Securing Linux

Hyungjoon Koo and Anke Li

Outline

- Overview
  - Background: necessity & brief history
  - Core concepts
- LSM (Linux Security Module)
  - Requirements
  - Design
- SELinux
  - Key elements
  - Security context: identity (SID), role, type/domain
- AppArmor
  - Key elements
  - Application policy profile
- SELinux vs AppArmor

Why a new access control model

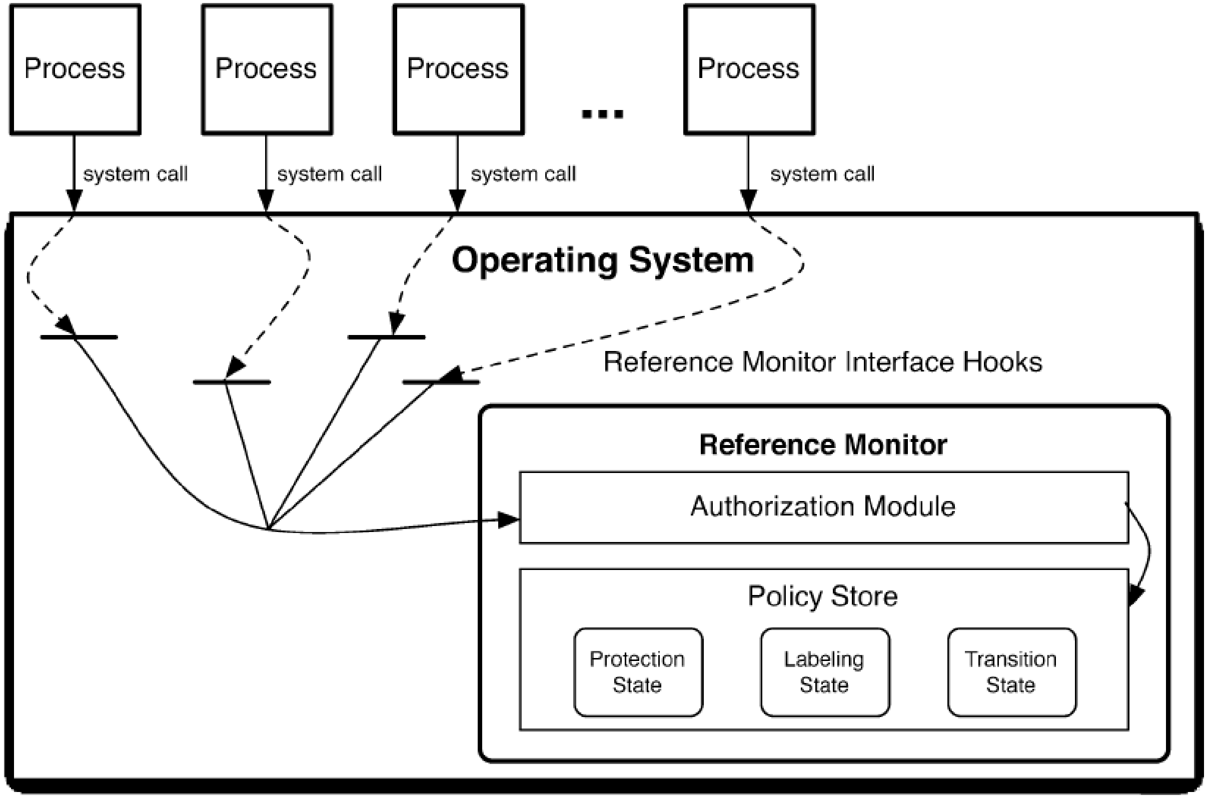
- Limited traditional access control for Linux
  - Discretionary Access Control (DAC)
    - Provide only a coarse access control
    - 9 bits model (`rwx` per owner, group and others)
    - Has *setuid*, *setgid* and *sticky* bit - not enough
- Cases when a fine-grained access control needs
  - Does *passwd* require root access to printers?
  - Suppose I have a secret diary and the app to read it
    - Can I restrict my app from reading/writing a socket over network?
  - Alice might have multiple roles
    - Surfing the web, writing a report, and managing a firewall

Brief history

- Increasing the demand for reference monitor in Linux
  - A mechanism to enforce access control
  - Originate from orange book from the NSA: too generic
- Adopting LSM in Linux Kernel
  - Originally a set of kernel modules in 2.2, updated in 2.4
  - LSM (Linux Security Module) Feature in 2.6
    - *SELinux* developed by the NSA and released in 2001
    - Default choice for Fedora/RedHat Linux
- Lots of early works
  - Subdomain (*AppArmor*), Flask (*SELinux*), OpenWall, …

