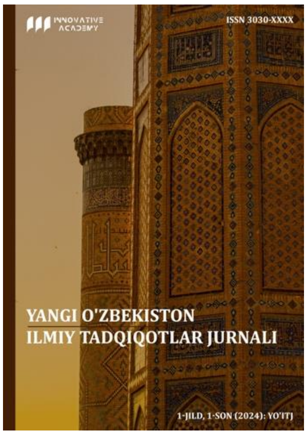

SECURITY CHALLENGES IN MODERN COMPUTER NETWORKS AND THEIR MITIGATION

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https://doi.org/10.5281/zenodo.18032826

ARTICLE INFO

Qabul qilindi: 20-dekabr 2025 yil
Ma'qullandi: 21-dekabr 2025 yil
Nashr qilindi: 23-dekabr 2025 yil

KEY WORDS

computer network security; security challenges; cyber threats; intrusion detection; network protection; security mitigation strategies.

ABSTRACT

The rapid evolution of modern computer networks has significantly increased their complexity, scalability, and exposure to security threats. The widespread adoption of cloud computing, mobile networks, Internet of Things devices, and software-defined infrastructures has introduced new attack surfaces and vulnerabilities. This paper examines the major security challenges faced by contemporary computer networks, including unauthorized access, data breaches, malware propagation, denial-of-service attacks, and insider threats. In addition, the study analyzes mitigation strategies based on cryptographic mechanisms, network monitoring, intrusion detection systems, access control models, and intelligent security solutions. The findings indicate that an integrated and layered security approach is essential for protecting modern network environments. The study emphasizes the importance of combining traditional security mechanisms with adaptive and intelligent techniques to effectively mitigate emerging network threats.

INTRODUCTION

The increasing reliance on computer networks as the backbone of digital communication has made network security a critical concern in modern information systems. Contemporary networks support a wide range of services, including cloud computing, mobile communications, Internet of Things (IoT) applications, and large-scale data exchange. While these technologies enhance connectivity and efficiency, they also introduce new vulnerabilities and expand the attack surface, making modern computer networks more susceptible to security threats than ever before. Security challenges in modern networks arise from multiple factors, including network heterogeneity, high traffic volume, distributed architectures, and the integration of third-party services. Traditional perimeter-based security models are no longer sufficient in environments where users, devices, and applications operate across dynamic and decentralized infrastructures. As a result, cyber threats such as unauthorized access, data breaches, malware propagation, distributed denial-of-service attacks, and insider threats have become more frequent and sophisticated, posing serious risks to confidentiality, integrity, and availability of network resources. Previous research has extensively investigated network security mechanisms aimed at mitigating these threats. Studies have explored cryptographic techniques for secure communication, authentication and access control models, intrusion detection and prevention systems, and firewall-based protection mechanisms. More recent works have focused on advanced solutions such as software-defined networking–based security frameworks, behavior-based anomaly detection, and machine learning–driven threat analysis. These approaches have demonstrated improvements in detecting and responding to attacks; however, their effectiveness often depends on specific network conditions and deployment scenarios.

Despite significant progress in the field, several challenges remain unresolved. Many existing security solutions operate in isolation and lack the adaptability required to address rapidly evolving threats. Moreover, the growing scale and complexity of modern networks make real-time monitoring and threat response increasingly difficult. Issues related to scalability, interoperability, and false-positive detection continue to limit the practical deployment of advanced security mechanisms, particularly in large and heterogeneous network environments. The primary objective of this study is to analyze the key security challenges affecting modern computer networks and to examine effective mitigation strategies for addressing these issues. The paper aims to provide a structured overview of both traditional and emerging security solutions, highlighting their strengths, limitations, and applicability in contemporary network architectures. By synthesizing current research and identifying existing gaps, this study contributes to a deeper understanding of how integrated and adaptive security approaches can enhance the protection of modern computer networks.

Network security has been a central research topic since the early development of computer networks. Initial studies primarily focused on perimeter-based defense mechanisms, such as firewalls, access control lists, and basic authentication protocols. These approaches aimed to protect network boundaries by preventing unauthorized access and filtering malicious traffic. While effective in relatively static environments, such methods proved insufficient as networks became more open, distributed, and dynamic. Subsequent research expanded toward cryptographic solutions to ensure secure data transmission. Encryption techniques, secure key management, and authentication protocols were widely studied to protect data confidentiality and integrity during communication. Public key infrastructures and secure communication protocols significantly improved trust between communicating entities. However, cryptographic mechanisms alone were not sufficient to address attacks targeting network availability or internal threats originating from compromised nodes.

