Enhancing IoT Security: Intelligent System Design with Machine Learning Framework

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Abstract

IoT functions as a system of devices connected through networks where each object possesses distinct identifiers (UIDs) among computing appliances and digital and mechanical items and living entities. The initial connected network known as ARPANET led to the development of IoT which has emerged since 1982 as a fast expanding technological sphere. The world will have more than 27 billion IoT devices active worldwide during the last quarter of 2025. The networked devices exchange information between global networks through automated operations that skip traditional human-to-computer or direct human-to-human contacts. The independent operation of IoT systems depends on human participation for instruction input and data retrieval functions. IoT exists as a system of connected devices which generate and transfer data through an information network that also stores and operates this data. The progress of IoT relies on the significant developments across Cloud Computing and Big Data and Artificial Intelligence sectors. Security challenges have remained steadfast as one of the primary concerns which impact the IoT framework. As IoT devices multiply at lightning speed attackers have launched more cyber-frauds that especially target retail businesses along with manufacturing industry and health care operations and financial establishments. IoT systems exhibit multiple security weaknesses because of default telnet service passwords and unsecured execution zones together with expired software and poor encryption standards as well as insufficient access controls and extensive attack options and inadequate industrial security measures. IDS security along with IoT protection benefits from improvement through Meta-Learning as well as Ensemble Learning and Anomaly Detection while Light Gradient Boosting Machine combines with Fuzzy C Means (FCM) and Particle Swarm Optimization (PSO). These specific algorithms enhance intrusion detection capabilities.

Keywords: Internet of Things (IoT) Security; Machine Learning; Meta-Learning; Ensemble Learning; Anomaly Detection; Light Gradient Boosting Machine; Fuzzy C Means (FCM); Particle Swarm Optimization (PSO); Intrusion Detection System (IDS)

1) Introduction

The Internet of Things (IoT) has emerged as a significant area of research due to its diverse applications and growing popularity. The rapid expansion of IoT technologies provides numerous benefits, ranging from enhancing everyday household items to transforming entire environments into smart systems. Unlike other technological advancements, IoT facilitates seamless integration among devices, enabling a network where billions of objects are interconnected. This connectivity allows for effective data collection, device sensing, information analysis, and control of various gadgets, thereby addressing complex challenges and offering innovative solutions. IoT networks consist of numerous intelligent devices or "things" that communicate with one another to collect, exchange, and analyze data. Despite their advantages, the widespread growth of IoT networks introduces several issues related to security, privacy, storage, communication, and processing. The pervasive nature of internet connectivity makes these systems vulnerable to cyberattacks aimed at compromising sensitive user information [1]. Addressing these challenges requires a comprehensive approach, considering the interconnected nature of IoT systems, which presents higher risks compared to traditional networks.

Dealing with data security from end-to-end analysis to transmission processes remains essential to stop privacy violations. An intruder can take advantage of system vulnerabilities by carrying out DoS and DDoS attacks as well as spoofing and jamming and privacy leakage attacks. There is an essential need to identify proper solutions which address security concerns. Security issues intensify within IoT networks because of the data exchange process between heterogeneous systems on Local Area Networks (LANs) [2] while The size of the network directly affects the degree of security threats. Multiple security points exist throughout typical IoT networks starting from the sensing level to network infrastructure and extending to middleware functions and applications. The foundational branch of Artificial Intelligence known as Machine Learning serves to boost IoT systems through its capability to make them function effectively while demonstrating intelligent behavior. ML methods are increasingly being applied to IoT frameworks to address critical phases such as malware detection.

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The proposed approach depends on multiple ML techniques to enhance IoT network intrusion detection capabilities. SEM functions as a meta-learner that enhance prediction accuracy through analyzing error data from base classifiers that consist of Decision Trees (DT), Naive Bayes (NB), Multi-Layer Perceptron (MLP), Linear Discriminant Analysis (LDA) and Random Forest (RF). The Light Gradient Boosting Machine cooperates with Genetic Algorithms to perform hyperparameter optimization. A natural selection process enabled by the GA will identify optimal hyperparameter individuals from the population search space. The application of ensemble learning together with Grid Search (GS) and Randomized Search (RS) advanced ML techniques enables our system to attain better performance alongside enhanced efficiency. The approach minimizes hardware requirements through efficient optimization of cluster centers while it improves Intrusion Detection System detection capabilities. The various security issues connected to IoT networks depend strongly on the implementation of ML approaches for their resolution.

