The Future of AI-Driven Cybersecurity for Advanced IoT/ Original article

Estqlal Hammad Dhahi[1],

Sanaa Hammad Dhahi[2],

Ohood Fadil Alwan[3]

1 Information Technology Center, University of Kerbala, Kerbala / Iraq

2 Dept. of Computer Science, College of Basic Education, University of Diyala, Diyala / Iraq

3 Dept. of Psychological Counseling, College of Muqdad Education, University of Diyala, Diyala / Iraq

Abstract

Internet of Things technologies experience rapid advancement because of 5G networks and upcoming 6G technologies, which resulted in transformational changes to security dynamics. This study examines the functionality of artificial intelligence through platforms developed to secure Internet of Things systems. The demand for improved security capabilities has become essential because IoT devices generate new assault channels, and their market penetration speed is escalating. Machine learning algorithms, together with deep learning and natural language processing methods, are investigated in this paper for enhancing the security protocols of IoT systems through studies found in academic literature. The paper explores upcoming developments and risk-related obstacles to design a detailed strategy regarding how AI implements cybersecurity risk reduction for IoT systems. The analysis focuses on the security implications of 5G/6G technology because it both expands weaknesses in systems and offers protection benefits through enhanced data processing and improved networking features. The research provides essential data to researchers and practitioners developing resilient AI-security solutions that meet the requirements of next-generation communication systems' dynamic environment.

Keywords: AI, Cybersecurity, DDoS, IoT network, 5G and 6G Technologies

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1. Introduction

The deployment of AI solutions in cybersecurity has significantly improved effectiveness during the previous several years. The combination of AI technologies that includes machine learning, deep learning, and natural language processing allows fundamental transformations in detecting and resolving cyber threats found in IoT systems [1-6]. IoT devices continue to increase alongside the introduction of 5G technology together with predicted 6G communication networks, which results in widespread vulnerability to security threats. The discovery of new IoT technology necessitates that organizations evaluate their conventional security practices since protecting interconnected network systems depends on AI development [7].

An analysis of present conditions examines both advantages and challenges that protect IoT systems within 5G/6G environments. The research examines current research and emerging trends as it handles obstacles to present constructive insights for academic research and industrial service delivery. AI implementation in cybersecurity practice improves detection capabilities through automated systems that deliver instant risk management routines [8-12].

Studies from various databases entered the investigation by following a pre-established research design to acquire suitable literature. Academic resources, including SCOPUS, Science Direct, IEEE Xplore, Web of Science, ACM, and MDPI, were accessed for the researchers to run extensive electronic research. This structured methodology lets the review identify multiple methodological as well as perspectival elements to deliver a thorough understanding of current conditions [13-20].

This paper assesses four vital topics, which include digital threat detection mechanisms from AI systems and their responses, the implementation barriers faced during IoT deployments, and ethical considerations in this field alongside research and developmental potentialities. The four essential domains create a necessary basis for students to use AI systems effectively when safeguarding modern IoT systems that quickly evolve.

Strategic collaboration between cybersecurity and AI technology leads to major challenges in building new policies alongside developing regulatory frameworks. AI's evolutionary trajectory requires precise development of current laws and ethical principles whenever sensitive matters about data protection and security are involved. This evaluation identifies requirement points that need members from technology developer groups and policy drafting units together with end-user organizations to enhance powerful cybersecurity postures.

This review studies the significant transformative aspects of AI in cybersecurity meant to protect IoT ecosystems during the 5G and 6G network evolution. The review combines previous research with identified gaps to create initial directions for future studies and innovations that secure the expanding global network systems.

2. Background Theory

2.1. Cybersecurity Convergence of IoT

The anticipated increase in connected devices is remarkable, with estimations suggesting that up to 100 billion devices will be smoothly integrated into the Internet infrastructure by 2025. Exponential growth is

also observed in data traffic, with projections indicating that the total volume of data transmission is expected to experience approximately a threefold increase from 2016 to 2021 [21]. Remarkably, it is projected that almost 75% of this increase will be produced by devices other than personal computers, emphasizing the crucial significance of other endpoints in driving the data revolution—the increase in data traffic and IoT-connected devices from 2010 to 2025 is explained in Figure 1.

The rapid proliferation of IoT devices has fundamentally transformed how we interact with technology in both personal and professional contexts. Smart homes, industrial automation, healthcare monitoring, and smart cities represent just a few domains where IoT deployment has become increasingly prevalent. This widespread adoption has created new challenges in terms of network infrastructure, data management, and security protocols that need to be addressed to ensure sustainable growth [22-24].

