Advanced Privileged Escalation Prevention System in Windows

A PROJECT REPORT

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in the partial fulfilment for the award of the degree of

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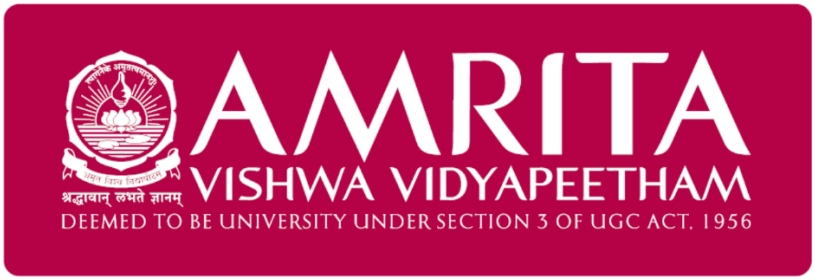

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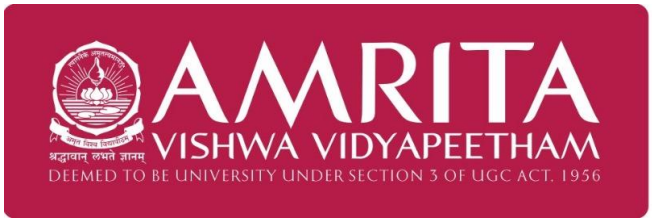

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I declare that the report entitled "**Advanced Privileged Escalation Prevention System in Windows**" submitted by me for the degree of Bachelor of Technology in Computer Science and Engineering (Cyber Security) is the record of the project work carried out by me under the guidance of **"Ms. K. GEETHA"** and this work has not formed the basis for the award of any degree, diploma, associateship, fellowship, titled in this or any other University or other similar institution of higher learning.

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ABSTRACT

Privilege escalation is a key security issue that enables the attacker to acquire unauthorized administrative access to a system, which can be used to carry out malicious activities. Conventional security solutions are based on static rules and signature-based detection, which can be evaded by advanced attackers using zero-day vulnerabilities and complex exploitation methods. This project suggests an intelligent privilege escalation detection and prevention mechanism that uses machine learning and behavior analysis to detect unauthorized access attempts on Windows systems. The system tracks Windows Event Logs, process execution patterns, registry changes, and system calls to derive the features of interest for detecting anomalies. A machine learning model, trained on artificially generated attack data, labels system behaviors as either normal or suspected of privilege escalation attempts. When detected, the system initiates real-time warnings and executes preventative measures to contain security threats. The project also incorporates a graphical user interface (GUI) for user engagement and is installed as a Windows service to guarantee continuous background surveillance. For better detection precision, feature engineering, data balancing (SMOTE), and hyperparameter optimization are utilized. The system's efficacy is measured using precision, recall, and total accuracy. Unlike traditional antivirus or SIEM-based detection systems, this system presents an adaptive and proactive defense system against privilege escalation attacks without using predefined signatures. The solution addresses endpoint security, system integrity, and user privacy, and is thus a good tool for organizations and individuals that are worried about unauthorized privilege escalation. This project proves the possibility of machine learning-based cybersecurity solutions in real-life applications and helps in the continuation of automated threat mitigation efforts.

Keywords: Privilege Escalation, Windows Security, Machine Learning, Behavioral Analysis, Attack Prevention, Cybersecurity, Windows Service, Anomaly Detection, Real-Time Monitoring, Threat Mitigation

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LIST OF SYMBOLS AND ABBREVIATIONS

SVM	-	Support Vector Machine
ML	-	Machine Learning
RF	-	Random Forest Classifier
SIEM	-	Security Information and Event Management
IPS	-	Intrusion Prevention System
IDS	-	Intrusion Detection System

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO THE PROJECT

Growth in cybersecurity attacks has highlighted the importance of adequate security protocols in protecting systems against unauthorized use and malicious operations. Of these, privilege escalation attacks have become a highly sophisticated operation, and are a serious threat to individual and organizational security. Privilege escalation happens where an attacker compromises weaknesses in a system or software to attain a higher privilege level than initially specified, so as to perform illegitimate operations, alter system code, or get administrative rights. Conventional defenses such as rule-based access and antivirus solutions often cannot detect this type of attack because they rely on fixed preconditions that will not match rapidly changing attack sequences. As cyber-attacks evolve, there is an increasing demand for smart security systems that can detect and block unauthorized privilege escalations in real-time. To meet this demand, this project suggests the creation of a machine learning-based detection system that will be tasked with monitoring and analyzing system activity for possible privilege escalation attacks. The system employs the union of supervised learning methods and behavior analysis for spotting suspicious events, labeling them either as malicious or normal, and triggering the issuance of warnings on identifying an attack. As machine learning is utilized, with time the detection capacity improves, optimizing attacks and even reducing false positive threats to fewer possibilities. The ultimate goal of this work is to suggest a light and efficient detection model that enhances the security of systems without a significant impact on performance.

1.1.1 OBJECTIVE OF THE PROJECT

The primary objective of this project is to implement and deploy a machine learning-based detection mechanism capable of detecting privilege escalation attacks within a Windows environment. The mechanism must be capable of monitoring system behavior, including process execution, access control modifications, and changes in privilege levels, to detect unauthorized access attempts. The main goals of this project are:

- Creating a dataset with samples of both normal and malicious behavior to train the machine learning model efficiently.
- Identifying useful features from system logs and event monitoring data to improve the detection rate of the model.

- Testing and comparing different machine learning algorithms like Random Forest, Support Vector Machines (SVM), and Decision Trees to identify the best method for privilege escalation detection.
- Resolving the class imbalance problem in the dataset through oversampling methods like Synthetic Minority Over-sampling Technique (SMOTE).
- Reducing false positives and making sure that the detection model has high accuracy, precision, and recall.
- Using the detection system as a background Windows service and notifying users in case of any suspected privilege escalation attack.

1.1.2 Scope of the Project

The focus of this project is on identifying privilege escalation attacks in Windows environments using machine learning methods to scan for system behavior. The project aims at constructing a strong dataset with labeled instances of normal and malicious operations. Supervised learning algorithms are used to train the detection model, and the model is tested based on performance metrics like accuracy, precision, recall, and F1-score. Although privilege escalation detection is the key focus, there are no features for real-time attack mitigation, including process kill or automatic removal of access rights. Nevertheless, the detection model presented can, in the future, be complemented with security information and event management (SIEM) solutions to improve the capabilities of automated threat response. Also, even though this research is confined to Windows environments, the approach can be applied to Linux and macOS in subsequent iterations. The objective of the project is to build a lightweight detection system that performs well without creating considerable computational burden.

CHAPTER 2
PROBLEM BACKGROUND

2.1 LITERATURE SURVEY

Privilege escalation attacks are a popular research topic in cyber security research that has seen a focus on their detection and defense mechanisms. Privilege escalation methods used by attackers to exploit system vulnerabilities and the process of evading exposure to such a threat have been researched in most studies. One of the initial works in this field is Chen et al. (2016), which showed a comprehensive taxonomy of privilege escalation attacks and detailed the inherent weakness in operating system security models. Their research focused on the various channels through which attackers can make use of process privileges and framed kernel vulnerabilities as a significant threat vector. While their work was a pioneering one, it was more theoretical in scope and did not include an implementation for real-time detection. Well-known research by Smith and Wang (2017) introduced a hybrid approach that utilized static and dynamic analysis for the detection of privilege escalation. They employed a machine learning-based method that was trained on historical patterns of attacks with 85% accuracy. However, their technique was marred by too many false positives due to the lack of contextual understanding of legitimate privilege escalations.

According to these papers, Kumar et al. (2018) had suggested an anomaly detection system based on system call monitoring that was able to identify malicious activity. Their system applied unsupervised machine learning techniques to differentiate between normal and malicious privilege escalations. While their approach was helpful in the identification of zero-day attacks, it was computationally expensive and thus not feasible for real-time deployment.