1.1) Research Significance and Motivation

The Internet of Things (IoT) is poised to enhanced progressively integral to daily life in the near future, offering significant benefits across various domains, from healthcare to home environments. IoT devices are designed to operate autonomously, providing relevant data through seamless intercommunication without the need for human intervention. Despite their advantages, the complexity of data involved in IoT systems has led to various security challenges. IoT nodes are often protected using methods such as neural networks, supervised learning approaches, and data mining systems [3]. However, security threats remain a significant concern, as they can lead to both security breaches and economic damage. IoT devices frequently handle sensitive data related to daily activities and personal information, making them crucial targets for cyberattacks.

The primary challenges within the IoT security framework include ensuring privacy, securing connected devices, and maintaining data confidentiality. Addressing these challenges is essential to mitigate risks and safeguard the integrity of IoT systems [3].

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1.2) Problem Statement

This paper addresses two key research challenges:

i) An ensemble learning meta-learner detects IoT network anomalies through an effective approach.
ii) The ensemble learning model requires optimization of its hyper parameters to achieve increased learning efficiency and better accuracy within anomaly detection tasks.

1.3) Research Methodology

This research focuses on identifying vulnerabilities within IoT networks by employing advanced machine learning techniques. The study involves the development and application of two primary machine learning-based approaches to differentiate between normal and anomalous activities within a system or device. The detection of irregularities in IoT devices benefits from our implementation of Stacking Ensemble Meta-Learning (SEM) as an enhancement technique. The goal of this approach is to strengthen machine learning algorithms through the strategic merging of their best operational features.

The detection of malicious activities within IoT networks uses an evolutionary algorithm-based Light Gradient Boosting Machine (LGBM) technique which we have developed. The LGBM model performance received optimization through the implementation of a Genetic Algorithm (GA) for sorting and adjusting its hyper parameter values. This optimization process is designed to refine the model’s accuracy and effectiveness in detecting malware.

1.4) Research Aims and Objectives

i) **Leverage Machine Learning (ML) Approaches:** Develop and apply machine learning techniques to enhance IoT security by building predictive models and generating actionable insights based on observed behaviours.
ii) **Address Denial of Service (DoS) Attacks:** Evaluate and compare the behaviour of networks under normal conditions versus those under attack, focusing on DoS vulnerabilities, and implement protective measures to mitigate these attacks.
iii) **Enhance IoT Security Frameworks:** Utilize advanced tools within IoT security frameworks to safeguard networks from breaches and threats. These tools are designed to identify and monitor risks, and to address and rectify various vulnerabilities.
iv) **Ensure Comprehensive Security:** Ensure the integrity, availability, and confidentiality of IoT systems through robust security measures and proactive threat management.

1.5) Contributions of This Study

i) The research introduces Stacking Ensemble Meta-Learning (SEM) as a specific approach for IoT Security Framework usage. The substantial operational benefits brought by IoT technology require management of security vulnerabilities which prove difficult to resolve. T

ii) The research develops an optimized version of Light Gradient Boosting Machine (LGBM) 10 for malicious access detection through Genetic Algorithm (GA) enhancements. The LGBM method detects malicious activities in IoT networks and the combination of LGBM with GA performs hyper parameter optimization to achieve better accuracy and efficiency for intrusion detection.

iii) The research applies swarm-based fuzzy clustering techniques for identifying intrusive behaviours which occur inside IoT networks. The IDS system with its alert mechanism detects harmful activities when users face suspicious situations to help improve network security while managing traffic data better. Through fuzzy clustering techniques IDS attains better capabilities to detect possible threats while responding to them.

