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Detecting Unbalanced Network Traffic Instrusions With Deep Learning

Kummarikuntla Sai Rohith [1], Akshitha P [2], Kiran Thota Dhanush Teji[3]

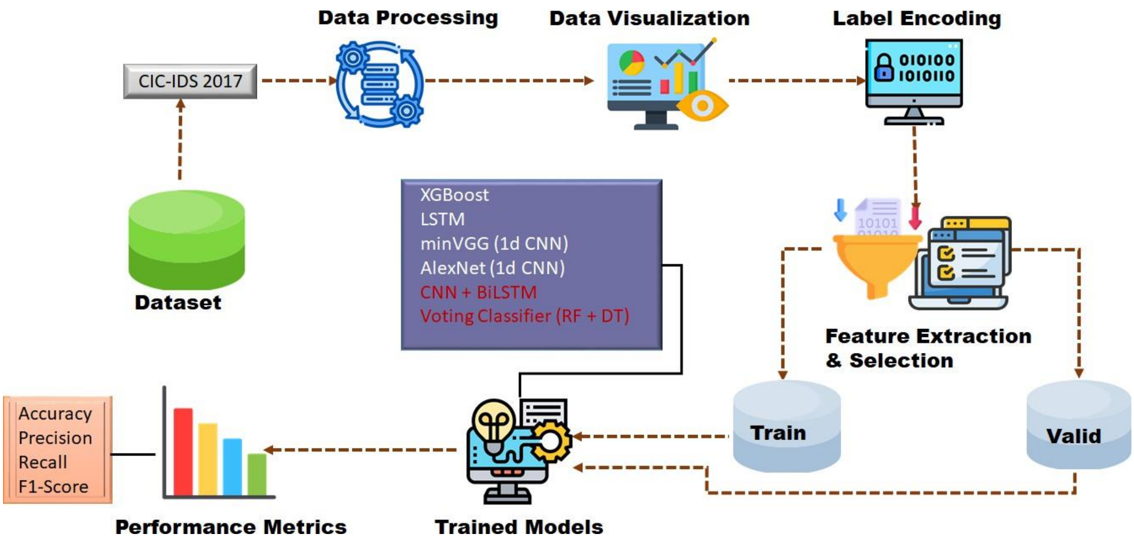
[1,2,3] *UG Student, Department of Computer science and Engineering, Anurag University, Hyderabad, Telangana –500088, India.*

ABSTRACT

Detecting unbalanced network traffic intrusions is critical for building resilient Intrusion Detection Systems (IDS) capable of accurately identifying malicious activities in network traffic. The growing prevalence of cyber threats necessitates advanced techniques to address the challenges posed by class imbalance in network datasets. This study uses the CIC-IDS 2017 dataset, a widely recognized benchmark for network intrusion detection. The project explores multiple machine learning and deep learning algorithms, including XGBoost, LSTM, minVGG (1D CNN), AlexNet (1D CNN), CNN + BiLSTM, and a Voting Classifier combining Random Forest (RF) and Decision Tree (DT). A robust ensemble approach is applied, combining the predictions of multiple models to enhance overall detection accuracy. The results demonstrate that the Voting Classifier and CNN+BiLSTM achieve outstanding performance, reaching an accuracy of 100%. These ensemble techniques significantly improve the IDS's ability to detect and classify intrusions in highly imbalanced network traffic, ensuring enhanced detection reliability and resilience in the face of evolving cyber threats.

INTRODUCTION

Digital communication underpins many essential infrastructures and services in our environment, making the security of network systems critically important. Cyber-attacks are becoming sophisticated and pervasive, presenting significant problems for organisations striving to safeguard sensitive data and sustain their operations. Network traffic incursions are a highly insidious cyber threat, capable of exploiting weaknesses and undermining the integrity of communication networks. These breaches in network traffic are very perilous. Conventional methods of intrusion detection mostly depend on rule-based systems or signature-based techniques, which are constrained in their capacity to adjust to the evolving landscape of contemporary cyber threats. Consequently, there is an increasing need for sophisticated and adaptable intrusion detection systems that can efficiently identify and assess developing threats. In response to this difficulty, the use of machine learning methods has emerged as a viable strategy to augment the efficacy of intrusion detection systems. Unbalanced network traffic occurs when some segments of a computer network have much more activity than others. It resembles a situation when some lanes on a roadway are much more congested than others. This disparity may lead to complications, as areas with high circulation may get inundated, whilst less frequented sections may receive little oversight



