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AI-Driven Cybersecurity Frameworks for SME Development: Mitigating Risks in a Digital Economy

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Abstract
Small and medium-sized enterprises (SMEs) are critical in driving innovation and economic growth in the digital economy. However, their growing reliance on digital technologies exposes them to significant cybersecurity threats, such as ransomware, phishing, and data breaches. Limited resources, technical expertise, and inadequate security infrastructure make SMEs particularly vulnerable. This paper explores the potential of AI-driven cybersecurity frameworks to address these challenges, emphasizing technologies like machine learning, anomaly detection, and automated threat response. It highlights the scalability, real-time threat detection, and cost-efficiency of AI solutions tailored to SMEs. The paper also underscores the importance of policy and regulatory frameworks, collaboration with technology providers, and ethical considerations, such as data privacy and algorithmic fairness, in ensuring the responsible deployment of AI in SME cybersecurity. Practical recommendations are provided to guide SMEs in implementing AI-driven solutions, fostering resilience, and securing their position in an increasingly interconnected digital economy.

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Keywords: AI-driven cybersecurity, SMEs, Digital economy, Cybersecurity threats, Machine learning, Data privacy

1. Introduction

1.1 Background on SMEs in the Digital Economy

Small and Medium-sized Enterprises (SMEs) serve as the backbone of many economies worldwide, driving innovation, employment, and economic growth. With the ongoing digital transformation, SMEs are increasingly adopting digital technologies to enhance their operations, reach global markets, and improve customer engagement (Bhuiyan *et al.*, 2024) [15]. Cloud computing, e-commerce platforms, and digital payment systems are becoming indispensable tools for these businesses. However, this shift towards digitalization has also exposed SMEs to a variety of cyber threats, such as phishing attacks, ransomware, and data breaches. Unlike larger corporations, SMEs often lack the resources and expertise to effectively manage cybersecurity risks, leaving them particularly vulnerable (Opoku, Okafor, Williams, & Aribigbola, 2024) [34].

The digital economy, characterized by the integration of information technology in business processes, demands robust cybersecurity measures. As SMEs continue to integrate digital tools, they must navigate a landscape fraught with sophisticated cyberattacks that target their limited defenses (Möller, 2023) [32]. A single successful cyberattack can have devastating consequences, including financial loss, reputational damage, and, in some cases, business closure. Consequently, addressing cybersecurity challenges is not just a technical issue but also a strategic imperative for the long-term sustainability of SMEs in the digital age (Perera, Jin, Maurushat, & Opoku, 2022) [34].

1.2. Importance of Cybersecurity for SME Development

Cybersecurity is fundamental to the survival and growth of SMEs in the digital economy. Without adequate protection, SMEs face financial losses and a significant erosion of trust from customers and business partners. As digital transactions and data exchanges become more prevalent, maintaining information systems' integrity, confidentiality, and availability is critical. Cybersecurity ensures that SMEs can confidently operate, secure their intellectual property, and comply with regulatory requirements (De Fréminville, 2020) [20].

Moreover, cybersecurity contributes to the competitive advantage of SMEs. Businesses demonstrating robust security measures are more likely to attract customers, secure partnerships, and gain access to new markets. For instance, larger organizations are increasingly scrutinizing the cybersecurity practices of their suppliers and partners to mitigate risks in their supply chains. SMEs with strong cybersecurity frameworks are better positioned to meet such expectations, unlocking growth opportunities (Lloyd, 2020) [29].

1.3. Role of AI in Modern Cybersecurity Solutions

Artificial Intelligence (AI) has emerged as a transformative force in cybersecurity, offering advanced tools and techniques to detect, prevent, and respond to cyber threats. Traditional cybersecurity methods, such as manual monitoring and signature-based detection, struggle to keep pace with modern cyberattacks' volume, velocity, and sophistication. AI addresses these limitations by enabling automation, real-time analysis, and predictive capabilities (Manoharan & Sarker, 2023) [30].

Machine learning algorithms, a subset of AI, can analyze vast datasets to identify patterns and anomalies that may indicate malicious activity. For example, AI-powered intrusion detection systems can recognize unusual network traffic and flag potential threats before they escalate. Additionally, AI enhances incident response by providing automated tools that can neutralize threats quickly, minimizing damage and downtime (Prince *et al*., 2024) [37].