2.1) IoT Security Using ML

Through the IoT technology has reached a new milestone which supports efficient research activities throughout multiple disciplines. The extensive use of IoT technology now extends to domestic spaces and complex smart environments resulting in a new way for people to interact with technology. The IoT device market is expected to surpass 20 billion connections in the near future showing robust expansion of IoT technology. The wide-ranging nature of IoT networks presents both advantages and disadvantages because it produces multiple security vulnerabilities within connected systems. Security challenges increase dramatically in IoT systems because of their complex structures and their rising popularity makes them vulnerable to malicious attacks. Machine learning (ML) stands as the essential instrument to tackle security problems which occur in this scenario.

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The large volumes of IoT device data can effectively be handled through machine learning algorithms. The utilization of advanced techniques allows ML to both find and stop malicious activities inside network systems. Studies have demonstrated that ML methods offer high accuracy in identifying threats, enhancing the overall security of IoT systems. Researchers have extensively explored how ML algorithms can handle complex data and improve network security [12] . These techniques facilitate the interconnection of wireless devices and nodes, enabling them to operate with minimal human intervention. ML applications extend across various fields, including transportation, power quality management, simulations, control systems, data mining, aerospace, and weather forecasting.

The secure management of IoT security faces the essential challenge of responding to significant threats from denial of service (DoS) attacks, data disruption, network congestion and hacking. Security concerns can be categorized into technical issues related to the operational environment of electronic devices and software failures within the system [13]. Effective solutions often require a combination of physical interventions and robust software structures to ensure secure and reliable IoT operations.

2.2) ML Techniques

ML enables computers to perform cognitive tasks similarly to human beings by utilizing advanced research methodologies within the field. These techniques can process and analyze vast quantities of data, extracting valuable insights efficiently. Various ML approaches offer impressive accuracy and effectiveness. Multiple approaches will be explained in more detail throughout the next sections.

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2.3) Hyper parameter Optimization

2.3.1) Grid Search

The model's performance gains significant improvements through hyper parameter optimization because of its ability to adjust model parameters [7]. Grid Search serves as a standardized approach for accomplishing this operation [8]. A systematic investigation of all inventory combinations of predefined hyper parameter values helps identify the best matching configuration. The evaluation process in Grid Search method checks every possible combination to identify the model with best performance while covering all hyper parameter space fully. This method is widely employed across various machine learning approaches to achieve optimal model performance.

2.3.2) Randomized Search

Randomized Search is a hyper parameter optimization technique that involves sampling a subset of possible hyper parameter combinations randomly. Unlike Grid Search, which exhaustively evaluates every combination, Randomized Search selects a fixed number of configurations at random from the hyper parameter space. The method improves parameter space exploration efficiency which enhances the chance to find optimal hyper parameters. It is particularly effective for high-dimensional spaces and can be applied to both discrete and continuous hyper parameter domains [11].

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2.4) Performance Evaluation Metrics

Machine learning algorithms need performance evaluation metrics to determine their effectiveness when solving regression and classification problems. Selection of evaluation metrics establishes the basis through which programmers determine the efficiency of algorithm execution and performance assessment. Assessing the algorithm's performance becomes meaningful by choosing proper metrics which demonstrate its quality relative to specified requirements. The selected metrics define which aspects of evaluation outcomes matter most because they determine interpretation and assessment of the modeling performance.

3) Proposed Method

This section describes an ensemble-based approach for meta-learning together with its operational design and system functionalities for the IoT environment.

3.1) Stacking Ensemble Meta-Learning (SEM) for IoT Security Framework

The IoT represents the most significant development in intellectual technologies through recent decade development. Research regarding Internet of Things alignment has established itself as the essential field that scientists across multiple domains now pursue through its diverse applications including residential automation and intelligent environmental management and urban computing. Unlike some other technological advancements that may face limitations after a period of initial success, IoT’s popularity continues to surge, driven by its transformative impact on everyday life and its ability to connect diverse devices seamlessly.

IoT has revolutionized how people interact with their surroundings, enabling remote access and control of household items and other devices without the constraints of traditional setups. By facilitating the connection of numerous devices for data collection, information analysis, and machine sensing, IoT has generated innovative solutions for complex problems and created new opportunities for development. As of late 2020, the number of IoT devices connected to the internet surpassed 20 million, underscoring the rapid and expansive growth of this technology.

