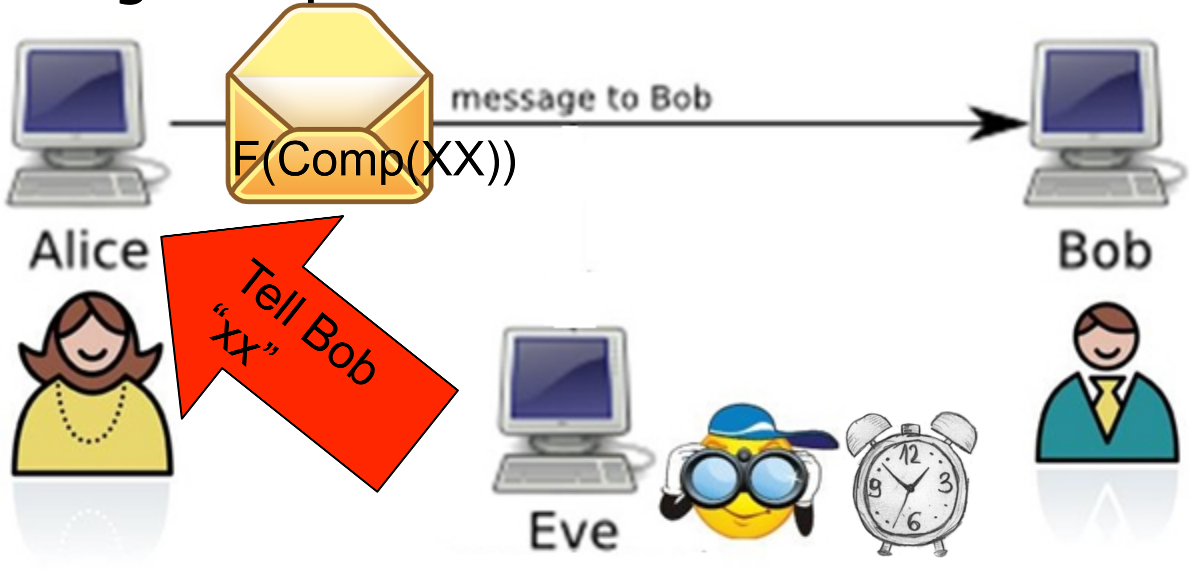
TIME

TIME

- Imperva – 2013
- Timing Info-leak Made Easy (TIME)
- Chosen Plaintext Attack
- Targets compression and timing information leakage

Attack Model

- Attacker has the capability to choose arbitrary plaintexts to be <u>compressed</u> and obtain timing observations on their traffic
- Attacker is no longer an Eavesdropper - attack might be useful against plaintext too!



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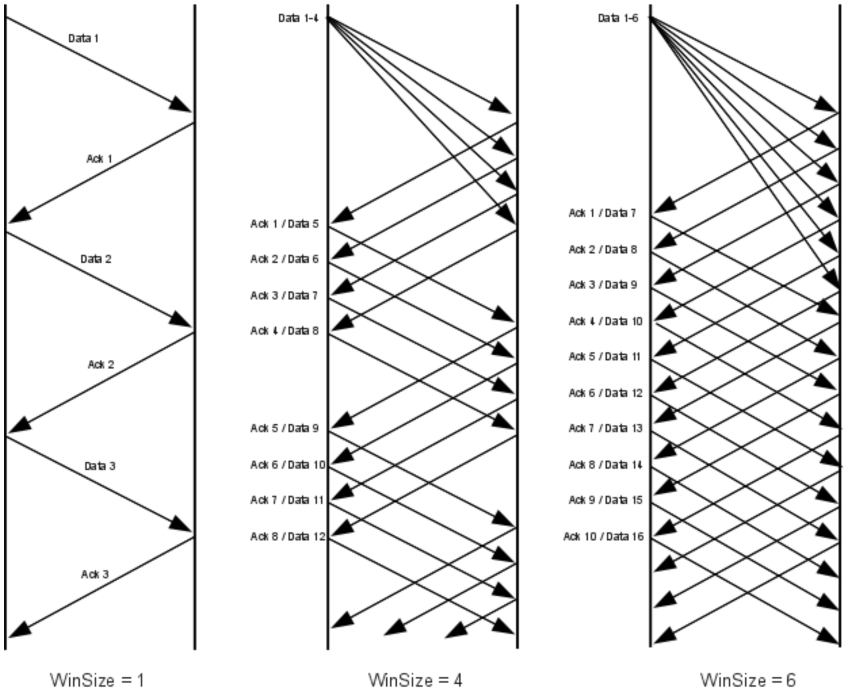
Timing oracle