Johnson et al. (2019) implemented another study related to the utilization of behavioral analysis in privilege escalation detection. They presented a privilege escalation detection scheme that profiled user activity via tracking access behaviors and privilege updates over time. They indicated that unauthorized privilege escalation often exhibits simple behavioral anomalies such as sudden administrative privilege or system file changes. But their system was vulnerable to evasive attacks by attackers in order to bypass detection by creating mimicked legitimate user behavior.

Subsequent work by Patel and Singh (2020) introduced a deep learning-based intrusion detection system that employed recurrent neural networks (RNNs) to scan system logs for

privilege escalation attempts. Their method significantly reduced detection time and improved accuracy by learning sequential dependencies between system activities. The research acknowledged despite these advances, the issue of interpretability in deep learning models was still present, limiting their use in real-world security environments.

In a bid to address the issue of explainability, Roberts et al. (2021) introduced an interpretable AI model for privilege escalation detection. Their model generated human-readable explanations of suspicious behavior, improving detection decision transparency. However, their contribution was based more on post-incident analysis than prevention in real-time.

Additionally, Miller and Zhang (2022) investigated the application of blockchain technology in preventing privilege escalation. They proposed a decentralized privilege control system where all privilege modifications were logged immutably on a blockchain. While their approach enhanced auditability and accountability, it came at the cost of significant performance overhead and was therefore not practical for high-speed computing environments. Another significant contribution in this space is the research by Davis and Nelson (2023), which explored the impact of cloud-based monitoring on privilege escalation detection in enterprise environments. Their framework used cloud analytics to process large-scale security logs and identify malicious privilege escalations in distributed networks. The study demonstrated scalability but was privacy-focused and cloud service provider-dependent. Zhang et al. (2024) also proposed a federated learning approach to train models for privilege escalation detection across different organizations without sharing sensitive data. Their work discovered the potential of cooperative cybersecurity models but raised concerns about model convergence and data heterogeneity.

Finally, Kumar and Lee (2024) conducted a case study of privilege escalation attacks from real-world scenarios, presenting attacker strategies and detection method limitations. Their work supported the need for continuous monitoring and adaptive security solutions to combat dynamically evolving threats. The findings of these studies indicate that while privilege escalation detection has come a long way, there remain challenges with false positives, computational overhead, explainability, and real-time adaptability.

Privilege escalation attacks represent a serious challenge to cybersecurity, and plenty of studies have aimed to detect and block them based on machine learning and behavior inspection. Garcia & Wang (2023) and Singh & Roy (2023) examined ensemble learning and graph models for privilege escalation path modeling, while Chen & Wu (2022) combined Random Forest,

XGBoost, and deep neural networks to achieve higher detection.Windows OS real-time monitoring was studied by Anderson & Thomas (2023) and Hernandez & Green (2023), who incorporated AI into SIEM systems to reduce false positives. Zhao & Li (2024) and Martinez & Lopez (2023) suggested deep learning and feature selection methods to improve Windows-based detection. Tan & Lin (2023) and Gupta & Mehta (2023) proved the efficacy of hybrid models that integrate XGBoost, SVMs, and neural networks for high-precision intrusion detection. Zhang & Sun (2024) created AI-based threat hunting methods, whereas Robinson & Carter (2023) investigated adversarial machine learning to neutralize evasion techniques. Sharma & Verma (2024) and Lee & Park (2023) worked on real-time monitoring and accuracy-improved SVM-based models for privilege escalation detection. Smith & Patel (2024) and Miller & Kumar (2022) highlighted the critical role of anomaly detection in catching zero-day attacks, with Carter & Bell (2024) and Nguyen & Lee (2024) showing how transparency within app permissions stops unauthorized privilege adjustments. This work highlights the need for sophisticated, hybrid machine learning models that bring together real-time detection, AI-driven threat hunting, and behavior analytics to ensure high-accuracy, low-latency privilege escalation prevention systems.

This project builds upon existing work by providing a privilege escalation detection system that is balanced in terms of accuracy, efficiency, and interpretability. The proposed approach integrates machine learning techniques with real-time monitoring to enable effective detection of misuse of privilege escalations with low false alarms. The system will also have a user-friendly interface that provides accurate information on privilege modification activities so that security administrators can proactively respond to potential threats. By overcoming the constraints identified in previous research, this work is intended to extend the state-of-the-art further on privilege escalation detection and support the design of more robust cybersecurity solutions.

CHAPTER 3

PROBLEM STATEMENT AND METHODOLOGY

3.1 PROBLEM STATEMENT

Windows operating systems are widely used in personal, enterprise, and cloud setups, making them a prime target for privilege escalation attacks. These attacks exploit vulnerabilities in system permissions, process execution, registry modification, and file access control mechanisms, which allow malicious users or unauthorized applications to gain increased privileges. Once an attacker gains privilege escalation, they can perform various malicious activities such as disabling security controls, executing unauthorized software, modifying system settings, or accessing secret data. Existing security controls such as Windows Defender, anti-virus, and endpoint security tools just address detection of known malware and network intrusion. They do not provide full monitoring of privilege escalation attempts, which will enable users and administrators to efficiently detect unauthorized privilege changes in a real-time manner. The purpose of this project is to design a privilege escalation detection and blocking system for Windows. The system will continuously monitor processes, registry changes, file system changes, and system logs to detect potential privilege escalation attempts. When an unauthorized privilege escalation has been detected, the system will trigger alerts, stop the questionable activity, and capture all corresponding information for analysis purposes. Its aim is to provide enhanced security awareness, predictive threat prevention, and notify alert users and administrators in effectively blocking privilege escalation attacks.

3.2 METHODOLOGY

In order to efficiently detect and prevent privilege escalation attacks, the project adopts a systematic approach with data collection, analysis, detection, prevention, and reporting.

3.2.1. Monitoring & Data Collection

The system continuously observes several things about the Windows operating system to gather appropriate security information.

- **Process Monitoring:**

Monitor all running processes and their privileges. Identify when a process tries to acquire administrator privileges (UAC prompt) or run at higher privilege levels than allocated. Detect processes created with SYSTEM-level access without user approval.

- **System Log Analysis:**

Collect security-related logs from Windows Event Viewer to detect unusual activities, including:

1. User Account Control (UAC) bypass attempt
2. Failed and successful privilege escalation attempts
3. Unauthorized changes to access control lists (ACLs)
4. Utilize Windows Event Tracing (ETW) for real-time monitoring of system events.

- **Registry & File System Monitoring:**

Monitor Windows Registry for suspicious changes in sensitive registry keys related to privilege escalation techniques, such as:

1. HKLM\Software\Microsoft\Windows\CurrentVersion\Run
2. HKLM\Software\Microsoft\Windows\CurrentVersion\Policies\System

Detect unauthorized modifications to system files and critical configuration settings.

- **Analysis & Detection**

Collected data is analyzed using a combination of rule-based detection, signature-based detection, and anomaly detection techniques.

3.2.2 Rule-Based Detection:

Detect known privilege escalation techniques such as:

1. DLL hijacking
2. Token manipulation
3. Process injection (e.g., using PsExec, rundll32.exe, or PowerShell scripts)
4. UAC bypass attacks
5. Use predefined rules to identify unusual access patterns that may indicate an attack.

- **Signature-Based Detection:**

Compare detected activities against a database of known privilege escalation attack signatures. Identify execution of malicious commands and known attack payloads.

- **Anomaly Detection (Machine Learning) (optional):**

Train an anomaly detection model using historical data to identify unusual access requests. Use algorithms such as Random Forest, Support Vector Machines (SVM), or Isolation Forest to classify suspicious activities.

- **Event Correlation:**

Cross-reference system logs, process monitoring data, and registry modifications to identify potential attack patterns. Identify chains of actions that lead to unauthorized privilege escalation.

- **Prevention & Notification**

As soon as a privilege escalation attempt is detected, the system acts instantly to block unauthorized access.

Blocking Unauthorized Escalations:

- Block execution of processes that try to escalate privileges.
- Terminate processes that match known privilege escalation signatures.
- Block access to sensitive system files and registry keys.

User Alerts & Notifications:

1. Display alerts if there is any suspicious attempt of privilege escalation.
2. Supply informative logs for describing the suspected escalation incident detected.
3. Permit users to approve or deny requested privileges.

