MesaLock Linux

Towards a memory-safe Linux distribution

Mingshen Sun
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Shanghai Jiao Tong University, 2018

whoami

- Senior Security Research in Baidu X-Lab, Baidu USA
- PhD, The Chinese University of Hong Kong
- System security, mobile security, IoT security, and car hacking
- MesaLock Linux, TaintART, Pass for iOS, etc.
- `mssun @ GitHub` | `https://mssun.me`

MesaLock Linux

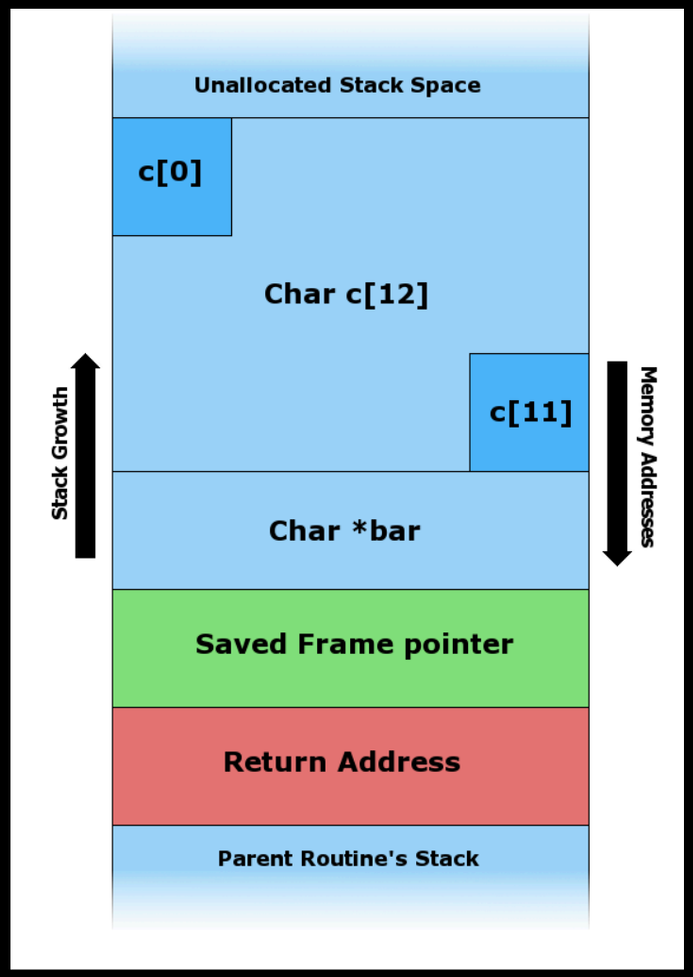
- Why
- What
- How

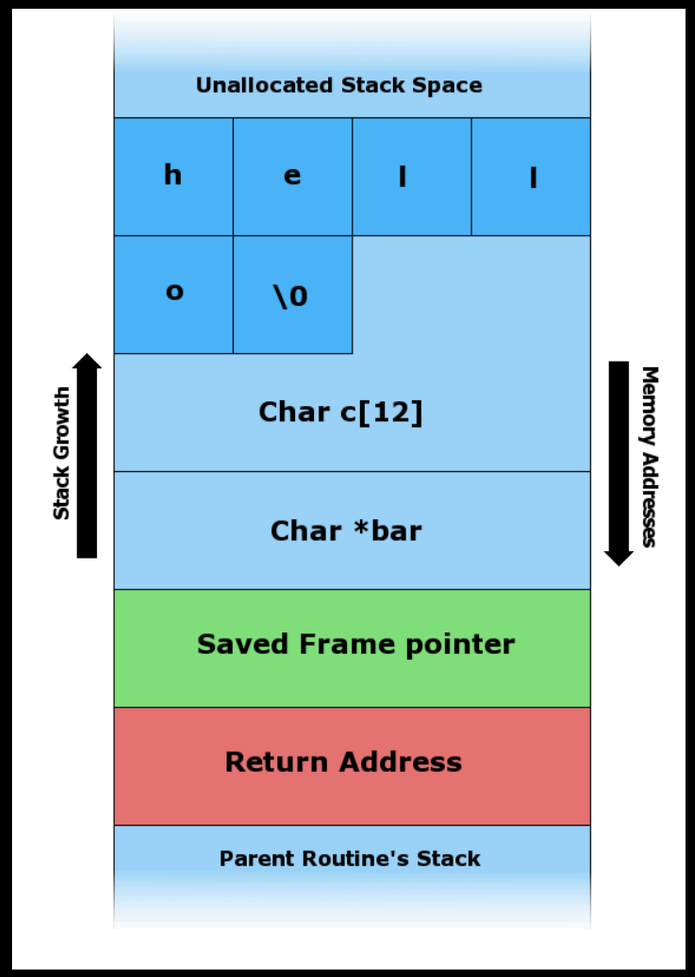
Why

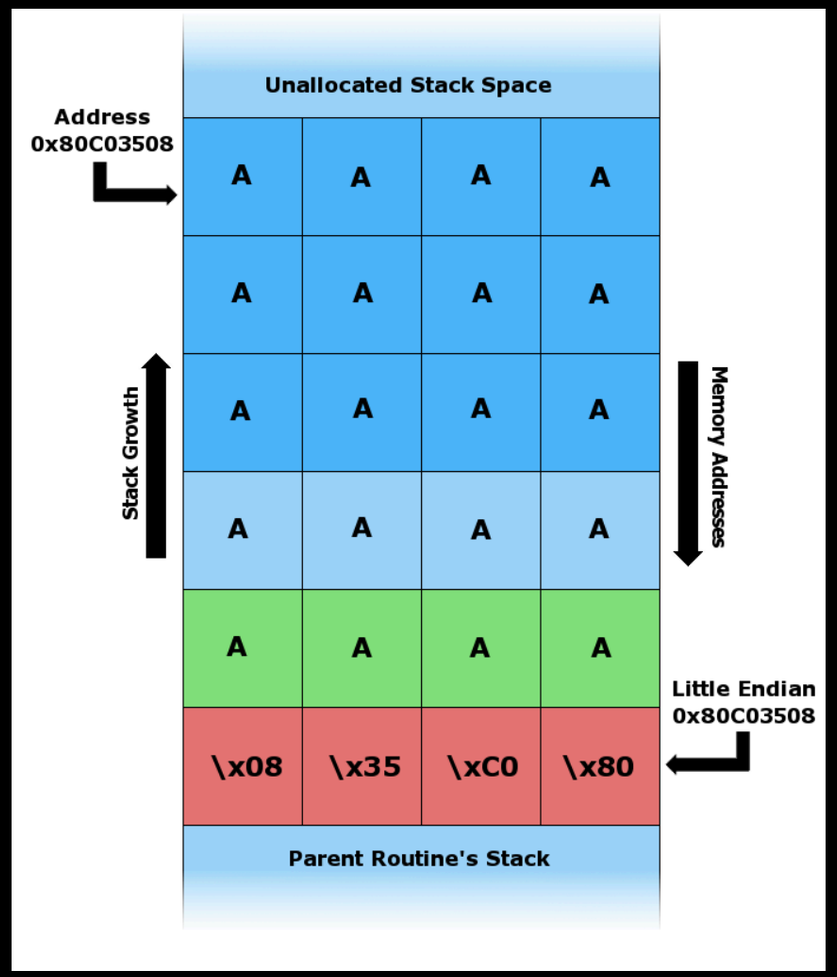
- **Memory corruption** occurs in a computer program when the contents of a memory location are **unintentionally modified**; this is termed violating memory safety.

- **Memory safety** is the state of being protected from various software bugs and security vulnerabilities when dealing with memory access, such as **buffer overflows and dangling pointers**.

Stack Buffer Overflow







- https://youtu.be/T03idxny9jE

Types of memory errors

- Access errors
  - Buffer overflow
  - Race condition
    - Use after free
- Uninitialized variables
- Memory leak
  - Double free

Memory-safety in user space

- CVE-2017-13089 **wget**: Stack-based buffer overflow in HTTP protocol handling

- A **stack-based buffer overflow** when processing chunked, encoded HTTP responses was found in wget. By tricking an unsuspecting user into connecting to a malicious HTTP server, an attacker could exploit this flaw to potentially **execute arbitrary code**.

- https://bugzilla.redhat.com/show_bug.cgi?id=1505444

- POC: https://github.com/r1b/CVE-2017-13089

What

- Linux distribution
- Memory-safe user space

Linux Distribution

- A Linux distribution (often abbreviated as distro) is an operating system made from a **software collection**, which is based upon the **Linux kernel** and, often, a **package management system**.

Linux Distros

- **Server**: CentOS, Federa, RedHat, Debian
- **Desktop**: Ubuntu
- **Mobile**: Android
- **Embedded**: OpenWRT, Yocto
- **Hard-core**: Arch Linux, Gentoo
- **Misc**: ChromeOS, Alpine Linux

Security and Safety?

- Gentoo Hardened: enables several risk-mitigating options in the toolchain, supports **PaX**, **grSecurity**, SELinux, **TPE** and more.
- Kernel hardening patches
- Safety? No.
- User space? GNU.

