accu 2022

SANDBOXING A LINUX APPLICATION

MARTIN ERTSÅS

Sandboxing a Linux application

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April 7, 2022

$ Whoami

```
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C++ Programmer
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```

Important

Important

Never run code from these slides!

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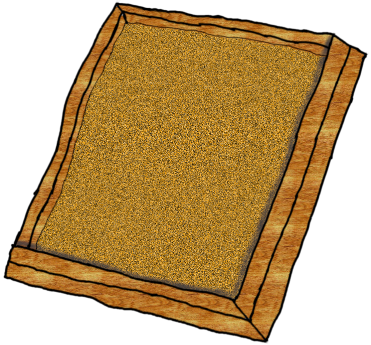
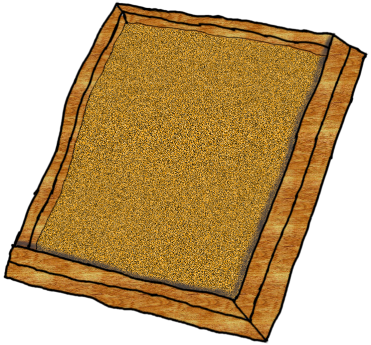
Never run code from these slides!

I take no responsibility if you do!

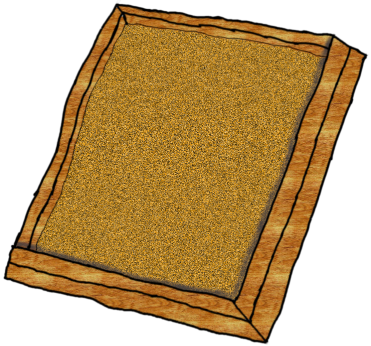


What is a sandbox?



What is a sandbox?

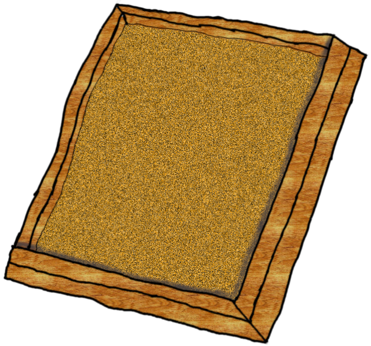
“A mechanism to run applications in a controlled and restricted environment, with the goal of mitigating the impact of vulnerabilities”



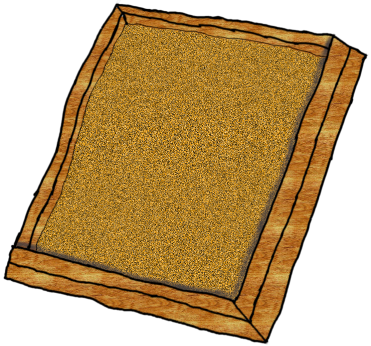
What is a sandbox?

“A mechanism to run applications in a controlled and restricted environment, with the goal of mitigating the impact of vulnerabilities”

– Martin Ertsås

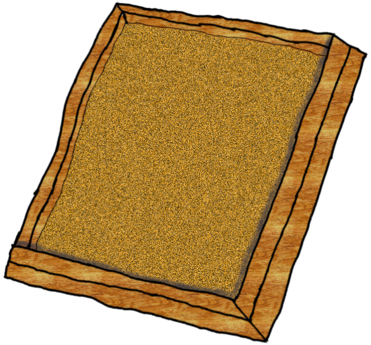


Why Sandbox?



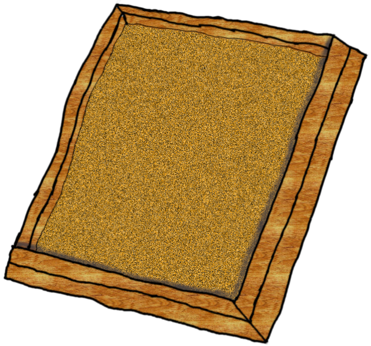
Why Sandbox?

- Untrusted applications



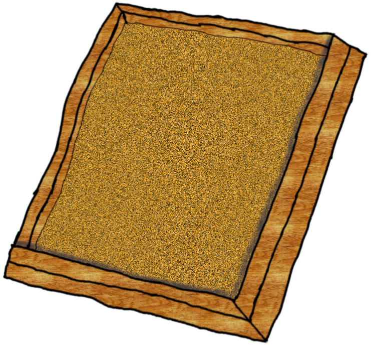
Why Sandbox?

- Untrusted applications
- Running downloaded code



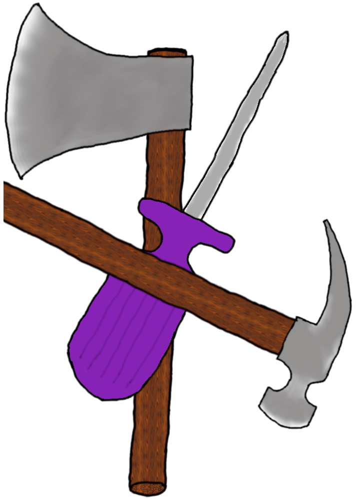
Why Sandbox?

- Untrusted applications
- Running downloaded code
- Application expectations of environment



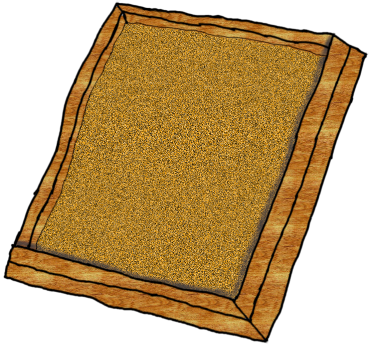
Why Sandbox?

- Untrusted applications
- Running downloaded code
- Application expectations of environment
- They are fun!



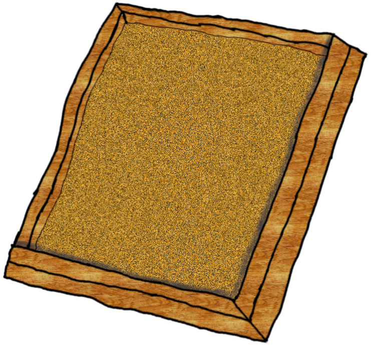
Tools available

- Namespaces
- Seccomp
- Cgroups
- ++



Alternative

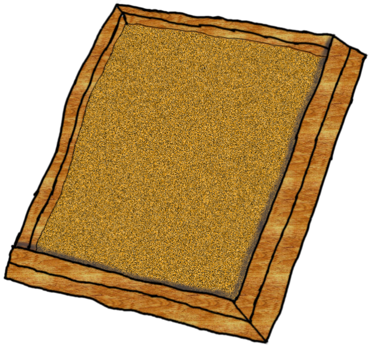
```
int main(int argc, char ** argv)
{
    setup_sandbox();
    execvp(argv[1], &(argv[1]));
}
```



Alternative

