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A SMART ZERO TRUST SECURITY FRAMEWORK TAILORED FOR MODERN SMES: A REVIEW PAPER

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Abstract
Small and Medium Enterprises (SMEs) face in- creasingly sophisticated cyberattacks due to inadequate security infrastructure, limited budgets, and lack of cybersecurity exper- tise. Traditional perimeter-based security models are inadequate for the era of cloud computing, remote working, and BYOD. A new security paradigm that has promise through zero trust architecture (ZTA) which operates under the principle of never trust, always verify has proven to be effective. It is a review of the existing Zero Trust models, their applicability to an SME and the challenges related to adopting it. In addition, it addresses how smart and automated Zero Trust tools, including AI-driven policy and behavioral controls have emerged in recent years. As per the literature reviewed, the paper represents the need to develop the Zero Trust framework that is affordable, scalable, and easy to deploy and specifically oriented to the SMEs. The paper reveals the major gaps in the research and proposes further research opportunities in developing practical Zero Trust solutions that will be accessible to resource-strained organizations.

I. Introduction

The rapid process of digitalization of business has significantly improved the reliance on the services of clouds, remote access tools, and interconnectedness. The SMEs that form the basis of most economies are particularly vulnerable to cyberattacks due to inadequate funding, inadequate security systems, and the absence of specialized personnel [1], [2]. concerning IT security issues. SMEs constitute over 90% of global businesses and employ 70% of the workforce. However, they face disproportionate cybersecurity challenges compared to large organizations.

The traditional security practices are highly founded on the perimeter security that assumes the credibility of the elements within the network. Modern attackers, however, have rendered the assumption outdated with the help of phishing, ransomware, insider threats and supply chain attacks, among others, as Rose [3] and Campbell [4] have reported. The work environment has further undermined the traditional perimeter security because of the remote work forces, use of clouds, mobile phones as well as bring-your-own-device (BYOD) policies. Attackers access privileged accounts, obtain access to the networks, and move across them without much detection using the vulnerabilities and through breaching credential accounts, social engineering, and unpatched systems.

In response to it, Zero Trust Architecture (ZTA) has emerged as one of the most discussed models of security that requires the continuous authentication of the user, device, and application regardless of the whereabouts of the user or the type of the device and application used [5], [6]. The Zero trust model is founded on a general rule allowing nothing to be trusted automatically either inside or outside the network perimeter. Every access request must be authenticated, authorized and continuously checked based on a number of contextual variables, including user identity, device health, location, time, and data sensitivity.

The adoption of Zero Trust models by the SMEs is quite low despite its efficacy that has been established to work well in enterprise settings. The recent news in the industry can also contribute to the fact that over 60% of cyberattacks target SMEs, yet fewer than 14 percent have full Zero Trust security controls as of now established [7], [8]. The financial impact of data breaches on SMEs may be devastating and the average cost may exceed the figure of $200,000 and in most cases the company may close shop within six months [9] or even less. This is also a great vulnerability to not only the individual businesses but also the economic ecosystem at large since in most cases SMEs are the suppliers and partners of the larger business that might provide inroads into well fortified organizations.

The point is that the enterprise-level Zero Trust systems and real requirements and potentials of SMEs are so dissimilar that the gap between them results in the significant incongruity. The existing structures require substantial initial investment, security unit, complex integration with old systems, and con- tinuous operation skills, which most SMEs simply lack. That

has resulted in a compelling need of Zero Trust plans which are expressly designed in resource constrained environments and a balance between security functionality and cost, comfort, and manageability.

This review paper aims to discuss the existing Zero Trust-based models, how these models apply to SMEs, and reveal why smart and automated Zero Trust models would apply to the small business organizations. The article will contribute to the available literature on cybersecurity, providing a detailed analysis of the problems received by SMEs, evaluating the possibilities of the new technologies that can potentially bridge the gap in capability, and proposing the views of the promising studies. In this review, in particular, the following research questions will be addressed: (1) What are the inherent limita- tions of conventional security models to SMEs? (2) How can the principles of Zero Trust be applied to resource constrained environments? (3) What are the ways that automation and artificial intelligence are used in order to make Zero Trust accessible to SMEs? (4) What are the biggest research gaps

that are to be filled with a view to accelerating the adoption of SMEs?

