Heartbleed Attack

实验报告

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Heartbleed Attack Lab

1 Overview

The Heartbleed bug (CVE-2014-0160) is a severe implementation flaw in the OpenSSL library, which enables attackers to steal data from the memory of the victim server. The contents of the stolen data depend on what is there in the memory of the server. It could potentially contain private keys, TLS session keys, user names, passwords, credit cards, etc. The vulnerability is in the implementation of the Heartbeat protocol, which is used by SSL/TLS to keep the connection alive. The objective of this lab is to understand how serious this vulnerability is, how the attack works, and how to fix the problem. The affected OpenSSL version range is from 1.0.1 to 1.0.1f. The version of Ubuntu VM is 1.0.1.

2 Lab Environment

In this lab, we need to set up two VMs: one called attacker machine and the other called victim server. We use the pre-built SEEDUbuntu12.04 VM. The VMs need to use the NAT-Network adapter for the network setting. This can be done by going to the VM settings, picking Network, and clicking the Adaptor tag to switch the adapter to NAT-Network. Make sure both VMs are on the same NAT-Network. The website used in this attack can be any HTTPS website that uses SSL/TLS. However, since it is illegal to attack a real website, we have set up a website in our VM, and conduct the attack on our own VM. We use an open-source social network application called ELGG, and host it in the following URL: https://www.heartbleedlabelgg.com. We need to modify the /etc/hosts file on the attacker machine to map the server name to the IP address of the server VM. Search the following line in /etc/hosts, and replace the IP address **127.0.0.1** with the actual IP address of the server VM that hosts the ELGG application.

3 Lab Tasks

The heartbeat protocol consists of two message types: HeartbeatRequest packet and HeartbeatResponse packet. Client sends a HeartbeatRequest packet to the server. When the server receives it, it sends back a copy of the received message in the HeartbeatResponse packet. The goal is to keep the connection alive. The protocol is illustrated in Figure 1.