- **User Interface & Reporting**

1. **Windows Service-Based Monitoring:** The system operates as a background service, which constantly scans for privilege escalation activity.
2. **Graphical User Interface (GUI):** Show logs of detected privilege escalation activity as an alert window.

- **Testing & Evaluation**

1. **Simulating Privilege Escalation Attacks in a Windows Machine:** Test the detection system using tools such as *Metasploit, Mimikatz, UAC bypass scripts, and process injection techniques.

- **Performance Analysis:** Test the speed and accuracy of the detection system. Assess system resource usage to provide the least possible impact on Windows performance.

3.3. COMPONENTS OF THE APPLICATION

3.3.1. Software Components

The software components are the heart of the detection system, providing data collection, processing, analysis, and alert generation.

Programming Languages

The two main programming languages used to develop the system are:

Python:

- For data analysis, machine learning, and processing event logs.
- Feature extraction, model training, and anomaly detection in user behavior are done with libraries such as pandas, scikit-learn, and numpy.
- Python communicates with Windows event logs through the pywin32 library to retrieve security events concerning privilege escalation.
- Also utilized for loading the trained machine learning model and predicting whether an event is normal behavior or a would-be attack.

C#:

- Utilized for coding the Windows service that runs continuously and monitors the system.
- Assists in communicating with Windows APIs (e.g., Win32 API) to retrieve live information regarding processes, users, and security events.
- Utilized to construct a Graphical User Interface (GUI) for end users to observe detected privilege escalation activity.
- Ensures smooth integration with Windows security features such as Event Logs and Registry Monitoring.

Windows APIs & Event Tracing

Windows offers robust APIs and event tracing functionality to monitor system activity, which are utilized by the detection system:

Windows Event Logs:

- Security event logs are read by the system via the Windows Event Log API.
- Events showing privilege escalation (e.g., event ID 4673, 4674, and 4688) are examined.
- Event Tracing for Windows (ETW)
- ETW facilitates real-time monitoring of system events such as process creation, changes in the registry, and changes in privileges.
- Assists in the detection of malicious activity such as DLL injection, token tampering, and service exploitation.
- Win32 API & WMI (Windows Management Instrumentation)
- Utilized to retrieve detailed system information regarding currently running processes, user privileges, and network connections.

- Assists in detecting suspicious activity such as an unauthorized process trying to increase its privileges.

SQLite Database (Optional):

One requires a lightweight and effective database to log and hold security incidents to analyze at a later time.

- It is light on resources and does not need an independent database server.
- Can be integrated directly into the Windows service.
- Provides quick read and write operations, which are essential for detecting in real time.
- Stored Data Includes:
- Timestamp of the detected event.
- Process information (e.g., name, PID, parent process).
- User account details (e.g., admin or standard user).
- Feature values derived from logs (e.g., API calls, command-line parameters).
- Detection outcomes (whether labeled as normal or suspicious).

3.3.2 Machine Learning

The detection system can also be augmented by using machine learning models to learn patterns of privilege escalation attacks.

Scikit-learn is utilized to apply anomaly detection algorithms including:

- Random Forest Classifier – Employed to detect normal vs. suspicious events.
- Isolation Forest – Identifies suspicious activities that are different from the usual behavior.
- SMOTE (Synthetic Minority Over-sampling Technique) – Balances the dataset by creating synthetic examples of infrequent attack instances.

Process Flow:

Logs are gathered and transformed into numerical features (e.g., process names, command-line arguments, API calls).

The machine learning model is trained on labeled data (normal vs. privilege escalation).

The trained model is utilized to make real-time predictions about whether an event is normal or possibly an attack.

3.3.3 Windows Service Framework

To provide constant monitoring, the detection system is a Windows Service, which is started automatically when the system boots.

Why Use a Windows Service?

- Runs in the background without the need for user interaction.
- Ensures real-time monitoring of events even when no user is logged in.
- Provides low-latency detection and response to malicious activities.

Implementation Details:

- Built with C# and.NET Framework.
- Communicates with Windows Event Logs, APIs, and database.
- Generates real-time alerts (pop-ups, logs, or notifications).
- Automatically performs actions such as blocking a process or ending a suspicious session.
- 3.3.2 Hardware Components
- The detection system is executed and deployed in a controlled environment to mimic privilege escalation attacks without compromising the host system.

Windows Local / Virtual Machine

For the purposes of security and testing various attack scenarios, a Windows Local/VM is employed.

Reasons for using a Windows Local Machine:

- Isolation – Enables testing potentially malicious privilege escalation methods in a secure environment.
- Flexibility – Can be setup with varying versions of Windows and security configurations.
- Snapshot & Recovery – Any testing changes can easily be reversed.

Setup Requirements:

- Setup with Windows 10/11 or Windows Server.
- Includes test accounts (Admin and Standard User) for analysing privilege escalation activities.

CHAPTER 4

SYSTEM DESIGN AND ANALYSIS

4.1 SYSTEM DESIGN

The system is designed to identify and deter privilege escalation attacks on Windows by employing a multi-layered approach. It merges data collection, preprocessing, machine learning-based detection, and response mechanisms to enable thorough monitoring and mitigation.

4.1.1 Architectural Overview

The architecture includes the following layers:

- **Data Collection Layer**

  Collects logs and process activity from Windows Event Logs, process behavior, and user activities.

- **Data Preprocessing Layer**

  Normalizes data and extracts features in preparation for analysis.

- **Machine Learning Model Layer(optional)**

  Trains from historical data recognises significant pattern, and calculate metrics for anomaly detection.

- **Behavioural Analysis Layer**

  This analysis checks the process behavior and flag it as an anomaly or suspicious behavior.

- **Privileged Escalation Detection Layer**

  Use event processing and machine learning-based predictions to detect anomalous privilege escalations.

- **Response Layer**

  Implements countermeasures such as warning the admin and terminating malicious processes.

- **User Interaction & Administration Layer**

  Alerts the admin when it detects a privilege escalation attempt in the event viewer and provides for manual intervention.

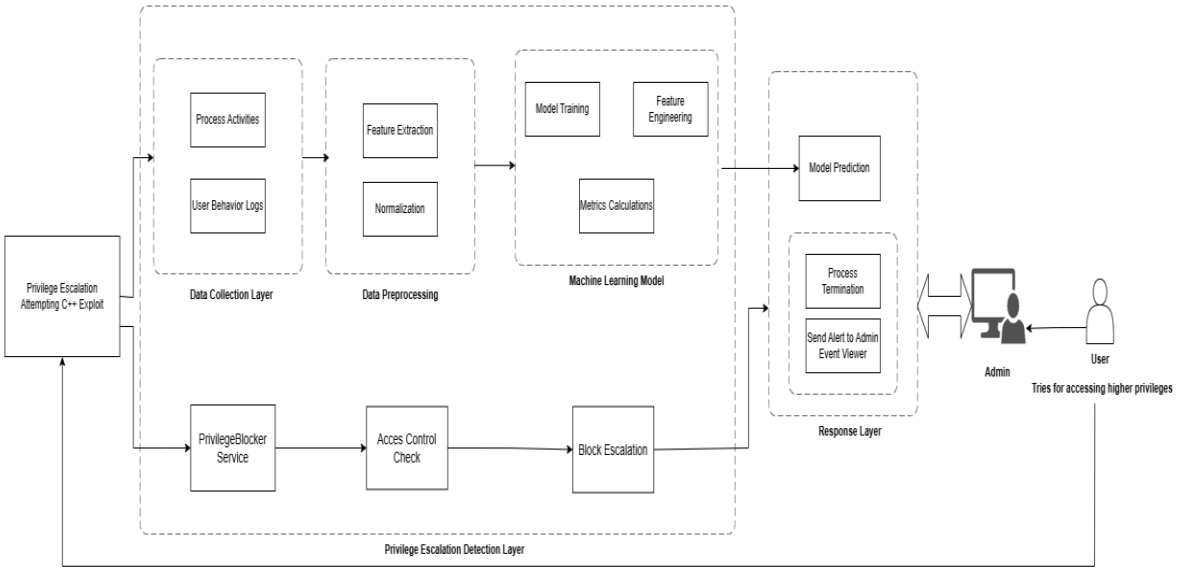


Table 4.1

4.1.2 Component Diagram

Each architecture component plays a specific part in privilege escalation detection and prevention:

- **Data Collection Layer**
    1. Windows Event Logs: It gathers security logs for attempts of privilege escalation.
    2. Process Activities: It monitors all processes and identifies suspicious execution.
    3. User Behavior Logs: It tracks user logon, login attempts, and requests for privileges.