- Client send a window of TCP packets
- Waits RTT for ACK to send another
- RTT time is noticeable
- attacker can easily distinguish
  - Size(request) <= window
  - Size(request) > window
- If payload length is exactly on data boundary, attacker can determine 1 byte differences



Sliding Windows, bandwidth 6 packets/RTT

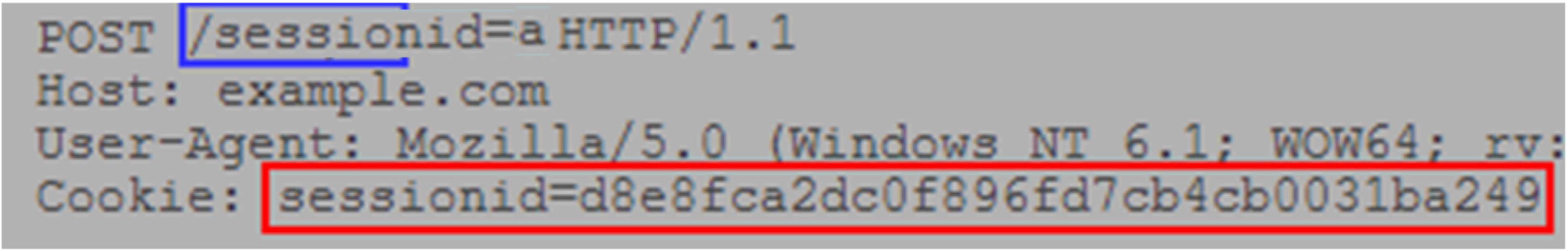
http://ulam2.cs.luc.edu/ebook/chap03.html

HTTP Request’s Time Measurements

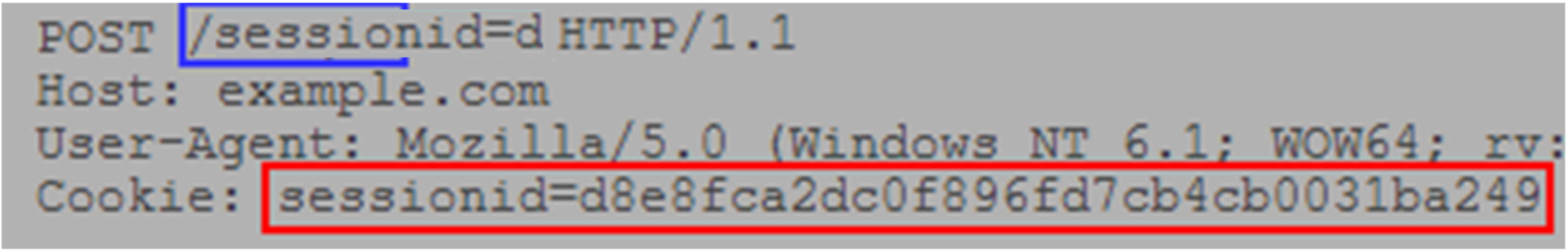
- Create HTTP request with XHR
  - XHR adheres to SOP
  - Allows GET requests to flow
    - If headers allow show response
    - If not, abort
  - We don’t care for the response
  - Timing leaks the request size
- Use getTime() on XHR events
  - onreadystatechange
- Noise elimination
  - Repeat the process (say 10 times) and obtain **Minimal** time

Compression leaks data

- Again
  - + Use the URL attacker controls
  - + Guess byte by byte
  - + Verify with an oracle
    - – If we had guessed correctly: packet size will be shorter and so will the time



```
POST /sessionid=a HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249
```