Introducing MesaLock Linux

- MesaLock Linux is a general purpose Linux distribution which aims to **provide a safe and secure user space environment**. To eliminate high-severe vulnerabilities caused by memory corruption, the whole user space applications are **rewritten in memory-safe programming languages like Rust and Go**.

Programming Language

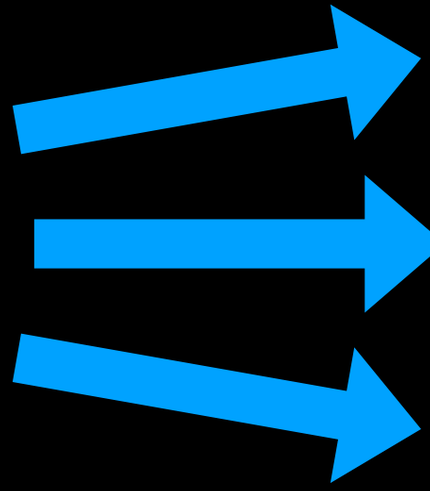
	Non-safe	Safe
Control	C/C++	Rust
Less control	Python	Go

Rust

- Rust is a **systems programming language** that runs blazingly **fast**, prevents segfaults, and guarantees **thread safety**.

How Does Rust Guarantee Memory Safety?

- Ownership
- Borrowing



- No need for a runtime (C/C++)
- Memory safety (GC)
- Data-race freedom

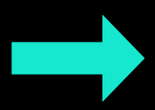
Ownership

Alice


```
fn main() {
    let alice = vec![1, 2, 3];;
    {
        let bob = alice;
        println!("bob: {}", bob[0]);
    }
    println!("alice: {}", alice[0]);
}
```

Ownership (T)

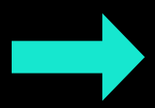
Alice **Bob**



```
fn main() {
    let alice = vec![1, 2, 3];;
    {
        let bob = alice;
        println!("bob: {}", bob[0]);
    }
    println!("alice: {}", alice[0]);
}
```

Ownership (T)

Alice **Bob**



```
fn main() {
    let alice = vec![1, 2, 3];;
    {
        let bob = alice;
        println!("bob: {}", bob[0]);
    }
    println!("alice: {}", alice[0]);
}
```

Ownership (T)

Alice


```
fn main() {
    let alice = vec![1, 2, 3];;
    {
        let bob = alice;
        println!("bob: {}", bob[0]);
    }
    println!("alice: {}", alice[0]);
}
```

Ownership (T)

Alice

```
error[E0382]: use of moved value: `alice`
 --> src/main.rs:7:27
  |
4 |         let bob = alice;
  |             --- value moved here
...
7 |     println!("alice: {}", alice[0]);
  |                           ^^^^^ value used here after move
  |
  = note: move occurs because `alice` has type
`std::vec::Vec<i32>`, which does not implement the `Copy` trait
```

```
fn main() {
    let alice = vec![1, 2, 3];;
    {
        let bob = alice;
        println!("bob: {}", bob[0]);
    }
    println!("alice: {}", alice[0]);
}
```

Ownership (T)