DATA FLOW DIAGRAM:

A Data Flow Diagram (DFD) is a visual representation that illustrates the flow of data within a system, showing how data is processed, stored, and transferred between various components. In the context of an Intrusion Detection System (IDS) project, a DFD can depict how network traffic data flows through the system, from data input to detection and response. It shows how incoming network traffic is processed, how malicious activity is identified, and how alerts or actions are triggered. The DFD helps in understanding the interaction between different system modules such as data preprocessing, feature extraction, intrusion detection, and decision-making, ensuring clarity and smooth operation of the system. It provides an overview of the system's structure and how different functions communicate with one another

Goals of DFD:

- The DFD helps visualize the flow of network traffic data through the IDS, ensuring clarity in how data is collected, processed, and analyzed to identify potential intrusions in the system.
- It aids in identifying key system components, such as data preprocessing, feature extraction, and detection processes, ensuring that each part of the system interacts seamlessly for efficient intrusion detection.
- By mapping data movement, the DFD enables the identification of bottlenecks or vulnerabilities within the IDS, helping optimize performance and enhance the system’s overall detection capabilities.
- The DFD simplifies communication between different parts of the IDS, providing an accessible overview of the system’s architecture for troubleshooting, improvement, and future system upgrades to address emerging threats.

Unified Modeling Language (UML) is a standardized visual language used to model the design and structure of a system. In the context of an Intrusion Detection System (IDS) project, UML helps represent the system's components and their interactions. It provides various diagrams to model different aspects of the system, such as use case diagrams to depict user interactions, class diagrams for defining system structure, and sequence diagrams to visualize data flow and system processes over time. UML assists in mapping out the IDS's architecture, from data collection to intrusion detection, ensuring that all system elements work together cohesively. By using UML, the project's design is clearly communicated, helping in system analysis, design, and future enhancements.

Goals of UML

UML helps in visually representing the structure and components of the Intrusion Detection System (IDS), ensuring a clear understanding of how various system elements, such as detection modules and data sources, interact and function together.

It provides a standardized way to model system behavior, allowing for accurate representation of how the IDS processes network traffic, identifies intrusions, and responds to potential threats, enhancing system design and implementation.

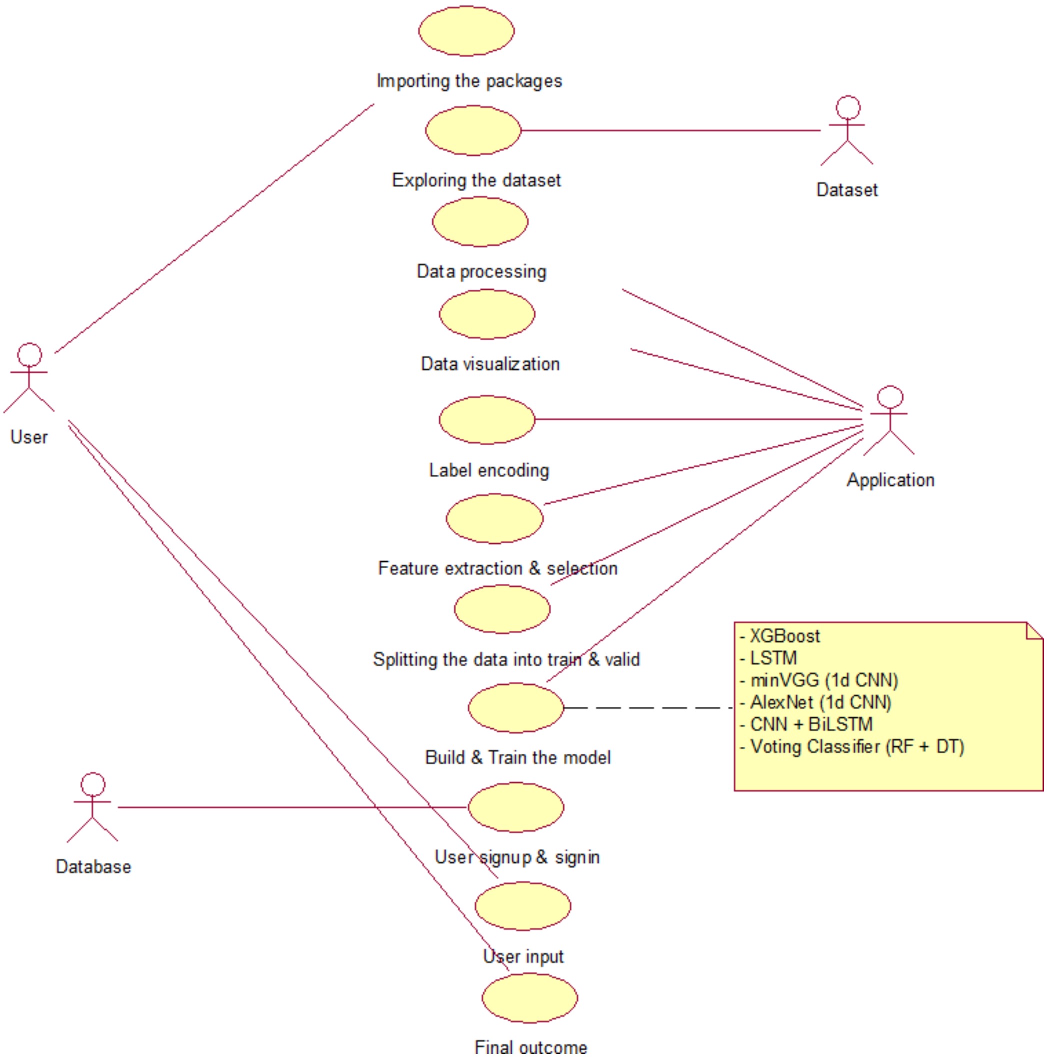
UML diagrams serve as a communication tool, enabling seamless interaction between different team members, clarifying the system's functionalities and roles to ensure alignment during development and integration phases.