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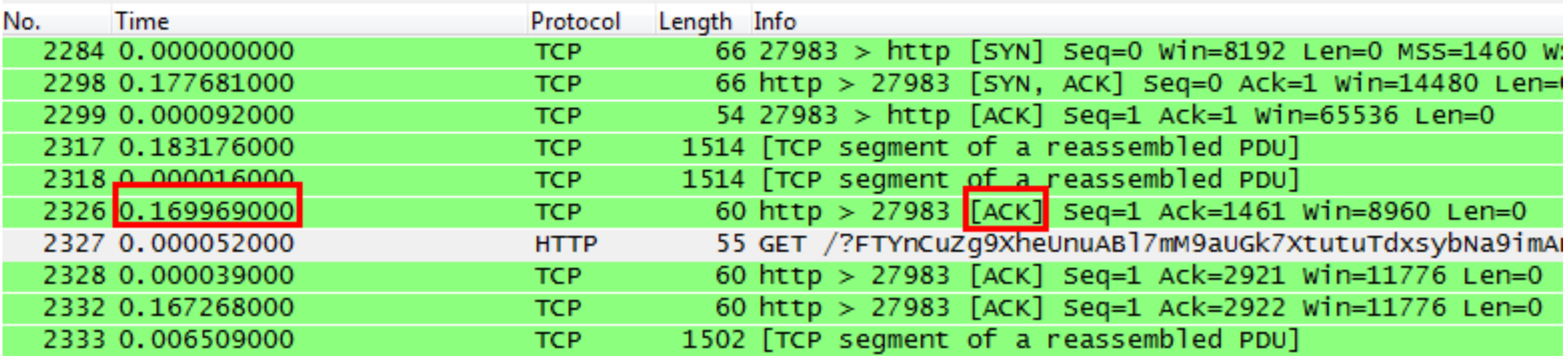
POST /sessionid=d HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Windows NT 6.1; WOW64; rv:
Cookie: sessionid=d8e8fca2dc0f896fd7cb4cb0031ba249
```

RTT Gap in the wild

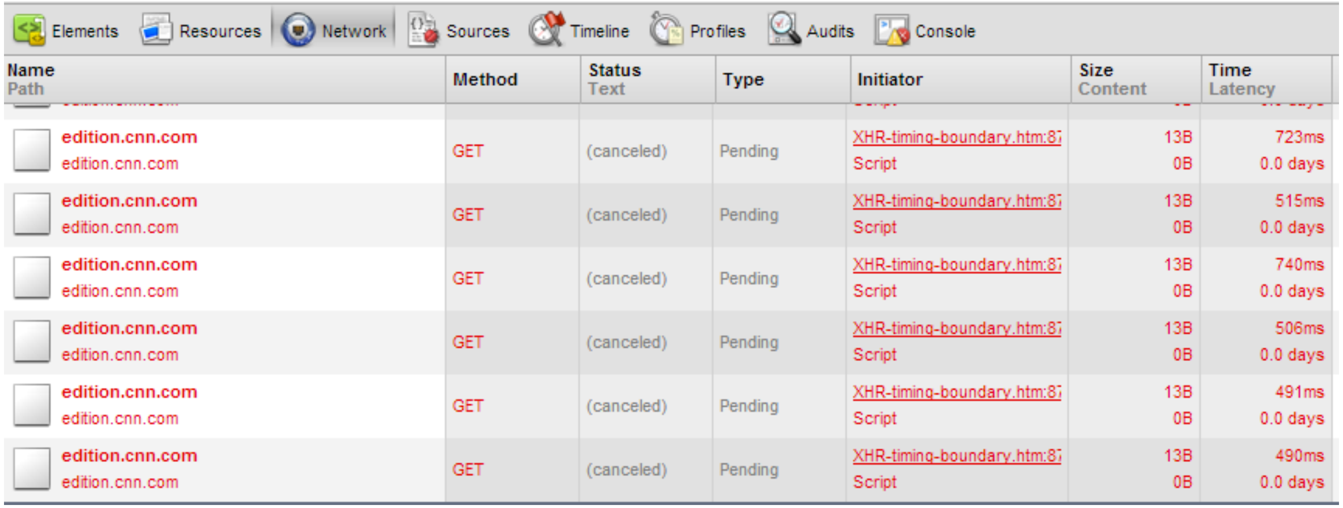
- Sent with Chrome
- Sends 2 packets and wait
- If you need to send 3 packets – pay extra RTT



No.	Time	Protocol	Length	Info
2284	0.000000000	TCP	66	27983 > http [SYN] Seq=0 Win=8192 Len=0 MSS=1460 W
2298	0.177681000	TCP	66	http > 27983 [SYN, ACK] Seq=0 Ack=1 Win=14480 Len=
2299	0.000092000	TCP	54	27983 > http [ACK] Seq=1 Ack=1 Win=65536 Len=0
2317	0.183176000	TCP	1514	[TCP segment of a reassembled PDU]
2318	0.000016000	TCP	1514	[TCP segment of a reassembled PDU]
2326	0.169969000	TCP	60	http > 27983 [ACK] Seq=1 Ack=1461 Win=8960 Len=0
2327	0.000052000	HTTP	55	GET /?FTYnCuZg9XheUnuABl7mM9aUGk7XtutuTdxsybNa9imA
2328	0.000039000	TCP	60	http > 27983 [ACK] Seq=1 Ack=2921 Win=11776 Len=0
2332	0.167268000	TCP	60	http > 27983 [ACK] Seq=1 Ack=2922 Win=11776 Len=0
2333	0.006509000	TCP	1502	[TCP segment of a reassembled PDU]

RTT Gap in the wild – implementing the Oracle

- HTML with Javascript Sending method is XHR
- Testing cnn.com
- Timing can be correctly captured
- Results are conclusive



Name Path	Method	Status Text	Type	Initiator	Size Content	Time Latency
edition.cnn.com edition.cnn.com	GET	(canceled)	Pending	XHR-timing-boundary.htm:87 Script	13B 0B	723ms 0.0 days