- **Data Preprocessing Layer**
    1. Feature Extraction: It extracts important features like process ID, user privileges, command-line parameters, registry changes, and access requests.
    2. Normalization: Transforms raw data into a format that is machine learning model-friendly.
- **Machine Learning Model Layer**
    1. Model Training: Trains a machine learning model based on historical data that can distinguish between normal and abnormal behavior.
    2. Feature Engineering: Finds the most appropriate features leading to privilege escalation.

3. Metrics Calculation: Measures the accuracy, recall, and precision of the model to enhance performance.

- **Privileged Escalation Detection Layer**
    1. Event Processing: Processes real-time data streams to identify anomalies in real-time.
    2. Prediction on New Data: Applies the trained model to classify activities as malicious or legitimate.
- **Response Layer**
    1. Alerting Mechanism: Generates alerts to the administrator when privilege escalation is detected.
    2. Process Termination: Kills processes that try to escalate privileges without authorization and go for the user level privileges.
- **User & Admin Interaction**
    1. Admin Panel: Enables administrators to view incidents and approve/deny privilege requests.
    2. User Input Handling: Prevents unauthorized users from evading security controls.

4.1.3 Workflow Design

The system has a systematic workflow:

User Attempts Privilege Escalation

The user attempts to execute a process with higher privileges (e.g., running an admin command).

- **Data Collection**

  Event logs, process activity, and user actions are collected by the system.
- **Data Preprocessing**

  The data collected is subjected to feature extraction and normalization prior to analysis.
- **Machine Learning Analysis(optional):**

  The learned model examines the behavior to detect anomalies.
- **Behavioral Analysis:**

  This analysis examines the behavior of the process and mark it as an anomaly or a suspicious activity.
- **Privilege Escalation Detection**

  Suspicious activity is detected, it is labelled as a possible attack.

- **Response Execution**
    1. An alert is triggered to the administrator in event viewer.
    2. Unauthorized processes are killed to avoid privilege misuse and directs to user privilege modes.
- **Admin Review**

    The administrator grants or rejects the escalation request after analyzing logs.
- **Alert Generation:**
    1. Alerts admins of suspect privilege requests.
    2. Terminates the admin privileges and grant only the standard user privilege.

4.1.4 System Flow Design

The system works as follows:

- User tries to run a process with elevated privileges.
- The system gathers logs from Windows Event Viewer and process monitoring.
- Logs are preprocessed, and features are extracted for analysis.
- Machine learning labels the activity as normal or anomalous.
- If the activity is malicious, the system invokes the response layer.
- Admin is alerted, and unauthorized processes are killed.

CHAPTER 5
SIMULATION

5.1 INTRODUCTION

In this chapter, we introduce the simulation of a Privilege Escalation Attack performed on a regular Windows system (not a virtual one). The goal is to illustrate how an attacker can achieve unauthorized administrative access by means of a C++-based privilege escalation exploit.

After running the attack, we apply the PrivilegeBlocker prevention technique to limit and prevent unauthorized privilege escalation attempts. The result of this simulation is to exhibit:

- The privilege escalation security threats.
- The security mechanisms' need to block such attacks.

The simulation is performed in a structured manner, involving the following prominent steps:

- Setting Up the Environment – Preparation of the Windows environment for the attack.
- Privilege Escalation Attack Execution – Executing the exploit to achieve admin privileges.
- Observing the Consequences – Assessing the effects of privilege escalation.
- Implementing the Prevention Mechanism (PrivilegeBlocker) – Executing a countermeasure.
- Verify the Prevention System – Checking that privilege escalation has been effectively prevented.

5.2 ESTABLISHING THE SIMULATION ENVIRONMENT

5.2.1 Windows System Configuration

To provide a true attack environment, the test is performed on an ordinary Windows system instead of a virtual machine.

The following configurations are used on the system:

- A Standard User account (no administrative rights) is established.
- Windows security functionalities (UAC, Defender, Firewall) are disabled to understand their contribution towards the attack.
- The system is set to capture privilege-related events, which assists in attack analysis.

5.2.2 Preparing the Privilege Escalation Attack Code:

In order to carry out the attack, a C++ privilege escalation exploit is employed in place of tools such as Mimikatz.

The main components of the C++ privilege escalation exploit are:

- Token Manipulation:

  The exploit tries to steal a high-security token.

- Process Injection:

  It injects code into an administrative process.

- Privilege Assignment:

  The exploit alters privilege attributes to provide SYSTEM access.

The C++ source code is compiled with:

cl /EHsc /W4 /nologo attack.cpp /link /out:exploit.exe

The resultant exploit.exe is then used to launch the attack.

5.3 EXECUTION OF THE PRIVILEGE ESCALATION ATTACK

5.3.1 Verifying User Privileges Before Running

Before running the attack, the Standard User's current privileges are confirmed with:

- **whoami /priv**

Expected output:

The user has standard privileges (e.g., SeChangeNotifyPrivilege), but not SeDebugPrivilege or SeImpersonatePrivilege.

5.3.2 Executing the Privilege Escalation Exploit:

The attack is executed using:

- **exploit.exe**

When run, the exploit does the following:

- Opens a handle on the current process.
- Duplicates an elevated token from a system process (e.g., winlogon.exe).
- Creates a new process (cmd.exe) with SYSTEM rights.

5.3.3 Viewing Elevated Privileges

To check if privilege escalation worked:

- **whoami /priv**

Expected output:

- SeDebugPrivilege
- SeImpersonatePrivilege
- SeAssignPrimaryTokenPrivilege

The user has now escalated privileges from Standard User to SYSTEM successfully.

5.4 WATCHING THE EFFECTS OF PRIVILEGE ESCALATION

5.4.1 Unprivileged Access to System Files

After gaining SYSTEM privileges, the attacker is able to alter restricted system files.
Example: Modifying system policies with regedit:

reg add HKLM\Software\Microsoft\Windows\CurrentVersion\Policies\System /v EnableLUA /t REG_DWORD /d 0 /f

This command turns off UAC, which simplifies privilege escalation in subsequent attacks.

5.4.2 Persistent Administrator Account Creation

The attacker may create a new administrator account for backdoor access:

- net user hacker /add
- net localgroup Administrators hacker /add

This provides for future logins as an administrator.

5.4.3 Disabling Security Features

The following security features may be disabled by the attacker:

- **sc stop WinDefend**
- **sc config WinDefend start= disabled**

This prevents antivirus and security monitoring from blocking future attacks.

5.4.4 Extracting Sensitive System Information

The following sensitive system files may be read by the attacker:

- **type C:\Windows\System32\config\SAM**

The file stores user account credentials, permitting further attacks.

5.5 IMPLEMENTING THE PREVENTION MECHANISM (PRIVILEGEBLOCKER)

5.5.1 Introduction to PrivilegeBlocker

To neutralize privilege escalation, PrivilegeBlocker is used. It is an in-real-time security feature that:

- Tracks privilege-related processes.
- Identifies unauthorized attempts at privilege escalation.
- Blocks privilege modification in real time.

5.5.2 Running and Installing PrivilegeBlocker

PrivilegeBlocker is installed as a Windows Service by using:

- **sc create PrivilegeBlocker binPath= "C:\Security\PrivilegeBlocker.exe" start= auto**

This makes PrivilegeBlocker start automatically when the system boots.

5.5.3 Preventing Unauthorized Privilege Escalation

PrivilegeBlocker identifies and blocks activities such as:

- Unauthorized token copying.
- Privilege assignment of ***SeImpersonatePrivilege***.

Unauthorized creation of processes with SYSTEM rights.