```
int main(int argc, char ** argv)
{
    setup_sandbox();
    run_application_code();
}
```

Start of sandbox



```
static main_func actual_main = nullptr;

int my_main(args) {
    return actual_main(args);
}

int __libc_start_main(main_func main,
                      args) {
    actual_main = main;
    auto actual_start_main =
        dlsym("__libc_start_main");
    return actual_start_main(
             my_main,
             args);
}
```

std::

nlohmann::

fmt::

boost::

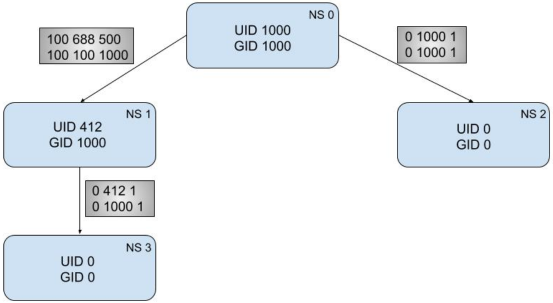
Namespaces

- Wraps a global system resources to provide isolation
- Several different Namespace types in Linux
- Some Hierarchical, some not
- Created by calling either *clone* or *unshare*

User Namespace

- Isolates users and groups available
- *CLONE_NEWUSER*
- Hierarchical

User Namespace



User Namespace

```
 int my_main(int argc,
             char ** argv,
             char ** argenv)
 {
+    unshare(CLONE_NEWUSER);
     return actual_main(argc,
                        argv,
                        argenv);
 }
```

User Namespace

```
+uid_t uid = geteuid();
+uid_t gid = getegid();
+
 unshare(CLONE_NEWUSER);
+ofstream ufs("/proc/self/uid_map");
+ufs << 0 << ' ' << uid << ' ' << 1;
+
+ofstream gfs("/proc/self/gid_map");
+gfs << 0 << ' ' << gid << ' ' << 1;
+
 return actual_main(argc,
                    argv,
                    argenv);
```

User Namespace

