CS 423
Operating System Design:
MP4 Walkthrough

Mohammad Noureddine
Spring 2018

Goals for Today

- Learning Objective:
  - Understand Linux Security Modules
  - Go through implementation details of MP4
- Announcements, etc:
  - MP3 Soft Extension
  - No office hour next week!
  - Make up office hour: Monday 04/30 at 3:30 pm and Piazza

Reminder: Please put away devices at the start of class

Preliminaries

- Please **do NOT revert to snapshots** taken prior to the migration of the VMs
- **Take stable snapshots** before starting this MP
- Your security module will **affect kernel boot**
  - Work incrementally
  - Start with empty functions, add logic in small doses
- Follow MP **submission instructions** carefully

Goals of this MP

- Understand Linux Security Modules
- Understand basic concepts behind Mandatory Access Control (MAC)
- Understand and use filesystem extended attributes
- Add custom kernel configuration parameters and boot parameters
- Obtain least privilege policy for `/usr/bin/passwd`

Linux Security Modules

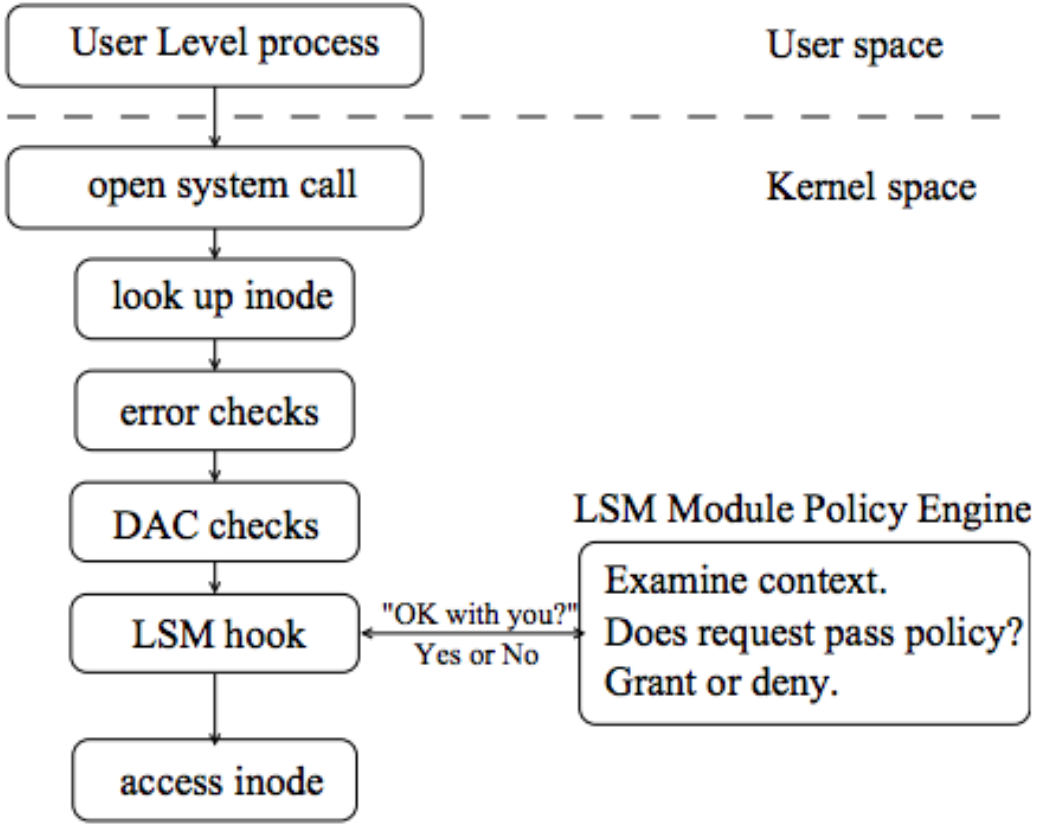
- Came out of a presentation that the NSA did in 2001
  - Security Enhanced Linux (SELinux)
- Kernel provided support for Discretionary Access Control
  - Did not provide framework for different security models w/o changes to core kernel code
- Linux Security Modules (LSM) proposed as a solution
  - Not to be fooled by the term "module"
  - LSMs are **NOT** loadable at runtime

Example LSMs

- Some of the LSMs approved in the current kernel
  - AppArmor
  - SELinux
  - Smack
  - TOMOYO Linux
  - Yama
- Must be configured at build-time and at boot time

How Do LSMs Work?