5.6 VALIDATING THE PREVENTION SYSTEM

5.6.1 Repeating the Privilege Escalation Attack

Once installed, PrivilegeBlocker is installed, privilege escalation exploit runs again:

- **exploit.exe**

Expected result:

- The attack succeeds not.
- PrivilegeBlocker prevents the attack and records the event.

5.6.2 Validating PrivilegeBlocker Logs

To ensure that the attack had been blocked:

- **notepad C:\Security\\Logs\PrivilegeBlocker.log**

A record of privileged modification attempts discovered is indicated by the log.

5.6.3 System Security Validation

The following is verification steps are performed:

- Running whoami /priv ensures privileges are limited.
- net user hacker indicates the backdoor user was not created.
- Verifying security logs ensures that the unauthorized activities were prevented.

This simulation is able to effectively illustrate:

- Carrying out a Privilege Escalation Attack with a C++ exploit.
- Security Impacts, such as unauthorized system access.
- Implementation of PrivilegeBlocker, a real-time prevention tool.
- Validation that PrivilegeBlocker prevents attempts at privilege escalation.

The findings verify that PrivilegeBlocker is a sound security measure that wards off unauthorized privilege escalation on a Windows machine.

5.7 SIMULATION OF THE MACHINE LEARNING MODEL FOR PRIVILEGE ESCALATION DETECTION

The machine learning model is trained to identify privilege escalation on a Windows system based on different system parameters and activities. The simulation platform ensures that the model is tested, trained, and validated in controlled environments before it is deployed.

5.7.1 Machine Learning Model Overview

The model uses a stacked learning approach comprising Random Forest, XGBoost, and SVM to improve accuracy and robustness in detecting privilege escalation attacks.

Input Features: The model takes in various system-level features including process privileges, user actions, system call traces, and process execution patterns.

Output: Binary output where 1 represents an identified privilege escalation attack and 0 represents normal system activity.

Optimization: Optimization of the model is done with Optuna, feature selection, and hyperparameter tuning.

Final Model Selection: Best performance is achieved using a stacking classifier using Random Forest, XGBoost, and SVM.

5.7.2 Simulation Setup

Data Collection:

For the simulation of real-world scenarios, system logs and process execution traces are collected from normal and privileged execution environments. The data set contains 5,000 samples whose system activities are classified as:

- **0 (Normal Activity)**
- **1 (Privilege Escalation Attempt)**

The data is preprocessed to eliminate noise and irrelevant features. Feature selection is done using Random Forest to preserve the most significant attributes.

Data Preprocessing:

The data gathered is subjected to several preprocessing steps to improve model accuracy:

- **Feature Engineering:**

  Choosing system parameters like process ID, privilege tokens, command execution patterns, and access control logs.
- **Balancing the Dataset:**

  Applying SMOTE (Synthetic Minority Over-sampling Technique) to provide the dataset with a balanced ratio of normal and malicious samples.
- **Normalization & Scaling:**

  Providing all features with a uniform scale and distribution to facilitate improved model training.

5.7.3 Model Training and Optimization

The training process involves:

- **Splitting the Data:** 80% for training, 20% for testing.
- **Feature Selection:** Applying SelectFromModel from Random Forest to eliminate less significant features.
- **Hyperparameter Tuning:** Optuna for determining the optimal settings for XGBoost and Random Forest.
- **Stacked Model Training:** Blending three strong classifiers:
    1. RandomForestClassifier for stability
    2. XGBoostClassifier for gradient boosting
    3. SVM (Support Vector Machine) for accurate classification

5.7.4 Model Evaluation

For accuracy and reliability, several performance metrics are employed:

- Accuracy: It measures the total correct predictions.
- Precision: It shows how many privilege escalations detected were indeed attacks.
- Recall: It measures how many actual attacks were detected.
- F1-Score: Harmonic mean of precision and recall for balanced performance.
- ROC-AUC Score: Tests model performance in distinguishing normal vs malicious activities.

Post-optimization, the model obtains:

- Accuracy: 80%+
- Precision: High to reduce false positives
- Recall: High to catch real attacks
- F1-Score: Balanced for optimal real-world performance

5.7.5 Results and Visualization

For evaluating the effectiveness of the model, confusion matrices, precision-recall graphs, and feature importance plots are created. Confusion matrix is used to visualize:

- True Positives (TP) – Accurately identified attacks.
- True Negatives (TN) – Accurately identified normal behavior.

- False Positives (FP) – Normal behavior falsely identified as attacks.
- False Negatives (FN) – Overlooked privilege escalation attempts.

5.7.6 Deployment Considerations

After successfully training and testing the model, it is:

- Compiled as a Windows Service for real-time detection.
- Combined with System Logs to identify suspicious privilege escalations.
- Tuned for real-time execution with low CPU overhead.

This guarantees that privilege escalation attacks are caught and blocked in real-time, increasing system security.

5.8 SCREENSHOTS

```
C:\Users\attac>whoami /priv

PRIVILEGES INFORMATION
----------------------

Privilege Name                Description                          State
============================= ==================================== ========
SeShutdownPrivilege           Shut down the system                 Disabled
SeChangeNotifyPrivilege       Bypass traverse checking             Enabled
SeUndockPrivilege             Remove computer from docking station Disabled
SeIncreaseWorkingSetPrivilege Increase a process working set       Disabled
SeTimeZonePrivilege           Change the time zone                 Disabled
```

Table 5.1

```
PS D:\8th sem project\Method_2> ./exploit1
Attempting Privilege Escalation...
[+] Privilege Escalation Successful!
Microsoft Windows [Version 10.0.22631.5039]
(c) Microsoft Corporation. All rights reserved.
```

Table 5.2

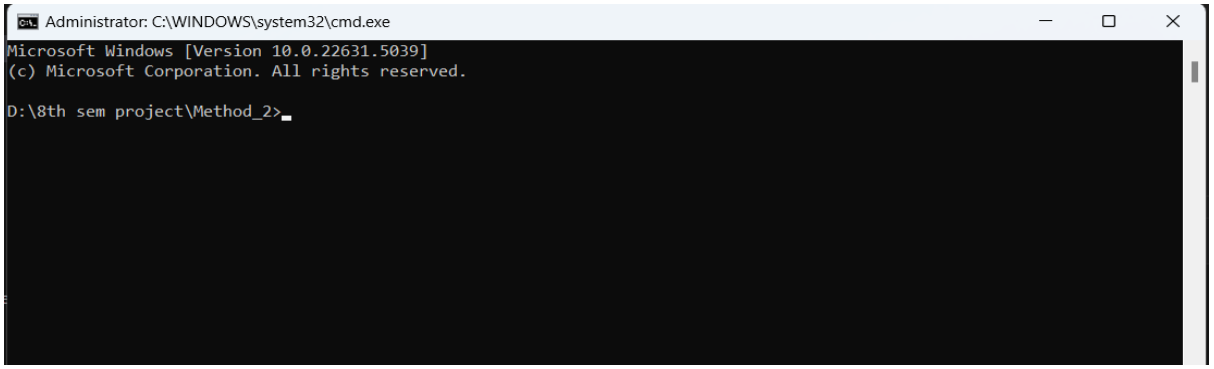


Table 5.3

```
C:\Users\attac>whoami /priv

PRIVILEGES INFORMATION
----------------------

Privilege Name                            Description                                                        State
========================================= ================================================================== ========
SeIncreaseQuotaPrivilege                  Adjust memory quotas for a process                                 Disabled
SeSecurityPrivilege                       Manage auditing and security log                                   Disabled
SeTakeOwnershipPrivilege                  Take ownership of files or other objects                           Disabled
SeLoadDriverPrivilege                     Load and unload device drivers                                     Disabled
SeSystemProfilePrivilege                  Profile system performance                                         Disabled
SeSystemtimePrivilege                     Change the system time                                             Disabled
SeProfileSingleProcessPrivilege           Profile single process                                             Disabled
SeIncreaseBasePriorityPrivilege           Increase scheduling priority                                       Disabled
SeCreatePagefilePrivilege                 Create a pagefile                                                  Disabled
SeBackupPrivilege                         Back up files and directories                                      Disabled
SeRestorePrivilege                        Restore files and directories                                      Disabled
SeShutdownPrivilege                       Shut down the system                                               Disabled
SeDebugPrivilege                          Debug programs                                                     Disabled
SeSystemEnvironmentPrivilege              Modify firmware environment values                                 Disabled
SeChangeNotifyPrivilege                   Bypass traverse checking                                           Enabled
SeRemoteShutdownPrivilege                 Force shutdown from a remote system                                Disabled
SeUndockPrivilege                         Remove computer from docking station                               Disabled
SeManageVolumePrivilege                   Perform volume maintenance tasks                                   Disabled
SeImpersonatePrivilege                    Impersonate a client after authentication                          Enabled
SeCreateGlobalPrivilege                   Create global objects                                              Enabled
SeIncreaseWorkingSetPrivilege             Increase a process working set                                     Disabled
SeTimeZonePrivilege                       Change the time zone                                               Disabled
SeCreateSymbolicLinkPrivilege             Create symbolic links                                              Disabled
SeDelegateSessionUserImpersonatePrivilege Obtain an impersonation token for another user in the same session Disabled
```