However, with the increase in IoT applications and demand, the complexity of IoT architectures and operational models has also grown. This evolution presents new challenges in ensuring the security and effectiveness of IoT systems, highlighting the need for advanced techniques such as Stacking Ensemble Meta-Learning (SEM) to address these emerging issues and enhance IoT security frameworks.

3.2) Simulated IoT Environment DS2OS and Connection Traces

The creation of dataset 5 started as the first step in identifying unusual access patterns for the DS2OS IoT environment displayed in Fig. 3.3. The monitoring of application-layer service connections resulted in valuable traffic traces for evaluation purposes. Data acquisition involved four different IoT sites that included smart doors and smartphones as well as light controllers which were connected to washing machines and thermostats with motion sensors and thermometers and batteries. The research concentrated on creating a detection structure to spot service connection discrepancies. Our research creates a stacking ensemble meta-learning framework as its fundamental goal to address various cyber security challenges in IoT systems. Through training this model collects information from its mistakes during prediction thus resulting in better accuracy. A proposed ensemble framework outperformed DT, LDA, MLP, NB and LR model performance when utilizing a shared dataset for testing purposes..

Ensemble forecasting based on multiple solutions has proven superior to independent solution methods through simulation tests by achieving better results across multiple performance indicators specifically accuracy as well as precision and true negative rate (TNR) combined with false positive rate (FPR) and F1 score The method successfully detects a range of IoT attacks which include Wsu, spying, scan, mO, mC, Denial of Service (DoS), and dP. The proposed method demonstrates better performance than others in recognizing Wsu and DoS and dP and mO attacks. This study focuses exclusively on stacking ensemble learning due to possible effectiveness shown by bagging and boosting ensemble techniques for IoT security analysis purposes. This research approach should be expanded to address micro services challenge and boost IoT security level in future investigations. Thankfully an anomaly detection model with precise accuracy will enhance the solutions available for security frameworks that utilize IoT technology.

The predictive system involves five base classifiers with DT and KNN and DT and SGD and SVM to confirm attack type predictions. Let $I =\{ I_1, I_2 .... I_n\}$ be the recorded IoT network activity data consists of Botnet attacks that were collected over time through the instances, I_i (Eq.3.1) denotes i^{th} instances of past recorded network data.

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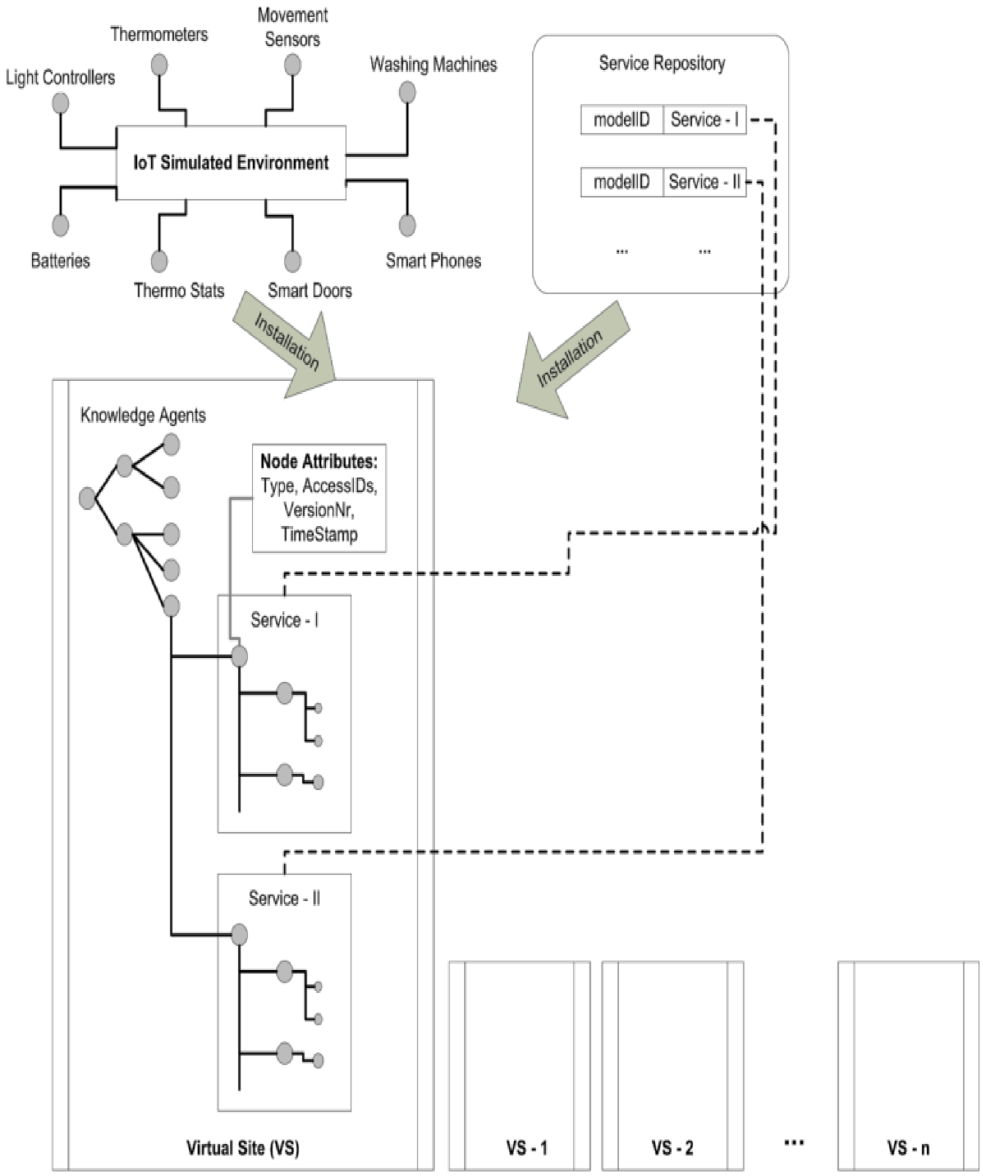