AI-driven cybersecurity solutions are particularly valuable for SMEs because they offer scalable and cost-effective protection. Cloud-based AI tools, for example, allow SMEs to access cutting-edge security features without the need for significant upfront investment in hardware or personnel. Furthermore, AI can be integrated seamlessly into existing business processes, allowing SMEs to adapt to evolving cyber risks (Yaseen, 2023) [46].

1.4. Objectives and Scope of the Paper

The primary objective of this paper is to explore how AI-driven cybersecurity frameworks can mitigate the risks faced by SMEs in the digital economy. By analyzing the unique challenges that SMEs encounter and the potential of AI to address these issues, the paper aims to provide a comprehensive understanding of the subject.

This discussion will encompass the following key areas: the cybersecurity challenges specific to SMEs, the potential of AI-driven solutions to address these challenges, and the policy and strategic considerations necessary for effective implementation. Additionally, the paper will outline practical recommendations for SMEs to adopt AI-based cybersecurity measures while considering ethical and regulatory implications.

The scope of this paper is limited to conceptual analysis and theoretical insights. By focusing on AI's strategic and technological aspects in cybersecurity, the paper seeks to offer actionable guidance for SMEs, policymakers, and other stakeholders. In conclusion, the introduction establishes the foundation for a critical discussion on leveraging AI to strengthen SME cybersecurity. The increasing reliance on digital technologies necessitates proactive measures to safeguard SME operations and foster sustainable development in the digital economy. As a game-changing technology, AI promises to transform the cybersecurity landscape, enabling SMEs to thrive in an increasingly interconnected world.

2. Challenges Facing SMEs in Cybersecurity

2.1. Overview of Cybersecurity Threats in the Digital Economy

The digital economy, while offering immense opportunities for growth and innovation, also presents a vast array of cybersecurity challenges. As businesses increasingly rely on interconnected systems, digital tools, and online transactions, the volume and complexity of cyber threats continue to rise (Comite, 2022) [17]. Cybercriminals, often leveraging sophisticated tools, target vulnerabilities in digital infrastructure to carry out attacks such as phishing, ransomware, malware infiltration, and distributed denial-of-service (DDoS) attacks (Möller, 2023) [32].

Phishing attacks, for instance, exploit human error by tricking employees into revealing sensitive information such as passwords or financial details. Ransomware has become a particularly pervasive threat, encrypting critical data and demanding payments for its release. Malware and spyware are designed to infiltrate systems, steal confidential data, and monitor business activities. Furthermore, SMEs often face the risk of insider threats, whether through malicious intent or unintentional actions by employees who lack adequate cybersecurity awareness (Rains, 2020) [38].

The rapid evolution of cyberattacks compounds these threats. Advanced Persistent Threats (APTs), for example, involve prolonged and targeted efforts by attackers to gain unauthorized access to a business's network. Such threats are difficult to detect and can cause significant damage before they are neutralized. SMEs are particularly vulnerable to these multifaceted risks in a digital economy characterized by interconnectedness and data-driven operations (Jabar & Mahinderjit Singh, 2022) [25].

2.2. Unique Vulnerabilities of SMEs Compared to Larger Enterprises

SMEs are uniquely vulnerable to cybersecurity threats due to their limited resources, lack of expertise, and often inadequate cybersecurity measures. Unlike large enterprises, which typically have dedicated IT departments and advanced security protocols, SMEs often operate with small teams and rely on basic security tools. This lack of sophistication in cybersecurity infrastructure makes them an attractive target for cybercriminals (Chidukwani, Zander, & Koutsakis, 2022) [16].

A key vulnerability lies in the inadequate prioritization of cybersecurity. Many SMEs perceive cybersecurity as a secondary concern, focusing instead on immediate business operations and revenue generation. This perception leaves critical systems and data exposed to potential threats. Additionally, SMEs are often unaware of the full scope of

cyber risks or the potential consequences of a breach, which may include financial loss, legal repercussions, and damage to reputation (Wilson, McDonald, Button, & McGarry, 2023) [44].

