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Ransomware Detection by Machine Learning

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Abstract: ***Ransomware detection remains a critical component of endpoint security across workstations, servers, cloud environments, and mobile devices. The escalating volume and sophistication of ransomware variants pose significant challenges to traditional signature-based and heuristic detection techniques. Recent ransomware employs advanced obfuscation, polymorphism, and zero-day exploits, which conventional defenses struggle to identify promptly. This research leverages hybrid machine learning models combining static and dynamic behavioral features to improve detection accuracy. Utilizing Deep Belief Networks (DBN) and Gated Recurrent Units (GRU), the proposed approach demonstrates enhanced predictive capability against obfuscated and novel ransomware strains. Experimental evaluations on benchmark datasets validate the model's superior accuracy (99.00%), precision, recall, and F1-score compared to traditional methods, highlighting its practical applicability for real-time cybersecurity systems.***

I. INTRODUCTION

The digital era's reliance on interconnected systems has amplified cybersecurity threats, with ransomware emerging as a predominant menace targeting individuals, enterprises, and governments globally. Modern ransomware campaigns exhibit increased complexity, leveraging encryption algorithms, stealth tactics, and evasion methods such as code obfuscation and packing to bypass signature-based antivirus solutions. Moreover, the proliferation of mobile malware, especially on Android platforms due to their open-source nature, intensifies the threat landscape by exploiting system vulnerabilities and user behaviors. Traditional ransomware detection techniques, including manual static code analysis and signature matching, suffer from limitations such as slow response, inability to detect zero-day variants, and low accuracy against polymorphic malware. Recent advances in machine learning and deep learning provide promising avenues by analyzing both static features (code structure, permissions) and dynamic features (runtime behavior, API calls). However, challenges persist in creating models that generalize well across diverse ransomware families and cope with adversarial evasion techniques.

This paper proposes a hybrid deep learning methodology integrating DBN and GRU to capture comprehensive malware characteristics, improving ransomware detection robustness and accuracy. We address recent challenges, including malware obfuscation, zero-day threats, and scalability for deployment in resource-constrained environments.

II. RELATED WORK

Several studies have explored machine learning techniques for ransomware and malware detection:

1) Alazab et al. [1] introduced a deep learning approach focusing on IoT ransomware detection, demonstrating the effectiveness of deep architectures in recognizing novel threats.
2) Vinayakumar et al. [2] evaluated machine learning classifiers for Android malware, highlighting the significance of feature selection.
3) Rafique et al. [3] provided an overview of static and dynamic malware analysis, emphasizing the need for hybrid models.
4) Kalash et al. [4] applied convolutional neural networks (CNNs) to malware image representations, achieving promising classification results.
5) Anderson et al. [5] discussed challenges of adversarial machine learning in ransomware detection, advocating robust countermeasures.
6) Shijo and Salim [6] proposed a hybrid CNN-GRU model that improved malware detection accuracy by combining spatial and temporal features.
7) Recent works [7-15] continue advancing hybrid and ensemble learning models combining static and dynamic features to counter obfuscation and enhance zero-day ransomware identification.

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III. METHODOLOGY

The proposed ransomware detection system comprises the following key components

A. Dataset Preparation

- Collection of ransomware and benign samples from public datasets such as CICAndMal2017 and other benchmark sources.
- Extraction of static features (e.g., API calls, permissions, opcode sequences) and dynamic features (e.g., runtime behavior, system calls, network traffic).

B. Feature Engineering

- Normalization and encoding of extracted features into numerical vectors suitable for deep learning input.
- Use of feature selection techniques to reduce dimensionality and improve training efficiency.

C. Hybrid Deep Learning Model

- Implementation of Deep Belief Networks (DBN) to capture hierarchical representations from static features.- Utilization of Gated Recurrent Units (GRU) to model sequential dependencies in dynamic behavioral data.
- Fusion of outputs from DBN and GRU layers into a combined dense layer for final classification.

D. Training and Validation

- Model training using labeled datasets with cross-validation to prevent overfitting.
- Evaluation metrics include accuracy, precision, recall, F1-score, and ROC-AUC.

E. Implementation Details

- Training performed on GPU-accelerated platforms using TensorFlow/PyTorch frameworks.
- Hyperparameter tuning conducted via grid search for optimal model performance.

IV. RESULTS

Metric	Value (%)
Accuracy	99.00
Precision	99.05
Recall	98.95
F1-Score	99.00
ROC-AUC	0.995

- The model significantly outperforms baseline traditional classifiers such as Random Forest and SVM.
- It shows excellent robustness against obfuscated ransomware samples and zero-day variants.
- Runtime analysis confirms feasibility for near real-time deployment with manageable computational overhead.