Figure 1. IoT Simulated Environment with Virtual Sites Middleware and Knowledge Agents

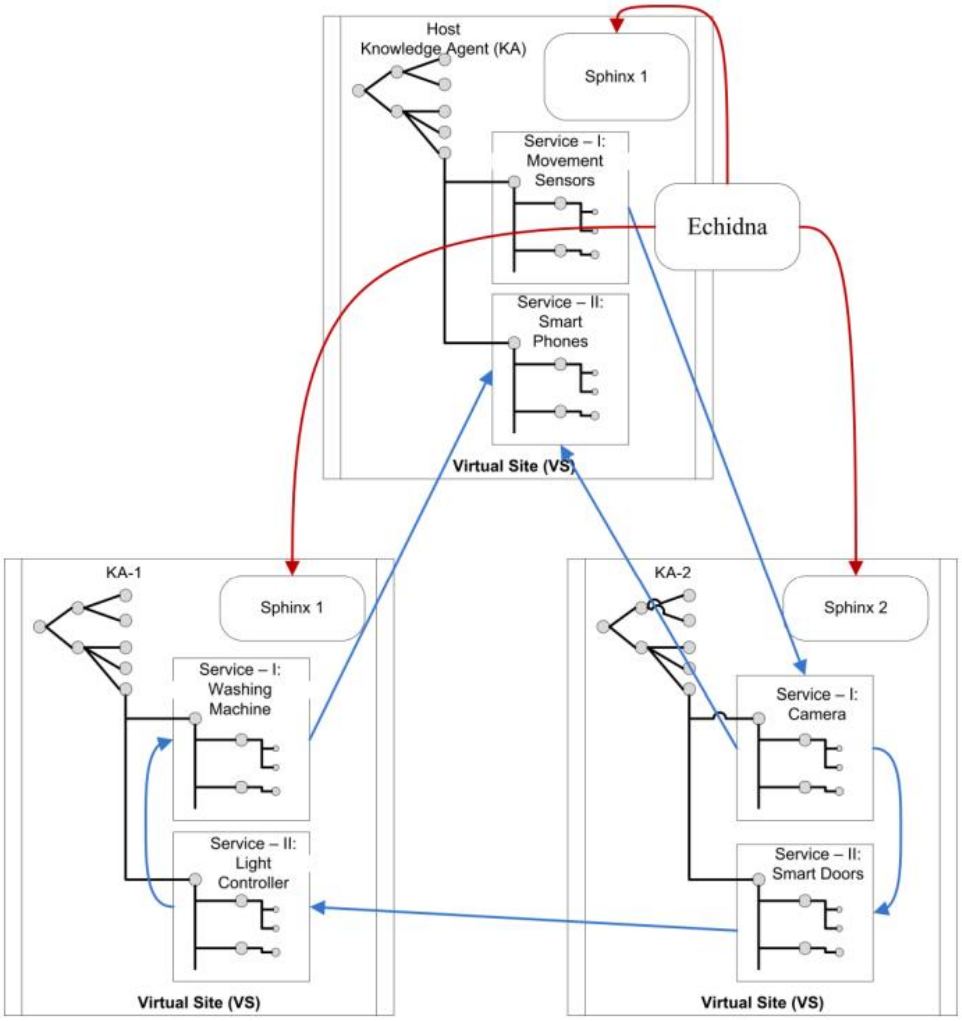
Host
Knowledge Agent (KA)
Sphinx 1
Service – I: Movement Sensors
Echidna
Service – II: Smart Phones
Virtual Site (VS)
KA-1
Sphinx 1
Service – I: Washing Machine
Service – II: Light Controller
Virtual Site (VS)
KA-2
Sphinx 2
Service – I: Camera
Service – II: Smart Doors
Virtual Site (VS)

