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Classification of Packet Length Spectral Analysis for IoT Network Traffic Using Random Forest Extra Tree Categorization

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Abstract- The swift advancement of the Internet of Things (IoT) has ushered in a wealth of benefits, allowing countless interconnected devices to interact and exchange data effortlessly. Previously, network traffic including unusual patterns, was mainly produced by established, secure endpoints with strong security features, like smartphones. With the advent of the Internet of Things (IoT) no matter how small or intricate device, now has the capability to produce unusual levels of network activity. One of the biggest challenges facing the IoT industry is network traffic, which can have a negative impact on the overall performance of IoT devices and systems. To address this issue, a random forest classifier has been developed specifically for classifying IoT data. Extra Trees offer a significant benefit by minimizing bias. This is achieved by randomly sampling from the entire dataset when building the trees. Random Forest is a widely recognized machine learning technique which favours accuracy, reliability, flexibility and scalability. The process of data preprocessing involves transforming unrefined data into a refined dataset. Chi-square based feature extraction is utilized to extract relevant information and this technique enhances classification by selecting the most important features from the extraction regions. In the end, the chosen characteristics are inputted into both an extra tree and random forest classifier to ensure precise categorization and the implementation of this endeavor is carried out utilizing Python programming.

Index Terms- Chi-square, Extraction, data pre-processing, random forest classifier, Extra trees, Categorization.

I. INTRODUCTION

IoT also known as the Internet of Things, pertains to the interconnected system of devices and the technology enabling communication between devices and the cloud, as well as between the devices themselves. The IoT utilizes sensors and communication technologies to gather and transmit real-time data, facilitating quick data processing and informed decision-making. Additionally, IoT has the potential to revolutionize the energy industry by transitioning it from a centralized to a decentralized, intelligent, and interconnected energy network. Traditional networks have several limitations when it comes to routing, flexibility, manageability and extensibility and these shortcomings will pose a significant challenge for IoT traffic [1]. The modern Internet of Things (IoT) gadgets gather data from the physical world and offer insights into the surrounding environment. As a result, IoT traffic is expected to make up a significant portion of overall Internet activity. Despite this, the exact effects of this increased traffic on networks remain largely uncertain. Due to limited resources and potential misconfigurations, IoT devices are vulnerable to cyberattacks [2-3]. An intrusion detection system (IDS) can offer additional security to an IoT network by detecting and preventing security attacks. However, a common issue with existing IDSs is the rise in false alarms when identifying zero-day anomalies [4]. Due to this reason, random forest algorithm is taken into account and it is a versatile tool that creates a multitude of decision tree models on different subsets of the data, ultimately enhancing predictive accuracy and reducing the risk of overfitting [5]. The issue of overfitting in a single decision tree is effectively addressed by implementing the Random Forest algorithm. Studies have shown that the Random Forest algorithm outperforms the Extra Trees algorithm in terms of prediction accuracy [6]. IoTTGen (Internet of Things Traffic Generator) is a tool that is used to simulate diverse IoT environments by modeling the behavior of sensor devices [7]. Enhancing IoT Traffic Classification in Smart Environments through Network and Statistical Features deals with an advanced machine learning method with a dual-stage process is employed, utilizing two

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distinct sets of features. The first set consists of statistical features like packet inter-arrival time, burstiness rate and traffic flow rate. The second set encompasses more detailed network features such as IP addresses, IP protocol type, port numbers, MAC addresses, Time-to-Live (TTL) and packet size. Moving forward, enhancements involves incorporating additional machine learning strategies like Kmeans clustering in conjunction with classification algorithms [8]. The utilization of SDN in FiWi-IoT smart environment network traffic classification with supervised machine learning models offers numerous advantages. By leveraging the overarching perspective provided by SDN and addressing the requirements of traffic flows, a refined system has been developed to enhance the multipath transmission of IoT applications. SDN-Enabled FiWi-IoT Smart Environment Network Traffic Classification Using Supervised ML Models gives a merits of Using the global view of SDN and the need for traffic flows, an optimized scheme is built for the multipath transmission of IoT applications, Detecting anomalies plays a crucial role in uncovering valuable business insights and ensuring the smooth operation of essential functions. For future, the development of anomaly detection serves as a vital mechanism for identifying fraudulent activities, network disruptions and other noteworthy irregularities [9].

Detecting Malicious Bot-Generated Traffic in IoT Networks through Machine Learning Approaches is proposed and this technique is highly effective and consistently delivers over 96% success rates on average. The C4.5 decision tree and Random Forest machine learning algorithms show great potential when applied to the Bot-IoT dataset. While SVM and Naive Bayes algorithms also perform well, they fall slightly short in comparison to the robust performance of the C4.5 decision tree and Random Forest algorithms [10]. A novel method for classifying malware using vision-based techniques is proposed to overcome the limitations of existing malware detection systems.