Alice

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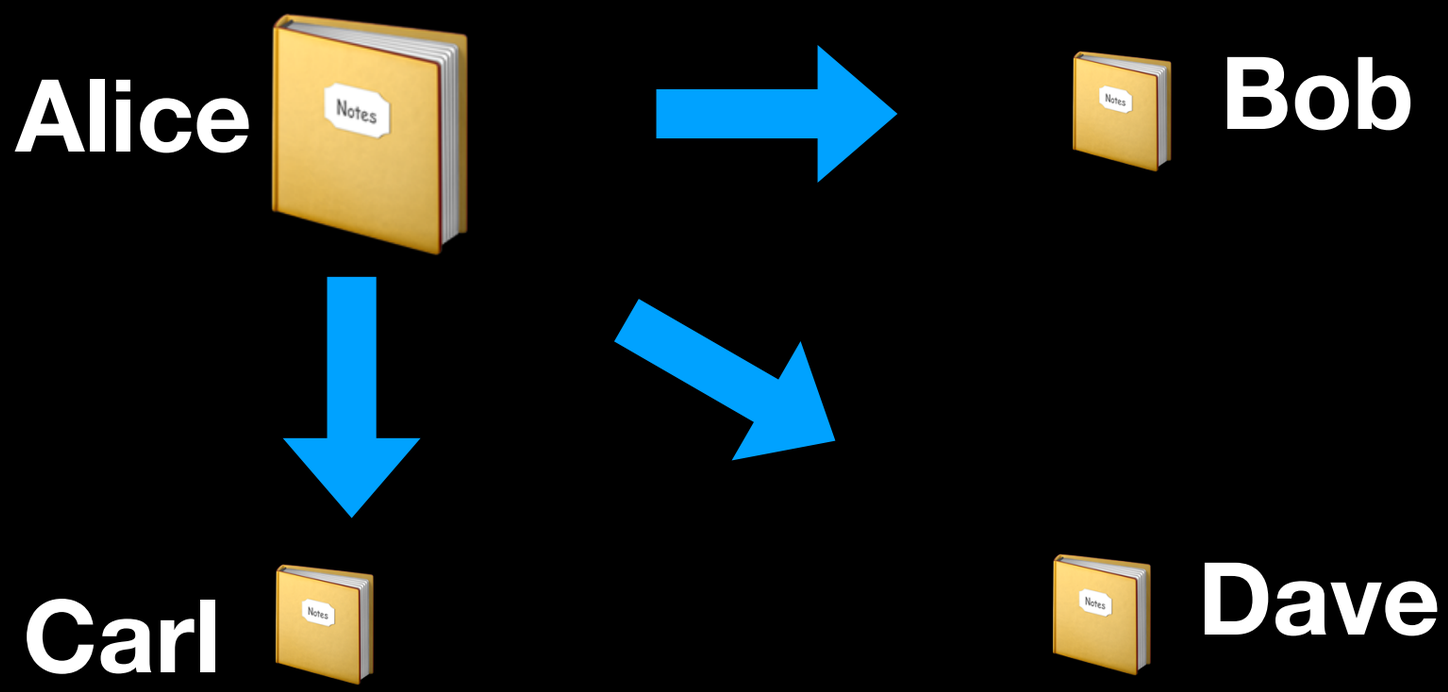
  |                           ^^^^^ value used here after move
  |
  = note: move occurs because `alice` has type
`std::vec::Vec<i32>`, which does not implement the `Copy` trait
```

```
fn main() {
    let mut alice = vec![1, 2, 3];;
    {
        let mut bob = alice;
        println!("bob: {}", bob[0]);
    }
    println!("alice: {}", alice[0]);
}
```

Shared Borrow (&T)

Aliasing + ~~Mutation~~



Mutable Borrow (&mut T)

Alice


```
fn main() {
    let mut alice = 1;
    {
        let bob = &mut alice;
        *bob = 2;
        println!("bob: {}", bob);
    }
    println!("alice: {}", alice);
}
```

Mutable Borrow (&mut T)

Alice **Bob**


```
fn main() {
    let mut alice = 1;
    {
        let bob = &mut alice;
        *bob = 2;
        println!("bob: {}", bob);
    }
    println!("alice: {}", alice);
}
```

Mutable Borrow (&mut T)

Alice


```
fn main() {
    let mut alice = 1;
    {
        let bob = &mut alice;
        *bob = 2;
        println!("bob: {}", bob);
    }
    println!("alice: {}", alice);
}
```

Mutable Borrow (&mut T)

Alice


```
fn main() {
    let mut alice = 1;
    {
        let bob = &mut alice;
        *bob = 2;
        println!("bob: {}", bob);
    }
    println!("alice: {}", alice);
}
```

Mutable Borrow (&mut T)

~~Aliasing~~ + Mutation

Alice

The lifetime of a borrowed reference should end before the lifetime of the owner object does.

Rust's Ownership & Borrowing

~~Aliasing~~ + ***~~Mutation~~***

- Compiler enforced:
  - Every resource has a unique **owner**
  - Others can **borrow** the resource from its owner (e.g., create an **alias**) with restrictions
  - Owner **cannot** free or mutate its resource while it is borrowed

Use-After Free in C/Rust

C/C++

```
void func() {
    int *used_after_free = malloc(sizeof(int));

    free(used_after_free);

    printf("%d", *used_after_free);
}
```

Rust

```
fn main() {
    let name = String::from("Hello World");
    let mut name_ref = &name;
    {
        let new_name = String::from("Goodbye");
        name_ref = &new_name;
    }
    println!("name is {}", &name_ref);
}
```

Use-After Free in Rust

