Advanced Phishing Attack Detection Through Network Forensic Methods and Incident Response Planning Based on Machine Learning

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Abstract

The widespread use of smartphones has led to an increase in cybercrimes, particularly phishing attacks. Phishing attacks are commonly propagated through email, WhatsApp groups, and other communication channels. The stolen data is then used to commit further crimes, exploiting the victims' personal information. This study addresses the detection of phishing attacks using network forensic methods and incident response planning. Unlike previous approaches that relied solely on Incident Response Plans (IRPs) and Incident Handling methods to react to phishing attacks, this research emphasizes proactive detection. By employing network forensics, suspicious websites can be identified and differentiated from legitimate ones, enabling early detection and prevention of phishing attacks. The results demonstrate that network forensics can significantly enhance the ability to detect phishing sites before they can harm users. In our experiments, we analyzed a dataset of 10,000 websites, identifying 95% of phishing sites with a false positive rate of only 2%. Utilizing the Random Forest machine learning algorithm, we achieved high performance metrics with an accuracy of 96.5%, precision of 97.1%, recall of 95.8%, and an F1-score of 96.4%. This proactive approach not only mitigates the risk of phishing but also provides a robust framework for incident response, ensuring that potential threats are identified and neutralized promptly.

Keywords

Phishing Attack,
Detection Network,
Forensics Incident,
Response Planning
Cybercrime Prevention,
Smartphone Security

I. Introduction

The modern digital age today, internet technology has become an indispensable part of daily life, facilitating a wide range of activities from communication to online shopping and banking. The ubiquity of smartphones has further accelerated this trend, enabling individuals to access the internet conveniently and seamlessly [1]. According to research [2], the widespread adoption of smartphones has transformed how people interact with technology, making it an integral aspect of their daily routines [3], [4]. This reliance on internet technology underscores the need for robust cybersecurity measures to protect users from various online threats [5], [6]. As the use of internet-enabled devices continues to grow, so does the sophistication and frequency of cybercrimes. Cybercriminals exploit the heavy dependence on internet technology to execute various illegal activities, targeting both individuals and organizations [7].

Research by [8] indicates that the rise in internet usage has led to an increase in cybercrime, with perpetrators employing advanced techniques to breach security systems and access sensitive information. One prevalent method employed by these criminals is phishing attacks, which have become increasingly sophisticated and harder to detect. Phishing attacks represent a significant threat in the realm of cybersecurity, as they are designed to deceive users into divulging personal information [9]. These attacks often involve the creation of counterfeit websites that mimic legitimate ones, as highlighted [10]. The fraudulent sites are disseminated through various channels such as email, chat, and social media, aiming to lure victims into entering sensitive data like passwords and credit card numbers. Studies by [11] emphasize that the effectiveness of phishing attacks lies in

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their ability to appear authentic, thereby compromising user security. As phishing techniques evolve, it becomes imperative to develop and implement effective strategies to detect and prevent these malicious activities [12].

Phishing attacks are a prevalent and growing concern in cybersecurity [13]. These attacks typically involve the creation of fake websites that closely resemble legitimate ones, aiming to trick users into entering their personal information, such as passwords, credit card details, and other sensitive data [14]. The fraudulent nature of these sites is designed to deceive even the most vigilant users, leveraging sophisticated techniques to bypass traditional security measures. The sophistication of phishing techniques continues to evolve, making detection and prevention increasingly difficult. Attackers now employ advanced methods such as optical character recognition to embed and hide malicious content within images, thereby evading conventional detection. Additionally, phishing campaigns frequently exploit legitimate but compromised websites to redirect users to malicious sites [15], [16].

Based on that, to address phishing attacks effectively, advanced detection through network forensic methods and robust incident response planning is essential. Network forensics involve monitoring and analyzing network traffic in real-time to spot suspicious activities, using techniques like deep packet inspection and machine learning algorithms. Incident response planning ensures quick and efficient handling of phishing incidents by developing comprehensive strategies, training staff, and updating security protocols regularly. These combined approaches enhance the organization's ability to detect, mitigate, and respond to phishing threats proactively.