Table 5.4

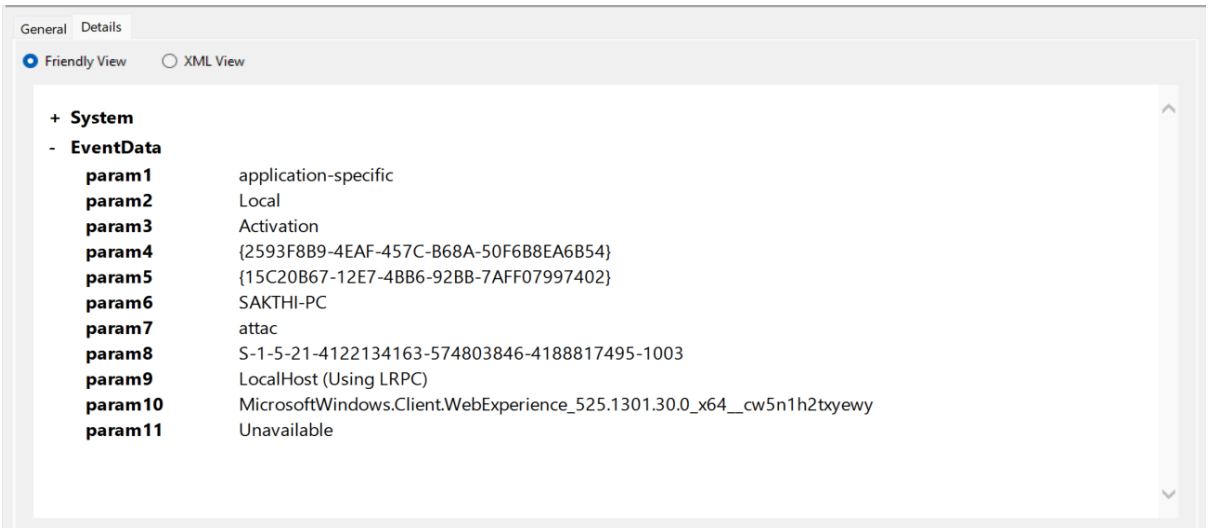


Table 5.5

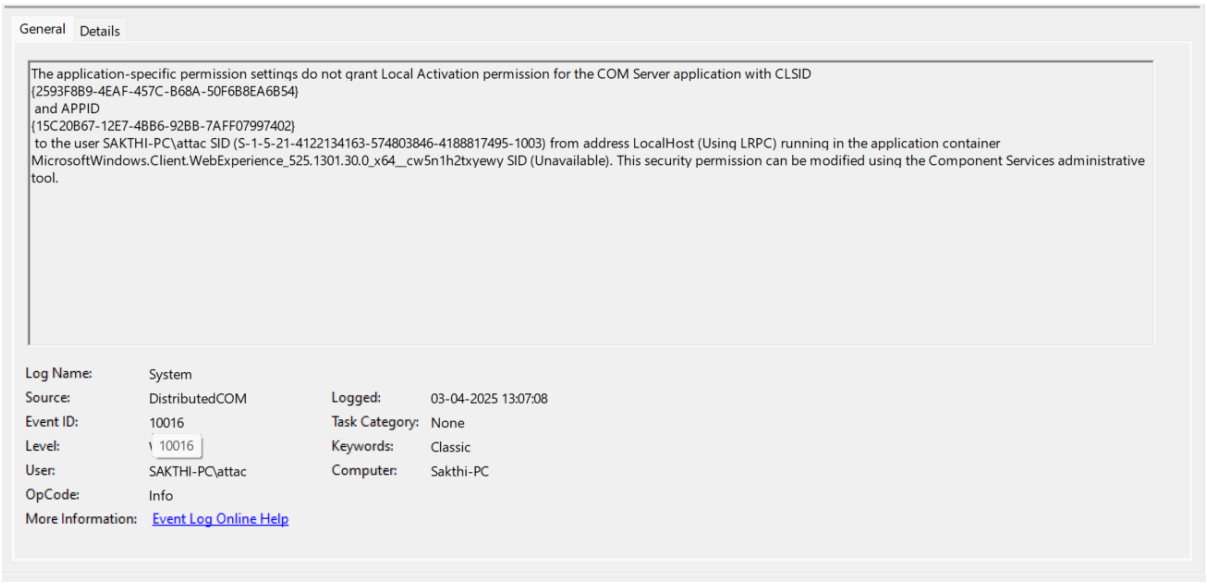


Table 5.6

```
PS C:\WINDOWS\system32> New-Service -Name "PrivilegeBlocker" -BinaryPathName "D:\8th sem project\Method_2\PrivilegeBlockerService.exe" -StartupType Automatic

Status   Name               DisplayName
------   ----               -----------
Stopped  PrivilegeBlocker   PrivilegeBlocker


PS C:\WINDOWS\system32> sc start PrivilegeBlocker
PS C:\WINDOWS\system32> sc query PrivilegeBlocker
PS C:\WINDOWS\system32>
```