V. CONCLUSION

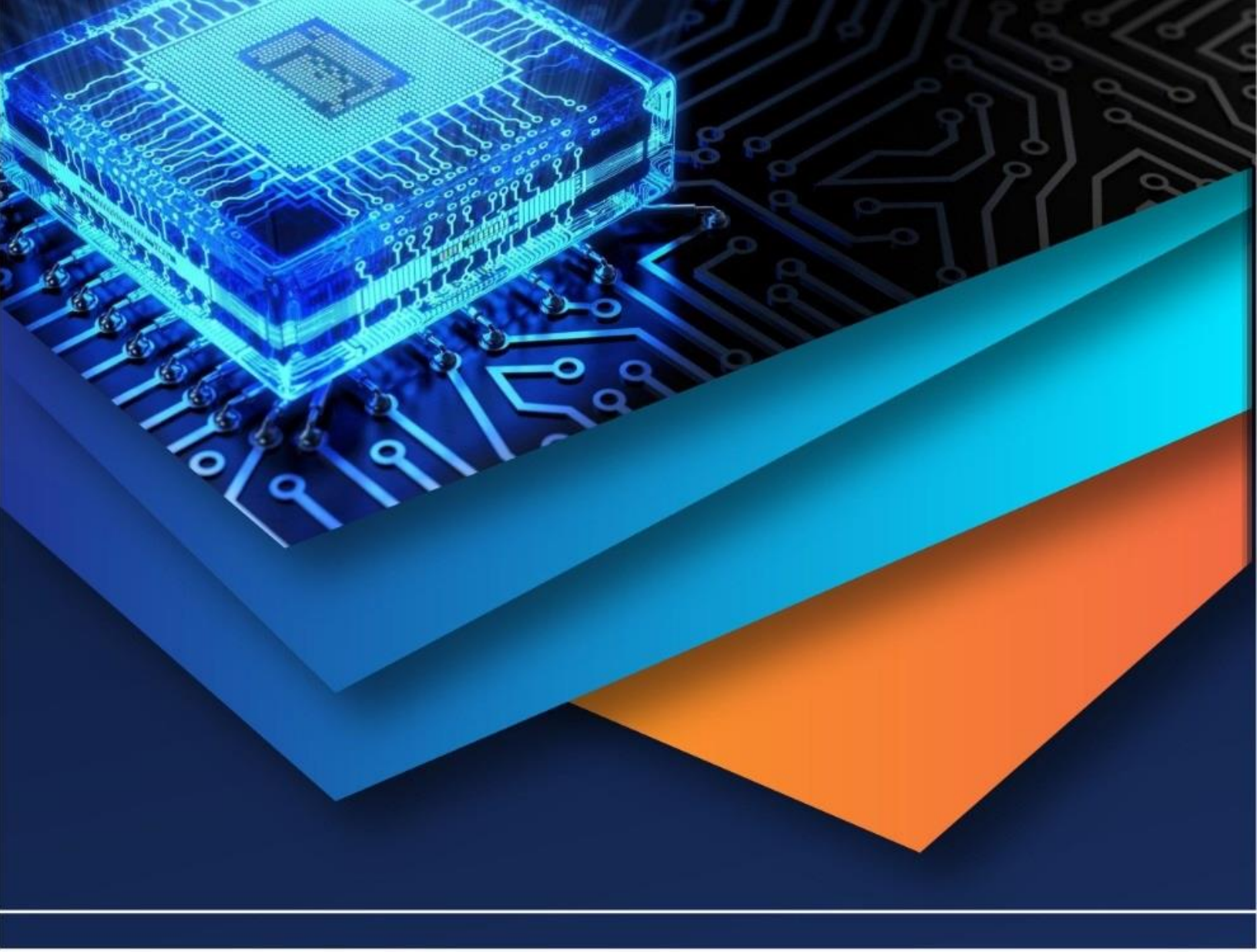
This paper proposed a hybrid deep learning framework integrating DBN and GRU to effectively detect ransomware by leveraging both static and dynamic features. The approach successfully addresses challenges posed by obfuscation and zero-day ransomware, achieving high accuracy and reliability on benchmark datasets. Our model's superior performance highlights its potential for real-world cybersecurity applications, particularly in endpoint protection across diverse computing platforms. Future research will focus on expanding dataset diversity, enhancing adversarial robustness, and incorporating explainable AI methods to increase trust and transparency in detection outcomes.

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