- Hooks inserted throughout important functionalities of the kernel



Question

- In which context does the LSM run?

Question

- Q: In which context does the LSM run?
- A: In the kernel context just before the kernel fulfills a request

```
union security_list_options {
        int (*binder_set_context_mgr)(struct task_struct *mgr);
        int (*binder_transaction)(struct task_struct *from,
                                  struct task_struct *to);
        int (*binder_transfer_binder)(struct task_struct *from,
                                  struct task_struct *to);
        int (*binder_transfer_file)(struct task_struct *from,
                                  struct task_struct *to,
                                  struct file *file);

        int (*ptrace_access_check)(struct task_struct *child,
                                  unsigned int mode);
        int (*ptrace_traceme)(struct task_struct *parent);
        int (*capget)(struct task_struct *target, kernel_cap_t *effective,
                      kernel_cap_t *inheritable, kernel_cap_t *permitted);
        int (*capset)(struct cred *new, const struct cred *old,
                      const kernel_cap_t *effective,
                      const kernel_cap_t *inheritable,
                      const kernel_cap_t *permitted);
        int (*capable)(const struct cred *cred, struct user_namespace *ns,
```

Major and Minor LSM

- Major LSM
  - Only one major LSM can run in the system
  - Examples: SELinux, Smack, etc.
  - Can access **subjective security blobs**
    - Data structures reserved only for the use of major LSMs
- Minor LSM
  - Can be stacked
  - Does not have access to the security blobs
  - Examples: YAMA

Security Blobs?

- Reserved fields in various kernel data structures
  - `task_struct`, `inode`, `sk_buff`, `file`, `linux_binprm`
- Controlled by the major security module running
- `struct cred` is the security context of a thread
  - `task->cred->security` is the tasks's subjective security blob
  - A task can only modify its own credentials
    - No need for locks in this case!
    - Need rcu read locks to access another tasks's credentials

MAC

- Q: What is Mandatory Access Control anyway?

MAC

- Q: What is Mandatory Access Control anyway?
- Access rights are based on regulations defined by a central authority
- Strictly enforced by the kernel
- Label objects by sensitivity
  - Unclassified, confidential, secret, top secret
- Label users (subjects) by clearance
  - Grant access based on combination of subject and object labels

Labeling our System

- We will developed a major security module
- To keep things simple, we will focus on tasks that carry the label target
- We will focus on only labeling inodes
  - We can use the security blobs
  - Alternatively, we will use extended filesystem attributes
- How do we label our tasks then?
  - We will use the inode label of the binary that is used to launch the process

FS Extended Attributes

- Provides custom file attributes that are not interpreted by the file system
- Attributes under the prefix `security` will be used for interpretation by an LSM
- We will be using `security.mp4` in our implementation
- e.g.,
  - `setfattr -n security.mp4 -v target target_binary`
  - `setfattr -n <prefix>.<suffix> -v <value> <file>`
  - `getfattr -d -m - <file>`

MP4 Challenges

- Label management
  - How to assign and maintain labels
  - How to transfer labels from inodes to tasks
- Access control
  - Who gets to access what
  - Enforce MAC policy
- Kernel configuration
  - `Kconfig` environment
  - Change boot parameters

Step 1: Compilation

- Customize kernel configuration using the `Kconfig` environment
- First add custom config option to `security/mp4/Kconfig`

```
config SECURITY_MP4_LSM
        bool "CS423 machine problem 4 support"
        depends on NET
        depends on SECURITY
        select NETLABEL
        select SECURITY_NETWORK
        default n
        help
          This selects the cs423 machine problem 4 security lsm to be
          compiled with the kernel.
          If you are unsure how to answer this question, answer N.
```