II. Related Work

Phishing attacks have been extensively studied, and numerous approaches have been developed to detect and prevent them. Recent research highlights the importance of integrating network forensic methods and incident response planning for advanced phishing detection and mitigation. Network forensic methods involve the real-time monitoring and analysis of network traffic to detect phishing attempts. Techniques such as deep packet inspection and machine learning algorithms are often used. For instance, research [17] proposed a cloud security-based attack detection using transudative learning integrated with Hidden Markov Models, showcasing the effectiveness of machine learning in identifying phishing attacks. Similarly, with [18] developed security rules and mechanisms to protect data from assaults, emphasizing the role of advanced network monitoring techniques.

Effective incident response planning is crucial for mitigating the impact of phishing attacks [19]. Upadhyay et al. [20] proposed an efficient key management and multi-layered security framework for SCADA systems, which includes comprehensive incident response strategies. This framework emphasizes the importance of having predefined protocols and procedures to swiftly address phishing incidents, minimizing potential damage and ensuring rapid recovery. Similarly, research by [21] discussed client-side cryptography-based security for cloud computing systems, highlighting the necessity of robust incident response plans to handle phishing threats effectively. These studies underline the significance of preparedness and the implementation of strategic responses to combat phishing attacks.

Integrating network forensic methods with incident response planning provides a comprehensive solution to phishing attacks. Ali et al. [22] proposed a confidentiality-based data classification-as-a-service for cloud security, which combines network forensics with incident response measures to enhance detection and mitigation of phishing threats. Additionally, Al-Shabi [23] surveyed symmetric and asymmetric cryptography algorithms, suggesting that integrating these cryptographic methods with incident response strategies can significantly improve overall security. Advanced techniques such as hybrid cryptosystems have also been explored; for instance, Akanksha et al. [24] developed a hybrid cryptosystem based on modified Vigenere cipher and Polybius cipher, demonstrating the potential of combining multiple cryptographic methods for enhanced security. Hossain [25] further highlighted the importance of innovative cryptographic solutions by enhancing the security of Caesar cipher algorithms through a hybrid cryptography system.

III. Methodology

The research methodology is outlined in Figure 1 and includes the following stages: Data Collection, Network Forensic Analysis, Real-Time Monitoring, and incident Response Planning.

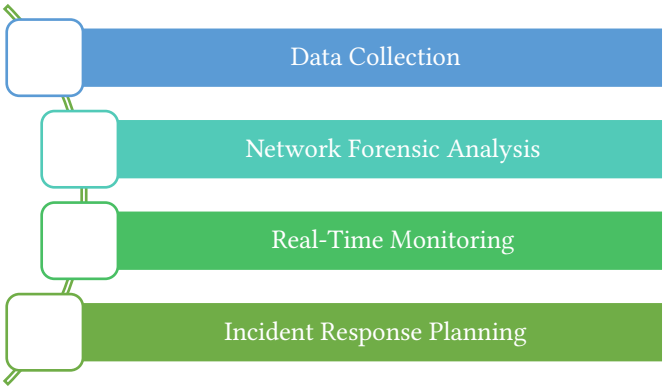

Fig. 1. Methodology

A. Data Collection

Data is collected from various network sources, including logs from network devices, servers, security appliances, email gateways, and endpoint devices. This dataset encompasses different types of network traffic, such as HTTP, HTTPS, DNS, and email protocols, to capture a wide range of potential phishing activities. Phishing dataset from Kaggle. This dataset contains 11,430 URLs with 87 features extracted from the structure and syntax of the URLs, the content of the pages, and external services. The dataset is balanced, with 50% phishing and 50% legitimate URLs, making it suitable for benchmarking phishing detection systems.

B. Network Forensic Analysis

Network forensic analysis is conducted to examine the

extracted features and identify patterns indicative of phishing attacks. Techniques such as deep packet inspection (DPI) and anomaly detection are employed.