```
 ofstream ufs("/proc/self/uid_map");
 ufs << 0 << ' ' << uid << ' ' << 1;

+ofstream deny("/proc/self/setgroups");
+deny << "deny";
+
 ofstream gfs("/proc/self/gid_map");
 gfs << 0 << ' ' << gid << ' ' << 1;
```

DEMO!!!!

Mount Namespace

- Isolates list of mount points
- *CLONE_NEWNS*
- Can share view of subtrees with the parent process

Mount Namespace

```
 uid_t uid = geteuid();
 uid_t gid = getegid();

-unshare(CLONE_NEWUSER);
+unshare(CLONE_NEWUSER | CLONE_NEWNS);
+
 set_uid_gid_mappings();
```

Mount Namespace

```
 uid_t gid = getegid();

 unshare(CLONE_NEWUSER | CLONE_NEWNS);
+mount(NULL, "/", NULL,
+        MS_PRIVATE | MS_REC, NULL);
+
 set_uid_gid_mappings();
```

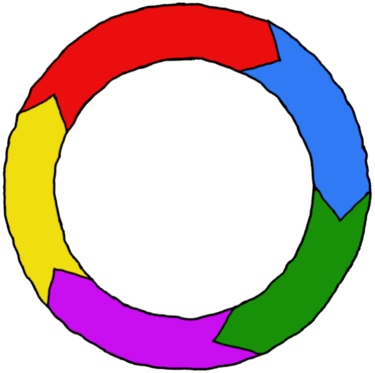
Mount Namespace

```
 set_uid_gid_mappings();

+mount("tmpfs", "/tmp", "tmpfs", 0, NULL);
+
+fs::create_directories("/tmp/lib64");
+mount("/lib64", "/tmp/lib64", NULL,
+          MS_REC | MS_BIND, NULL);
+
+fs::create_directories("/tmp/etc");
+mount("/etc", "/tmp/etc", NULL,
+          MS_REC | MS_BIND, NULL);

 return actual_main(argc,
```

Mount Namespace

```
 fs::create_directory("/tmp/etc");
 mount("/etc", "/tmp/etc", NULL,
       MS_REC | MS_BIND, NULL);

+fs::create_directory("/tmp/oldroot");
+pivot_root("/tmp", "/tmp/oldroot");
+chdir("/");
+umount2("/oldroot", MS_DETACH);
+fs::remove("/oldroot");
+
 return actual_main(argc,
```

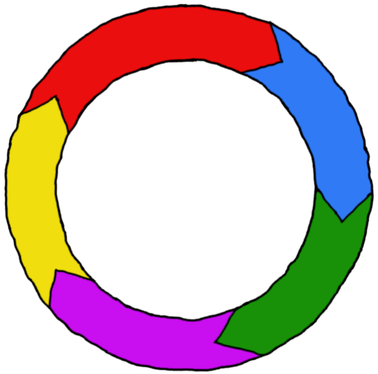
DEMO!!!!

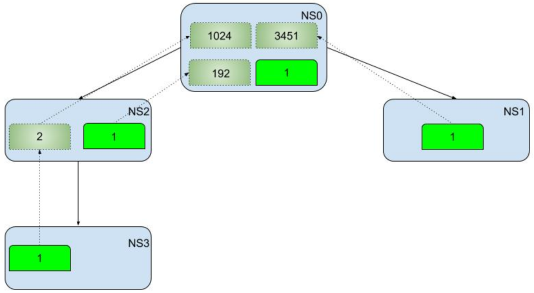


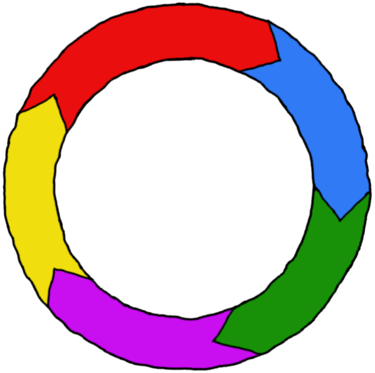
PID Namespace

- Isolates process ID number space
- *CLONE_NEWPID*
- First process in the namespace gets PID 1
- unshare does not move the process into the namespace
- Hierarchical

PID Namespace



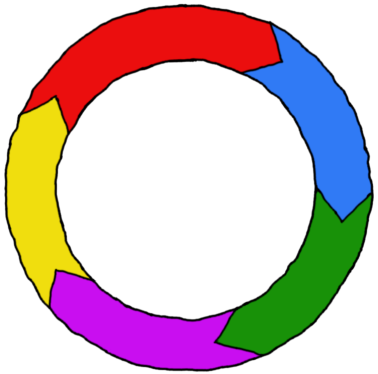




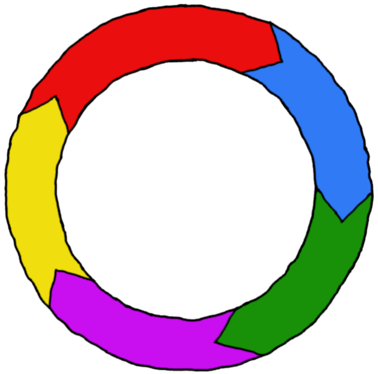
PID Namespace

