

CMPS 443: Introduction to Computer and Network Security

Spring 2022

Project 3: Integrity Access Controls

Due: 11:59 pm (eastern time), April 8, 2022

March 21, 2022

1 Introduction

In this project, you will implement a reference monitor that enforces various methods for protecting integrity of data and process using Mandatory Integrity protection systems. More specifically your implementation should accommodate the **Biba Integrity** policy, **Windows Mandatory Integrity Control (MIC)** policy and the **Low Water-Mark Mandatory Access Control (LOMAC)** policy.

You are already given the project repository with few important missing pieces. First, you will understand the code structure and implementation of the reference monitor. Finally, with your understanding of the integrity access control policies, you will complete the missing pieces in the project with your own code. How to run and test your code will be explained in the later sections of this handout.

NOTE: Please read the entire report in its entirety before starting any part of the project!

2 Prerequisites

a) It is necessary to know the three **access control policies** in detail. Knowledge about how users, processes and files with different integrity levels interact with and affect each other is required to successfully complete this project. We have summarised it in the Background section, however, it is advisable to refer to course slides and other online resources to get a better understanding. If you have any doubts related to the rules in each policy, you may reach out to the course staff during office hours or through Piazza.

b) It is advisable to brush up some concepts in C including **structs**, **pointers**, **pointer arithmetic**, **malloc/free**, **typedef** and **type casting**. The code heavily uses these concepts to set up the platform to handle multiple different access control policies.

c) The code heavily uses **doubly-linked lists**. It is highly recommended (if you're not already comfortable with) to understand the data structure and its implementations in C before proceeding to understand the code.

Some free online resources:

https://www.tutorialspoint.com/data_structures_algorithms/doubly_linked_list_program_in_c.htm

<https://www.youtube.com/watch?v=VOQNf1VxU3Q>

3 Project Platforms

For this project, we recommend using **any Linux machine** as long as it supports compiling and running C. You can use the same VM from the previous project. Or you can boot a new VM in Oracle VirtualBox, VMWare etc. You might need to run the following command to install the gcrypt module:

```
sudo apt-get install -y libgcrypt-dev
```

You may require GDB debugger to constantly debug your code and evaluate your progress in the project. Although, using GDB is highly recommended, it is not necessary.

NOTE: Please finish setting up your project environment within the first week. The course instructors will accommodate and fix the project environment related issues only in that time. They may not be able to help you if you come up with setup related issues in the last week of project deadline.

4 Background

The goal of integrity protection is to prevent a system's processes from receiving untrusted inputs and files from being updated or read by untrusted processes. However, allowing no interactions between trusted and untrusted processes at all might prevent many useful interactions from occurring in a system. Therefore, many researchers have in the past come up with different approaches to this problem by proposing various mandatory access control policies. In this project, we will only focus on three of them:

Biba Integrity Policy

1. Every Process is assigned an integrity Level.
2. Every File is assigned an integrity level.
3. All the levels in a system form a Lattice structure. In this project, for Biba policy we have a 2-level lattice - Low and High.
4. Read Policy: A process/user is allowed to read from a file of the same integrity level or above.
“Read Up”
5. Write Policy: A process/user is allowed to write to a file of the same integrity level or below.
“Write Down”
6. Exec Policy: Same as Read Policy.

Windows Mandatory Integrity Control (MIC) Policy

1. Every Process is assigned an integrity Level.
2. Every File is assigned an integrity level.
3. All the levels in a system form a Lattice structure. In this project, for MIC policy we have a 3-level lattice - Internet(low), User(high) and System(highest).
4. Read Policy: All reads are allowed.
5. Write Policy: A process/user is allowed to write to a file of the same integrity level or below.
“Write Down”
6. Exec Policy: A process/user is allowed to execute a file of the same integrity level or above.
“Exec Up”

Low Water-Mark Mandatory Access Control (LOMAC) Policy

1. Every Process is assigned an integrity Level.
2. Every File is assigned an integrity level.
3. All the levels in a system form a Lattice structure. In this project, for LOMAC policy we have a 2-level lattice - Low and High.
4. Read Policy: A process's integrity level is changed to the read file's level that has the lowest integrity level.
5. Exec Policy: A process's integrity level is changed to the executed file's level that has the lowest integrity level.
6. Write Policy: A file's integrity level is changed to the writing process's level that has the lowest integrity level.

5 Code and Compiling

The initial code for the project is provided here : <https://syed-rafiul-hussain.github.io/index.php/teaching/cmpsc443-s22/projects/cmpsc443-s22-p3.zip>. You are only allowed to edit “**cmpsc443-refmon.c**” and “**cmpsc443-lattice.c**”. Editing any other file for the sake of finishing the project might work locally, but for grading your code files will be run in a different environment. Please refrain from changing any other file apart from these two.

Once you have some changes done in your files, to compile the code run this command:

```
make
```

The Makefile provided in the project directory will handle all the necessary compiling for your code. Once compiled, an updated binary is created with the name “**cmpsc443-p3**”.