Another significant vulnerability is the reliance on third-party services and cloud-based solutions. While these tools offer cost-effective scalability, they also introduce risks associated with data breaches and unauthorized access. Cybercriminals frequently exploit vulnerabilities in third-party systems to gain access to SME networks. Furthermore, many SMEs lack robust incident response plans, leaving them ill-prepared to handle cyberattacks effectively.

Human factors also play a critical role in SME cybersecurity. Employees often lack the training and awareness needed to recognize and respond to cyber threats. Simple actions, such as clicking on suspicious links or using weak passwords, can create entry points for attackers. This lack of cybersecurity culture exacerbates the risks faced by SMEs in a highly interconnected digital landscape (Fagbule, 2023) [21].

2.3. Financial and Technical Constraints in Addressing Cybersecurity Issues

Financial constraints are one of SMEs' most significant challenges in enhancing their cybersecurity posture. Implementing robust cybersecurity measures often requires substantial technology, personnel, and training investment (Mmango & Gundu, 2023) [31]. However, SMEs typically operate on tight budgets, with limited capacity to allocate funds to non-revenue-generating activities. This financial barrier leads many SMEs to rely on free or low-cost security tools, which may provide only basic protection and leave critical vulnerabilities unaddressed.

Hiring skilled cybersecurity professionals is another challenge. The cybersecurity workforce gap is a global issue, with demand for expertise far outstripping supply. SMEs, unable to offer competitive salaries and benefits, often struggle to attract and retain qualified personnel. As a result, they are left with inadequate in-house expertise to manage and respond to cybersecurity threats effectively (Rawindaran, Jayal, Prakash, & Hewage, 2023) [41].

Technical constraints also hinder the ability of SMEs to adopt comprehensive cybersecurity measures. Many SMEs use outdated hardware and software, which are more susceptible to vulnerabilities and lack critical security updates. Migrating to newer systems or implementing advanced technologies such as intrusion detection systems, encryption, and multifactor authentication requires technical expertise and resources many SMEs do not possess (Yudhiyati, Putritama, & Rahmawati, 2021) [47]. Additionally, SMEs face challenges in keeping up with the rapidly changing cybersecurity landscape. Threat actors continuously develop new tactics, techniques, and procedures, requiring businesses to adopt a proactive and adaptive approach to cybersecurity. However, SMEs often lack the tools and capabilities to monitor emerging threats and implement timely countermeasures (Xie, Jin, Wei, & Chang, 2023) [45].

The lack of awareness and understanding of cybersecurity regulations further complicates matters. SMEs operating in multiple jurisdictions may struggle to comply with data protection laws such as the General Data Protection Regulation (GDPR) or other regional standards. Non-compliance can result in significant financial penalties and reputational harm, adding another layer of complexity to SMEs' cybersecurity challenges (Ilca, Lucian, & Balan, 2023) [23].

3. AI-Driven Solutions for SME Cybersecurity

3.1. Key AI Technologies and Tools for Cybersecurity

Artificial Intelligence has revolutionized the field of cybersecurity by introducing advanced tools and technologies capable of addressing complex and evolving threats. These technologies leverage AI's ability to process vast amounts of data, detect patterns, and predict potential risks, making them invaluable for Small and Medium-sized Enterprises.

One of the most critical AI technologies in cybersecurity is machine learning (ML). ML algorithms analyze historical data to identify patterns and anomalies that may indicate malicious activity. For instance, ML can recognize deviations in network traffic that suggest a potential breach or flag unauthorized access attempts. This predictive capability enables SMEs to detect and prevent attacks before they cause significant damage (Jimmy, 2021) [27].

Another essential tool is anomaly detection, which focuses on identifying unusual behaviors or activities within a system. Unlike traditional signature-based systems that rely on predefined rules, anomaly detection uses AI to establish baseline behaviors and flag deviations that could indicate a threat. This is particularly useful for SMEs, as it helps protect against new and unknown attack vectors, including zero-day vulnerabilities (Jeffrey, Tan, & Villar, 2023) [26].

Natural Language Processing (NLP) is also becoming increasingly relevant in cybersecurity. NLP tools can analyze unstructured data, such as emails or social media posts, to detect phishing attempts or potential insider threats. For example, AI-driven email filters can identify and block phishing messages based on subtle linguistic patterns and contextual clues (Arjunan, 2024) [7]. Finally, automated incident response systems powered by AI enable faster and more effective cyberattack responses. Without human intervention, these systems can execute predefined actions, such as isolating affected devices or blocking suspicious IP addresses. By automating these tasks, SMEs can mitigate threats more quickly, reducing the risk of prolonged damage (Alhogail & Alsabih, 2021) [5].