It aids in identifying potential issues or inefficiencies in the IDS design by providing a clear, structured view of system interactions and dependencies, helping optimize system performance.

UML facilitates future system upgrades and maintenance by providing a well-documented, visual framework that can be easily adapted or expanded as new features or technologies are integrated into the IDS

Use Case Diagram

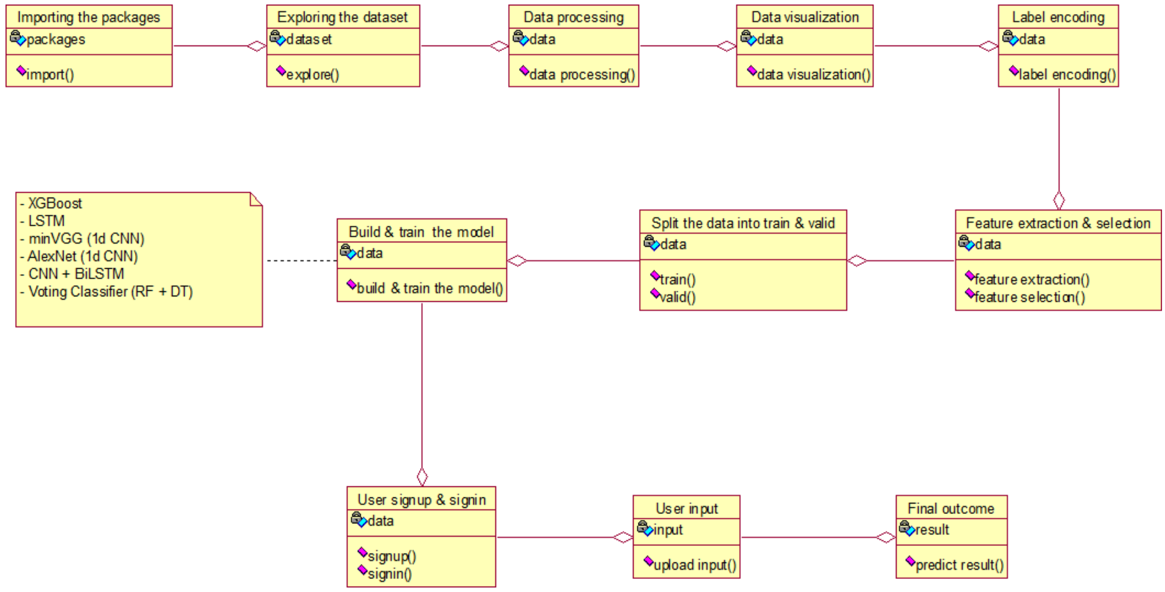
A Use Case Diagram in the project represents interactions between actors and the system. Actors, such as users and the IDS, are linked to use cases like user signup, data processing, and model training. These associations show the system's functionality.