```
error[E0597]: `new_name` does not live long enough
 --> main.rs:7:5
  |
6 |         name_ref = &new_name;
  |                    --------- borrow occurs here
7 |     }
  |     ^ `new_name` dropped here while still borrowed
8 |     println!("name is {}", &name_ref);
9 | }
  | - borrowed value needs to live until here

error: aborting due to previous error
```

Formal Verification

- RustBelt: Securing the Foundations of the Rust Programming Language (POPL 2018)

- *In this paper, we give the first **formal (and machine-checked) safety proof** for a language representing a realistic subset of Rust.*

- https://people.mpi-sws.org/~dreyer/papers/rustbelt/paper.pdf

Rust's Performance vs C

The Computer Language Benchmarks Game

Rust programs versus C gcc

all other Rust programs & measurements

by benchmark task performance

k-nucleotide

source	secs	mem	gz	cpu	cpu load
Rust	**4.86**	137,656	1748	15.42	57% 100% 75% 88%
C gcc	6.67	130,160	1506	19.33	76% 50% 92% 75%

reverse-complement

source	secs	mem	gz	cpu	cpu load
Rust	**0.37**	250,708	1376	0.66	100% 28% 28% 31%
C gcc	0.48	200,492	820	0.66	4% 19% 25% 98%

spectral-norm

source	secs	mem	gz	cpu	cpu load
Rust	**1.98**	2,580	817	7.90	100% 99% 100% 99%
C gcc	2.00	1,300	569	7.89	99% 99% 100% 99%

pidigits

source	secs	mem	gz	cpu	cpu load
Rust	**1.74**	4,532	1366	1.74	100% 1% 0% 2%
C gcc	1.74	2,716	452	1.74	100% 1% 1% 2%

Rust's Performance vs Go

The Computer Language Benchmarks Game

Rust programs versus Go

all other Rust programs & measurements

by benchmark task performance

regex-redux

source	secs	mem	gz	cpu	cpu load