The digital transformation features Machine-to-Machine (M2M) communication as its fundamental element because experts expect M2M connections to reach 42% of the total network links. The technological foundation establishes more than 10 billion devices that autonomously exchange data with no human involvement for direct control. This technological evolution holds major consequences for production and farming alongside shipping industries because they benefit from optimized performance and higher output numbers through automated management systems [25-30].

The explosive rise in data creation brings organizations and infrastructure providers both opportunities and difficulties. Unprecedented data opportunities and optimization potential exist because of vast data

accumulation, but the massive volume requires organizations to invest in data management systems and transmission networks. Edge computing operates as the essential technology to resolve data processing strain by performing calculations at local sites proximate to data origin points [31].

The continuous growth of the IoT environment now requires both privacy and security protocols to maintain their essential status. Cybercriminals have gained access to extensive attack space through the growth of sensitive data-handling devices installed worldwide. Highly secure encryption functions together with authentication mechanisms maintained by recent security updates form the core basis for safeguarding devices and their processed information [32].

The rapid surge of digital technology inevitably leads to multiple negative environmental consequences. Data centers, combined with cooling requirements and the network upkeep of billions of connected devices, produce major sustainability problems because of excessive energy usage [33]. Major industries work toward two goals: reduce energy waste and embrace renewable power methods to manage environmental problems.

The IoT will experience rapid development starting from 2025 until succeeding future years. The expansion of IoT rests on 5G and upcoming 6G connectivity networks as they provide robust data transfer capabilities with fast processing speed along with stable signal reception. Advanced technologies will boost the ability to extract IoT data value by using artificial intelligence and machine learning methods [34].

New technological dimensions such as IoT produce economic effects that will produce multiple business opportunities across different industries, according to research. IoT technology drives economic development through

wider application areas, including manufacturing, predictive maintenance, and personalized healthcare solutions.

The rate at which this data-driven shift is occurring is astounding; estimates suggest that by 2030, cellular data traffic may have increased up to 10,000 times. The surge under discussion is not just a theoretical idea; rather, it is deeply ingrained in the real-world needs of an increasingly networked environment. Demand for data traffic and apps created especially for Machine-Type Communication (MTC) is predicted to rise significantly. Self-driving cars, healthcare monitoring, smart factories, smart cities, and AI-powered personal assistants are just a few of the use cases that this expansion will cover. The core capabilities of next-generation wireless networks are being closely studied in the middle of this deluge of digital activity [35].

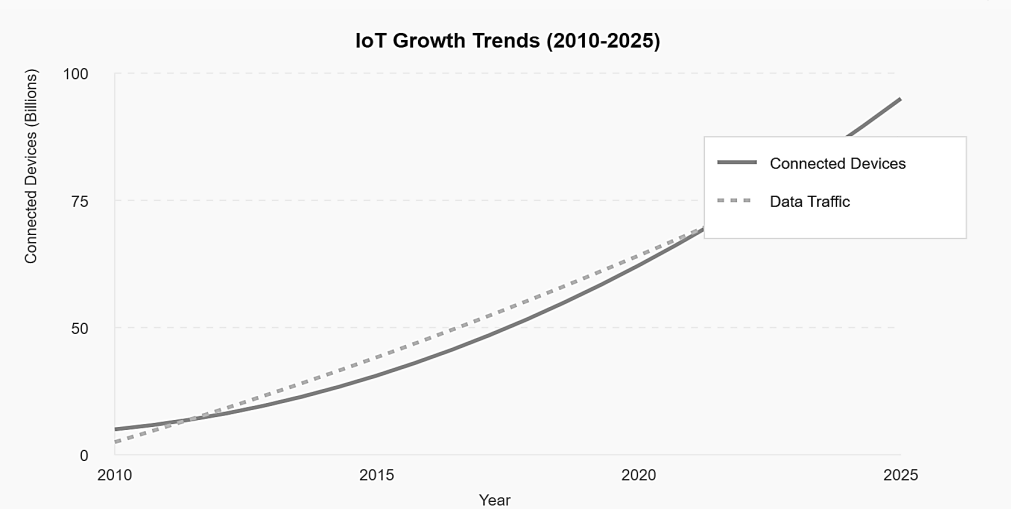

Fig. 1 Increase in data traffic and IoT-connected devices from 2010 to 2025

The coexistence of services that prioritize human needs and machine-oriented services, sometimes entwined to create complex

hybrids, is a noteworthy feature of this changing world. This duality's existence gives the emerging wireless network ecosystem an extra degree of complexity. Since conventional forms of communication now coexist with the constant exchange of data between computers, the modern human communications landscape has changed to include a varied and dynamic network paradigm [36].