Reference monitor

- A component that authorizes access requests at the *RMI* defined by individual hooks which invokes module to submit a query to the *policy store*



From Operating System Security (Fig 2.3)

Core concepts

- Idea: Define policies to decide if applications/users have the privilege to proceed a given operation
  - MAC: Mandatory access control
  - Least Privileges
- Broadly covered security policy
  - To all subjects, all objects and all operations
  - As everything in Linux is represented as a FILE
    - files, directories, devices, sockets, ports, pipes, and IPCs

Linux Security Module (LSM)

- Implementation of a reference monitor
- Requirements
  - Modularized security
  - Loadable modules
  - Centralized MAC
  - LSM API

LSM design

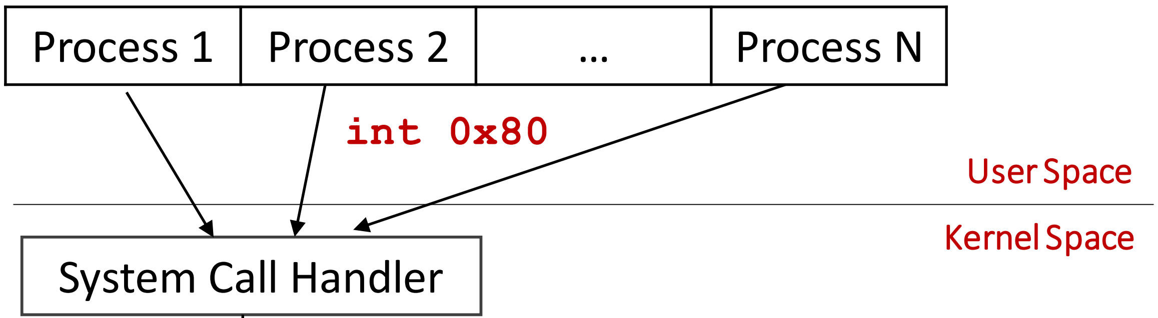
- Definition
  - How to invoke permission check?
    - By calling the initiated function pointers in *security_ops*
    - Aka LSM hooks
  - One hook is shown below:

```
static inline int security_inode_create (struct inode *dir,
                                          struct dentry *dentry,
                                          int mode)
{
     if (unlikely (IS_PRIVATE (dir)))
          return 0;
     return security_ops->inode_create (dir, dentry, mode);
}
```

- Placement
- Implementation

LSM design - hooking

- Simple diagram of hooking



System call	Func ptr	Hook to LSM
open()	0xffffaaaa	lsm_open(), 0xffffbbbb
read()	0xffffaaba	lsm_read(), 0xffffbbcb
write()	0xffffaaca	lsm_write(), 0xffffbbdb
getdents()	0xffffaada	lsm_getdents(), 0xffffbbeb
…	…	…

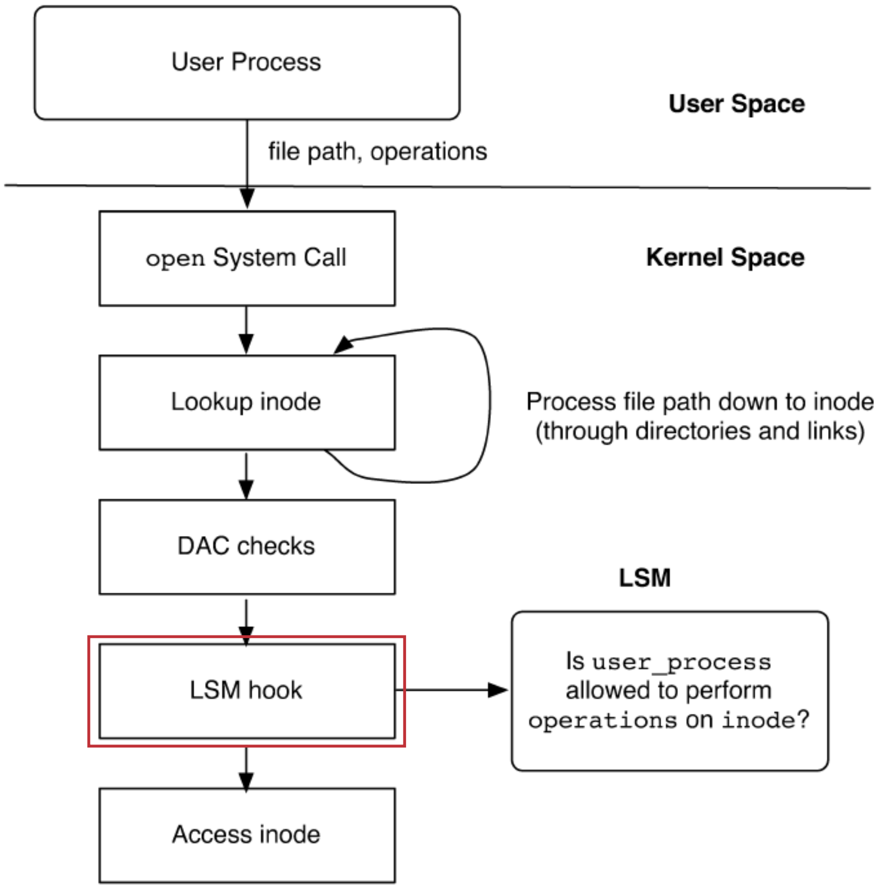
LSM
lsm_open()
lsm_read()
lsm_write()
lsm_getdents()