edition.cnn.com edition.cnn.com	GET	(canceled)	Pending	XHR-timing-boundary.htm:87 Script	13B 0B	515ms 0.0 days
edition.cnn.com edition.cnn.com	GET	(canceled)	Pending	XHR-timing-boundary.htm:87 Script	13B 0B	740ms 0.0 days
edition.cnn.com edition.cnn.com	GET	(canceled)	Pending	XHR-timing-boundary.htm:87 Script	13B 0B	506ms 0.0 days
edition.cnn.com edition.cnn.com	GET	(canceled)	Pending	XHR-timing-boundary.htm:87 Script	13B 0B	491ms 0.0 days
edition.cnn.com edition.cnn.com	GET	(canceled)	Pending	XHR-timing-boundary.htm:87 Script	13B 0B	490ms 0.0 days

Script results

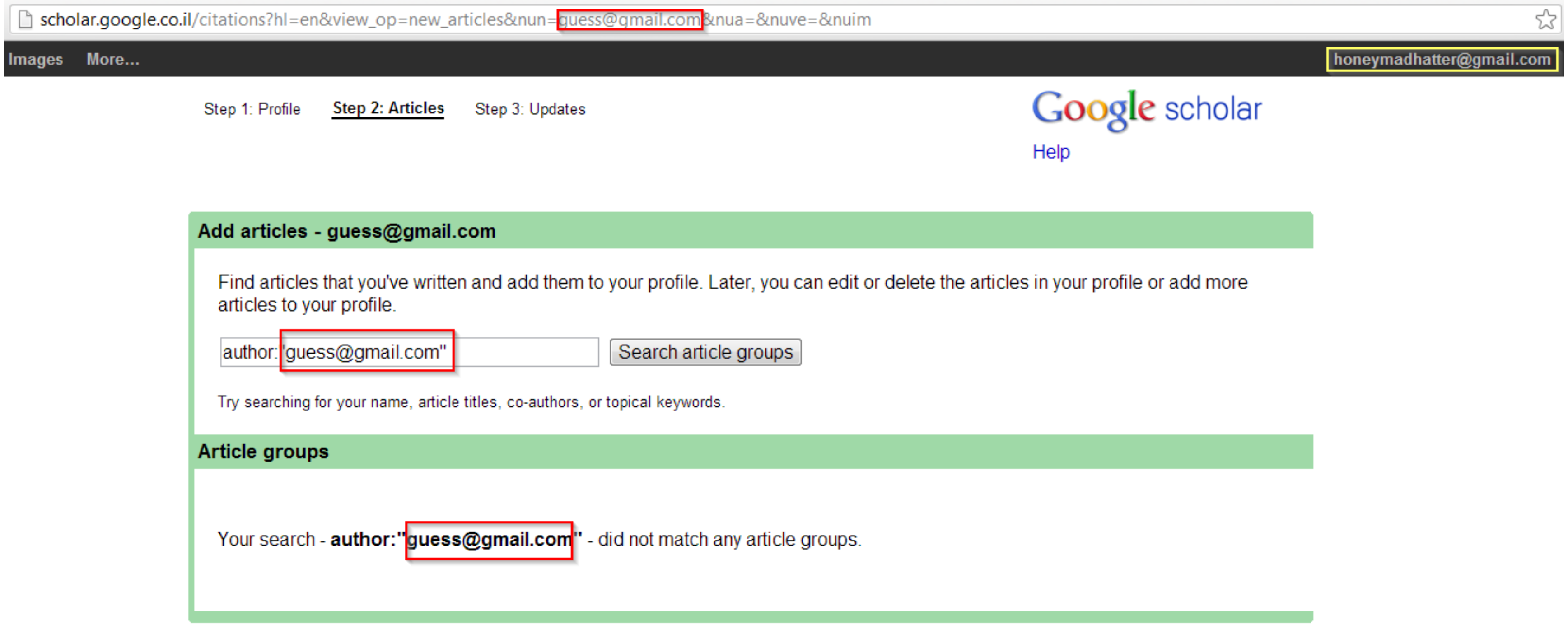
2515,717
2514,512
2515,738
2514,504
2515,490
2514,490
Min first 468
Min Second 246

Attacking responses

Attacking response

- Detecting size – remains the same
- Generating requests – remains the same
- Main change
  - Attacker can only control the response indirectly
  - For example with the search functionality

Attack PoC



scholar.google.co.il/citations?hl=en&view_op=new_articles&nun=guess@gmail.com&nua=&nuve=&nuim

Add articles - guess@gmail.com

Find articles that you've written and add them to your profile. Later, you can edit or delete the articles in your profile or add more articles to your profile.

author:"guess@gmail.com"

Try searching for your name, article titles, co-authors, or topical keywords.

Article groups

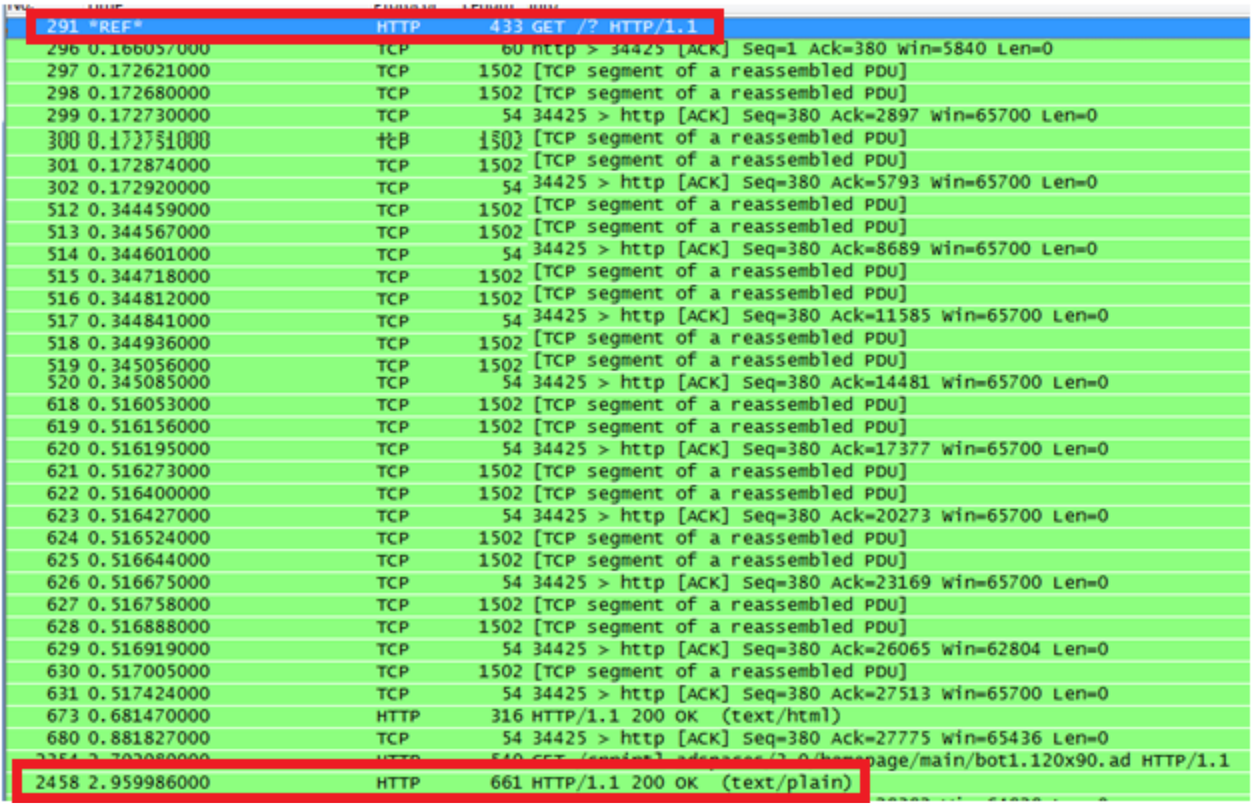
Your search - **author:"guess@gmail.com"** - did not match any article groups.