The challenge in navigating the future is to coordinate the peaceful coexistence of several communication modes while simultaneously increasing the capacity and efficiency of wireless networks. Our increasingly digital lifestyles are based on the seamless integration of people, intelligent technology, and self-governing systems. Given the current revolutionary era, it is becoming clearer that wireless networks with the characteristics of durability, scalability, and flexibility are desperately needed. Future developments in wireless communication will be shaped by innovation, flexibility, and the ongoing quest to harness the limitless potential of data in a dynamic digital landscape [37-39].

To successfully support IoT applications, several technological obstacles must be overcome in 5G/6G and beyond, including network architecture, network resource allocation systems, improved signal processing techniques, etc. [40]. But with IoT systems, hardware security assurance is a critical and evolving issue. More than 70% of IoT devices are thought to be readily hackable. It has also been hypothesized that using deep learning and artificial intelligence approaches would unleash the full potential of 5G/6G networks, the Internet of Things, and cyber-physical systems.

2.2. Cybersecurity Risks and Attacks in the Internet of Things

Recent comprehensive analyses of IoT cybersecurity have revealed a complex landscape of threats, vulnerabilities, and security challenges that demand immediate attention from the research community. Through extensive examination of scholarly literature, researchers have identified multiple critical areas of concern and innovative approaches to addressing these security challenges in IoT environments [41].

The protection of critical infrastructure in power grids required the invention of special attack detection models that researchers developed to a crucial stage [42]. The new models serve as essential points for protecting basic services from cyber threats. The field of attack detection using fog computing has achieved a new and groundbreaking level of understanding by investigating Denial of Service (DoS) and User to Root (U2R) and remote-to-local (R2L) attacks [42]. The threat classification system establishes a complete understanding of diverse security risks that aim at IoT systems.

The creation of harmful software requires new security solutions with an emphasis on protecting network-based ransomware and malware within IoT systems [8]. The advancement of research led to the implementation of collaborative intrusion detection systems that achieved better precision rates and reduced false detection incidents [9]. Exceptional Android device power metrics form a fresh method for ransomware detection that shows great promise for security surveillance.

The requirement to stop unauthorized entry and protect accounts has risen to essential security status for IoT systems. Research documents the major safety risks associated with unauthorized local user account entries and R2L attack-driven data breaches, according to [11].

Authentication methods and access control mechanisms prove indispensable during IoT technology deployments. The detection of untracked vulnerabilities in IoT communication protocols produces severe security risks because research shows these vulnerabilities breach both system data and security protection [12].

The security threats of IoT systems generate extensive results that damage individual equipment alongside entire IoT network infrastructure. The increasing complexity of IoT systems demands that complete security solution implementation takes precedence because system complexity continues to rise. The distributed design of IoT devices generates multiple security problems that only effective protective security protocols can prevent system vulnerabilities and safeguard sensitive information [43].

Security research demonstrates organizational need for active monitoring to defend IoT environments together with existing preventive security measures. The operation of real-time threat detection depends on synchronized development with secure communication standards since security frameworks must protect against both existing and new security risks. Security solutions must evolve with student cyber threat patterns because threats continuously evolve by creating new attack routes while discovering vulnerabilities within the environment [19].

The research field now aims to merge artificial intelligence and machine learning platforms into IoT security development. The application of advanced technology enables automatic threat spotting as well as predictive security methods and improved response functions across new security threats. Research about IoT security keeps advancing because of continuously evolving cyber dangers and the necessity for better defensive measures [3].

IoT security needs robust protection measures because a synthesis of published research findings demonstrates their vital importance. The growing nature of IoT requires businesses to prioritize implementing complete security measures to protect all devices that form part of the IoT infrastructure. Research investigations in progress yield crucial findings that help develop better security solutions for protecting IoT systems from multiple security risks.

2.3 The Evolution of Artificial Intelligence in Cybersecurity

The development of artificial intelligence started in the 1950s to create a revolutionary technological paradigm that revolutionized industrial innovation across various sectors. Artificial Intelligence stands as an advanced computer science discipline for building smart systems that duplicate along with exceeding human intellectual operations. AI differs from standard human computing because it functions based on the goal to fully understand and duplicate human intelligence through advanced computational methods, as explained in Figure 2.