With the growth of large-scale and high-speed networks, intrusion detection and prevention systems gained significant attention. Signature-based detection techniques were effective against known attack patterns, whereas anomaly-based approaches aimed to identify deviations from normal network behavior. Studies have shown that anomaly-based systems can detect previously unseen attacks, but they often suffer from high false-positive rates and require extensive tuning. This limitation has driven researchers to explore more adaptive detection mechanisms. Recent literature highlights the increasing role of software-defined networking in enhancing network security. By centralizing control and enabling programmable network management, SDN-based security frameworks allow dynamic traffic inspection, flexible policy enforcement, and rapid response to threats. Research demonstrates that SDN can improve visibility and control over network flows; however, it also introduces new security concerns related to controller vulnerability and scalability.

In parallel, machine learning and artificial intelligence techniques have emerged as promising tools for addressing complex network security challenges. Numerous studies report improved detection accuracy when applying supervised and unsupervised learning models to network traffic analysis. These approaches enable real-time threat detection and adaptive security policies, particularly in environments characterized by high traffic variability. Nevertheless, issues such as data quality, model interpretability, and computational overhead remain significant obstacles to widespread adoption. Overall, the existing literature reflects substantial progress in developing network security solutions, ranging from traditional rule-based mechanisms to intelligent, data-driven approaches. However, most studies focus on individual techniques or specific attack scenarios, often neglecting the need for integrated and scalable security frameworks. This gap indicates a need for comprehensive analyses that evaluate multiple security challenges and mitigation strategies within unified network architectures. The present study seeks to address this gap by systematically examining security challenges in modern computer networks and the effectiveness of corresponding mitigation approaches.

RESULTS and DISCUSSION

This study employs a structured methodological framework to analyze security challenges in modern computer networks and evaluate corresponding mitigation strategies. The research approach combines qualitative analysis of existing security mechanisms with comparative evaluation of network security models. The methodology is designed to identify how different protection techniques address threats related to confidentiality, integrity, and availability in contemporary network environments. The research materials consist of peer-reviewed journal articles, conference proceedings, and authoritative technical documentation related to computer network security. The selected sources cover both traditional security mechanisms and modern solutions, including intrusion detection systems, cryptographic protocols, software-defined networking–based security, and intelligent threat detection approaches. Only materials that provide measurable or clearly defined security outcomes were included to ensure analytical consistency. In addition, conceptual network models commonly used in security research were examined to understand how threats manifest in real-world scenarios such as enterprise networks, cloud-based infrastructures, and heterogeneous environments with mobile and IoT devices[3].

The methodological framework is based on a layered security perspective. Security challenges and mitigation strategies are analyzed across multiple layers of the network architecture. At the network layer, routing security, traffic filtering, and denial-of-service mitigation techniques are examined[4]. At the transport and application layers, authentication mechanisms, encryption methods, and secure communication protocols are analyzed. This layered approach allows the evaluation of how individual security measures interact and complement each other. A comparative analysis method is applied to assess the effectiveness of different mitigation strategies. Security mechanisms are compared based on their ability to detect threats, prevent attacks, and respond to security incidents. This comparison highlights the strengths and limitations of each approach under varying network conditions.

To evaluate network security effectiveness, several criteria are considered. Detection capability is used to assess how accurately a security mechanism identifies malicious activity. Response efficiency measures how quickly the system reacts to detected threats. Scalability evaluates whether a solution can maintain performance as network size and traffic volume increase. Finally, adaptability reflects the ability of a security mechanism to respond to evolving attack patterns and dynamic network behavior. These criteria provide a consistent basis for evaluating both traditional and emerging security solutions, enabling a balanced assessment of their practical applicability[5]. The analysis relies on logical reasoning and scenario-based evaluation rather than experimental deployment. Typical attack scenarios, such as unauthorized access attempts, malware propagation, and denial-of-service attacks, are conceptually modeled to examine how different security mechanisms respond. This approach allows the identification of potential weaknesses and strengths without dependence on specific hardware or proprietary systems. Although the adopted methodology enables a comprehensive and systematic analysis, it does not fully capture all real-world constraints, such as unpredictable user behavior or hardware-specific limitations. Nevertheless, the chosen methods provide a reliable foundation for understanding security challenges and evaluating mitigation strategies in modern computer networks[6].