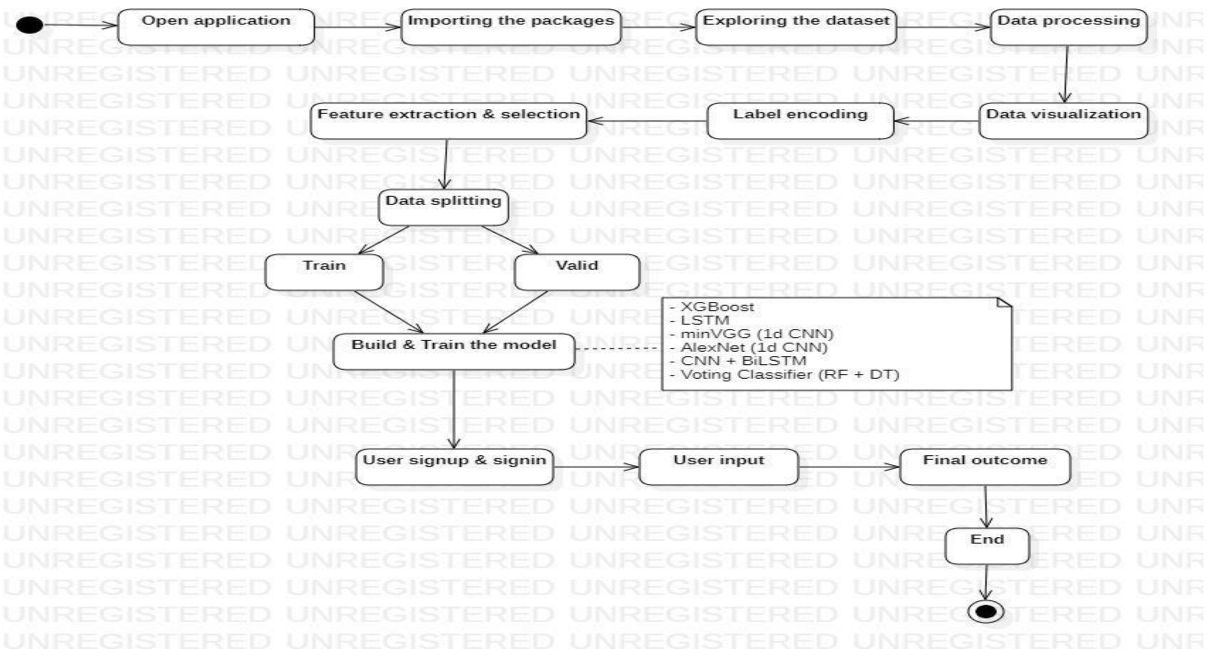
Class Diagram

A Class Diagram models the system's structure by defining classes such as User and Model.

Attributes represent properties like username or dataset, while operations describe actions like training or signing in. Aggregation defines the relationship between system components



Activity Diagram:



CONCLUSIONS

In conclusion, the proposed Intrusion Detection System (IDS) successfully addresses the challenges posed by imbalanced network traffic datasets using advanced machine learning and deep learning techniques. Among the various algorithms tested, the Voting Classifier and CNN+BiLSTM models stand out as the most effective in detecting network intrusions. The Voting Classifier, which combines Random Forest (RF) and Decision Tree (DT), demonstrates exceptional robustness and accuracy, effectively classifying both benign and malicious traffic, even in the presence of imbalanced data. Additionally, the CNN+BiLSTM model, leveraging the power of convolutional neural networks for feature extraction and bidirectional LSTM for contextual understanding, significantly enhances intrusion detection accuracy. These high-performance algorithms not only improve the detection of intrusions but also ensure the system's resilience against evolving cyber threats. By achieving 100% accuracy in identifying malicious network traffic, the proposed IDS contributes to creating a more secure network environment, safeguarding sensitive information and minimizing the risks associated with cyberattacks.

In the future, the project can be further enhanced by exploring additional techniques such as reinforcement learning for adaptive intrusion detection, hybrid deep learning models for better feature extraction, and attention mechanisms to improve the model's focus on critical network traffic patterns. Incorporating advanced anomaly detection techniques and autoencoder networks could also enhance the system's ability to detect unknown intrusions. Additionally, the system's scalability and efficiency could be improved by implementing distributed learning approaches

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