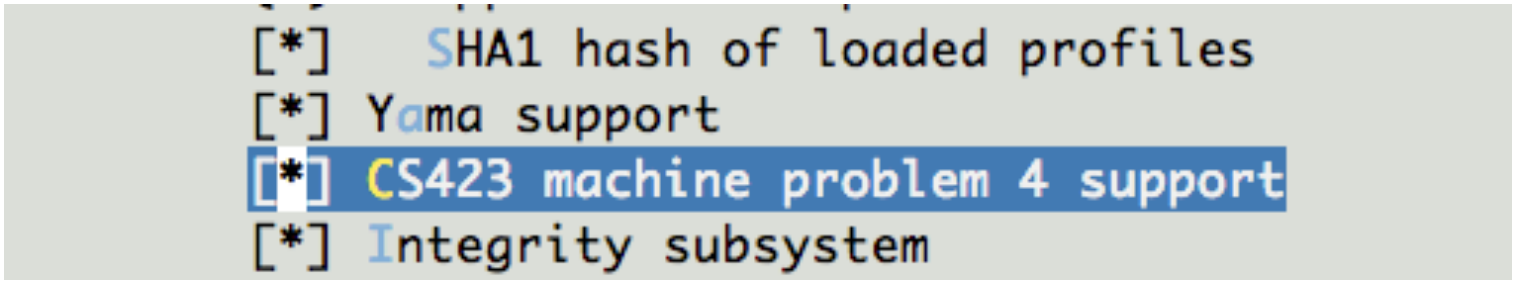
Step 1: Compilation

- Now when you run `make oldconfig`, make will ask you whether to enable
  - `CONFIG_SECURITY_MP4_LSM`
- You can also use it for static compiler macros in your code. e.g.

```
#ifdef CONFIG_SECURITY_MP4_LSM
void do_something(void) { printf("MP4 active\n"); }
#else
void do_something(void) { }
#endif
```

Step 1: Compilation

- You can also use `make menuconfig` to see your config option visually



- You might want to turn `DEBUG_INFO` off to speed up the generation of the `.deb` files

Step 1: Compilation

- After the first compilation, you do not need to recompile the entire kernel again
- Reminder: `make clean` removes all of the object files and will cause the entire kernel to be recompiled
- For incremental builds, use: `make -j<num_proc>`
- To produce `.deb` files again:
  - `make bindeb-pkg LOCALVERSION=...`

Step 1: Boot params

- Next we want to enable the mp4 module as the major security module in our system
- The kernel accepts the key-value pair `security=<module>` as part of its boot parameters
- Update `/etc/default/grub`:

```
GRUB_CMDLINE_LINUX_DEFAULT="security=mp4"
```

- Don't forget to update grub!

Step 2: Implementation

- We will implement our module in three steps:

  1. Register the module and enable it as the only major security module (Provided to you at no cost in mp4.c)
  2. Implement the labels initialization and management
  3. Implement the mandatory access control logic

- We provide you with helper functions in mp4_given.h
- Use pr_info, pr_err, pr_debug, pr_warn macros
  - `#define pr_fmt(fmt) "cs423_mp4: " fmt`

Step 2.1: Startup

- We provide you with the startup code to get your started
- We will implement the following security hooks:

```
static struct security_hook_list mp4_hooks[] = {

   LSM_HOOK_INIT(inode_init_security, mp4_inode_init_security),
   LSM_HOOK_INIT(inode_permission, mp4_inode_permission),

   LSM_HOOK_INIT(bprm_set_creds, mp4_bprm_set_creds),

   LSM_HOOK_INIT(cred_alloc_blank, mp4_cred_alloc_blank),
   LSM_HOOK_INIT(cred_free, mp4_cred_free),
   LSM_HOOK_INIT(cred_prepare, mp4_cred_prepare)
};
```