Figure 2. Detection components in a smart space

4) Experimental Results

This section defines the model setting and the result analysis of the experiment.

4.1) Experimental Setup

The HP (ProDesk 600 G2 MT) facilitates experiments via its system running Windows 10 Pro (64 bit,10.0, Build 17134) (17134.rs4_release.180410-1804). The system includes an Intel(R) processor with Core(TM) i7-6700 CPU @ 3.40GHz (8 CPUs), ~3.4GHz. The HP (ProDesk 600 G2 MT) system comes equipped with 4096MB RAM for its memory operations. For this work researchers applied various software tools which composed of Imblearn framework alongside

Numpy framework and pandas framework. Similarly, the Matplotlib and Mlxtend frameworks are used for data visualization, and sklearn and classification-metrics frameworks were used for data analysis.

4.2) Result Analysis

Multiple machine learning models were selected for testing purposes together with the ensemble stacked approach. The testing of all methods used 10-fold cross validation as the evaluation method. To achieve higher precision the dataset uses stratified sampling with 10-fold data because it has many samples. Table 3.1 shows the accuracy results from decision tree DT, LDA, MLP, NB, LR methods for predicting the performance on 10-fold data. DT exhibits the highest accuracy of 90.75% from all methods and demonstrates minimal variation during fold4 testing. The accuracy performance of MLP stands as the lowest among all the methods at 48.06%. Tests of LDA and NB produced equivalent accuracy results for all tested folds. The training data evaluation incorporates parameters including ‘recall’, ‘precision’ together with FPR, TNR, F1 score, and ROC-AUC which are displayed in Table 3.2 next to the proposed stacking ensemble technique. DT achieves superior performance in recall, precision and F1 score alongside TNR according to Table 3.2 when evaluated by other methods. The proposed method demonstrates high performance which establishes itself as a proficient classification technique.

Table 1. Prediction Performances of SEM Model using 10_Fold Cross Validation Data

10_Fold Cross validated Data using Stratified Sampled	**Prediction Models**							
	DT	**LDA**	**MLP**	**NB**	**LR**	**RF**	**Bagging**	**Proposed Stacking Ensemble Model**
Fold1	0.907585	0.819444	0.461538	0.719017	0.620192	0.919465	0.929465	0.965012
Fold2	0.902778	0.831731	0.366453	0.715278	0.603632	0.918393	0.919464	0.965080
Fold3	0.893526	0.82397	0.281969	0.698769	0.588015	0.919464	0.928393	0.954678
Fold4	0.87413	0.835029	0.412962	0.709695	0.611676	0.918393	0.919464	0.951676
Fold5	0.899839	0.821103	0.363685	0.692555	0.574719	0.917322	0.927858	0.956431
Fold6	0.896034	0.832262	0.397106	0.72508	0.658628	0.918393	0.928393	0.955260
Fold7	0.890617	0.82252	0.354424	0.691689	0.605362	0.919464	0.919464	0.959010
Fold8	0.893834	0.826273	0.314745	0.726542	0.637534	0.919464	0.919464	0.951003