The rest of the paper is organized as follows: Section II presents the systematic review methodology. Section III provides a comprehensive review of traditional security constraints, Zero Trust concepts, adoption barriers, and emerging solutions. Section IV introduces our proposed Smart Zero Trust Framework. Section V presents the problem statement. Section VI discusses key findings. Section VII outlines future research directions, and Section VIII provides conclusions and recommendations for researchers, practitioners, and policy- makers.

II. Review Methodology

Here we will introduce the literature on Zero Trust Architecture and SME cybersecurity identification, selection, and analysis method. The review is carried out in line with the established rules, in which all the aspects are covered, the effect of bias is minimized, and a clear report on the research process has been observed.

A. Search Strategy and Data Sources

This systematization review follows the PRISMA (Preferred Reporting Items to Systematic Reviews and Meta-Analyses) to achieve [10]a total and unbiased review in regard to the literature. The review contains scholarly research articles, industry white papers, technical reports and security guidelines that were published as of 2020-2025. This time frame was selected to cover the emerging trend of the Zero Trust concepts because the earliest pioneer publications to the current-day applications, but at the same time, it was also not out of date of the current cybersecurity concern.

A large literature review has been conducted in various academic databases and databases of industry sources, including IEEE Xplore, ACM Digital Library, Google Scholar, ScienceDirect, Scopus, and individual publications in the sphere of cybersecurity. The credentials such as NIST, Gartner, Forrester, Cisco and Microsoft were also consulted to reach the views of the practical implementation and real life imple- mentation experiences.

The search strategy employed the following keyword combinations using Boolean operators:

- ("Zero Trust" OR "Zero Trust Architecture" OR "ZTA") AND ("SME" OR "Small Medium Enterprise" OR "Small Business")
- ("Zero Trust") AND ("Cybersecurity" OR "Network Se- curity") AND ("Cloud" OR "Remote Access")
- ("Zero Trust") AND ("AI" OR "Machine Learning" OR "Automation" OR "Behavioral Analytics")
- ("Access Control") AND ("Micro-segmentation" OR "Least Privilege")
- ("ZTNA" OR "Zero Trust Network Access") AND ("Im- plementation" OR "Deployment")

B. Selection Criteria and Screening Process

Such a process will be addressed in the next subsection on the selection criteria and screening.

Inclusion Criteria: Publications that discuss the most recent development; peer-reviewed journal articles and con- ference papers; official industry reports and technical white papers; research on Zero Trust principles, architectures, im- plementation strategies, or adoption issues; articles, in which automated or AI-driven or cloud-based security solutions are described; articles that are published in the English language. **Exclusion Criteria:** Articles that do not focus on small organization scaling, are only based on opinion and not a research and methodology; articles that are not scholarly with the exception of the official industry standards and guidelines. The initial search availed 487 potentially useful publications. Abstract and title screening was performed on 356 unique publications. Two reviewers screened these abstracts and both communicated with the inconsistencies with the inclusion criteria. This process was discovered to result in 128 publications that met minimum relevancy criteria and were worth reading in their entire contents. The initial screening of these publications with the help of the full-text selection assisted in the ultimate selection of 68 studies that

directly addressed the research questions and met all the quality
criteria.

C. Data Extraction and Quality Assessment

To derive the required information of the study, the following data were organized and documented based on each of the selected studies in the following manner: publication details (authors, year, venue, type); description of the Zero Trust framework or approach applied; target environment and size of organization; technical requirements (infrastructure, skills and integration requirements) and cost and resources requirements in implementation, significance findings and contribution, lim- itations, challenges chronologically identified, automation and AI integration opportunity, methodology of validation, and practical relevance of the proposed research to the SMEs.

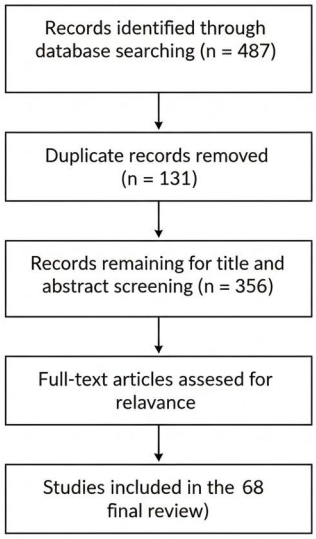

Fig. 1. PRISMA-style visualization of the literature review process described in Section II.