Step 2.2: Label Semantics

```
/* mp4 labels along with their semantics */
#define MP4_NO_ACCESS 0         /* may not be accessed by target,
                                 * but may by everyone other */

#define MP4_READ_OBJ 1          /* object may be read by anyone */

#define MP4_READ_WRITE 2        /* object may read/written/appended by the target,
                                 * but can only be read by others */

#define MP4_WRITE_OBJ 3         /* object may be written/appended by the target,
                                 * but not read, and only read by others */

#define MP4_EXEC_OBJ 4          /* object may be read and executed by all */

/* NOTE: FOR DIRECTORIES, ONLY CHECK ACCESS FOR THE TARGET SID, ALL OTHER NON
 * TARGET PROCESSES SHOULD DEFAULT TO THE LINUX REGULAR ACCESS CONTROL
 */
#define MP4_READ_DIR 5          /* for directories that can be read/exec/access
                                 * by all */

#define MP4_RW_DIR 6            /* for directory that may be modified by the target
                                 * program */
```

Step 2.2: Label Map

```
if (strcmp(cred_ctx, "read-only") == 0)
    return MP4_READ_OBJ;
else if (strcmp(cred_ctx, "read-write") == 0)
    return MP4_READ_WRITE;
else if (strcmp(cred_ctx, "exec") == 0)
    return MP4_EXEC_OBJ;
else if (strcmp(cred_ctx, "target") == 0)
    return MP4_TARGET_SID;
else if (strcmp(cred_ctx, "dir") == 0)
    return MP4_READ_DIR;
else if (strcmp(cred_ctx, "dir-write") == 0)
    return MP4_RW_DIR;
else
    return MP4_NO_ACCESS;
```

Step 2.2: Label Mgmt

- We are interested in three operations:

1. Allocate/free/copy subject security blobs
2. When a process starts, check the inode of the binary that launches it.
    - If it is labeled with target, mark `task_struct` as target
    - mp4_bprm_set_creds
3. Assign read-write label to inodes created by the target application
    - mp4_inode_init_security