Machine learning and deep learning serve as the foundational pillars of AI's technological infrastructure. Sophisticated algorithmic systems allow assessment of large databases through pattern recognition and continuous development of their computational intelligence. Funding organizations seek to develop artificial systems that can reason like humans because their goal exceeds basic data processing [25].

The extensive capabilities of Artificial Intelligence operate across different vital domains, which include machine learning and natural language processing in addition to robotics and cybersecurity. The intersection of

different fields led to a modern security and innovation environment that connects security needs with technological developments. The advancement of AI technology reveals both rare chances and complicated system weaknesses in digital environments, according to [40].

Sophisticated technological interfaces now face sophisticated cyber threats because the modern cybersecurity field has become dramatically complex. Digital criminals and threat actors have established multiple sophisticated methods that extend from persistent complex threats to the financial exploitation of computer systems. Such advancements in security threats compel organizations to adopt forward-thinking approaches for their security management systems [9].

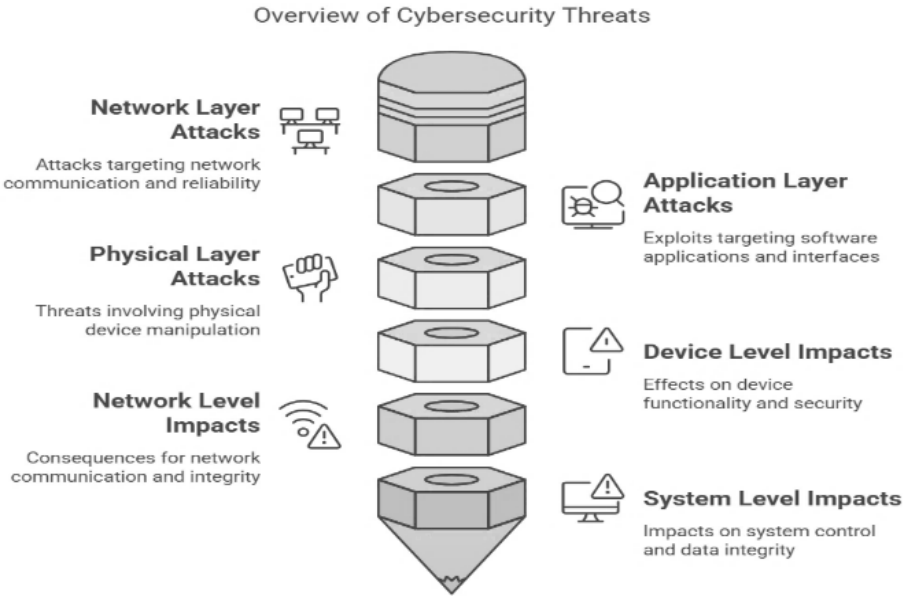

Fig. 2 Cybersecurity risks and attacks in the Internet of Things

The primary objective of present-day cybersecurity investigation has evolved from attempting to remove threats to developing robust security defense systems. Security researchers dedicate their research time to building robust defensive technologies to detect security breaches with anticipation of elimination. The fundamental change in security practices recognizes cybersecurity work as a continuous operation instead of static protective measures [1].

When AI belongs to cybersecurity frameworks, it develops a powerful technique for managing security threats. Standalone analytical capabilities of innovative systems provide security through self-sustained operations and thus reduce the constant requirement for human supervision and direction. Artificial intelligence and machine learning systems perform strong analytics to observe digital spaces by finding security weaknesses but resist new cybersecurity threats with quick protective applications.

The current technological industrial development needs stronger integration between artificial intelligence techniques and cybersecurity systems. Technological elements such as the Internet of Things, wholesale cloud solutions and big data repository systems, and autonomous operations have created a dense network of security needs that need dedicated threat management strategies. Organizations acquire unmatched threat detection abilities through artificial intelligence, predictive analysis, and adaptive defense systems.

The development of intelligent autonomous protection systems creates the foundation for future cybersecurity success because they gain the ability to discover and counter threats while operational activities continue. Security solutions require researchers to establish advanced

technological innovations while gaining full insight into digital threat landscapes until they can discover solutions through strategic research. Firms must maintain their learning strategies by implementing security frameworks that properly control digital world connections across their entire technological infrastructure.