Quality assessment was done based on the established standards which apply to different forms of study. Whereas, in the case of empirical research, the focus of estimation was on the methodology rigor, sample size and representativeness, data analytic methods and methodological conclusions. In conceptual and design papers, the appraisal was based on theoretical foundation, the development of solutions in a comprehensive manner, checking of its feasibility, and the contribution of knowledge. The industry reports have been as- sessed on the assessments based on data sources, transparency of the methodology, and bias of the report. The rating of all of the studies has been conducted to ensure that the review synthesis has been oriented towards the high-quality evidence, yet the quality of the research in the modern field cannot be neglected.

D. Research Contributions

Even though it is rather a systematic review of the existing literature on Zero Trust, this paper is not a typical survey research since it offers a new framework to be implemented in the context of SME constraints. The following are the contributions of this research:

1) **Comprehensive Review:** A literature review of the existing literature on Zero Trust Architecture, especially its application to the SME environment, and barriers to its implementation.

2) **Novel Framework Proposal:** The proposal is a new architecture of a Smart AI-driven Zero Trust Frame- work designed specifically to assist resource-constrained

SMEs and contains an intelligent search engine of the security threat in real-time and automatic creation of alerts.

3) **Architectural Design:** Detailed architectural plan, which provides the Zero Trust strategy and machine learning-based anomaly detectors, which are proactive to organizations with no security professionals.

4) **AI-Based Search Engine Integration:** The concept is to define a smart monitoring system which will continuously scan the network traffic, user activity, and system logs to detect security anomalies and issue instant alerts, which will significantly reduce the 24/7 security operations centers.

5) **Gap Analysis and Research Roadmap:** Processed identification of gaps in existing solutions and outlines of areas of critical research evidence that will be fully applied to the adoption of SME Zero Trust.

6) **Implementation Strategy:** Practical guidelines on how to implement security on a gradual basis, cost effectiveness plans, and automation plans to allow small enterprises to have enterprise-grade security.

Unlike purely descriptive reviews, the provided paper is a constructive work containing the proposed Smart Zero Trust Framework which contributes to the elimination of the existing conflict between high security requirements and the capabili- ties of small SMEs. The greatest innovation in the framework An AI-based security search engine, which is a threat hunting and alert generation system automated, is a viable means of democratizing state of the art cybersecurity services.

Section IV describes the architecture and implementation plan that will allow the closing of the capability gap so that the SMEs can achieve good security postures without the increase in staffing, expertise, and budget. Though complete validation will be achieved once future empirical research has been conducted, the framework gives the foundation upon which it is possible to transform the concept of Zero Trust security into a realistically achievable possibility within a resource-limited context.

III. Literature Review

A. *Traditional Security Models and Their Limitations*

Conventional cybersecurity models rely on perimeter security—firewalls, intrusion detection systems, and VPNs—assuming threats originate externally while internal entities are trusted by default [11], [12]. This model of a castle-and-moat has been the model of enterprise cybersecurity during the decades, where it is evident that there is a wall with trusted internal networks and untrusted external environments.

However, the model has increasingly been ineffective when it comes to modern cyber threats. It claims that 74% of breaches contain a human element, including credential theft, social engineering, and privilege abuse [2] according to the 2024 Verizon Data Breach Investigations Report it is stated. The conventional models are not very resistant to subsequent movement on the network after attackers have been able to breach the perimeter through phishing or stolen credentials or by using some vulnerability that has already been exploited to penetrate the network lateral movement on the network [13]. The assailants will be able to elevate privileges, access sensitive information and leave backdoors that can hardly be detected, since internal traffic is not as often checked as communication with the external world.