The results of the comparative analysis demonstrate notable differences in the effectiveness of various security mechanisms used in modern computer networks. The evaluation focuses on two key performance indicators: attack detection rate and false positive rate. These metrics provide insight into how accurately and efficiently different security approaches identify malicious activities while minimizing incorrect alerts. Figure 1 illustrates the attack detection rate across multiple network security methods. Traditional firewall-based security shows the lowest detection performance due to its reliance on predefined rules and limited visibility into complex attack patterns[7]. Signature-based intrusion detection systems improve detection accuracy by matching known attack signatures, but their effectiveness remains constrained when encountering novel threats. Anomaly-based intrusion detection systems demonstrate a higher detection rate by identifying deviations from normal network behavior, highlighting their suitability for detecting previously unknown attacks. A significant improvement is observed with software-defined networking–based security mechanisms. The centralized control and global network visibility provided by SDN enable more effective traffic inspection and dynamic policy enforcement[8]. The highest detection rate is achieved by AI-based security approaches, which leverage learning and adaptation to identify sophisticated and evolving threats. These results indicate that intelligent security mechanisms are particularly effective in modern, dynamic network environments.

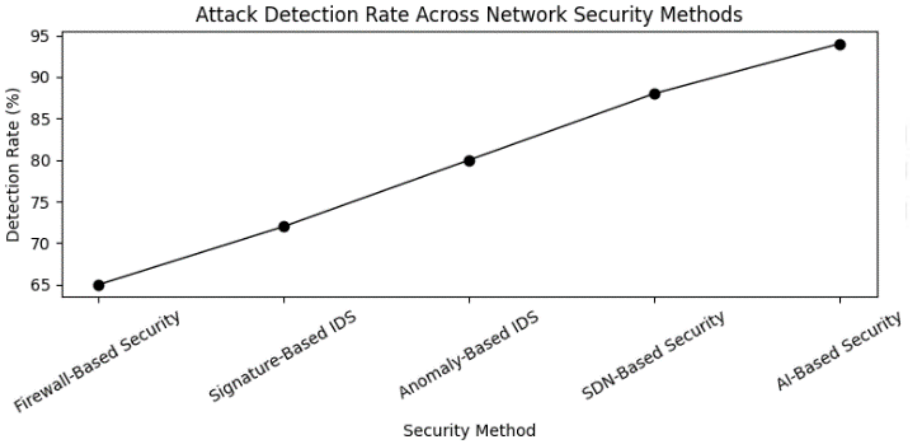

Figure 1. Attack detection rate across network security methods.

Figure 2 presents a comparison of false positive rates among the evaluated security solutions. Firewall-based and signature-based systems exhibit relatively high false positive rates, which can lead to unnecessary alerts and increased administrative overhead. Anomaly-based systems reduce false positives compared to traditional methods but still face challenges in accurately distinguishing benign anomalies from malicious behavior. SDN-based security solutions further decrease the false positive rate by enabling context-aware traffic analysis[9]. AI-based security mechanisms achieve the lowest false positive rate, reflecting their ability to refine detection decisions based on learned patterns and historical data.

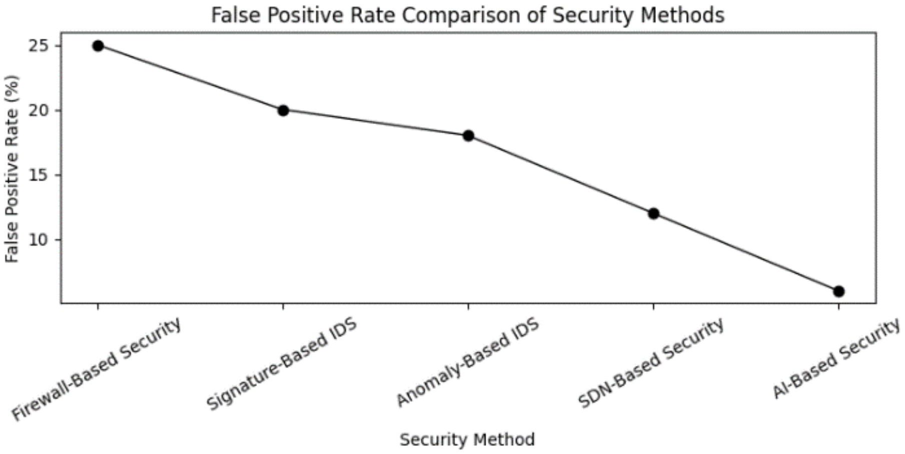

Figure 2. False positive rate comparison of network security methods.