2.4 Artificial Intelligence and Hardware-Driven Cybersecurity Detection

Artificial intelligence development, coupled with sophisticated hardware systems, creates necessary measures to detect complicated physical system attack vectors. Scientists prove that current machine learning systems integrated with sensor monitoring networks possess the ability to discover and thwart difficult cyber-attacks [37].

Research has shown that artificial intelligence proves essential through its decisive role in cybersecurity investigations of electromagnetic fault injection (EMFI) attacks. New detection systems created by scientific teams perform real-time operational and hardware assessments, leading to better accuracy than former threshold detection systems. The current use of machine learning algorithms for object detection surpasses conventional methods; therefore, researchers can identify fresh security threats [44].

By implementing multi-source data analysis systems, it became more complex and enhanced attack fault detection abilities. Healthcare organizations obtain better security performance through multi-source data integration in digital sensor fusion systems used for monitoring. Different elements of this method make it possible to predict electromagnetic and clock glitch fault injection attacks [2].

Sensor fusion procedures drive cybersecurity development through their ability to generate superior information by uniting diverse data sources. Security analysis evolved past observing one source to combine physical aspects and network characteristics, resulting in an entire security evaluation methodology. Scientific research spanning multiple information domains helps researchers develop attack detection systems that provide better accuracy when executing their functions [16].

Artificial intelligence detection tools for cybersecurity detection have proliferated remarkably by including several complex analytical methods. Technology researchers use multiple advanced methods to investigate their subjects, as shown in figure 3, which include:

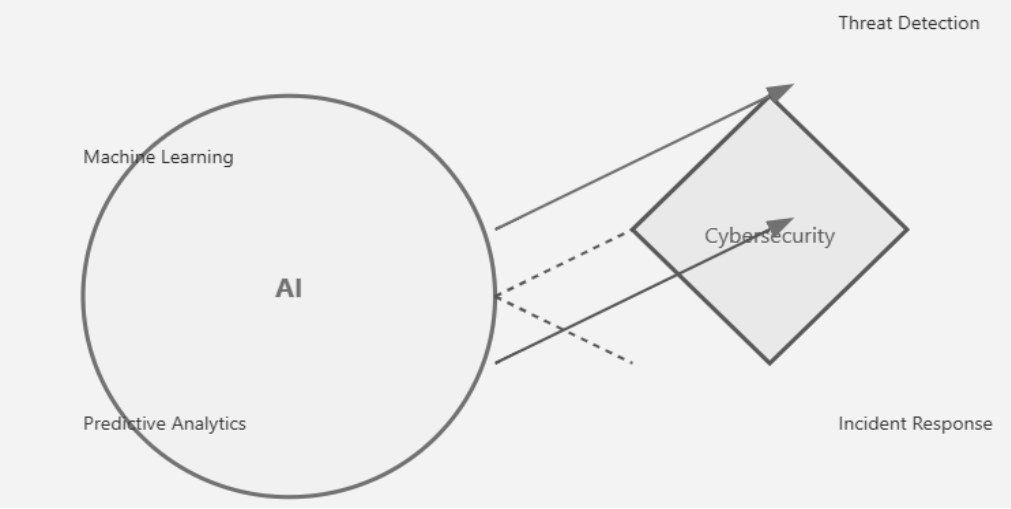

Fig. 3 Evolution of artificial intelligence in cybersecurity

- Genetic algorithms
- Deep belief networks
- Hybrid artificial intelligence systems

- Support vector machines
- Federated learning
- Convolutional neural networks
- Recurrent neural networks

These distinct security approaches present diverse capabilities to find and fight cyber threats that exist in modern complex technological domains.

The Internet of Things (IoT) creates special difficulties for implementers of cybersecurity detection systems. The interlinkages present in IoT systems require security solutions to deploy advanced and adaptive systems that operate between system layers. Numerical approaches controlled by artificial intelligence have shown essential value in responding to security difficulties by introducing dynamic automated surveillance and protection frameworks [4].

Artificial intelligence is vital for cybersecurity because cyber threats are developing more advanced and complex operations. A revolutionary transformation exists in our digital security response because we now use advanced machine learning and complete hardware monitoring systems together. Using these new approaches offers groundbreaking abilities to detect, validate, and respond to security vulnerabilities that target different technology spaces [17].

The progress of cybersecurity in the future will focus on building advanced detection systems that are adaptive and intelligent. Ongoing research shows that artificial intelligence and hardware monitoring, together with a comprehensive dataset analysis, will establish powerful proactive security architectures able to protect against complex cyber-attacks.