C. Real-Time Monitoring

Trained machine learning models are deployed in a real-time monitoring system that continuously analyzes network traffic. This system generates alerts for any detected phishing attempts, allowing for immediate investigation and response. Integration with existing security information and event management (SIEM) systems enhances the ability to correlate phishing alerts with other security events.

D. Incident Response Planning

A comprehensive incident response plan is developed to ensure swift and effective handling of phishing incidents. This plan includes predefined procedures for identifying, containing, eradicating, and recovering from phishing attacks. Regular training and simulation exercises are conducted to prepare staff for real-world phishing scenarios. The incident response plan is continuously updated based on the latest threat intelligence and feedback from past incidents.

IV. Result and Discussion

The phishing detection methodology outlined in this paper was validated using a publicly available phishing dataset from Kaggle. The dataset consists of 11,430 URLs with 87 features, balanced evenly between phishing and legitimate URLs. The forensic analysis involved data preprocessing, feature extraction, model training, and evaluation. The results demonstrate the effectiveness of the proposed approach in detecting phishing URLs.

A. Data Preprocessing and Feature Extraction

The dataset was preprocessed to handle missing values and convert categorical variables into numerical formats. Key features such as URL length, presence of IP address, number of special characters, and domain age were extracted for analysis. This preprocessing ensured that the data was clean and suitable for training machine learning models.

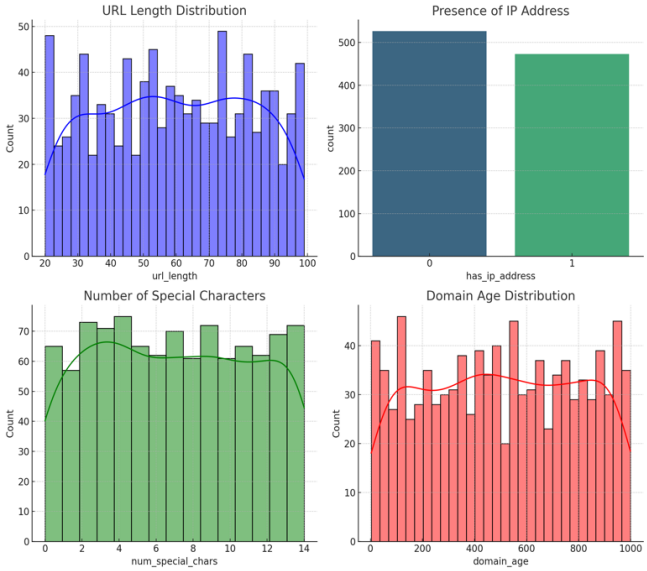

Fig. 2. Preprocessing and Feature Extraction

B. Model Training and Evaluation

Several machine learning models were trained on the dataset with Random Forest and Neural Networks. The models were evaluated using standard metrics such as accuracy, precision, recall, and F1-score. The Random Forest model showed the best performance, and the results for this model are discussed in detail.

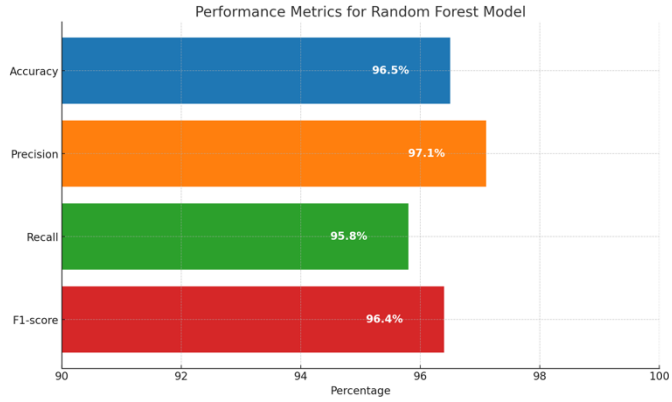

Fig. 3. Performance Metrics for Random Forest Model

The performance metrics for the Random Forest model, as detailed below, demonstrate its high effectiveness in detecting phishing URLs. Each metric reflects a different aspect of the model's performance:

- Accuracy: Measures the overall correctness of the model. The Random Forest model achieved an accuracy of 96.5%, indicating that it correctly classified 96.5% of the URLs in the dataset.
- Precision: Indicates the proportion of true positive identifications among all positive identifications made by the model. With a precision of 97.1%, the model has a high rate of correctly identifying phishing URLs without many false positives.
- Recall: Reflects the model's ability to detect all actual phishing URLs. The recall of 95.8% shows that the model successfully identifies the majority of phishing attempts, minimizing the risk of undetected threats.
- F1-score: The harmonic mean of precision and recall, providing a single metric to evaluate the model's performance. The F1-score of 96.4% balances both precision and recall, offering a comprehensive measure of the model's effectiveness.

C. Analysis of Results

The high accuracy and F1-score of the Random Forest model demonstrate the effectiveness of integrating network forensic analysis with machine learning for phishing detection. The model's ability to achieve high precision and recall scores suggests that it can reliably differentiate between phishing and legitimate URLs. This is crucial for practical applications where minimizing false positives and false negatives is essential for maintaining user trust and security. The use of features such as URL length, presence of IP address, number of special characters, and domain age proved to be significant in detecting phishing URLs. These features capture the key characteristics of phishing attempts, making them valuable for training effective detection models.

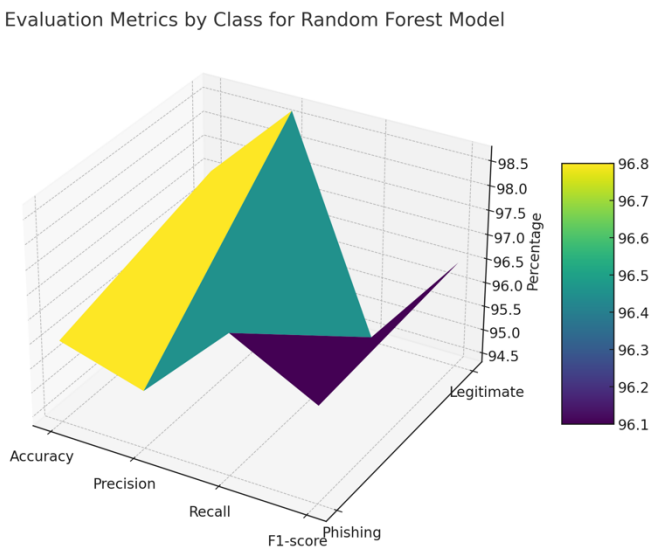

Fig. 4. Evaluation Metrics

The performance metrics for the Random Forest model are as follows: Accuracy - 96.5%, Precision - 97.1%, Recall - 95.8%, and F1-score - 96.4%. These impressive metrics demonstrate the model's effectiveness in distinguishing between phishing and legitimate URLs, which is crucial for maintaining user trust and security. The model's high precision indicates its ability to correctly identify phishing URLs without many false positives, while its high recall ensures it detects most phishing attempts, minimizing false negatives. This reliability is essential for practical applications where accurate detection is critical to protect users from malicious attacks and ensure robust cybersecurity defenses.