Overall, the results confirm that advanced and adaptive security approaches significantly outperform traditional mechanisms in both detection accuracy and reliability. The combination of programmable network control and intelligent analysis provides a strong foundation for addressing complex security challenges in modern computer networks. These findings support the adoption of AI-driven and SDN-enabled security frameworks as effective solutions for mitigating contemporary network threats[10].

The results obtained in this study provide a clear indication of how different security mechanisms perform in modern computer network environments. The comparative analysis highlights that traditional security approaches, such as firewall-based protection and signature-based intrusion detection, offer limited effectiveness when faced with complex and evolving cyber threats[11]. Their relatively low detection rates and higher false positive levels suggest that static and rule-based mechanisms are no longer sufficient for protecting contemporary networks. The improved performance of anomaly-based intrusion detection systems confirms their ability to identify previously unknown attacks by monitoring deviations from normal network behavior. However, the results also reveal that these systems still generate a noticeable number of false positives, which can increase operational complexity and reduce trust in automated detection mechanisms. This limitation emphasizes the need for more context-aware and adaptive security solutions capable of distinguishing malicious behavior from legitimate but unusual network activity.

The findings further demonstrate the advantages of software-defined networking–based security frameworks. The centralized control and global visibility provided by SDN enable more efficient traffic inspection and dynamic enforcement of security policies. As reflected in the results, SDN-based solutions achieve higher detection rates and lower false positive levels compared to traditional approaches[12]. Nevertheless, their effectiveness depends on the robustness and scalability of the control plane, which may introduce new attack vectors if not properly secured. The strongest performance is observed in AI-based security mechanisms. The high detection rate and minimal false positive rate indicate that intelligent models can effectively learn complex traffic patterns and adapt to emerging threats. These results support recent research suggesting that machine learning and artificial intelligence play a critical role in enhancing network security. However, the discussion must also acknowledge practical challenges associated with AI-driven solutions, including the need for high-quality training data, computational overhead, and limited interpretability of model decisions. Overall, the discussion suggests that no single security mechanism can fully address all network security challenges. Instead, a layered and integrated security strategy is required. Combining traditional protection mechanisms with programmable network control and intelligent threat detection appears to be the most effective approach for securing modern computer networks[13]. Future research should focus on hybrid security frameworks that balance detection accuracy, computational efficiency, and transparency, as well as on real-world deployment and validation of intelligent network security solutions.

CONCLUSION

This study analyzed the major security challenges faced by modern computer networks and evaluated effective mitigation approaches based on both traditional and advanced security mechanisms. The findings indicate that the increasing complexity, scale, and heterogeneity of contemporary networks significantly amplify security risks, making conventional static protection methods insufficient for ensuring robust network defense. The results demonstrate that traditional firewall-based and signature-driven security solutions provide a basic level of protection but struggle to cope with dynamic and sophisticated cyber threats. In contrast, software-defined networking–based security frameworks offer improved flexibility and visibility, enabling dynamic policy enforcement and more efficient threat response. The highest level of effectiveness is achieved through AI-based security mechanisms, which exhibit superior detection accuracy and reduced false positive rates by adapting to evolving network behavior. Despite their advantages, intelligent security solutions introduce challenges related to computational overhead, data dependency, and interpretability. These factors highlight the importance of carefully integrating AI-driven techniques with existing security infrastructures to ensure practical deployability and operational efficiency. The study confirms that relying on a single security mechanism is insufficient; instead, a layered and integrated security strategy is required to address the diverse and evolving threat landscape. In conclusion, enhancing security in modern computer networks requires the combination of traditional protection mechanisms, programmable network architectures, and intelligent threat detection techniques. Such an integrated approach provides a balanced solution that improves detection capability, reduces false alarms, and enhances overall network resilience. Future research should focus on developing hybrid security frameworks, improving the transparency of intelligent models, and validating these solutions in real-world network environments to ensure scalable and sustainable network security.

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