3. Challenges and Limitations

Continuous sophistication arises in the Internet of Things (IoT) security environment due to the swift development of cyber threats and system vulnerabilities. Security demands modern innovative tactics because organizations face different threats from the expanding number of Internet of Things devices. These challenges encompass complex network security issues, as shown in Figure 4, the critical need for efficient cyberattack identification, and the continuous development of advanced detection mechanisms. Artificial intelligence partnerships with deep learning represent an advanced technique to fight off cyber threats through threat detection and prevention systems. A wedding focuses on four essential elements, which involve constructing protected network defense systems that combine protective monitoring with threat prediction safeguards to combat digital security issues. Advanced technology combined with ongoing research and adaptive security frameworks needs to form an integrated solution system for IoT security because of its volatile nature to protect digital infrastructure from advanced evolving threats, as explained in Figure 5.

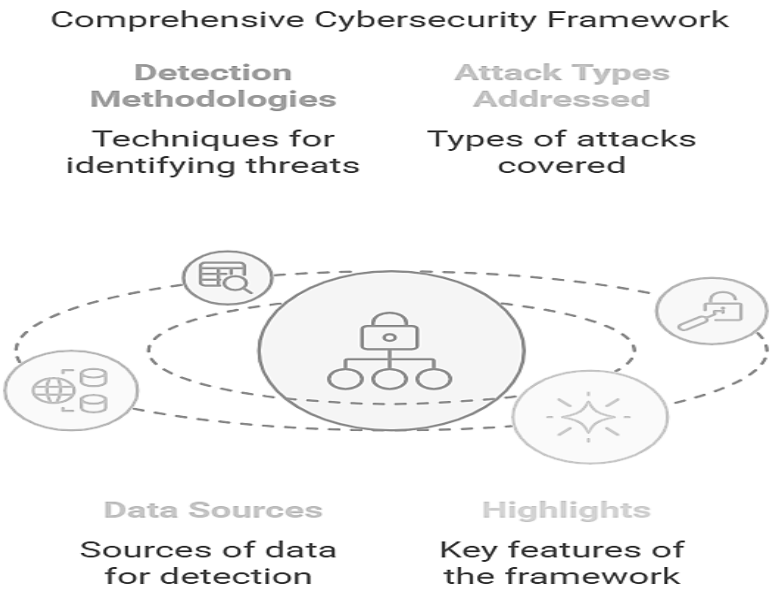

Fig. 4 Detection of IoT cyberattacks utilizing AI techniques

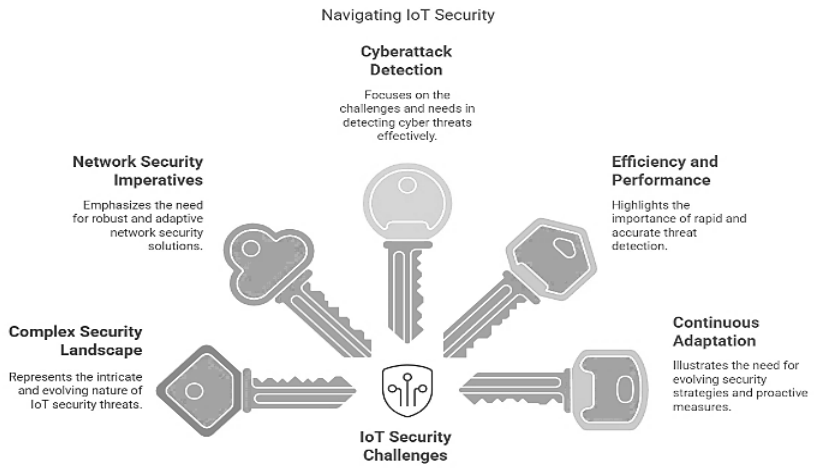

Fig. 5 Challenges and limitations

4. Conclusion

The paper demonstrates that AI is a critical element that strengthens IoT security systems. The study explores artificial intelligence methods that detect and minimize cyber threats affecting IoT networks. AI delivers multiple technological capabilities for detecting and forecasting dangers, with machine learning and deep learning among them. Security approaches in IoT ecosystems receive support from this technique while enabling businesses to prevent emerging threats. The research emphasizes preventive security needs at present because technology keeps evolving.

Conflict of interest

A conflict of interest statement must be placed at the manuscript as below: "The authors declare that there are no conflicts of interest regarding the publication of this manuscript".

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