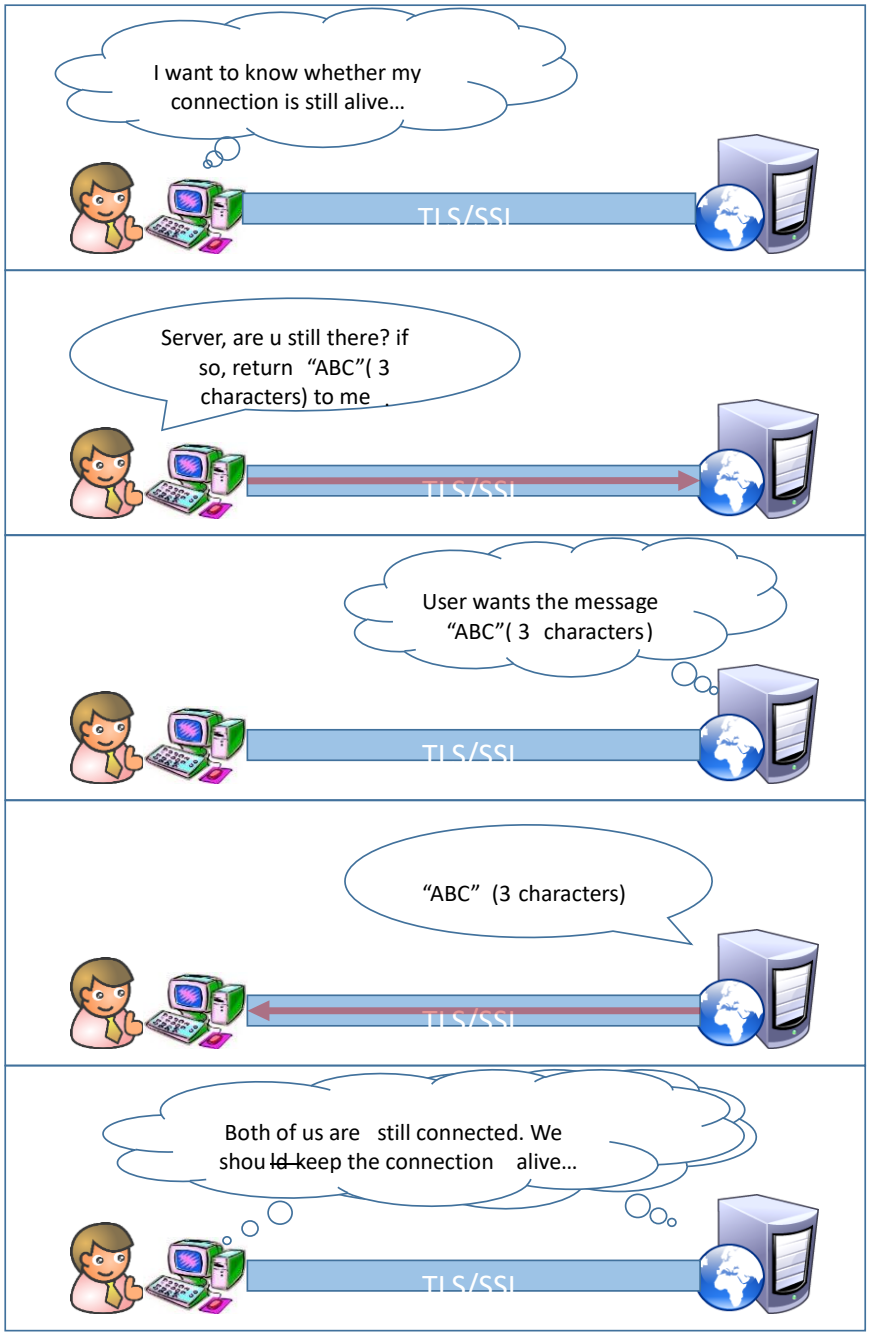
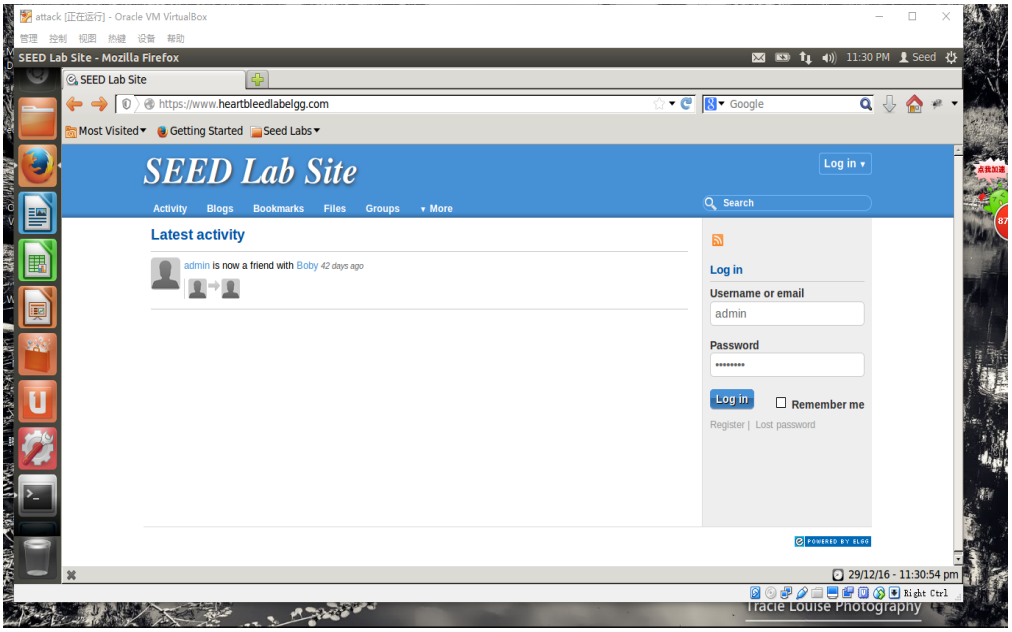
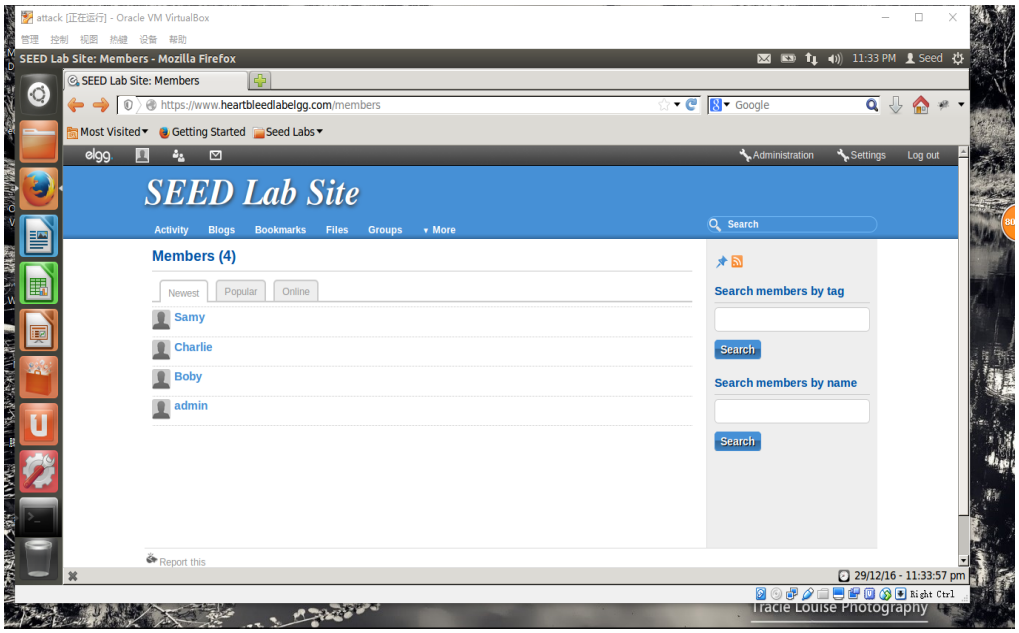