3.2. Benefits of Adopting AI-Driven Frameworks

The adoption of AI-driven cybersecurity frameworks offers numerous benefits for SMEs, making them a practical and effective solution for businesses with limited resources. One of the most significant advantages is scalability. AI systems are designed to handle large volumes of data and adapt to the growing needs of a business. As SMEs expand their digital footprint, AI can scale alongside their operations, providing consistent protection without requiring significant additional investment. This scalability is particularly important for SMEs operating in dynamic and competitive markets (Hokmabadi, Rezvani, & de Matos, 2024) [22].

Another critical benefit is real-time threat detection and prevention. Traditional cybersecurity systems often rely on manual processes or outdated databases, which can delay threat detection and response. Conversely, AI processes data in real time, enabling it to identify and neutralize threats almost instantly. This capability can mean the difference between a minor incident and a major security breach for SMEs (Perwej, Abbas, Dixit, Akhtar, & Jaiswal, 2021) [36].

AI-driven frameworks also enhance efficiency and cost-effectiveness. By automating routine tasks such as

monitoring, threat analysis, and incident response, AI reduces the burden on human resources and minimizes the need for extensive in-house expertise. This is especially advantageous for SMEs, which often lack dedicated IT or cybersecurity teams. Additionally, AI's predictive capabilities help businesses prioritize their cybersecurity investments by identifying and addressing the most critical vulnerabilities (Thethi, 2024) [43].

AI frameworks improve accuracy and reliability in threat detection. Unlike human analysts, who may overlook subtle indicators due to fatigue or inexperience, AI systems consistently identify threats with high precision. This reduces the likelihood of false positives and ensures that resources are allocated to genuine security concerns. For SMEs, this reliability is crucial for maintaining trust and operational continuity (Shandilya, Datta, Kartik, & Nagar, 2024) [42].

Finally, AI empowers SMEs to stay ahead of evolving threats. Cybercriminals continuously develop new attack methods, making it challenging for traditional systems to keep up. AI's ability to learn and adapt ensures that SMEs are protected against both known and emerging threats, providing a proactive rather than reactive approach to cybersecurity (Rawindaran, Jayal, & Prakash, 2021) [40].

3.3. Integration of AI with Existing SME Infrastructure

Integrating AI-driven solutions into an SME's infrastructure requires careful planning and execution. While AI offers numerous benefits, its effectiveness depends on seamless alignment with the business's current systems, processes, and goals. One of the first steps in integration is conducting a comprehensive assessment of the SME's cybersecurity needs and existing infrastructure. This involves identifying key assets, potential vulnerabilities, and areas where AI can provide the most value. For example, SMEs with extensive customer data may prioritize AI solutions for data protection and privacy, while those reliant on e-commerce platforms may focus on fraud detection (Oguta, 2024) [33].

Cloud-based AI solutions offer an accessible and cost-effective option for SMEs. These platforms provide advanced cybersecurity features without the need for significant upfront investment in hardware or software. Cloud-based tools are also easy to integrate with existing systems, enabling SMEs to leverage AI's capabilities with minimal disruption to their operations (Johnson, Seyi-Lande, Adeleke, Amajuoyi, & Simpson, 2024) [24].

Collaboration with third-party providers is another critical aspect of integration. Many technology companies offer AI-driven cybersecurity services tailored to the needs of SMEs. Partnering with these providers allows SMEs to access cutting-edge tools and expertise that may be otherwise out of reach. These partnerships also help SMEs stay updated on the latest cybersecurity trends and innovations (Attah, Garba, Gil-Ozoudeh, & Iwuanyanwu, 2024a) [9].

Training and awareness are equally important for successful integration. Employees must understand how AI systems function and how to use them effectively. This includes recognizing alerts generated by AI tools, responding to automated incident reports, and collaborating with AI systems to strengthen overall security. By fostering a culture of cybersecurity awareness, SMEs can maximize the benefits of their AI investments.