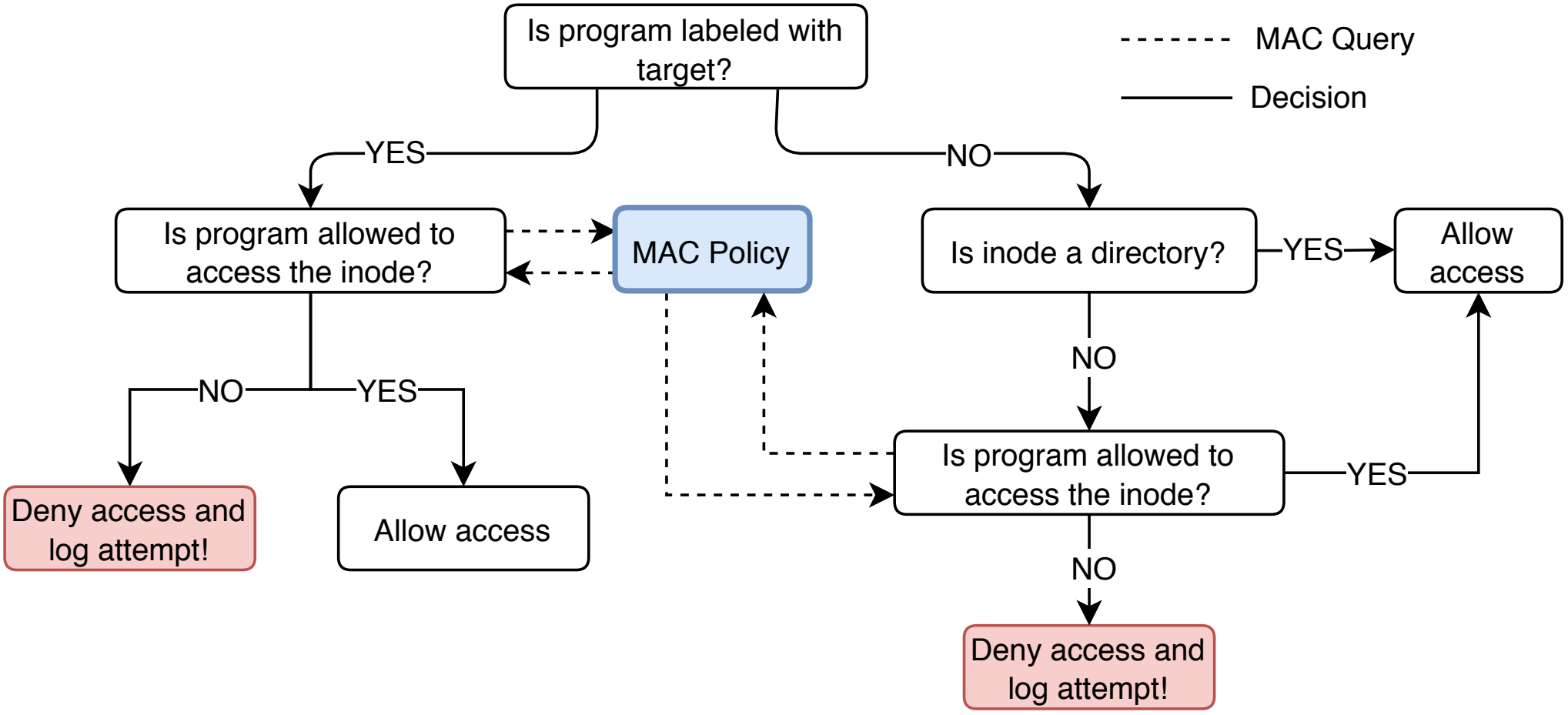
Step 2.2: Attributes

- How do we obtain an inode's extended attributes?
- Few hints:
  - Given an `struct inode *`, we can ask for its `struct dentry *`
  - You can query some kernel functions if there is something you need to know
    - This is important if you don't know how much memory to allocate
    - Watch for the `ERANGE` errno
  - It is **very important** to put back a dentry after you use it
    - `dput(dentry);`

Step 2.3: Implement AC

- Translate label semantics into code
  - mp4_inode_permission
- Operation masks are in `linux/fs.h`
- Obtain current task's subject blob using `current_cred()`
- To speed things up during boot, we want to skip certain directories
  - Obtain inode's path (hint: use dentry!)
  - Call mp4_should_skip_path from mp4_given.h

Step 2.3: Implement AC



Step 2.3: Implement AC

- You **MUST** log attempts that are denied access
- To minimize the chances of bricking your machine:
  - Always take a snapshot that takes you back to stable state
  - Implement AC logic, but always return access granted and print appropriate messages
  - Check you messages, if all is according to plan, update your code to return appropriate values
  - Test your return codes

Step 3: Testing

- Test your security module on simple functions
  - vim, cat, etc.
  - avoid operation critical programs (ls, cd, bash, etc.)
  - Note, to grant read access `/home/netid/file.txt`,
  - **must** have access to all three of `/home`, `/home/netid/`, **and** `/home/netid/file.txt`
- Always restore you system state to a place where all labels are removed before you reboot

Step 3: Testing

- Suggested method of testing:
  - Create two scripts: mp4_test.perm and mp4_test.perm.unload
  - source first script to load, source the other to unload
- In mp4_test.perm:

```
setfattr -n security.mp4 -v target /usr/bin/cat
...
setfattr -n security.mp4 -v read-only /home/netid/file.txt
```

- In mp4_test.perm.unload, undo everything before reboot:

```
setfattr -x security.mp4 /usr/bin/cat
...
setfattr -x security.mp4 /home/netid/file.txt
```

Final Step: Obtain Policy

- Goal is to obtain least privilege policy for the program `/usr/bin/passwd`
- **DO NOT TRY TO CHANGE THE PASSWORD FOR YOUR NETID ACCOUNT**
- Create dummy user account and change its password
- Use **`strace`** to obtain the set of files and access requests that `passwd` uses
- Generate `passwd.perm` and `passwd.perm.unload` based on the outcome
- Test your module's enforcement of the policy!