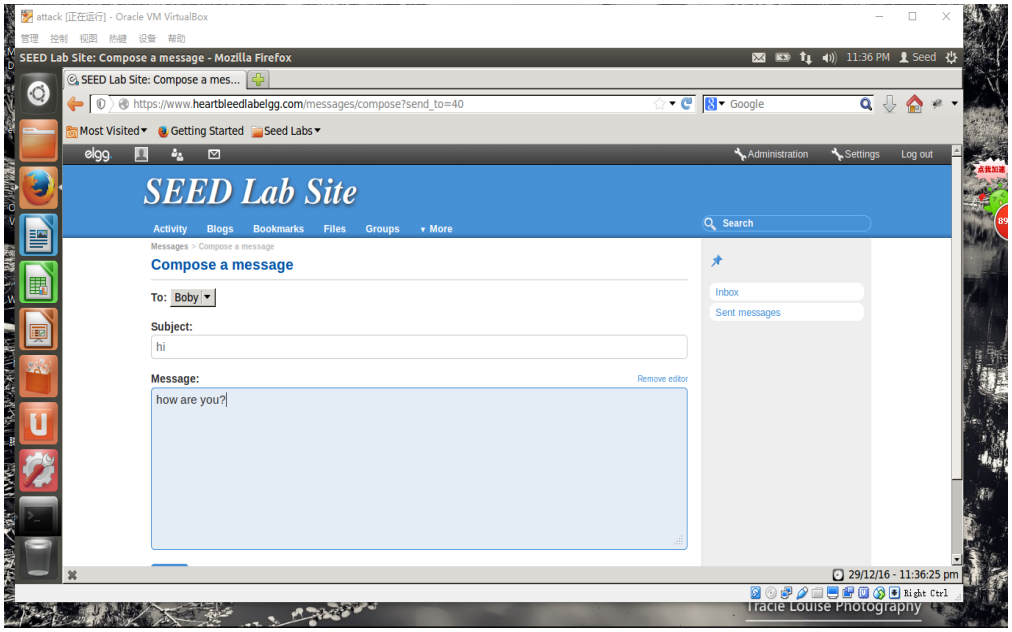
Figure 1: Overview of the Heartbeat Protocol