Rust	**2.99**	192,244	804	4.36	31% 16% 85% 16%
Go	28.49	318,144	802	59.96	74% 48% 41% 48%

binary-trees

source	secs	mem	gz	cpu	cpu load
Rust	**3.88**	173,136	721	14.24	90% 91% 100% 90%
Go	34.42	268,188	654	130.26	96% 94% 95% 94%

k-nucleotide

source	secs	mem	gz	cpu	cpu load
Rust	**4.86**	137,656	1748	15.42	57% 100% 75% 88%
Go	14.98	147,704	1722	55.60	97% 88% 92% 95%

mandelbrot

source	secs	mem	gz	cpu	cpu load
Rust	**2.02**	33,572	1332	8.00	99% 100% 99% 99%
Go	5.48	30,704	905	21.74	100% 100% 99% 100%

Rust's Performance

- Firefox Quantum includes Stylo, a pure-Rust CSS engine that makes full use of Rust's "**Fearless Concurrency**" to speed up page styling. It's the first major component of Servo to be integrated with Firefox, and is a major milestone for Servo, Firefox, and Rust. *It replaces approximately 160,000 lines of C++ with 85,000 lines of Rust.*

- Parallelism leads to a lot of performance improvements, including a **30% page load speedup** for Amazon's homepage.

Go?

- Type safe
- Fast GC
- Good at parallelization

MesaLock Linux

- Linux kernel
  - Compatible
  - Stable
- Memory-safe user space
  - Safe
  - Secure

Rules-of-thumb for Hybrid Memory-safe Architecture

- Unsafe components should be appropriately **isolated** and **modularized**, and the size should be small (or minimized).

- Unsafe components **should not weaken** the safe, especially, public APIs and data structures.

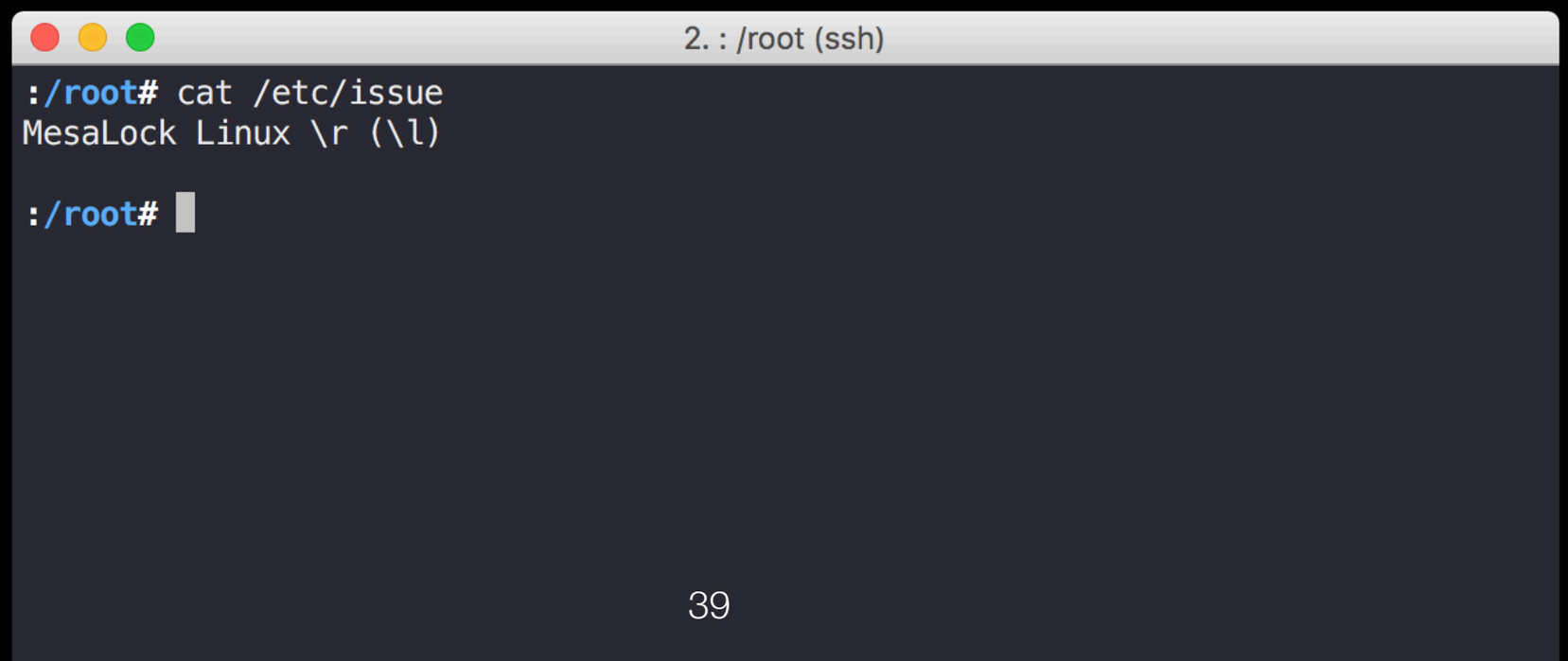
- Unsafe components should be **clearly identified** and **easily upgraded**.

MesaLock Linux

- Live ISO
- Docker image
- rootfs
- x86_64, arm in the near future

Quick Start