Attack PoC demo

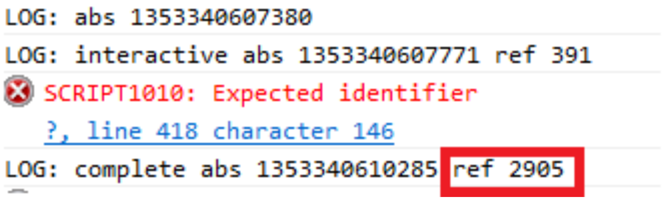
HTTP Response Time Measurements

- Create HTTP request with iframe
  - iframe adhere to SOP
  - Doesn’t allow parent to access the response content
  - Timing leaks the response size
- Use getTime() on iframe events
  - onLoad
  - Onreadystatechange (IE)
- Noise elimination – as before

HTTP Response Time Measurements



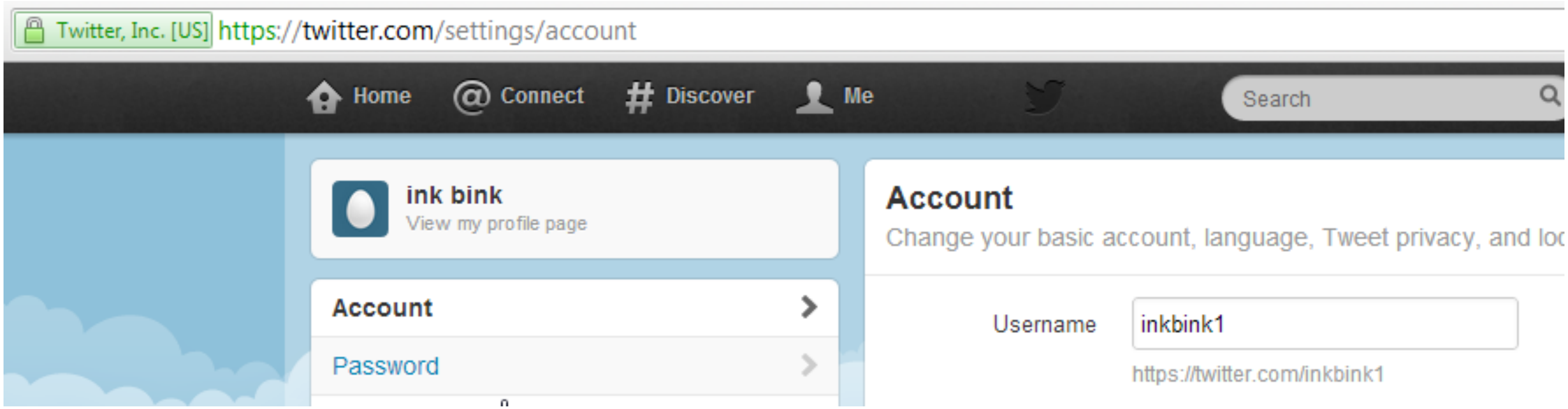
```
 291 *REF*          HTTP    433 GET /? HTTP/1.1
 296 0.166057000    TCP      60 http > 34425 [ACK] Seq=1 Ack=380 Win=5840 Len=0
 297 0.172621000    TCP    1502 [TCP segment of a reassembled PDU]
 298 0.172680000    TCP    1502 [TCP segment of a reassembled PDU]
 299 0.172730000    TCP      54 34425 > http [ACK] Seq=380 Ack=2897 Win=65700 Len=0
 300 0.172751000    TCP    1502 [TCP segment of a reassembled PDU]
 301 0.172874000    TCP    1502 [TCP segment of a reassembled PDU]
 302 0.172920000    TCP      54 34425 > http [ACK] Seq=380 Ack=5793 Win=65700 Len=0
 512 0.344459000    TCP    1502 [TCP segment of a reassembled PDU]
 513 0.344567000    TCP    1502 [TCP segment of a reassembled PDU]
 514 0.344601000    TCP      54 34425 > http [ACK] Seq=380 Ack=8689 Win=65700 Len=0
 515 0.344718000    TCP    1502 [TCP segment of a reassembled PDU]
 516 0.344812000    TCP    1502 [TCP segment of a reassembled PDU]
 517 0.344841000    TCP      54 34425 > http [ACK] Seq=380 Ack=11585 Win=65700 Len=0
 518 0.344936000    TCP    1502 [TCP segment of a reassembled PDU]