```
 uid_t uid = geteuid();
 uid_t gid = getegid();

-unshare(CLONE_NEWUSER | CLONE_NEWNS);
+unshare(CLONE_NEWUSER
+          | CLONE_NEWNS
+          | CLONE_NEWPID);

 set_uid_gid_mappings();
```

PID Namespace



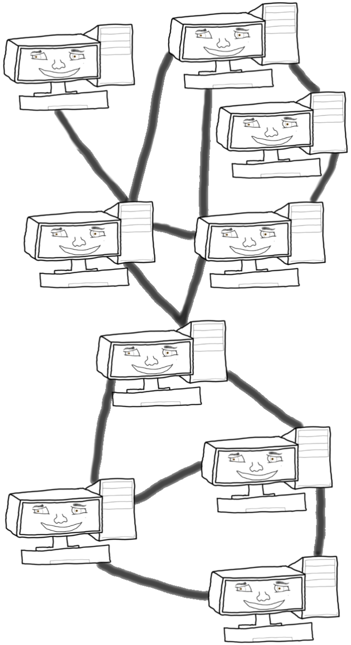
```
 mount_application(rootfs, argv[1]);

-swap_root();
-int result = actual_main(...);

+pid_t pid = fork();
+if (pid == 0) {
+  swap_root();
+  int result = actual_main(...);
+  _exit(result);
+}
+
+int status = -1;
+waitpid(pid, &status, 0);
+return status;
```



PID Namespace

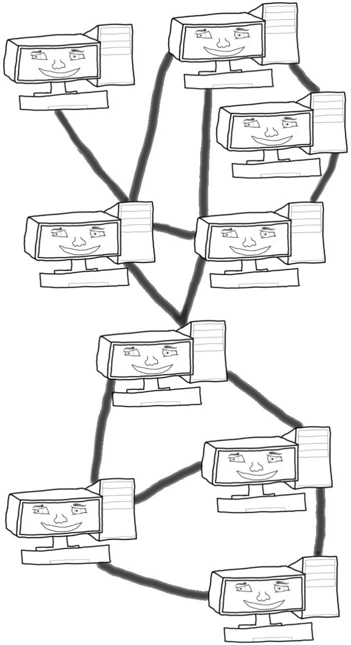
```
 pid_t pid = fork();
 if (pid == 0) {
     swap_root();
+
+    fs::create_directories("/proc");
+    mount("proc", "/proc", "proc",
+          0, NULL);
+
     int result = actual_main(...);
     _exit(result);
```

DEMO!!!!

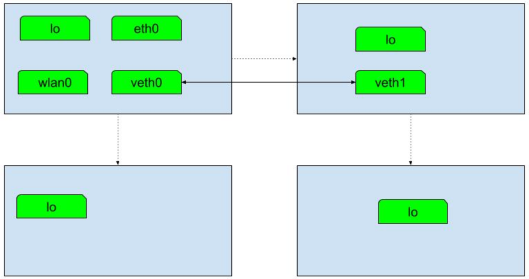


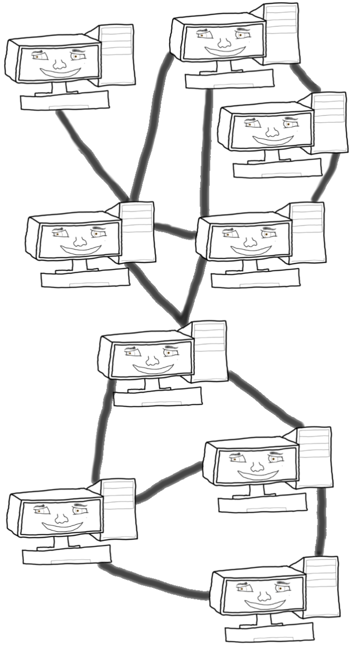
Network Namespace

- Creates a new network stack
- CLONE_NEWNET



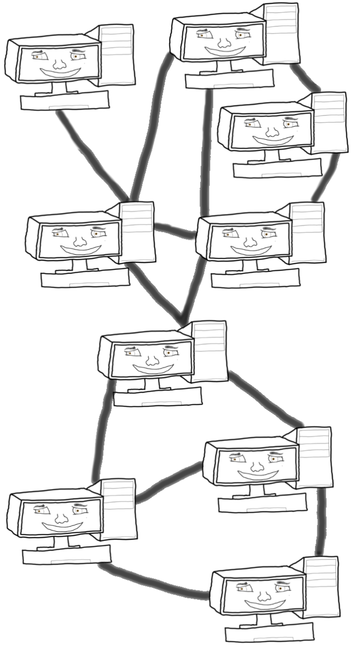
Network Namespace





Network Namespace