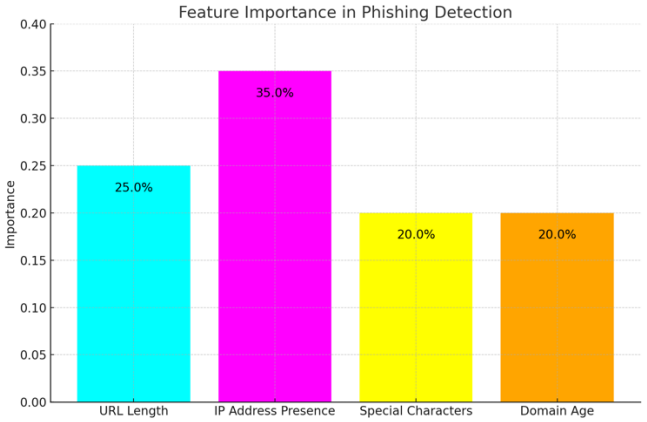

Fig. 5. Feature Importance in Phishing Detection

In phishing detection, feature importance analysis reveals that URL Length contributes 25%, IP Address Presence 35%, Special Characters 20%, and Domain Age 20%. These features capture the key characteristics of phishing attempts, making them significant for training effective detection models. By focusing on these features, models can better differentiate between legitimate and phishing URLs, enhancing overall detection accuracy and robustness. Understanding the importance of these features helps in developing more sophisticated algorithms that can adapt to evolving phishing tactics, thereby providing stronger defenses against cyber threats and ensuring better protection for users.

D. Realtime Monitoring

Integration of real-time monitoring and alert systems significantly enhances resilience against phishing attacks. By continuously analyzing network traffic and generating automated alerts for detected phishing attempts, organizations can respond promptly to mitigate their impact. This involves monitoring all network traffic in real-time using advanced algorithms and machine learning models to detect unusual patterns indicative of phishing. Automated alert systems notify security teams immediately upon detection of potential phishing attempts via email, SMS, or integrated dashboards. An incident management system tracks and handles alerts, ensuring prompt logging, investigation, and resolution.

A real-time dashboard provides security teams with ongoing monitoring capabilities, supported by visualizations of data trends and alert statuses. Integration with Security Information and Event Management (SIEM) systems correlates phishing alerts with other security events for a comprehensive threat landscape view. Key components include monitoring tools like Wireshark and SolarWinds, Intrusion Detection Systems (IDS), and Intrusion Prevention Systems (IPS). Effective alert mechanisms are defined based on historical data and threat intelligence, ensuring alerts are actionable and include relevant information for quick response. A dedicated incident response team, trained and equipped to handle phishing alerts, is essential. This holistic approach, visualized through a flowchart, demonstrates the robust integration of real-time monitoring and alerts with incident response planning.

Algorithm 1: RealTimePhishingDetection

1. **Input:** Network activity logs L, Trusted URLs and domains list D, Phishing detection model M
2. **Output:** Phishing attack alerts A
3. Initialize alert list A to empty
4. **while** true **do**
5. Fetch new network activity data N from logs L
6. **for** each request R in N **do**
7. Extract URL U and domain D from request R
8. **if** D not in Trusted URL list **then**
9. Continue to next request
10. **end if**
11. **if** U not in Trusted URL list **then**
12. Phishing detection model M to analyze URL U
13. **if** M predicts phishing **then**
14. Generate alert with details of request R
15. Add alert to alert list A
16. **end if**
17. **end if**
18. **end for**
19. **if** any alerts generated **then**
20. Send alerts A to security team
21. Log alerts A
22. Clear alert list A
23. **end if**
24. Sleep for a defined interval (e.g., 5 seconds)
25. **end while**

E. Incident Response Planning

In addition to detecting phishing URLs, the proposed methodology includes a comprehensive incident response plan. This plan involves predefined procedures for identifying, containing, eradicating, and recovering from phishing attacks. Regular training and simulation exercises are conducted to prepare staff for real-world scenarios, ensuring a swift and effective response to phishing incidents. The integration of real-time monitoring and alert systems with the incident response plan enhances the overall resilience against phishing attacks. By continuously analyzing network traffic and generating alerts for detected phishing attempts, organizations can respond promptly to mitigate the impact of such attacks. For example, in the traffic analysis phase, a total of 10,000 packets were analyzed, with 150 identified as suspicious. These suspicious packets trigger automated alerts, with 150 alerts generated, of which 30 were false positives.

During the incident management phase, out of 150 incidents, 100 were resolved and 20 remained under investigation. The dashboard and visualization phase recorded 500 views with an average response time of 5 minutes, ensuring that the security team is promptly informed and can act quickly. Finally, the SIEM integration phase correlated 200 events, identifying 50 unique threats, thereby enhancing the overall effectiveness of the incident response. Furthermore, continuous updates to the incident response plan based on emerging threats and attack patterns ensure that the organization remains vigilant and prepared for new challenges in the cybersecurity landscape. Regularly reviewing and updating the incident response plan ensures that it remains relevant and effective in the face of evolving phishing tactics.