 519 0.345056000    TCP    1502 [TCP segment of a reassembled PDU]
 520 0.345085000    TCP      54 34425 > http [ACK] Seq=380 Ack=14481 Win=65700 Len=0
 618 0.516053000    TCP    1502 [TCP segment of a reassembled PDU]
 619 0.516156000    TCP    1502 [TCP segment of a reassembled PDU]
 620 0.516195000    TCP      54 34425 > http [ACK] Seq=380 Ack=17377 Win=65700 Len=0
 621 0.516273000    TCP    1502 [TCP segment of a reassembled PDU]
 622 0.516400000    TCP    1502 [TCP segment of a reassembled PDU]
 623 0.516427000    TCP      54 34425 > http [ACK] Seq=380 Ack=20273 Win=65700 Len=0
 624 0.516524000    TCP    1502 [TCP segment of a reassembled PDU]
 625 0.516644000    TCP    1502 [TCP segment of a reassembled PDU]
 626 0.516675000    TCP      54 34425 > http [ACK] Seq=380 Ack=23169 Win=65700 Len=0
 627 0.516758000    TCP    1502 [TCP segment of a reassembled PDU]
 628 0.516888000    TCP    1502 [TCP segment of a reassembled PDU]
 629 0.516919000    TCP      54 34425 > http [ACK] Seq=380 Ack=26065 Win=62804 Len=0
 630 0.517005000    TCP    1502 [TCP segment of a reassembled PDU]
 631 0.517424000    TCP      54 34425 > http [ACK] Seq=380 Ack=27513 Win=65700 Len=0
 673 0.681470000    HTTP    316 HTTP/1.1 200 OK  (text/html)
 680 0.881827000    TCP      54 34425 > http [ACK] Seq=380 Ack=27775 Win=65436 Len=0
2354 2.702080000    HTTP    540 GET /script1 adspaces/2.0/homepage/main/bot1.120x90.ad HTTP/1.1
2458 2.959986000    HTTP    661 HTTP/1.1 200 OK  (text/plain)
```