```
 pid_t pid = fork();
 if (pid == 0) {
+      unshare(CLONE_NEWNET);
+
       swap_root();
```



Network Namespace

- This removes “all” network interfaces
- Use virtual network interfaces
- Use iptables
- Use bridge interfaces

std::

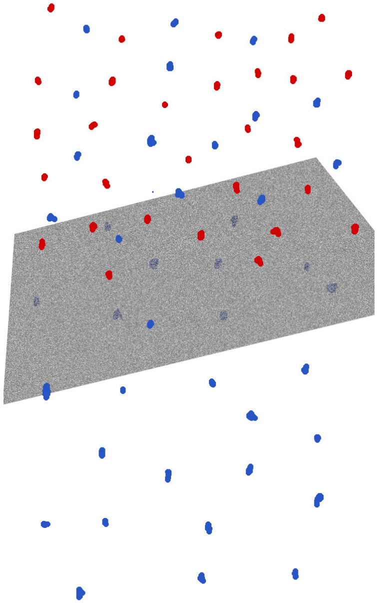
nlohmann::

fmt::

boost::

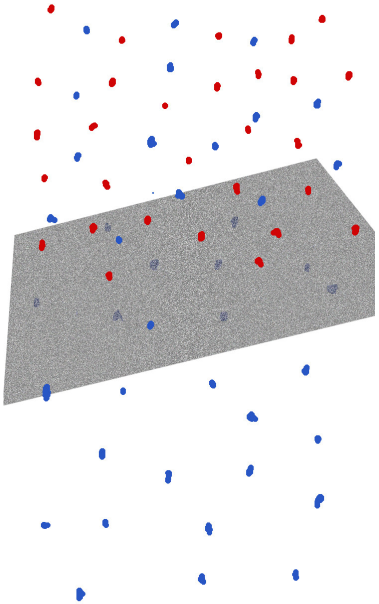
Other namespaces

- Cgroup
- IPC
- Time
- UTS



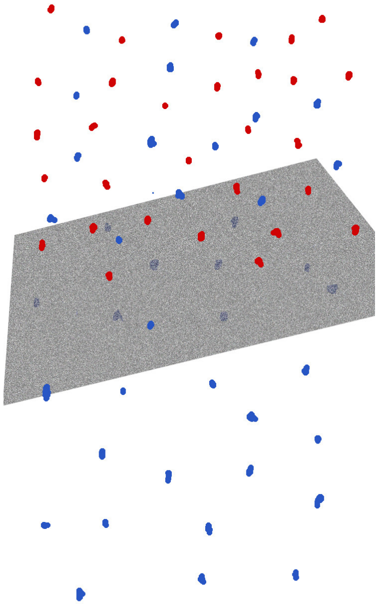
Seccomp

- Filtering of system calls
- Only allows *exit*, *sigreturn*, *read* and *write*



Seccomp

- Filtering of system calls
- Only allows *exit*, *sigreturn*, *read* and *write*
- Pretty useless for most applications



Seccomp-BPF

- Uses the Berkeley Packet Filtering
- An in-kernel programming language

Raw usage

```
struct seccomp_data {
    int   nr;
    __u32 arch;
    __u64 instruction_pointer;
    __u64 args[6];
};
```

Raw usage