The reference monitor takes in Policy files and Test instruction files as input. As an output, the reference monitor creates a results file. For example:

```
Input Policy file - ./policies/biba.policy
Input Test file - test
Output file path - ./results/biba.output
```

Commands to execute the test:

```
./cmpsc443-p3 ./policies/biba.policy test ./results/biba.output
./cmpsc443-p3 ./policies/mic.policy test ./results/mic.output
./cmpsc443-p3 ./policies/lomac.policy test ./results/lomac.output
```

We have provided results in the “sample_results” folder. The files provided are:

```
sample_results/biba.results
sample_results/mic.results
sample_results/lomac.results
```

Your code works exactly as expected if your output files **EXACTLY** match the results we have provided. E.g., your **biba.output** should match our **biba.results** exactly.

NOTE: Do not edit any “**fprintf**” statements provided in multiple files within the code repository as it may affect your grade. The test results are directly related to these **fprintf** statements.

6 Tasks

Most of your efforts would be spent in understanding the way the reference monitor is already implemented in the repo. Then, you need to finish four functions that have missing pieces of code to complete this assignment successfully. They are:

```
Function addLabelPolicy in cmpsc443-lattice.c
Function labelProcess in cmpsc443-refmon.c
Function checkAccess in cmpsc443-refmon.c
Function checkTrans in cmpsc443-refmon.c
```

You do not have to implement the entire function. More particularly, the missing pieces of code are marked by:

```
/* YOUR CODE */
```

There are code comments in most places to help you understand the flow of the program. However, these are some points to remember:

1. The file `cmpsc443-lattice.c` defines three global lists (doubly linked lists) namely **lattice**, **label_mapping** and **trans_mapping**.
2. The file `cmpsc443-refmon.c` defines one global list (doubly linked list) namely **system_mapping**.
3. Every list is made up of elements and each element is of the type “**elt**”. Definitions and other util functions for lists are provided in **cmpsc443-list.c** and **cmpsc443-list.h** files.
4. This reference monitor accepts policy files that express the **protection state** (pstates), **labeling state** (lstates), and **transition state** (tstates).
5. Adding protection states into the system is handled by the function “`addLattice`” and this has already been implemented for you.
6. Adding labeling states into the system is handled by the function “`addLabelPolicy`” and **you have to implement this function**.
7. Adding transition states into the system is handled by the function “`addTransPolicy`” and this has already been implemented for you.

• **addLabelPolicy Function**

1. Assigns a mapping from *name* to *level* based on the policy file’s lstate statements. This is the labeling state of the reference monitor’s mandatory protection system.
2. It is assigned to the global variable **label_mapping**, which is a list of name-level mappings.
3. In this function, you just need to find the lattice **level object** for the level provided from lattice, create a **map object** (defined in `cmpsc443-lattice.h`) that assigns the level to the name, and add a new element (elt defined in `cmpsc443-list.h`).

• **labelProcess Function**

1. Assigns a level to a process named *proc* using *name* from a mapping *mapping*.
2. At runtime, every new process must be labeled when it starts. This function applies the labeling state to produce such a label.
3. Processes are created in two ways: During login based on authenticated user name and during process create (fork) based on the parent process name.

4. The difference is determined by the mapping passed into this function. You simply have to retrieve the *level* associated with that *mapping name* and create a new level assignment for this process name *proc*.
5. Runtime level assignments are stored in the global variable *system_mapping*.

- **checkAccess Function**

1. Authorizes operations requested by processes.
2. Operations include open, exec, read, and write. All operations are on file names, including read and write.
3. The permissions required for the various operations are specified in *execCmds* in *cmpsc443-refmon.c*
4. From the *system_mapping* list, retrieve the element corresponding to the given *process* name.
5. From the *system_mapping* list, retrieve the element corresponding to the given *file* name.
6. Extract the *level* elements from the process element and the file element.
7. Write code to check if the given *operation* on the *file* by the *process* is allowed or not based on the retrieved levels information.
8. Note that all reads are allowed in MIC policy.

- **checkTrans Function**

1. Determines if the level of a particular *process* or *file* should be changed based on the transition state (tstate specifications in the policy).
2. From the *system_mapping* list, retrieve the element corresponding to the given *process* name.
3. From the *system_mapping* list, retrieve the element corresponding to the given *file* name.
4. Retrieve a transition state entry for the combination of subject level, object level, and operation.
5. If found, apply the transition.

7 Questions

1. In Biba policy testing, why don't we let process p2 read the file f1 ?
2. In MIC policy testing, why do we let process p2 read the file f1 ?
3. In MIC policy testing, why don't we let process p11 execute the file f1 ?
4. In LOMAC policy testing, why do we let process p11 execute the file f1 ?
5. In LOMAC policy, process p2 is able to write to file f3 sometimes. But other times it is denied to write. Explain all such occurrences and reason out.

8 Deliverables

All tasks in this project need to be completed individually without any help. Any sharing of code is forbidden. Please refrain from copying as your code will be thoroughly tested during grading. **Please submit a zip file containing the following:**

1. cmpsc443-refmon.c
2. cmpsc443-lattice.c
3. Report (pdf format) with answers to the questions mentioned above.

NOTE: Just submit the three files requested above. Do not add anything else.

9 Grading

The assignment is worth 180 points in total broken down as follows:

1. **Biba Policy:** 10 points for Policy setup. 40 points for Test case traces.
2. **MIC Policy:** 10 points for Policy setup. 40 points for Test case traces.
3. **LOMAC Policy:** 10 points for Policy setup. 40 points for Test case traces.
4. **Questions 1-4:** 5 points each.
5. **Question 5:** 10 points