```
LOG: abs 1353340607380
LOG: interactive abs 1353340607771 ref 391
ⓧ SCRIPT1010: Expected identifier
  ?, line 418 character 146
LOG: complete abs 1353340610285 ref 2905
```

Candidate?

- Get the Twitter username of a logged in user

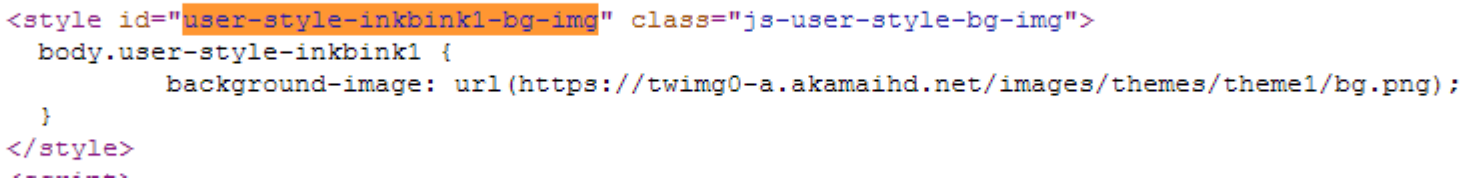


Account

Change your basic account, language, Tweet privacy, and loc

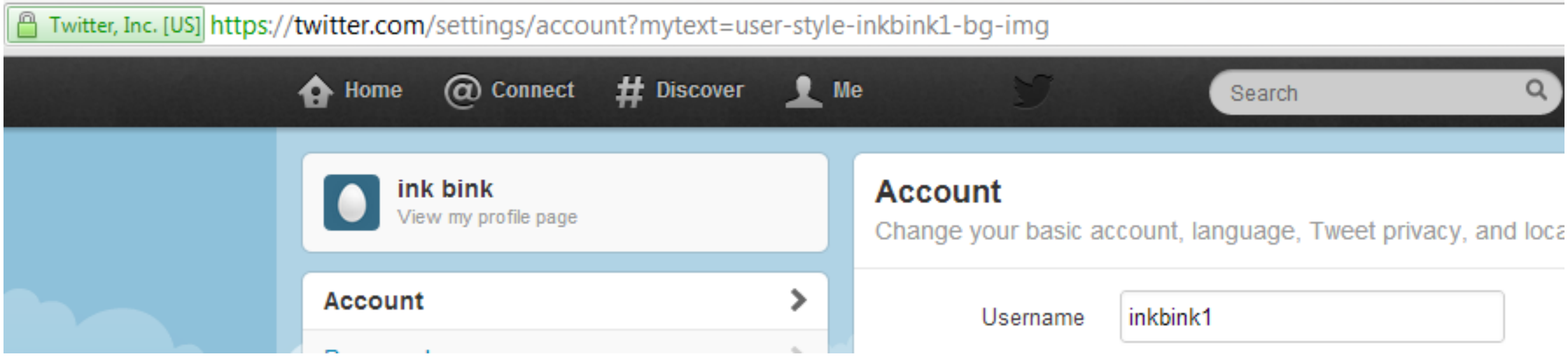
Username: inkbink1

https://twitter.com/inkbink1