```
+sock_filter filter[] = {
+  BPF_STMT(
+     BPF_RET|BPF_K,
+     SECCOMP_RET_ALLOW),
+};
+sock_fprog prog = {
+  .len = std::size(filter),
+  .filter = filter,
+};
+prctl(PR_SET_NO_NEW_PRIVS, 1, 0, 0, 0);
+syscall(SYS_seccomp,
+           SECCOMP_SET_MODE_FILTER,
+           0, &prog);
+
 int result = actual_main(...);
 _exit(result);
```

Raw usage

```
 sock_filter filter[] = {
+   BPF_STMT(
+      BPF_LD|BPF_W|BPF_ABS,
+      offsetof(seccomp_data, arch)),
+
+   BPF_JUMP(
+      BPF_JMP|BPF_JEQ|BPF_K,
+      AUDIT_ARCH_X86_64, 0, 1),
    BPF_STMT(
       BPF_RET|BPF_K,
       SECCOMP_RET_ALLOW),
+
+   BPF_STMT(
+      BPF_RET|BPF_K,
+      SECCOMP_RET_KILL),
 };
```

Raw usage

```
 BPF_JUMP(
    BPF_JMP|BPF_JEQ|BPF_K,
-   AUDIT_ARCH_X86_64, 0, 1),
+   AUDIT_ARCH_X86_64, 0, 3),

+BPF_STMT(
+   BPF_LD|BPF_W|BPF_ABS,
+   offsetof(seccomp_data, nr)),
+BPF_JUMP(
+   BPF_JMP|BPF_JEQ|BPF_K,
+   SYS_execve, 0, 1),

 BPF_RET(BPF_W|BPF_K, SECCOMP_RET_ALLOW)
 BPF_RET(BPF_W|BPF_K, SECCOMP_RET_KILL)
```

Raw usage

```
BPF_STMT(BPF_LD|BPF_W|BPF_ABS,
        (offsetof(struct seccomp_data, arch))),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K,
       AUDIT_ARCH_X86_64, 0, 24),

BPF_STMT(BPF_LD|BPF_W|BPF_ABS,
        (offsetof(struct seccomp_data, nr))),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_recvmsg, 22, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_sendto, 21, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_getsockname, 20, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_bind, 19, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_socket, 18, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_capget, 17, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_getdents64, 16, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_getegid, 15, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_geteuid, 14, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_getpid, 13, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_write, 12, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_munmap, 11, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_arch_prctl, 10, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_mprotect, 9, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_read, 8, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_close, 7, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_mmap, 6, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_fstat, 5, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_openat, 4, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_execve, 3, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_access, 2, 0),
BPF_JUMP(BPF_JMP|BPF_JEQ|BPF_K, SYS_brk, 1, 1),

BPF_STMT(BPF_RET|BPF_K, SECCOMP_RET_KILL),
BPF_STMT(BPF_RET|BPF_K, SECCOMP_RET_ALLOW),
```

Raw usage

```
-BPF_JUMP(
-   BPF_JMP|BPF_JEQ|BPF_K,
-   SYS_exit_group, 22, 0),
+BPF_JUMP(
+   BPF_JMP|BPF_JEQ|BPF_K,
+   SYS_exit_group, 0, 2),
+BPF_STMT(
+   BPF_LD|BPF_W|BPF_ABS,
+   offsetof(struct seccomp_data, args)),
+BPF_JUMP(
+   BPF_JMP|BPF_JEQ|BPF_K,
+   0, 22, 23),
 BPF_STMT(
    BPF_JMP|BPF_JEQ|BPF_K,
    SYS_sendto, 21, 0),
```

libseccomp usage

```
 set_new_root(rootfs);
+
+scmp_filter_ctx ctx =
+      seccomp_init(SCMP_ACT_KILL);
+seccomp_load(ctx);
+seccomp_release(ctx);

 int result = actual_main(...);
 return result;
```

libseccomp usage

```
 set_seccomp_arch(SCMP_ARCH_X86_64);
+
+seccomp_rule_add(ctx, SCMP_ACT_ALLOW,
+                 SCMP_SYS(execve), 0);
+
 seccomp_load(ctx);
 seccomp_release(ctx);
```

libseccomp usage