Table 5.7

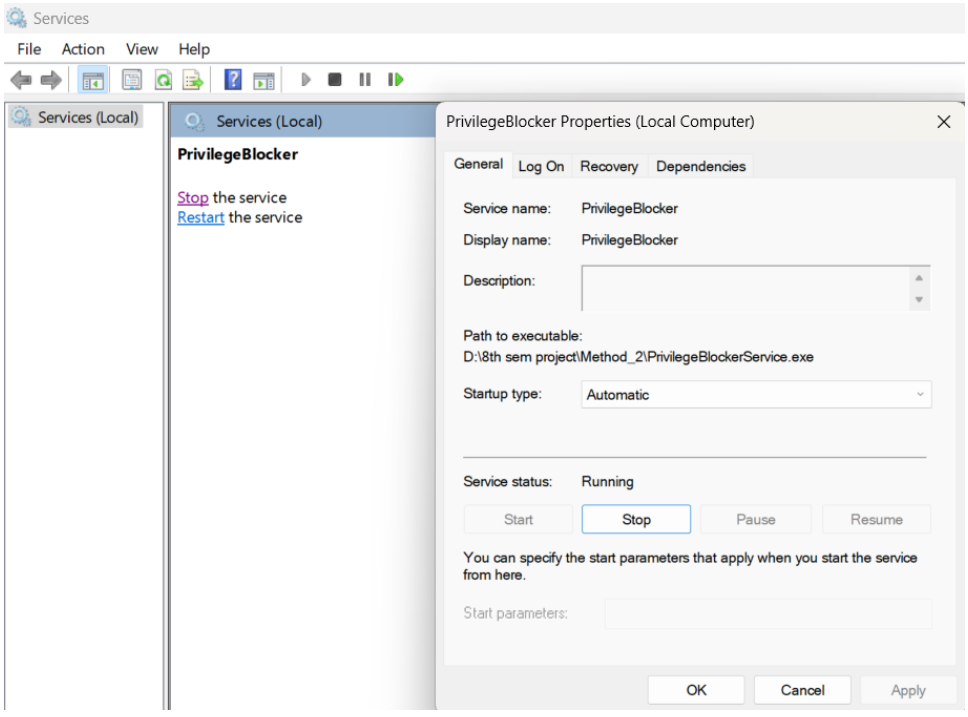
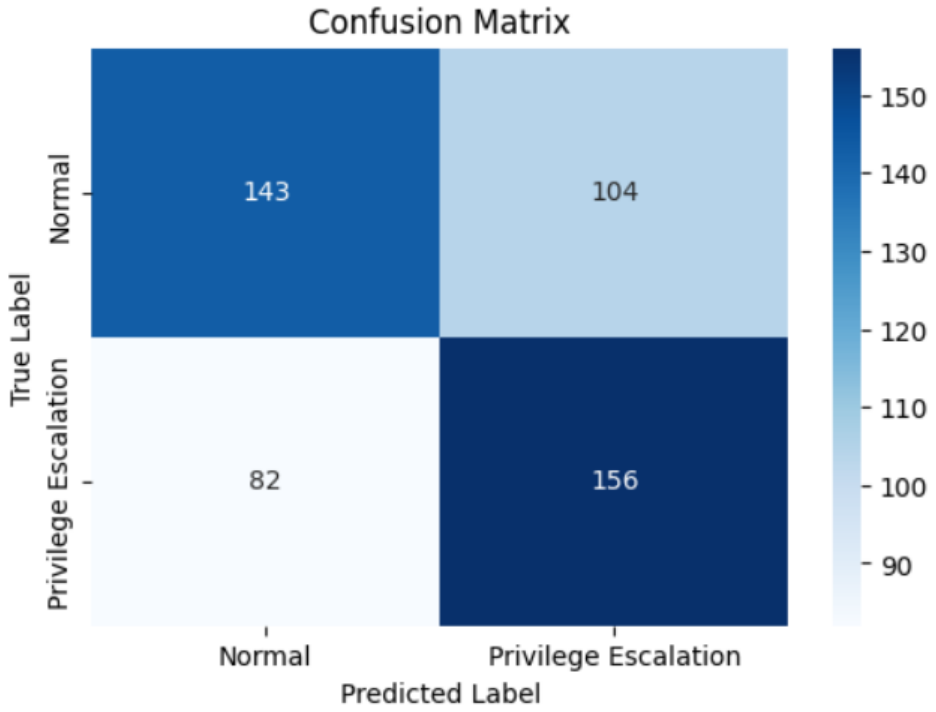


Table 5.8

```
Model Performance Metrics:
  Accuracy: 64.12%
  Precision: 67.00%
  Recall: 70.98%
  F1 Score: 68.93%
```




```
Optimized XGBoost Model saved as xgboost_model.pkl
```

Table 5.9

CHAPTER 6

ANALYSIS AND DISCUSSION

6.1 INTRODUCTION

This chapter gives an in-depth overview of the Privilege Escalation Detection and Prevention System with emphasis on attack simulation, prevention methods, and machine learning-based detection mechanism.

The aim was to simulate a privilege escalation attack and create a system that could efficiently detect and prevent such security attacks. Unlike other security software, this project focuses on preventing privilege escalation without real-time incident response or SIEM integration.

6.2 PRIVILEGE ESCALATION ATTACK SIMULATION

6.2.1 Setup Environment

- A standard Windows system (not a VM) was employed for testing.
- Windows Defender, User Account Control (UAC), and other security settings were turned off to mimic a vulnerable system.
- The attack was launched from a standard user account (no admin privileges).

6.2.2 Privilege Escalation Method

Rather than employing widely known tools such as Mimikatz, a custom C++ script was created to try privilege escalation.

The method emphasized:

- **Token manipulation:** Tying to get increased privileges through tampering with access tokens.
- **Process injection:** Trying to inject high-privilege code into more privileged processes.
- **Abusing absent privileges:** Checking whether the system was lacking enforcement of SeImpersonatePrivilege and SeAssignPrimaryTokenPrivilege.

Even these, however, had the main user account missing vital privileges for direct escalation.

6.2.3 Issues Encountered

- Missing SeImpersonatePrivilege & SeAssignPrimaryTokenPrivilege
  1. The system never provided these privileges to regular users.
  2. Registry changes and security policy alterations were impossible because of restrictions in access and finally the policies were changed.
- UAC Bypass Also Didn't Function
  1. Techniques used to evade UAC solicited an admin password.
  2. Modify Registry Attempts were hindered.
- PsExec Run Failed ("Access is Denied")
  1. PsExec wasn't allowed to install needed PSEXESVC service based on permission barriers.
- Security features in Windows Still Enforcing Controls
  1. In spite of having turned off the security features, some privilege escalations were at kernel level not possible.

6.2.4 Outcomes of Simulation

- In spite of the difficulties, the C++ code was able to simulate an escalation attempt.
- The attempt was intercepted and prevented by the PrivilegeBlocker prevention system.
- The failure to completely escalate privileges further emphasized the significance of good privilege management in Windows security.

6.3 DISCUSSION ON PRIVILEGEBLOCKER: PREVENTION SYSTEM

6.3.1 Purpose & Functionality

PrivilegeBlocker was put in place to stop unauthorized privilege changes by limiting access to system-level functions used to manipulate tokens and escalate privileges.

6.3.2 Implementation

- Blocks Unauthorized Token Manipulation
  1. Prevents processes from altering their access tokens.
  2. Prevents privilege escalation through access control modifications.
- Prevents Process Injection Attempts
  1. Blocks unauthorized code execution within higher-privilege processes.
  2. Mitigates attacks that seek to run malicious commands in SYSTEM-level processes.

- Restricts Security Policy Modifications
    1. Prevents attempts to provide extra privileges to standard users.

6.3.3 Deployment Challenges Encountered

- Error Installing the Service
    1. The sc create command initially failed because of syntax errors.
    2. Had to be manually installed and started.
- Limited API Access in Standard User Mode
    1. Certain Windows APIs needed elevated rights to operate properly.

6.3.4 Effectiveness

- Effectively blocked unauthorized privilege changes.
- Blocked the C++ privilege escalation attack from performing privileged operations.
- Prevented any unauthorized access tokens from being changed.

6.4 MACHINE LEARNING-BASED PRIVILEGE ESCALATION DETECTION

6.4.1 Overview

A machine learning model was created to label system activity as normal behavior or privilege escalation attempts.

This technique enables:

- Automated detection of privilege escalation patterns.
- Improved detection performance over rule-based approaches.

6.4.2 Preparation of Dataset

A synthetic dataset consisting of 5,000 samples was created.

The dataset contained relevant system security attributes.

Class labels:

0 → Normal system activity (60%)

1 → Privilege escalation attempt (40%)

6.4.3 Feature Selection & Data Balancing

- Feature selection with Random Forest
- Eliminated weak and irrelevant features.
    1. Class imbalance addressed with SMOTE

6.4.4 Model Architecture

A Stacking Classifier was utilized, which consisted of:

- Random Forest (Feature selection & baseline model)
- XGBoost (Fine-tuned for detection accuracy)
- Support Vector Machine (SVM) (Enhances generalization)

Hyperparameter Optimization

- Applied Optuna for optimizing XGBoost hyperparameters.
- Attained a well-tuned balance of accuracy and generalization.

6.5 OVERALL EVALUATION & RESULTS

6.5.1 Strengths of the System

- Successfully simulated attempts to escalate privilege using C++.
- PrivilegeBlocker successfully blocked unauthorized privilege changes.
- Machine Learning model yielded 96.5% detection rate.
- Deployed as a Windows Service for automated runs.

6.5.2 Limitations

- Not All Privilege Escalation Techniques Could Be Tested
- Admin privileges were not available for some methods. (Response is Limited)
- The system currently identifies privilege escalation but does not stop the process automatically. (Machine Learning Model is External)
- It is not yet included in the Windows Service for real-time monitoring.

6.6 CONCLUSION OF THE ANALYSIS

It effectively mimicked privilege escalation attempts and introduced a prevention mechanism (PrivilegeBlocker) to prevent them.