```
$ docker run -it mesalocklinux/mesalock-linux
```



MesaLock Linux From Scratch

- Bootloader
- Linux kernel
- init
- getty
- login
- iproute2
- coreutils
- syslinux
- Linux 4.9.58
- minit (Rust)
- mgetty (Rust)
- giproute2 (Go)
- uutils-coreutils (Rust)

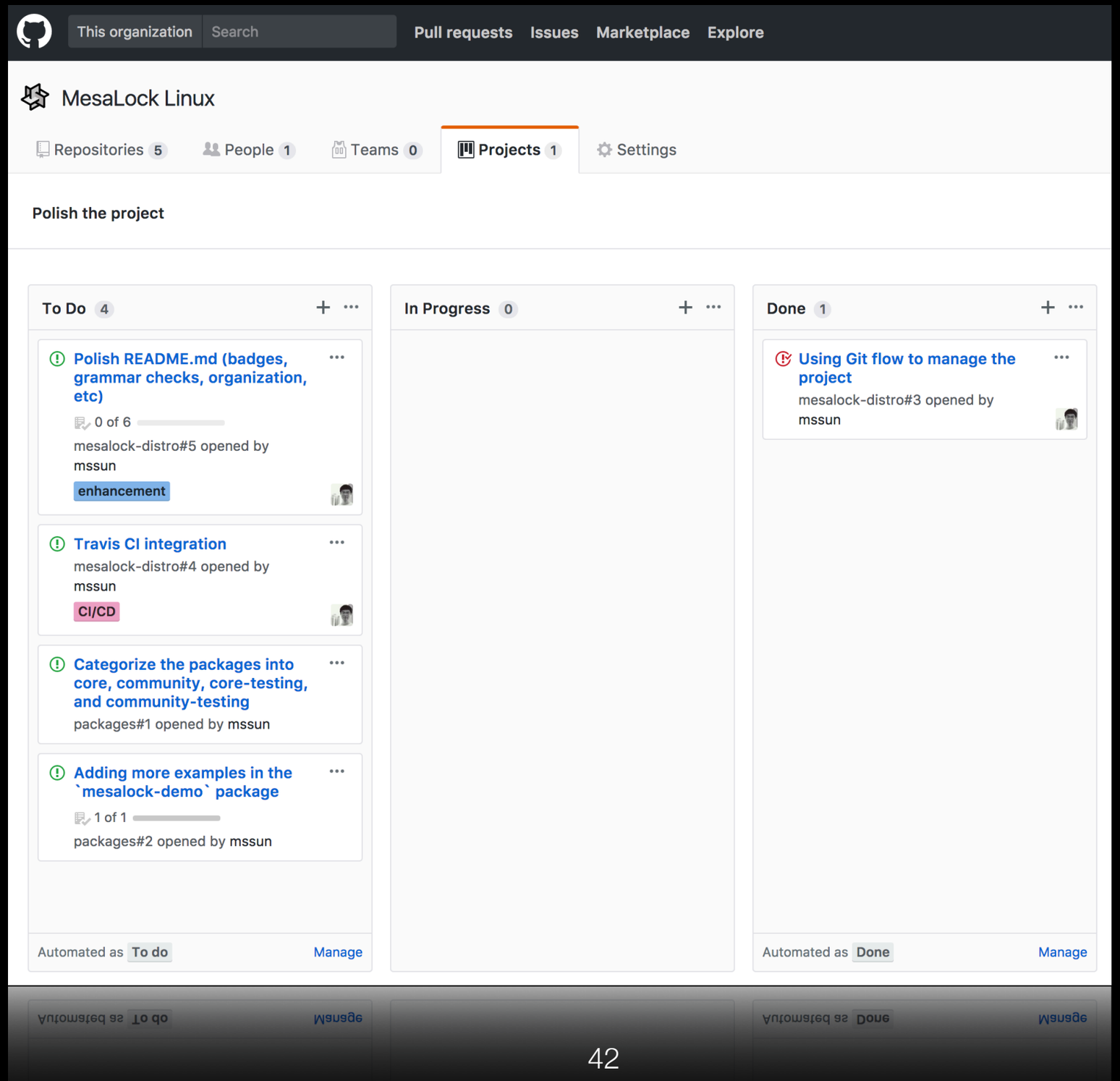
The MesaLock Linux Project

- Open source
  - BSD License (friendly)
  - Development (commit history)
  - Issue (GitHub issue tracking)
  - Discussion (IRC)
  - Roadmap (open)
  - etc

http://mesalock-linux.org

#mesalock-linux
#mesalock-linux-cn
#mesalock-linux-devel
@ Freenode

The MesaLock Linux Project



The MesaLock Linux Project

- Two parts:
  - MesaLock Linux: building scripts, etc
  - Core packages: `minit`, `mgetty`, `giproute2`, etc

The MesaLock Linux Project

- More specific:
  - `mesalock-linux/mesalock-distro`
  - `mesalock-linux/packages`
  - `mesalock-linux/giproute2`
  - `mesalock-linux/minit`
  - `mesalock-linux/mgetty`
  - `mesalock-linux/miproute2`

The MesaLock Linux Packages

- `brotli`: compression tool written in Rust
- `busybox`: busybox tool set for testing only
- `exa`: replacement for ls written in Rust
- `fd-find`: simple, fast and user-friendly alternative to find
- `filesystem`: base filesystem layout
- `gcc-libs`: GCC library, only libgcc_s.so is used
- `giproute2`: ip tool written in Go
- `glibc`: glibc library
- `init`: init script
- `ion-shell`: shell written in Rust
- `linux`: Linux kernel

The MesaLock Linux Packages

- `mesalock-demo`: some demo projects
- `mgetty`: getty written in Rust
- `micro`: modern and intuitive terminal-based text editor in written Go
- `minit`: init written in Rust
- `ripgrep`: ripgrep combines the usability of The Silver Searcher with the raw speed of grep, written in Rust
- `syslinux`: bootloader
- `tokei`: count your code, quickly, in Rust
- `tzdata`: timezone data
- `uutils-coreutils`: cross-platform Rust rewrite of the GNU coreutils
- `uutils-findutils`: rust implementation of findutils
- `xi-core`: a modern editor with a backend written in Rust
- `xi-tui:` a tui frontend for Xi

New Package?

- A package consist of a `BUILD` script and related files and patches.
- The build tool (`mkpkg`) will call following function in order:

1. `prepare()`: downloading source code and prepare configration stuff
2. `build()`: buiding sources
3. `package()`: zip the output as a package

New Package?

2. vim ripgrep/BUILD (ssh)