LSM design

- Definition
- Placement
  - Where to place those hooks?
    - Entry of system call (not all of them)
    - Determined by source code analysis
  - Inline function
    - E.g., `security_inode_create`
- Implementation

LSM design – hooking example

- *open*() hook process
  - Process *syscall* in user
    - file path
    - operation
  - Invoke *syscall* in kernel
  - Lookup *inode*
  - Check DAC
  - Hook & check MAC
  - Grant access



From *Operating System Security (Fig 9.2)*

LSM design

- Definition
- Placement
- Implementation
  - Where to find the function which hooks point to?
  - SELinux, AppArmor, LIDS, etc.
  - Does placement need to change in different LSMs?
    - Theoretically yes
    - Practically, the placement of hooks is stabilized

SELinux at a glance

- Security Policies
  - Centralized store for access control
  - Can be modified by the SELinux system administrator
  - Determined by security contexts (=user, role, type)
  - Specification of permissions
  - Labeled with information for each file
- Based on TE (Type Enforcement) and RBAC model
- Operations to objects for subjects
  - *append, create, rename, rwx, (un)link, (un)lock, …*
- Object classes
  - file, IPC, network, object, …

Some valid questions

- How can *SELinux* internally incorporate with DAC?
  - DAC then MAC
- Who writes the policy?
  - Admin
- Isn't it hard to write a policy?
  - Indeed, and complicated (for *SELinux*)
- What happens if there is wrong policy?
  - Hell

API names are admittedly confusing

Security context

- Consist of three security attributes
  - User identity (SID, Security identifier)
    - SELinux user account associated with a subject or object
    - Different from traditional UNIX account (i.e */etc/passwd*)
  - Type or domain
  - Role (RBAC)

Security context

- Consist of three security attributes
  - User identity (SID, Security identifier)
  - Type or domain
    - Postfix _t (i.e *user_t, passwd_t, shadow_t, …*)
    - Divide subjects and objects into related groups
    - Typically type is assigned to an object, and domain to a process
    - Primary attribute to make fine-grained authorization decisions
  - Role (RBAC)

Security context

- Consist of three security attributes
  - User identity (SID, Security identifier)
  - Type or domain
  - Role (RBAC)
    - Postfix _r (i.e *sysadm_r, user_r, object_r, …*)
    - User might have multiple roles
    - Associate the role with domains (types) that it can access
      - Not assign permissions directly
    - Limits a set of permission ahead of time
    - If role is not authorized to enter a domain then denied

Security context example

- Putting all together
  - Alice wants to change her password
    - SID alice with the user role, *user_r*
    - Role permitted to run typical user processes
    - Any process with *user_t* to execute the *passwd_exec_t* label

```
role user_r  types {user_t user_firefox_t}
```

```
<perm> <sub_type> <obj_type>:<obj_class> <op_set>
Allow  user_t     passwd_exec_t:file     execute
Allow  passwd_t   shadow_t:file          {read write}
```

```
<file_path_expr> <obj_context>
/usr/bin/passwd  system_u:object_r:passwd_exec_t
/etc/shadow.*    system_u:object_r:shadow_t
```