Finally, SMEs must ensure their AI systems comply with regulatory requirements and ethical standards. This involves implementing robust data privacy measures, obtaining necessary certifications, and adhering to industry best practices. Transparent and ethical use of AI is essential for building trust with customers and stakeholders, which is particularly important for SMEs seeking to establish themselves in competitive markets (Adewumi, Dada, Azai, & Oware, 2024; Dada, Okonkwo, & Cudjoe-Mensah, 2024) [4, 19].

4. Policy and Strategic Considerations

4.1. Importance of Government and Industry Regulations for SME Cybersecurity

The increasing digitization of small and medium-sized enterprises (SMEs) has made them a prime target for cyberattacks, underscoring the urgent need for robust regulatory frameworks to safeguard these businesses. Government and industry regulations play a pivotal role in establishing baseline cybersecurity practices, ensuring that SMEs adhere to consistent standards for data protection, threat mitigation, and operational resilience.

Government intervention through cybersecurity regulations provides SMEs with clear guidelines on managing digital risks. For example, data protection laws such as the General Data Protection Regulation (GDPR) in the European Union mandate stringent security measures to protect sensitive information. Compliance with such regulations minimizes risks and enhances SMEs' credibility with customers and stakeholders. Similarly, industry-specific standards, such as those in healthcare (HIPAA) or finance (PCI DSS), ensure tailored cybersecurity measures are implemented to meet sector-specific needs (Banji, Adekola, & Dada, 2024) [14].

Regulatory frameworks also help SMEs combat challenges associated with limited resources. Governments can alleviate the financial burden on SMEs by providing access to standardized tools, subsidies, or tax incentives for adopting cybersecurity measures. For instance, some governments offer grants for cybersecurity training or investments in advanced technology, enabling smaller businesses to enhance their defenses without overstretching their budgets. However, the effectiveness of regulations depends on their clarity, accessibility, and enforcement. Complex or ambiguous requirements can overwhelm SMEs, particularly those with limited technical expertise. Policymakers must strike a balance by designing rigorous yet adaptable frameworks, accommodating SMEs' diverse needs and capacities (Attah, Garba, Gil-Ozoudeh, & Iwuanyanwu, 2024b) [10].

4.2. Collaboration Opportunities with Tech Providers and Policymakers

Addressing SMEs' cybersecurity challenges requires collaborative efforts between businesses, technology providers, and policymakers. Such partnerships leverage the strengths of each stakeholder to create a more secure and resilient digital ecosystem. Tech providers play a crucial role in equipping SMEs with advanced cybersecurity solutions. By offering affordable and scalable tools tailored to the needs of smaller enterprises, providers can help bridge the resource gap that often leaves SMEs vulnerable. Collaboration initiatives such as managed security services or shared threat intelligence platforms enable SMEs to access state-of-the-art technology and expertise without incurring prohibitive costs (AD Adekola & SA Dada, 2024; Dada & Adekola, 2024) [2, 3].

Conversely, policymakers facilitate collaboration by creating an enabling environment for public-private partnerships

(PPPs). Governments can establish forums or task forces that bring together SMEs, tech providers, and regulators to identify challenges, share best practices, and co-develop innovative solutions. For example, national cybersecurity centers in several countries offer platforms for collaborative threat analysis and rapid response, enhancing collective resilience (Iwuanyanwu, 2024) [8].

Additionally, educational institutions and nonprofit organizations can contribute by providing cybersecurity training programs tailored to SMEs. These initiatives ensure that employees at all levels are equipped to recognize and respond to cyber threats, fostering a culture of security awareness. Cross-border collaboration is also essential, given the global nature of cyber threats. International frameworks and agreements enable knowledge sharing and coordinated responses, ensuring that SMEs operating in multiple jurisdictions are not left exposed to fragmented or inconsistent policies (Gil-Ozoudeh, & Iwuanyanwu, 2024b) [10].

4.3. Ethical Implications and Data Privacy Concerns in AI Deployment

While AI-driven solutions offer significant benefits for SME cybersecurity, their deployment raises important ethical and data privacy concerns that must be addressed to ensure responsible use. One of the primary concerns is the potential misuse of AI technologies. Advanced AI tools, such as those used for threat detection, can inadvertently be repurposed for malicious activities if they fall into the wrong hands. Policymakers and tech providers must establish robust safeguards, such as access controls and encryption, to prevent unauthorized use of these systems.