Fold9	0.893777	0.825107	0.480687	0.695815	0.708691	0.919464	0.928393	0.951211
Fold10	0.899142	0.821888	0.335837	0.697961	0.626609	0.919464	0.928393	0.961233

Table 2. Performance Measurement of different Models

Prediction Models	**Performance Metrics**						
	Accuracy	**Recall**	**FPR**	**Precision**	**TNR F1**	**Score**	**ROC-AUC**
DT	90.13	1.0	0.0	1.0	1.0	1.0	1.0
LDA	83.06	0.99361	0.0	1.0	1.0	0.99679	0.9968
MLP	59.93	1.0	1.0	0.96079	0.0	0.98000	0.5
NB	69.60	0.97537	0.0	1.0	1.0	0.98753	0.9876
LR	60.62	0.98615	0.3860	0.99667	0.613	0.99138	0.8000
RF	91.89	1.0	0.0	1.0	1.0	1.0	1.0
Bagging	92.48	1.0	0.0	1.0	1.0	1.0	1.0
Proposed SEM model	95.13	1.0	0.0	1.0	1.0	1.0	1.0

4.3) LGBM with Optimized Hyper-parameters for Detecting Malicious Access in IoT Networks

The Internet of Things (IoT) keeps boosting its popularity as it brings smarter technology into everyday life. Researchers have widely used this extensive procedure to evolve it into a sophisticated form which now supports modernized smart environments. Multiple large-scale applications now use IoT devices to enhance daily life by performing automatic task functions and streamlining procedures.

The IoT system growth rate reveals most significant changes within the domains of housing along with healthcare services and urban planning and manufacturing operations. IoT technology allows billions of devices to communicate with each other which produces detailed collection of data and instant analytic capabilities and device surveillance and management functions. The rapidly expanding number of connected devices produces system architectures that become more intricate which creates major difficulties for data security alongside management complexity.

The rising number of IoT devices creates more opportunities for cyber-attacks to occur. Big data management becomes more complex because networks connecting systems to the internet expose them to numerous cyber vulnerabilities. Consequently, ensuring robust security for IoT applications has become a critical concern, given the broad spectrum of potential security threats associated with these systems.

4.4) Environment Setup

An HP Pro Desk 600 G2 MT computer with Windows 10 Pro 64-bit as operating system served as the experimental system during this trial. The system was built with an Intel Core i7-6700 CPU at 3.40 GHz (8 CPUs) and contained 4096 MB of RAM. The research performed its analysis through combination of Python libraries NumPy, pandas and imbalanced-learn (imblearn) for data processing operations. Additionally, Matplotlib and Mlxtend were employed for data visualization, while scikit-learn (sklearn) was used for data analysis.

This approach aims to assist IoT security experts in identifying vulnerabilities within a network and enhancing existing security measures. However, deploying IoT security solutions in real-time presents challenges, as it relies on historical network access profile data. The model requires regular updates and retraining to adapt to changes in the deployed system. Moreover, personalizing connected devices for end-users or during the manufacturing process poses significant challenges, particularly in terms of cost. The encryption and decryption of data can be particularly resource-intensive and costly, further complicating device-to-device or device-to-server communications.

4.5) Identification of Malicious Access in IoT Networks Using Light Gradient Boosting Machine with Optimized Hyper parameters

The Internet of Things (IoT) has seen significant adoption and development over the past decade, evolving from traditional applications to sophisticated smart environments. This widespread use of IoT has transformed everyday life, enhancing efficiency and reducing effort through large-scale applications across various domains, including healthcare, housing, manufacturing, and urban planning. The IoT ecosystem, consisting of numerous connected devices, facilitates data collection, information interpretation, device sensing, and gadget monitoring. By the end of 2020, projections indicated that IoT devices would surpass 20 million globally, a rapid growth that has introduced increasing complexity into IoT architectures. This complexity, coupled with frequent internet connectivity, has heightened the risk of cyber-attacks and challenges in managing large datasets effectively.