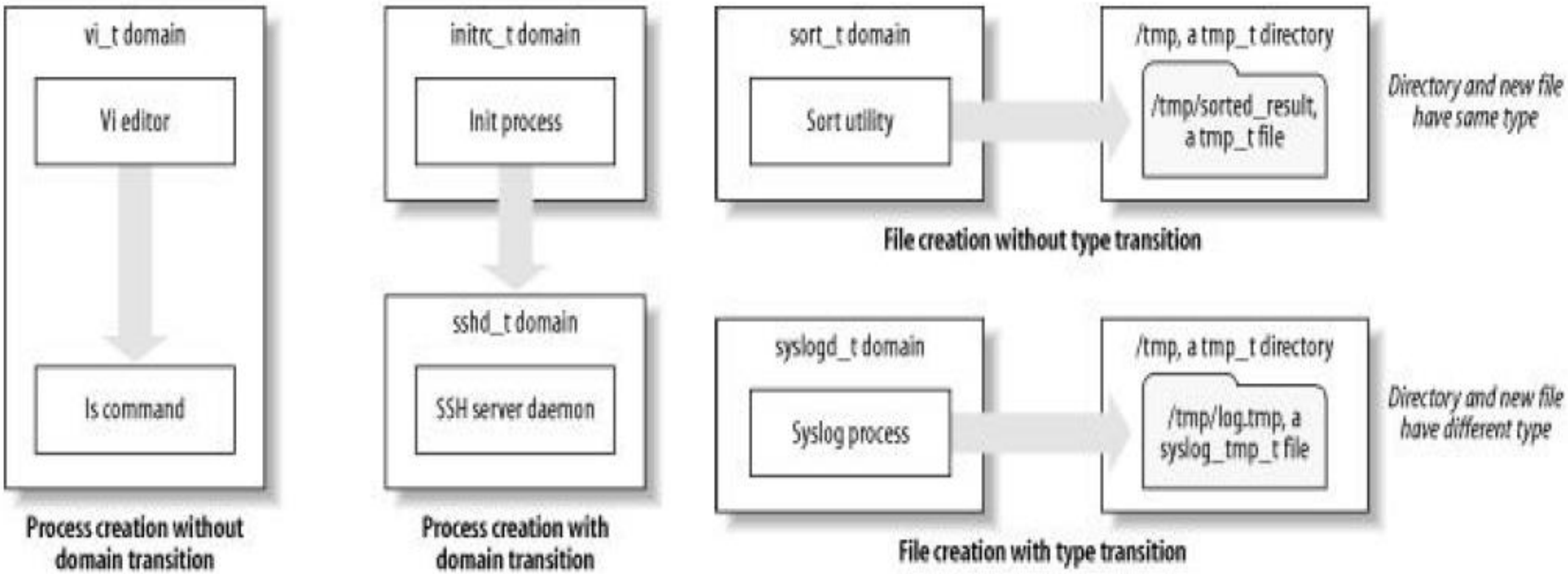
Decision making with policy

- Access decision
  - Based on security context
  - *allow, auditallow, dontaudit,* and *neverallow*
- Q: how can we decide policy for a temporary object?
  - temp processes (i.e fork) and files
- A: transition decision
  - Process creation: *domain* transmission
  - File creation: *type* transmission (labelling)

```
type_transition <curr_type> <exe_file_type>:process <res_type>
type_transition user_t      passwd_exec_t:process   passwd_t
```

Transition decision examples

- Process creation
  - *Domain* decision
- File creation
  - *Type* decision



From *SELinux Ch2*

Implementation

- Policy sources
  - *.te* files (type enforcement)
    - Define rules and macros(*m4*) & assign permissions
  - *.fc* files (file context)
    - Define file contexts, supporting regular expression
  - *RBAC* files
  - User declarations
- *Makefile* (target: policy, install, …)
- Policy compiler
  - Merge all policies to *policy.conf*
  - Generate policy binary, centralized policy storage

AppArmor at a glance

- Another mainstream of LSM implementation
- Much simpler framework than SELinux
  - Targeted policy
  - An “application security system”
  - Pathname based
  - Work in two modes:
    - enforce mode and complain mode
  - One policy file per application
- Used by some popular Linux distributions
  - Ubuntu, openSUSE, etc.

How AppArmor works?

- Designed to be a complement to DAC
  - Can’t provide complete access control
- Born to be targeted policy
  - `unconfined_t` in SELinux
- Application based access control
  - One policy file per application
  - Protect system against applications
- File + POSIX capabilities

AppArmor profile

- Capability rules:

```
capability setuid,
capability dac_override,
```

- Network rules:

```
network (read, write) inet,
deny network bind inet,
```

- File rules:

```
/path/to/file rw,
/dir/** r,
```

SELinux vs AppArmor

- Whole system vs. only a set of applications
- Types & domains vs. defining permission directly
- Strict MAC implementation vs. Partially implement
- Extended attributes vs. pathname
- Difficulty to configure
  - SELinux needs 4x bigger conf. file than AppArmor
- Overhead?
  - 7% vs. 2%

Conclusion

- SELinux and AppArmor can both greatly enhance OS security.
- Choice depends on what you need.