Another critical issue is bias and fairness in AI algorithms. AI systems may exhibit biases that disproportionately affect certain users or groups if not designed and tested carefully. For example, anomaly detection algorithms trained on data from large enterprises may fail to accurately detect threats in SME environments, leading to gaps in protection. Developers must prioritize transparency and inclusivity in algorithm design to ensure fair and effective outcomes for all users (Attah, Garba, Gil-Ozoudeh, & Iwuanyanwu, 2024c) [11].

Data privacy is also a major concern, particularly in the context of AI's reliance on large datasets for training and operation. SMEs often handle sensitive customer information, making it essential to ensure that AI systems comply with data protection regulations. Encryption, anonymization, and secure storage practices are critical for safeguarding this data against breaches and misuse. Furthermore, SMEs must maintain clear and transparent communication with customers about collecting, using, and protecting their data.

Accountability in decision-making is another ethical consideration. As AI systems become more autonomous, there is a risk of reduced human oversight in critical cybersecurity decisions. SMEs must establish protocols to ensure that humans control high-stakes decisions, such as determining the appropriate response to a detected threat. This approach mitigates the risk of errors and reinforces accountability and trust. Lastly, the use of AI in cybersecurity raises questions about job displacement and the future of work. While AI can automate many routine tasks, balancing automation with the upskilling and reskilling of employees is crucial. Providing training opportunities ensures that workers can adapt to evolving roles and continue to contribute meaningfully to their organizations (Anozie *et al*., 2024; Attah, Garba, Gil-Ozoudeh, & Iwuanyanwu, 2024a) [6, 9].

5. Conclusion and Recommendations

SMEs are crucial pillars of innovation and economic growth in the rapidly advancing digital economy. However, their increasing reliance on digital technologies exposes them to a heightened risk of cyberattacks, such as phishing, ransomware, and malware. Unique vulnerabilities, including limited financial and technical resources and the absence of robust cybersecurity infrastructure, make SMEs prime targets for cybercriminals. These challenges often result in severe financial losses and reputational harm, underlining the urgency of adopting more sophisticated and scalable cybersecurity measures. Artificial intelligence has emerged as a game-changing solution, providing SMEs with tools that enhance their ability to identify, mitigate, and prevent cyber threats through real-time detection, predictive analytics, and automated responses.

AI-driven cybersecurity solutions empower SMEs to overcome resource constraints by leveraging machine learning, anomaly detection, and natural language processing technologies. These tools offer scalability, cost efficiency, and adaptability, making them particularly suited for the dynamic threat landscape SMEs face. However, the integration of AI into SME cybersecurity efforts requires not only technological investment but also supportive policies and strategies. Collaborative efforts among governments, tech providers, and SMEs can strengthen regulatory compliance, provide access to resources, and address ethical considerations such as data privacy and algorithmic fairness. These measures are essential for fostering trust and ensuring responsible AI deployment across industries.

To fully realize the potential of AI-driven cybersecurity, SMEs must take practical steps toward implementation. Conducting comprehensive cybersecurity assessments allows SMEs to identify vulnerabilities and prioritize areas for improvement, ensuring informed decision-making. Investing in scalable and cloud-based AI solutions can help SMEs access advanced cybersecurity capabilities without incurring prohibitive costs. Additionally, enhancing employee awareness through regular training programs and leveraging AI-powered simulation tools ensures that human factors, a significant element in cybersecurity, are effectively managed. Collaboration with technology providers and industry consortia can further amplify SME capabilities, granting access to shared resources, expertise, and best practices.

Finally, establishing clear data privacy protocols and incident response plans is essential for building customer trust and ensuring regulatory compliance. AI-driven encryption and anonymization tools can safeguard sensitive information, while real-time threat monitoring systems help SMEs remain agile against emerging risks. Governments also play a vital role in bolstering SME cybersecurity, offering financial incentives, training programs, and participation in public-private partnerships. Continuous monitoring and evolution of cybersecurity strategies, supported by AI analytics, are critical for SMEs to maintain resilience in an ever-changing threat landscape. By adopting these measures, SMEs can fortify their cybersecurity frameworks, ensuring their sustainability and competitiveness in the digital economy.

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