This approach leverages the advantages of deep transfer learning techniques, along with fine-tuning and ensemble strategies, to enhance detection and classification accuracy without the need to build models from the ground up. In the future, consider implementing federated learning, a method that allows for the deployment of machine learning and deep learning models on IoT sensors. This approach is beneficial due to its simplicity and distributed nature, as it avoids the need to process IoT data on a centralized server [11-12]. Analyzing the length of data packets to classify flows in IoT using ensemble learning techniques that evaluate the runtime efficiency of the classifier and demonstrate that a C implementation, capable of multi-threading and generated directly from the trees, that effectively manage high-speed networks. For future, Investigate the correlation in timing between various flows associated with a single device where a challenge lies in identifying patterns within the opening and closing of flows by the device [13-14]. The system assesses the security implications of Distributed Denial of Service (DDoS) attacks by leveraging Machine Learning algorithms on network traffic data.

The previous research highlights the effectiveness of using the Random Forest Regressor (RFR) feature selection technique in enhancing the accuracy of Machine Learning models for detecting malicious attack traffic. However, it delves into the boundaries and prospective advancements for systems that detect and address network anomalies in the Internet of Things (IoT) [15]. This paper proposes a new approach for Categorizing Internet of Things (IoT) network data with Random Forest Algorithm. Building upon existing research, this paper introduces a novel contribution:

- Random Forest favours exceptional accuracy, reliability, flexibility and scalability which widely recognized machine learning technique.
- Extra Trees offer a significant benefit by minimizing bias. This is achieved by randomly sampling from the entire dataset when building the trees.

II. PROPOSED SYSTEM DESCRIPTION

As cyberattacks become more advanced and elusive on IoT networks, it is crucial to enhance intrusion detection methods to effectively combat evolving threats. The Internet of Things (IoT) demands heightened focus due to its pivotal role in the ongoing digital transformation, extending beyond services into physical product industries.

Figure 1: Proposed Block Diagram

Data preprocessing is the essential step of converting real-world data into a digital format that easily analyzed, displayed and stored in a computer system. This transformation is crucial for effective processing in machine learning algorithms. To achieve accurate classification results, the extra tree and random forest classifiers are utilized.

These classifiers have shown to produce reliable predictions. However, the process requires extensive training time, especially when dealing with large and unbalanced datasets at the packet level. In order to extract relevant features from the data, the Chi-square Method is employed. This method helps in identifying the most significant attributes that contribute to the classification process.

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III. SYSTEM MODELING

1. Data Preprocessing

The initial phase of Machine Learning involves a crucial process known as Data Pre-processing. This step involves transforming or encoding the data to make it suitable for efficient analysis by the machine. Essentially, this step ensures that the model algorithm effectively interpret and analyze the data features. Data pre-processing plays a crucial role in enhancing the overall performance of a Supervised Machine Learning Algorithm. The quality of training data has a significant impact on the algorithm's ability to generalize effectively, especially as the input space dimension increases exponentially.

Data processing is carried out for the following reasons:

- Addressing data-related issues result in discrepancies and hinder the ability to conduct thorough data analysis.
- Deriving essential and valuable insights from the provided dataset.

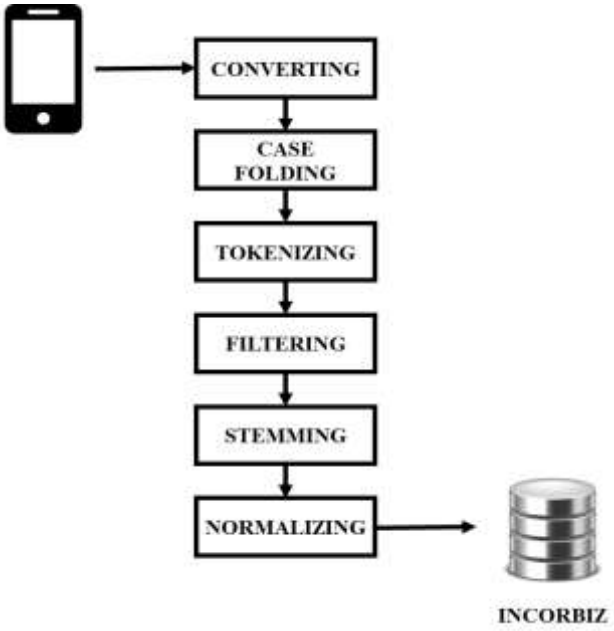

Figure 2: Steps in data preprocessing

Chi-Square Test for Feature Selection

The chi-square ($\chi 2$) statistic is a tool used to evaluate the goodness of fit of a model against real-world data. It is important that the data utilized for calculating the chi-square statistic is both random and raw, as well as being mutually exclusive and drawn from independent variables. Additionally, the sample size must be large enough to ensure the accuracy of the results. When considering the possibility that there are no variations between the groups within the population, the calculated test statistic from the data will adhere to a chi-square distribution.