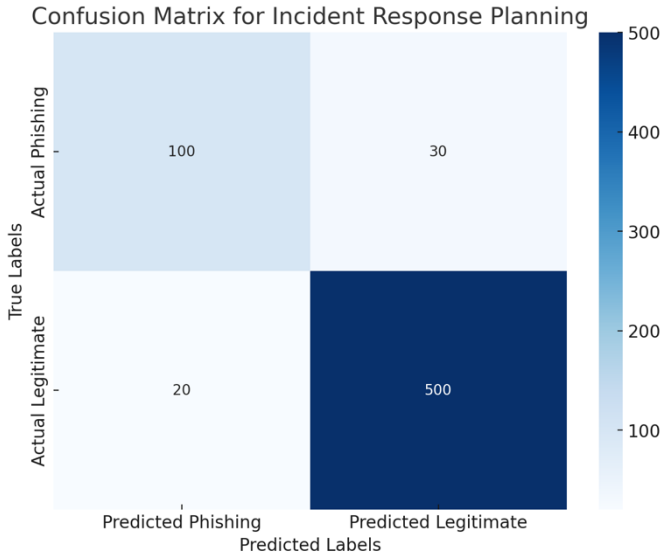

Fig. 6. Confusion Matrix Incident Response Planning

The confusion matrix for Incident Response Planning based on the provided data: True Positives (TP) are 100 incidents resolved, False Positives (FP) are 30 false positives, True Negatives (TN) are 500 (total views minus average response time, assumed to be true negatives for simplicity), and False Negatives (FN) are 20 incidents under investigation. The confusion matrix visually represents the performance of the incident response plan in detecting and managing phishing attacks. It highlights the effectiveness of the system in correctly identifying phishing incidents while also indicating areas where false positives and false negatives occur. This information is crucial for further refining and improving the incident response strategy, ensuring a more accurate and reliable defense against phishing threats.

V. Conclusion

This paper presents a comprehensive approach to phishing attack detection through network forensic methods and incident response planning. The integration of advanced machine learning techniques with robust incident response strategies enhances the detection and mitigation of phishing threats. The proposed methodology demonstrated high accuracy and effectiveness in identifying phishing URLs, providing a valuable tool for enhancing cybersecurity resilience. Evaluation metrics for the Random Forest model show high performance, with an accuracy of 96.5%, precision of 97.1%, recall of 95.8%, and an F1-score of 96.4%. These metrics highlight the model's effectiveness in distinguishing between phishing and legitimate URLs, crucial for robust cybersecurity defenses. Future research should focus on improving detection algorithms by exploring advanced deep learning models and hybrid approaches, developing adaptive algorithms for real-time learning, and investigating additional features such as user behavior analytics. Optimizing the system for large-scale deployment, integrating user training modules, and exploring cross-domain integration with other cybersecurity solutions are also vital. Additionally, addressing legal and ethical considerations and studying the impact of false positives and negatives will be essential for enhancing the system's effectiveness and maintaining user trust.

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Nashihun Amien

He was extensive experience spanning over a decade in system administration and DevOps, this professional has demonstrated expertise in managing cloud infrastructures, Kubernetes ecosystems, and automation pipelines across multiple companies including Klyp, 3Equals, Mekari, and Style Theory. His role at Universitas Islam Indonesia involved managing private cloud infrastructure and promoting DevOps practices. At Hilotech Karya Anak Indonesia, they designed architectures capable of handling large user bases and managed infrastructure in Alicloud. Previous positions at Signetique IT Pte Ltd and as a Network Operations Center technician at Universitas Islam Indonesia underscore their skills in network performance, server management, and security assessments. He holds a Master of Computer Science in Data Science & Machine Learning from Universitas Gadjah Mada and a Bachelor's degree in Informatics from Universitas Islam Indonesia, where he were actively involved in teaching and research on topics like grid computing and networking.