3.1 Task 1: Launch the Heartbleed Attack.

In this task, students will launch the Heartbleed attack on our social network site and see what kind of damages can be achieved. The actual damage of the Heartbleed attack depends on what kind of information is stored in the server memory. If there has not been much activity on the server, you will not be able to steal useful data. Therefore, we need to interact with the web server as legitimate users. Let us do it as the administrator, and do the followings:

- Visit https://www.heartbleedlabelgg.com from your browser.
- Login as the site administrator. (User Name:admin; Password:seedelgg) • Add Boby as friend. (Go to More -> Members and click Boby -> Add Friend)
- Send Boby a private message.
- 

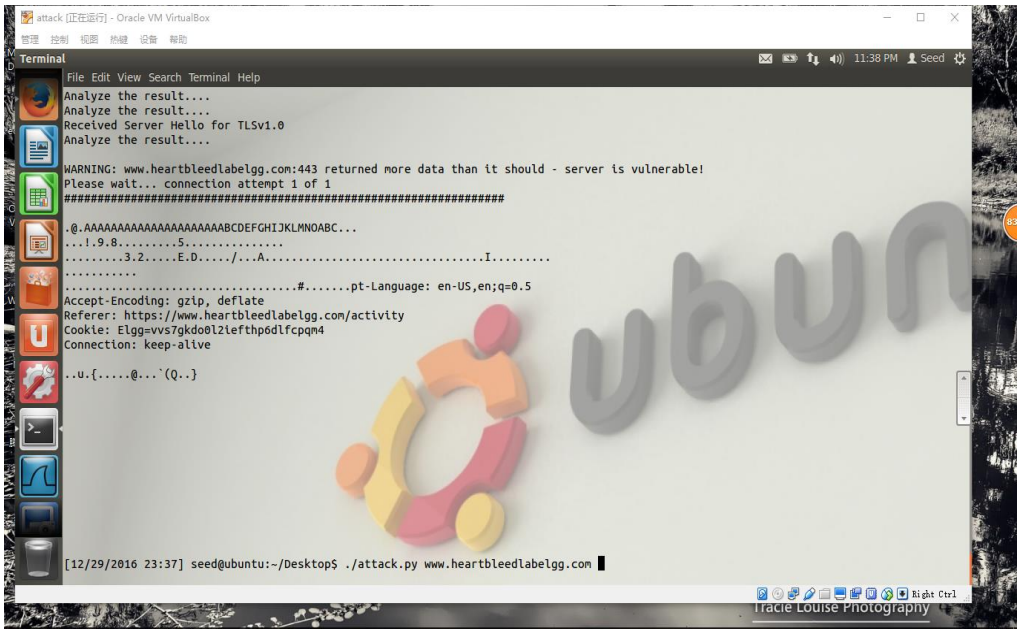




After you have done enough interaction as legitimate users, you can launch the attack and see what information you can get out of the victim server. Writing the program to launch the Heartbleed attack from scratch is not easy, because it requires the low-level knowledge of the Heartbeat protocol. Fortunately, other people have already written the attack code. Therefore, we will use the existing code to gain first-hand experience in the Heartbleed attack. The code that we use is called attack.py, which was originally written by Jared Stafford. We made some small changes to the code for educational purposes. You can download the code from the lab's web site, change its permission so the file is executable. You can then run the attack code as follows:

$ ./attack.py www.heartbleedlabelgg.com

- **User's activity (what the user has done).**



- **User name and password.**

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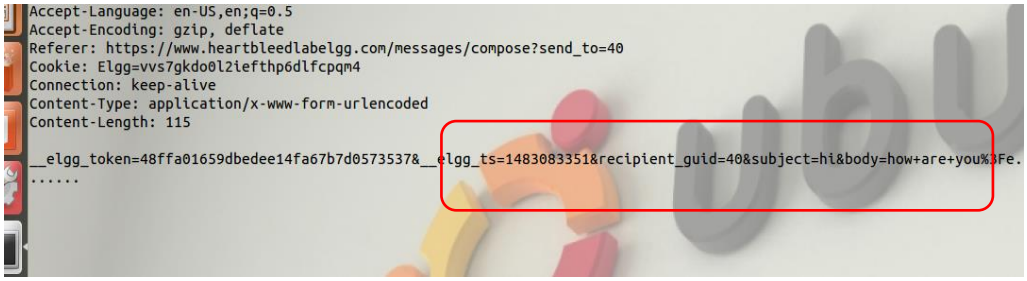
- **The exact content of the private message.**