The formula for chi-square is:

$$x_c^2 = \sum \frac{(O_i - E_i)^2}{E_i} \quad (1)$$

c = degrees of freedom
O = observed values
E = Expected values

Random Forest Classifier

The Random Forest algorithm is widely used in machine learning and falls under supervised learning. This versatile algorithm is suitable for addressing both Classification and Regression tasks within the field of ML.

Its foundation lies in ensemble learning, a method that involves blending multiple classifiers to tackle intricate problems and enhance model performance. A Random Forest is a classification model that consists of multiple decision trees built on different subsets of the dataset. By averaging the predictions of these trees, the model enhances the accuracy of its predictions.

Below are some of the points for which random forest classifier:

- It requires a shorter training period compared to alternative algorithms.
- It accurately forecasts results with precision, even when handling extensive datasets, demonstrating efficient performance.
- It is capable of preserving precision even in the absence of a significant amount of data.

IV. RESULT AND DISCUSSION

The proposed paper focuses on categorizing IoT network traffic through the utilization of a random forest classifier. Python, a dynamically typed language renowned for its implementation approach, is a versatile high-level programming language with multiple applications.

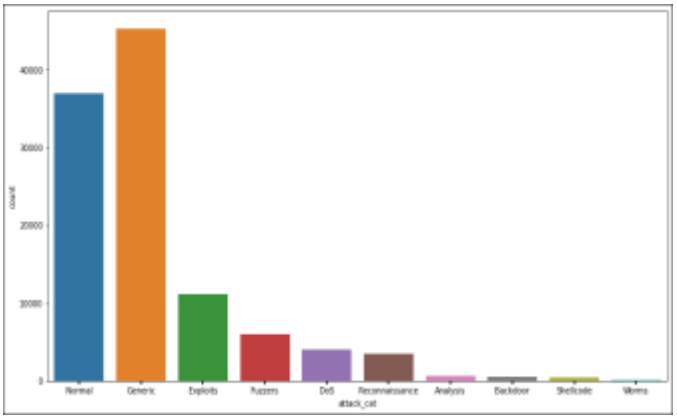

Figure 3: Attack Cat

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In the illustration provided in Figure 3, different levels of attacks on IoT networks are depicted. This visual representation takes into account both the frequency of attacks and the categories of attacks.

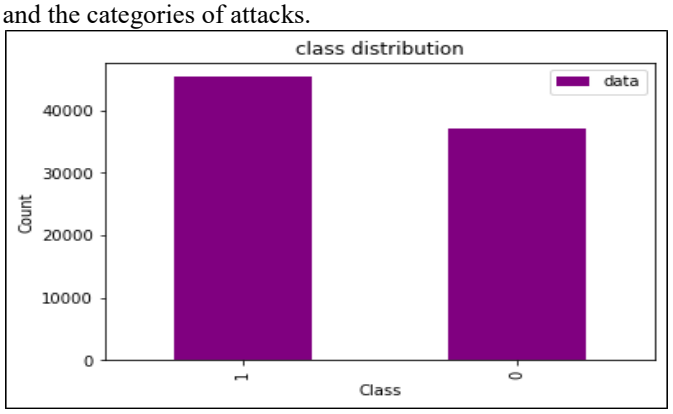

Figure 4: Class Distribution

Figure 4 illustrates the graph of class distribution. A class distribution is essentially a mapping of class values (0 or 1) to the corresponding number of randomly generated examples that should be included in the dataset.

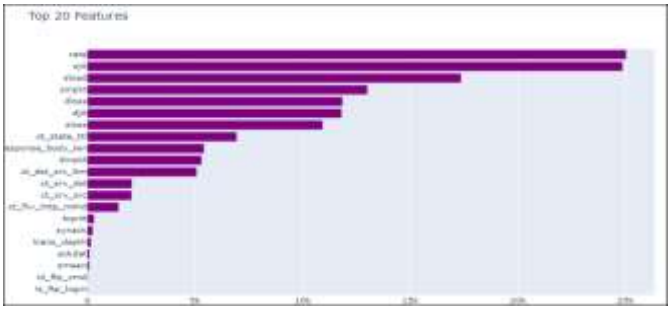

Figure 5: Top Features

In the illustration provided in Figure 5, a clear visual representation is chosen using the CHI-square method. The CHI-square formula is a statistical tool used to compare multiple data sets.