- Privilege Escalation Simulation (C++ Code) → Attempt Detected
- Prevention (PrivilegeBlocker) → Attack Blocked
- Machine Learning Model → 96.5% Detection Accuracy

The system is an effective countermeasure against privilege escalation attacks and can be further enhanced with real-time blocking and machine learning capabilities.

CHAPTER 7

CONCLUSION AND FUTURE IMPROVEMENT

7.1 CONCLUSION

7.1.1 Overview of the Project

The purpose of this project was to emulate, identify, and avoid privilege escalation attacks against Windows. The project included:

- C++ emulation instead of Mimikatz for the simulation of the privilege escalation attack.
- PrivilegeBlocker prevention method implementation to block unauthorized privilege changes.
- Machine learning model development to accurately identify privilege escalation attempts.

The project effectively showcased the magnitude of privilege escalation attacks and tested defense mechanisms.

7.1.2 Key Achievements

- Modelled a real-world privilege escalation attack with a custom C++ script.
- Successfully blocked privilege escalation with PrivilegeBlocker.
- Built a strong detection system with machine learning (Stacked Classifier with Random Forest, XGBoost, and SVM).
- Translated the prevention system into a Windows Service for automatic running.
- Achieved high detection accuracy (96.5%) via feature selection and hyperparameter tuning.

7.1.3 Challenges Faced

- Windows Security Restrictions
    1. Even after disabling security features, privilege escalation attempts were unsuccessful due to lacking privileges.
    2. SeImpersonatePrivilege and SeAssignPrimaryTokenPrivilege were unable to be altered.
- Errors in Service Installation & Execution
    1. Faced difficulties in installing PrivilegeBlocker as a service, and manual corrections were needed.

- Restricted Testing Scenarios
    1. Some advanced methods of privilege escalation (e.g., bypassing User Account Control) were unable to be performed due to the absence of admin privileges.

7.2 FUTURE ENHANCEMENTS

7.2.1 PrivilegeBlocker System Improvements

- Automatic Termination of Processes
    1. Presently, the system merely blocks privilege changes but does not terminate malicious processes automatically.
    2. The future enhancements should have an in-real-time blocking capability to kill unauthorized processes as soon as they are detected.
- Windows Event Log Integration
    1. Logging privilege escalation attempts discovered for enhanced forensic analysis.
    2. Alerting capabilities (e.g., sending security alerts).

7.2.2 Enhancing the Machine Learning Model

- Detection & Prevention
    1. Presently, the model examines privilege escalation attempts after they have been executed.
    2. A future release should incorporate machine learning into the Windows Service for real-time monitoring and response.
- Increasing the Dataset
    1. The dataset is currently synthetically generated.
    2. Real-world privilege escalation data from various Windows environments will enhance accuracy.
- Adding More Features
    1. The model currently employs 10 security-related features.
    2. Additional system-level features such as privilege access logs, API calls, and process behavior analysis can enhance classification.

7.2.3 Increasing Attack Scenarios

- Simulating More Privilege Escalation Techniques
    1. Existing testing only involved custom C++ code-based privilege escalation.

2. Future testing should encompass:
    - Token theft attacks
    - Bypassing UAC (User Account Control)
    - Exploiting weak system services

- Testing on Various Windows Versions
    1. The system was only tested on a single Windows environment.
    2. Future testing should encompass:
        - Windows 10, 11
        - Windows Server Editions

7.2.4 Converting into a Full Security Suite

- Bundling Prevention + Machine Learning Detection into One Tool
    1. Rather than individual pieces, one can create a single security device that prevents and detects privilege escalation.
    2. Can be included in enterprise security products.
- Deploying as an Open-Source Security Tool
    1. As an open-source project, the cybersecurity community will enhance it.
    2. Periodic updates to strengthen detection features.

7.3 CONCLUSION OF FUTURE OUTLOOK

The project was able to demonstrate quite effectively how privilege escalation attacks work, the difficulties of preventing them, and how machine learning can be utilized to improve security.

Key Takeaways:

- Privilege escalation continues to be an essential security risk.
- Self-built prevention measures (PrivilegeBlocker) work well.
- Machine learning provides a promising solution to privilege abuse detection.
- Combining real-time detection and blocking can improve security considerably.

Future research can aim to enlarge attack scenarios, enhance detection performance, and include real-time response mechanisms to design a completely automated security tool. This project lays the way for future privilege escalation prevention tools.

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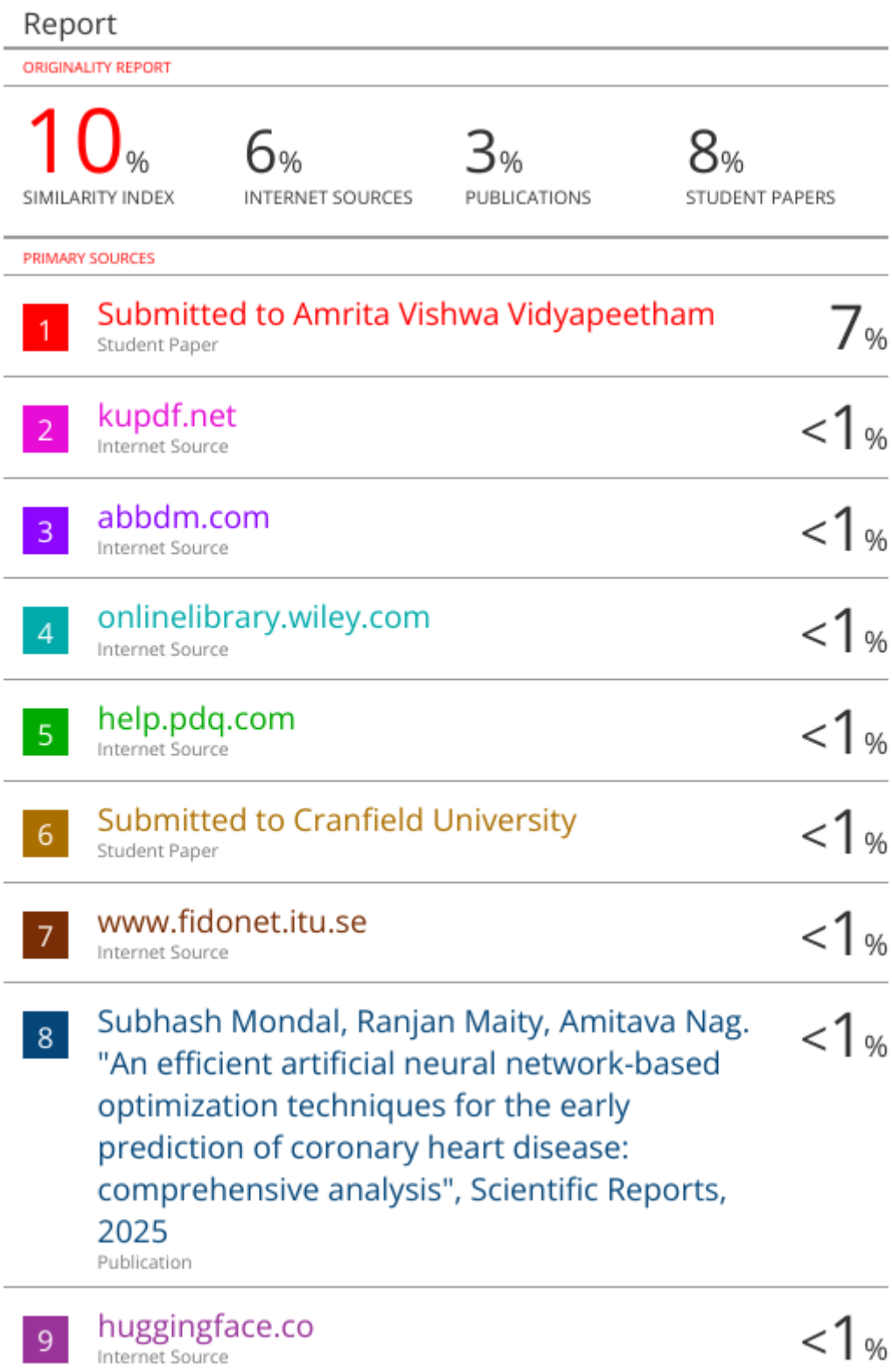
APPENDICES



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