1. The study delivered the following essential research outcomes: 1. An optimized version of Light Gradient Boosting Machine (LGBM) appears in this research as a solution to detect hostile activities inside IoT environments. An ensemble learning technique enhances cyber threat detection by using this method. 2. The LGBM model benefit from our implementation of two optimization approaches: Randomized Search combined with Grid Search for tuning its hyper parameters. Our objective adopts basic search approaches which target lightweight operations to effectively scan various parameters in the space. 3. Performance Evaluation determines the LGBM model effectiveness through comparison

with many ensemble learning techniques and several machine learning models to measure efficiency.

In our approach, we ensure that the communication pathways of IoT appliances are safeguarded within a simulated environment, addressing both typical and anomalous actions critical for secure data transmission. Despite the effectiveness of various machine learning methods in detecting inconsistencies in stable environments, unforeseen attacks may still occur. Therefore, an optimized ensemble learning technique, such as LGBM, is employed to detect malware activities in IoT networks. The hyper parameter optimization, achieved through Randomized Search and Grid Search, aims to explore the hyper parameter space efficiently with minimal complexity. Our results demonstrate that this method is both effective and robust compared to other approaches. The future study should examine Cat Boost ensemble learning methods alongside deep learning techniques to maximize anomalous detection in IoT networks.

4.6) Detecting Intrusive Behaviors Using Swarm-Based Fuzzy Clustering Approach

Data safety stands as the top priority during the present digital era because internet use continues to grow yet exposes organizations to elevated risks of data violations and file theft incidents. Due to rising cyber threats it has become more convenient for attackers to obtain sensitive information. Multiple security solutions have appeared to protect networks as these vulnerabilities grow in number. IDS stands out as a successful security solution after proving its ability to discover potential threats while notifying users. IDD systems actively inspect network activities to identify both policy violations and abnormal activities occurring in Internet of Things networks. The research develops an intrusion detection system that uses swarm-based fuzzy clustering for improved security capabilities. The integration of swarm intelligence principles with fuzzy clustering techniques aims to develop better accuracy levels while improving reliability for detecting intrusive behaviors within IoT networks. The method provides an advanced solution for security breach identification for better data protection in modern complex network environments.

4.7) Scope for Future Research

Machine Learning (ML), a subset of Artificial Intelligence, enables machines to emulate human-like intelligence through training algorithms. These algorithms iteratively optimize objective functions, such as loss or error functions, based on training data. Hyper parameter optimization techniques further enhance model accuracy by improving the detection of cyber-attack within networks. Future research can build upon our work by exploring advanced ML methods and hyper parameter optimization strategies to refine malware detection systems. There is significant potential to improve model performance by integrating emerging techniques and algorithms. By expanding the scope of ML applications in cyber security, researchers can develop more robust and accurate solutions for identifying and mitigating malicious activities in increasingly complex network environments.

5) Conclusion

Considering the growth of IoT networks the identification of protection problems and data protection needs urgent focus now. The research explores Machine Learning (ML) algorithms to detect anomalies inside IoT networks so security and privacy can improve simultaneously. The implementation of IoT technology makes significant improvements in social life by changing numerous everyday activities. The combination of smart health devices enables patient surveillance and medication management which produces better healthcare results. Smart buildings and offices use occupancy data to regulate temperature and illumination levels for energy savings and achieve better security through automated monitoring and continuous security measures. Smart therapeutic automobiles possess the capability to monitor traffic conditions as well as vehicle speed to produce safer roadways. This paper analyzed three ML algorithms that specifically target suspicious activity detection in IoT networks through Fuzzy Clustering Method (FCM), LGBM and SEM. Popular meta-heuristic search algorithms referred to as GA) together with PSO and RS and GS were employed to optimize model hyper parameters and enhance model performance. The accuracy of anomaly detection depends heavily on the implementation of these optimization methods for feature selection enhancement. A strong IoT security framework stands essential for both vulnerability management and cyber intrusion detection across networks according to this research. The study utilizes multiple machine learning algorithms to shed light on security threat detection methods as well as the systems needed to prevent potential dangers. Research results validate the effectiveness of our proposed algorithms which improve IoT security systems and provide strong groundwork for additional research in this essential field.