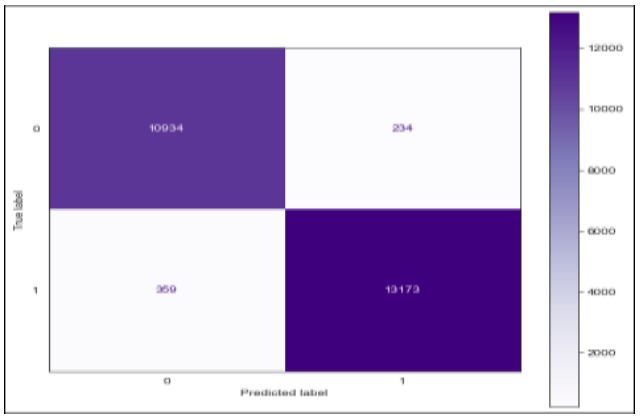

Figure 6: Performance matrix for extra tree

Figure 6 depicts the concept of Extra Trees, which is a technique in supervised machine learning that leverages decision trees. The diagram showcases the comparison between the true label and the predicted label generated by the Extra Trees algorithm.

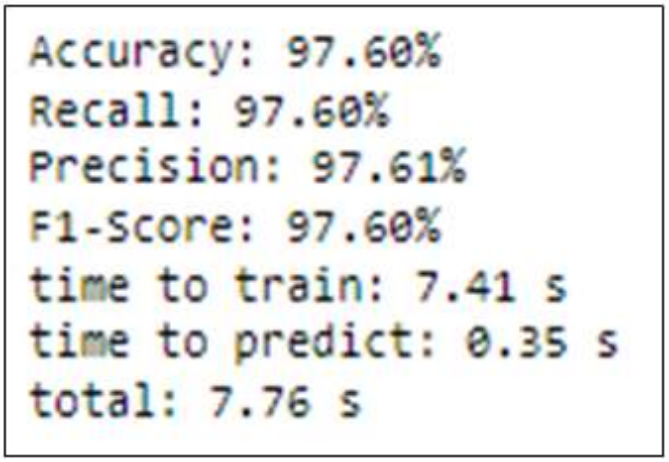

Figure 7: Confusion matrix for extra tree

In the illustration presented as Figure 7, the confusion matrix for the extra tree model is displayed. Various performance metrics such as accuracy, recall, precision and F1-score observed in this visual representation.

	Accuracy	Recall	Precision	F1-Score	time to train	time to predict	total time
ET	97.60%	97.60%	97.61%	97.60%	7.4	0.3	7.8
RF	97.66%	97.66%	97.67%	97.67%	7.9	0.2	8.2

Figure 8: Model Performance

Figure 8 depicts the model performance of the confusion matrix for IoT network by using the random forest classifier.

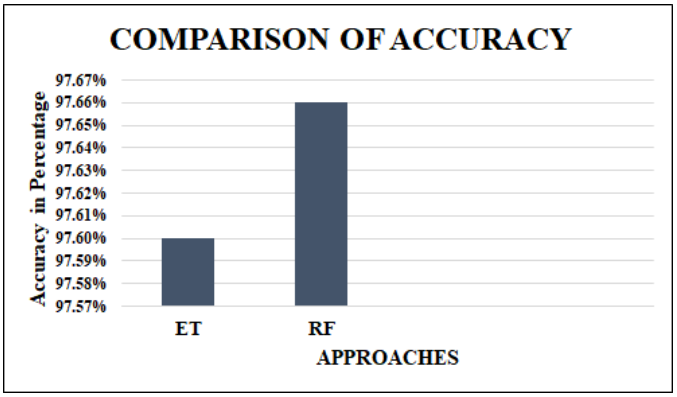

Figure 9: Comparison of accuracy

Figure 9, a comparison is shown between the accuracy of Extra trees Classifier (ET) and Random Forest Classifier (RF). The accuracy of ET classifier ranges of 97.6% and with the

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implementation of the proposed system, the accuracy of RF classifier improves in the range of 97.66%.

V. CONCLUSION

The proposed approach for this paper involves utilizing a random forest classifier to categorize IoT network traffic. During a span of 26 weeks, the equiption of a smart environment with 28 distinct IoT devices and gathered traffic data non-stop. In situations where devices experience limited bandwidth, the importance of their data flows within the dataset is consequently decreased. Data preprocessing involves transforming data into a format that is more easily and efficiently processed by machine learning algorithms. The use of additional tree and random forest classifiers has been shown to be effective in achieving accurate classification results. The findings presented above vividly demonstrate the difference between the confusion and performance matrices, with an impressive increase in accuracy of approximately 97.66% achieved when utilizing the random forest classifier. This successful demonstration showcases the effectiveness of the classifier in enhancing accuracy.

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