```
pkgname=ripgrep
pkgver=0.7.1
pkgdesc="ripgrep combines the usability of The Silver Searcher with the raw
speed of grep."
url="https://github.com/BurntSushi/ripgrep"
license=(MIT Unlicense)

prepare() {
  git clone -b 0.7.1 https://github.com/BurntSushi/ripgrep.git "$srcdir"
}

build() {
  cd "$srcdir" && ./compile
}

package() {
  install -D "$srcdir"/target/release/rg -t "$pkgdir"/bin/
}
~
~
~
~
~
~
                                                    1,1           All
```

Roadmap

- 0.1: public release
- 0.2: polish source code organization, improved development process
- 0.3: improving core packages
- 0.4: including more utilities
- 0.5: support multi-platforms
- ...
- 1.0: in production

Contributing

- You can get involved in various forms:
  - Try to **use** MesaLock Linux, report issue, enhancement suggestions, etc
  - **Contribute to MesaLock Linux**: optimize development process, improve documents, closing issues, etc
  - **Contribute to core packages of MesaLock Linux**: improving minit, mgetty, giproute2, etc
  - **Writing applications** using memory safe programming languages like Rust/Go, and joining the the MesaLock Linux packages
  - **Auditing source code** of the MesaLock Linux projects and related packages
- You are welcome to send **pull requests** and report **issues** on GitHub.

Feedbacks

微博搜索 综合 找人 文章 视频 图片

MesaLock Linux

热门

keithcool

百度安全实验室MesaLock Linux开源，这是一个通用 Linux 发行版本，其目标是用 Rust、Go 等内存安全语言重写全部用户空间应用（user space applications），以在用户空间中逐步消除高危的内存安全漏洞。这将极大的降低整个系统的攻击面，并且使得剩余的攻击面可审计、可收敛。

MesaLock L...

MesaLock Linux 开源：一个用户空间内...

MesaLock Linux 是一个通用 Linux 发行版本，其目标是用 Rust、Go 等内存安全语言重写用户空间应用（user space applications），以在用户

12月2日18:53 来自 微博 weibo.com

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按热度 | 按时间

老爷我瞌睡：这比那些“国产操作系统”有意义多了啊！

12月3日 15:39　　回复 | 9

keithcool 赞了这条评论

boywhp：会不会性能很差？用这些脚本语言？

12月3日 17:11　　回复 | 1

keithcool：Rust/Go都是编译语言...

12月3日 17:15　　回复 | 赞

胡争辉：重写整个GNU?

12月7日 18:02　　回复 | 赞

keithcool：是整合加补足，逐步形成一个完整的GNU的内存安全替代方案

12月8日 09:03　　回复 | 赞

胡争辉：回复@keithcool:谢谢

12月8日 23:08　　回复 | 赞

paiSing刘海舰：百度终于办了件有意义的事儿！

12月3日 20:21　　回复 | 赞

keithcool：现在微博配图的size不能自动适配，发个logo也被打败了

12月3日 10:53　　回复 | 赞

安全_云舒：干得漂亮。就看是否一直检查下去了。

12月3日 20:16　　回复 | 赞

Lucene田春峰

我的第一份 mesalock-linux iso 编译出来了。

mesalock 是一个内存安全的 linux 。

网页链接

非常棒!

12月4日15:30 来自 微博 weibo.com

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mesalock-linux / mesalock-distro

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Joined on Mar 18, 2016
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Thank you!

Future Work

- TrustZone OS in Rust
- Linux kernel driver in Rust

Memory-safety in Linux kernel

Vulnerability Trends Over Time

Year	# of Vulnerabilities	DoS	Code Execution	Overflow	Memory Corruption	Sql Injection	XSS	Directory Traversal	Http Response Splitting	Bypass something	Gain Information	Gain Privileges	CSRF	File Inclusion	# of exploits
1999	19	7		3						1		2			
2000	5	3										1			
2001	23	7								4		3			
2002	15	3		1						1	1				
2003	19	8		2						1	3	4			
2004	51	20	5	12							5	12			
2005	133	90	19	19	1					6	5	7			
2006	90	61	5	7	7			2		5	3	3			
2007	63	41	2	8						3	8	7			
2008	71	44	3	17	4					4	6	11			
2009	105	66	2	22	7					8	11	22			5
2010	124	67	3	16	7					8	30	14			5
2011	83	62	1	21	10					1	21	9			1
2012	115	83	4	25	10					6	19	11			
2013	189	101	6	41	13					11	57	26			7
2014	133	89	8	21	10					11	30	20			10
2015	86	55	6	15	4					11	10	17			
2016	217	153	5	38	18					12	35	52			1
2017	421	129	168	40	18			1		14	85	33			
Total	1962	1089	237	308	109			3		107	329	254			29
% Of All		55.5	12.1	15.7	5.6	0.0	0.0	0.2	0.0	5.5	16.8	12.9	0.0	0.0	

Warning : Vulnerabilities with publish dates before 1999 are not included in this table and chart. (Because there are not many of them and they make the page look bad; and they may not be actually published in those years.)

Memory-safe Linux Device Driver using Rust

- https://github.com/tsgates/rust.ko
- a minimal Linux kernel module written in rust
- FFI, unsafe