```
<style id="user-style-inkbink1-bg-img" class="js-user-style-bg-img">
  body.user-style-inkbink1 {
          background-image: url(https://twimg0-a.akamaihd.net/images/themes/theme1/bg.png);
  }
</style>
<script>
```

Candidate?

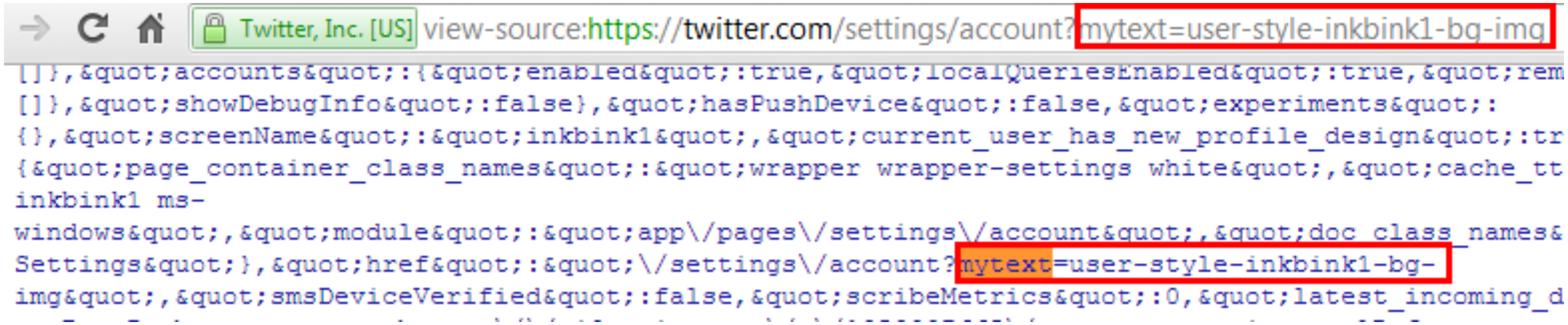


Twitter, Inc. [US] https://twitter.com/settings/account?mytext=user-style-inkbink1-bg-img

Account

Change your basic account, language, Tweet privacy, and loca

Username: inkbink1



Twitter, Inc. [US] view-source:https://twitter.com/settings/account?mytext=user-style-inkbink1-bg-img

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