```
scmp_filter_ctx ctx = seccomp_init(SCMP_ACT_KILL);

allow_libseccomp(ctx, SCMP_SYS(execve));
allow_libseccomp(ctx, SCMP_SYS(exit_group));
allow_libseccomp(ctx, SCMP_SYS(recvmsg));
allow_libseccomp(ctx, SCMP_SYS(sendto));
allow_libseccomp(ctx, SCMP_SYS(getsockname));
allow_libseccomp(ctx, SCMP_SYS(bind));
allow_libseccomp(ctx, SCMP_SYS(socket));
allow_libseccomp(ctx, SCMP_SYS(capget));
allow_libseccomp(ctx, SCMP_SYS(getdents64));
allow_libseccomp(ctx, SCMP_SYS(geteuid));
allow_libseccomp(ctx, SCMP_SYS(getegid));
allow_libseccomp(ctx, SCMP_SYS(getpid));
allow_libseccomp(ctx, SCMP_SYS(write));
allow_libseccomp(ctx, SCMP_SYS(munmap));
allow_libseccomp(ctx, SCMP_SYS(arch_prctl));
allow_libseccomp(ctx, SCMP_SYS(mprotect));
allow_libseccomp(ctx, SCMP_SYS(read));
allow_libseccomp(ctx, SCMP_SYS(close));
allow_libseccomp(ctx, SCMP_SYS(mmap));
allow_libseccomp(ctx, SCMP_SYS(fstat));
allow_libseccomp(ctx, SCMP_SYS(openat));
allow_libseccomp(ctx, SCMP_SYS(access));
allow_libseccomp(ctx, SCMP_SYS(brk));