3.2 Task 2: Find the Cause of the Heartbleed Vulnerability

In this task, students will compare the outcome of the benign packet and the malicious packet sent by the attacker code to find out the fundamental cause of the Heartbleed vulnerability. The Heartbleed attack is based on the Heartbeat request. This request just sends some data to the server, and the server will copy the data to its response packet, so all the data are echoed back. In the normal case, suppose that the request includes 3 bytes of data ”ABC”, so the length field has a value 3. The server will place the data in the memory, and copy 3 bytes from the beginning of the data to its response packet. In the attack scenario, the request may contain 3 bytes of data, but the length field may say 1003. When the server constructs its response packet, it copies from the starting of the data (i.e. “ABC”), but it copies 1003 bytes, instead of 3 bytes. These extra 1000 types obviously do not come from the request packet; they come from the server’s private memory, and they may contain other user’s information, secret keys, password, etc. In this task, we will play with the length field of the request. First, let’s understand how the Heartbeat response packet is built from Figure 2. When the Heartbeat request packet comes, the server will parse the packet to get the payload and the Payload length value (which is highlighted in Figure 2). Here, the payload is only a 3-byte string "ABC" and the Payload length value is exactly 3. The server program will blindly take this length value from the request packet. It then builds the response packet by pointing to the memory storing "ABC" and copy Payload length bytes to the response payload. In this way, the response packet would contain a 3-byte string "ABC".

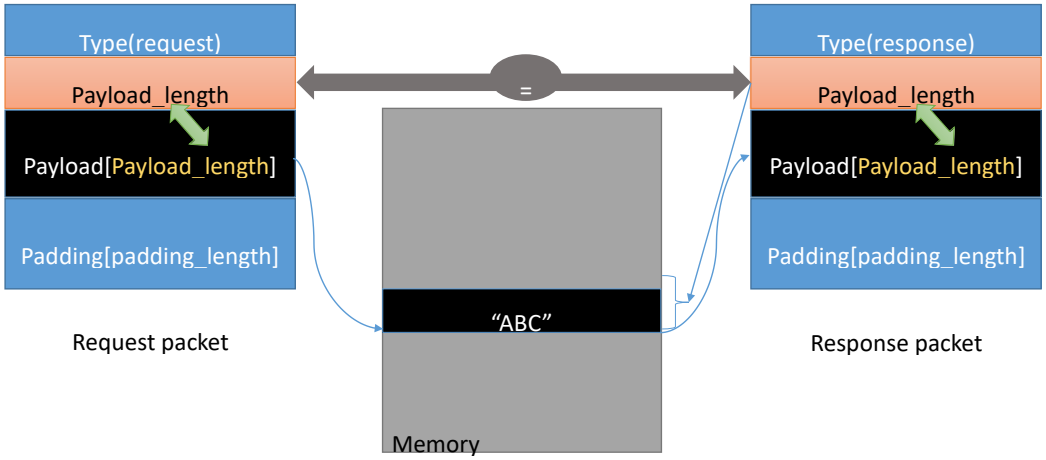


Figure 2: The Benign Heartbeat Communication

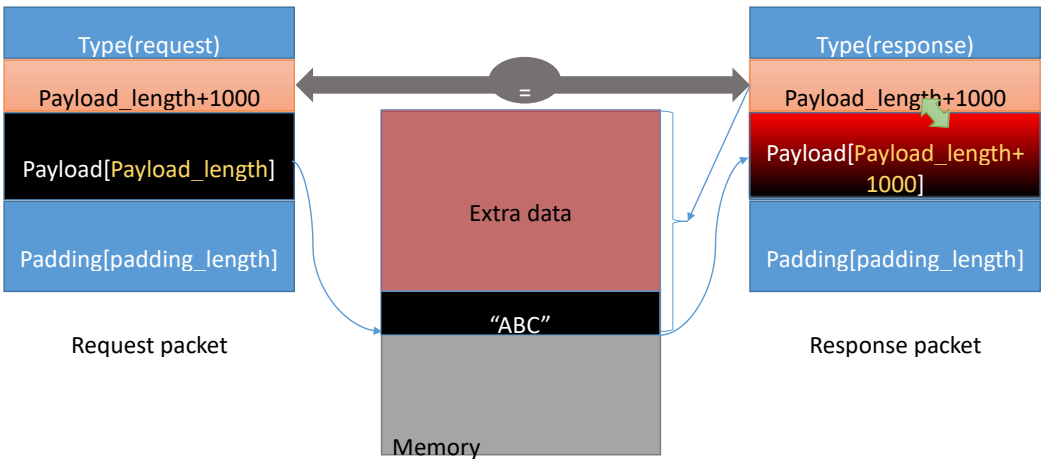


Figure 3: The Heartbleed Attack Communication

3.3 Task 3: Countermeasure and Bug Fix

To fix the Heartbleed vulnerability, the best way is to update the OpenSSL library to the newest version. This can be achieved using the following commands. It should be noted that once it is updated, it is hard to go back to the vulnerable version. Therefore, make sure you have finished the previous tasks before doing the update. You can also take a snapshot of your VM before the update.

```
#sudo apt-get update
#sudo apt-get upgrade
```

The following C-style structure (not exactly the same as the source code) is the format of the Heartbeat request/response packet.

```
struct {
    HeartbeatMessageType type; // 1 byte: request or the response uint16 payload_length;  //
    2 byte: the length of the payload opaque payload[HeartbeatMessage.payload_length];
    opaque padding[padding_length];
} HeartbeatMessage;
```

The first field (1 byte) of the packet is the type information, and the second field (2 bytes) is the payload length, followed by the actual payload and paddings. The size of the payload should be the same as the value in the payload_length field, but in the attack scenario, payloadlength can be set to a different value. The following code snippet shows how the server copies the data from the request packet to the response packet.

Listing 1: Process the Heartbeat request packet and generate the response packet

```
/* Allocate memory for the response, size is 1 byte
                                * message type, plus 2 bytes payload length, plus
                                * payload, plus padding
 */

unsigned int payload; unsigned int padding = 16; /* Use minimum padding
*/

// Read from type field first hbtype = *p++; /* After this instruction, the
pointer
                                * p will point to the payload_length field *.

// Read from the payload_length field
// from the request packet
n2s(p, payload); /* Function n2s(p, payload) reads 16 bits
                                * from pointer p and store the value
                                * in the INT variable "payload". */


pl=p; // pl points to the beginning of the payload content

if (hbtype == TLS1_HB_REQUEST)
{ unsigned char *buffer, *bp; int r;

        /* Allocate memory for the response, size is 1 byte
                                * message type, plus 2 bytes payload length, plus
                                * payload, plus padding
         */

        buffer = OPENSSL_malloc(1 + 2 + payload + padding); bp = buffer;

        // Enter response type, length and copy payload
        *bp++ = TLS1_HB_RESPONSE; s2n(payload, bp);

        // copy payload memcpy(bp, pl, payload); /* pl is the pointer which
                                * points to the beginning * of the payload content */

        bp += payload;

        // Random padding
```

```
RAND_pseudo_bytes(bp, padding);

// this function will copy the 3+payload+padding bytes // from the buffer and put
them into the heartbeat response // packet to send back to the request client side.
OPENSSL_free(buffer);
```

References

[1] Heartbleed attack - Implementation: https://alexandreborgesbrazil.files.wordpress.com/ 2014/04/hearbleed attack version a _1.pdf

[2] Heartbleed attack - Interesting explanation: http://xkcd.com/1354/