seccomp_load(ctx);
seccomp_release(ctx);
```

libseccomp usage

```
 seccomp_rule_add(ctx, SCMP_ACT_ALLOW,
                  SCMP_SYS(execve), 0);
 seccomp_rule_add(ctx, SCMP_ACT_ALLOW,
-                 SCMP_SYS(exit_group), 0);
+                 SCMP_SYS(exit_group), 1,
+                 SCMP_A0(SCMP_CMP_EQ, 0));
 seccomp_rule_add(ctx, SCMP_ACT_ALLOW,
                  SCMP_SYS(recvmsg), 0);
 seccomp_rule_add(ctx, SCMP_ACT_ALLOW,
```

How do I compare strings?

How do I compare strings?

- You don’t
- seccomp runs before value copied to the kernel
- Could compare memory location

DEMO!!!!

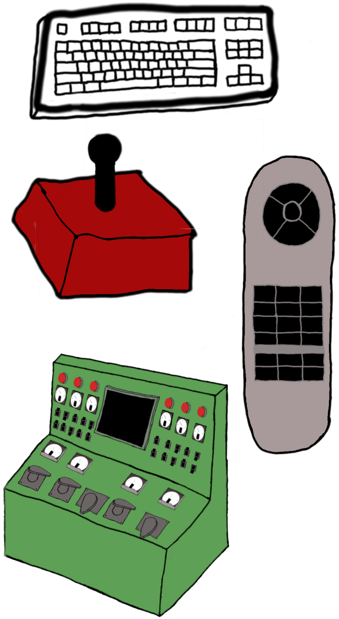
C++

C

C#

[C]

CGroups

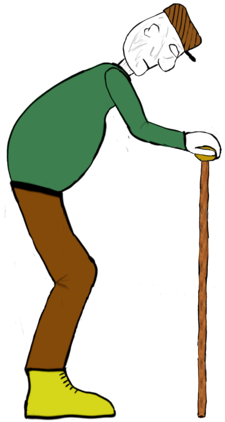


CGroups

- Controls a group of processes and their access to resources
- Limiting capabilities
- Monitoring capabilities
- Pseudo-filesystem API

CGroups v1

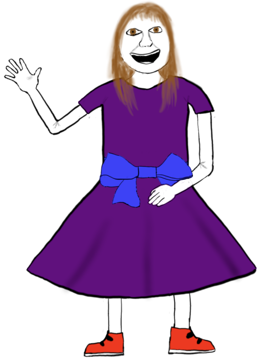
- First cgroups implementation
- Multiple controllers
- No development synchronization between controllers



CGroups v1

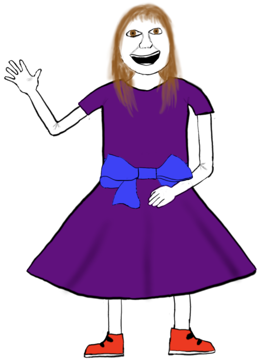
- First cgroups implementation
- Multiple controllers
- No development synchronization between controllers
- Will ignore v1

Cgroups v2

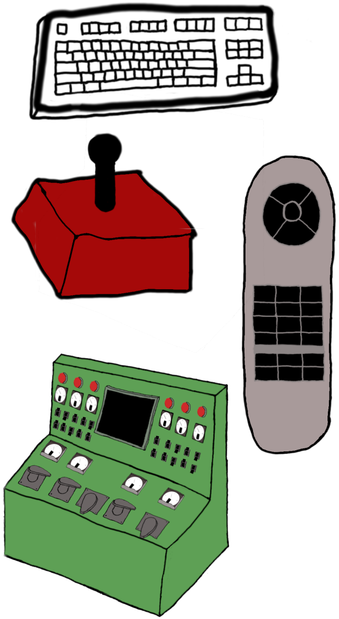


- Take 2
- This time they had to get it right, right?

Cgroups v2

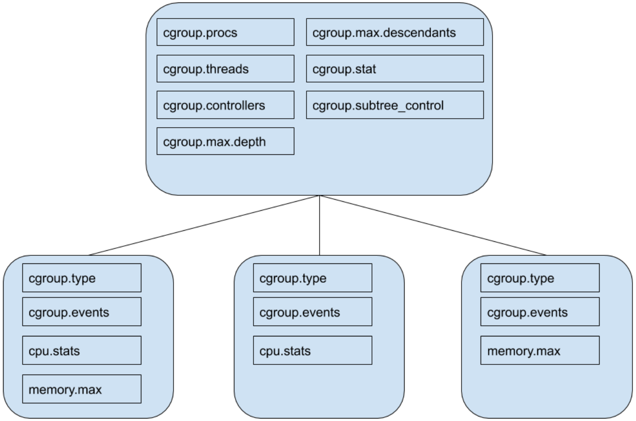


- Take 2
- This time they had to get it right, right?
- They have done a lot better
- One unified hierarchy
- Similar APIs for controllers
- Not all controllers available in v2

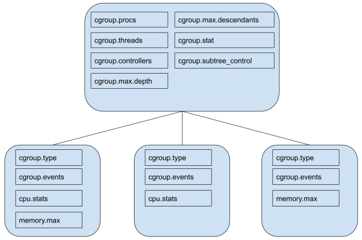


What can be controlled?

- Memory usage
- CPU usage
- CPU core access/pinning
- suspend/restore
- block device access
- Monitoring performance and cpu access
- Number of processes that might be created
- RDMA access
- huge pages usage
- Device creation
- Tagging network packets
- Prioritize network devices

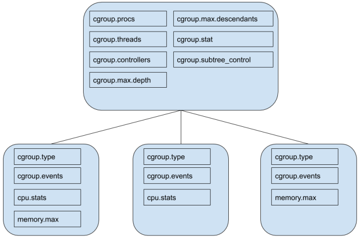

cgroup.procs
cgroup.max.descendants
cgroup.threads
cgroup.stat
cgroup.controllers
cgroup.subtree_control
cgroup.max.depth
cgroup.type
cgroup.events
cpu.stats
memory.max
cgroup.type
cgroup.events
cpu.stats
cgroup.type
cgroup.events
memory.max

Enabling/disabling controller



- Two files to look at
- cgroups.controllers lists available controllers in a cgroup
- cgroups.subtree_control lists controllers enabled in this cgroup

Enabling/disabling controller



- Two files to look at
- cgroups.controllers lists available controllers in a cgroup
- cgroups.subtree_control lists controllers enabled in this cgroup
- A controller is only available in a cgroup if it’s enabled in the parent cgroup

Demo!!!

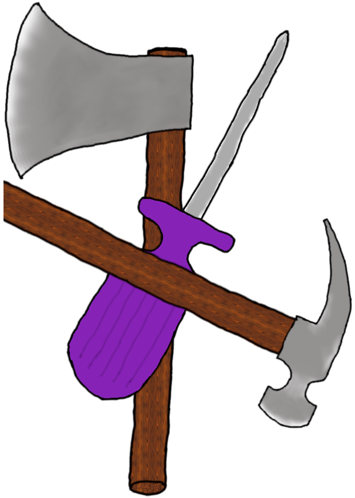
Limiting memory

CPU

cpuset

Events

Cgroup type



Other tools

- Cgroups
- SELinux

Thank you!