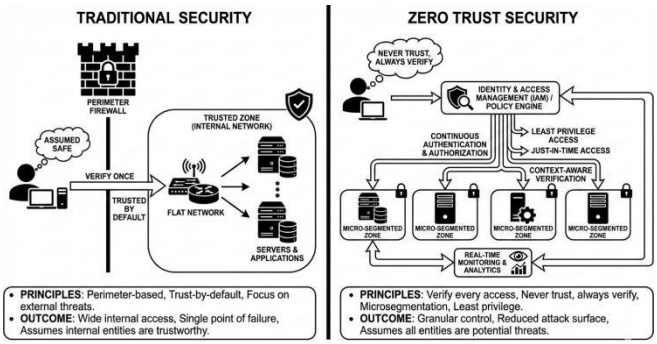

Fig. 2. Conceptual comparison of traditional perimeter-based security and Zero Trust Architecture.

SMEs experience the limitations of traditional security models particularly. The deployment of perimeter based security systems carries with it expensive appliances, software and maintenance, and strains tight budgets to continue operating the system as opposed to hardware based security systems such as intrusion detection systems and intrusion prevention systems among others which require less resources to run and maintain [14], [15]. The budget limit, old infrastructure is a common challenge to such organizations, inability to have 24-hour surveillance to detect any security breach, scarce resources that can be utilized to contain an incident, and the absence of personnel training on how to practice the best security measures. Research indicates that SMEs relying solely on perimeter defenses experience 3.5 times more successful breaches than organizations employing layered security controls [16].

The mean time to identify (MTTD) of SMEs breach is 287 days as compared to 197 days in large companies that have security operations centers that are committed to this task [17]. This will provide the attacker with a significant amount of time to fulfill his or her objectives, steal sensitive data, install ransomware, or have long-term access to exploit any time in the future. The effect is particularly immense to SMEs that do not necessarily enjoy financial stability and brand loyalty to outpace an influential security event.

Furthermore, the transition to the modern workplaces has virtually killed the concept of a network perimeter which can be defended. Turning to cloud services means that there is a place of cloud-based business applications and business data which are not within the organizational jurisdictions. Telecommuting has decentralized the workforce to the home networks and free WiFi networks. Mobiles are able to get access to the corporate resources wherever and whenever. BYOD policies endanger unregulated access points to the business premises. IoT devices augment the location of at- tack incorporating predominantly vulnerableness connected systems. These trends made the old concept of an internal network that may be trusted a myth and required a reevaluation of the security frameworks.

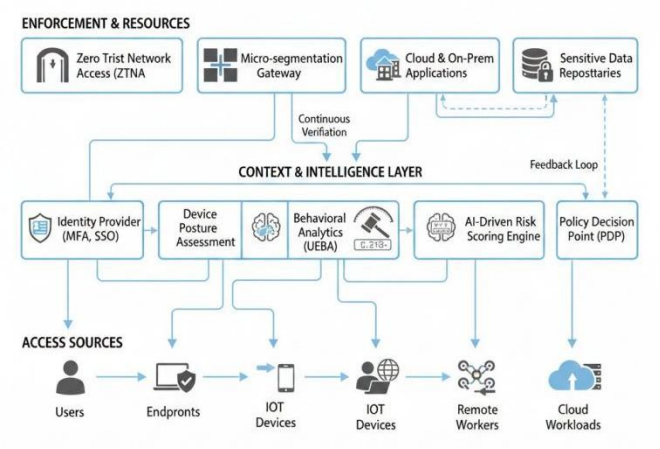

Fig. 3. Smart Zero Trust Architecture tailored for resource-constrained SMEs integrating AI-driven risk assessment, continuous verification, and cloud-based enforcement.

B. ***Zero Trust Architecture: Core Principles and Frameworks***

Zero Trust Architecture is a change in paradigm whereby zero users, devices, or applications, notwithstanding their place or point of connection to the network are not trusted in default, unlike perimeter-based security models [3], [4]. The term Zero Trust was coined by John Kindervag at Forrester Research in 2010 under the name Zero Trust, and since then it has been expanded to be a generalized security model that has been endorsed by organizations like NIST, CISA and the UK National Cyber Security Center.

The best definition of Zero Trust Architecture is the most significant detailed description provided in the National Insti- tute of Standards and Technology (NIST) Special Publication 800-207 and implemented guidance regarding the architecture is located there [3]. NIST defines Zero Trust as a collection of concepts and ideas that tend to minimize uncertainty when implementing accurate and least privilege per-request access to information systems and services as a response to a network considered compromised. The tenets that the implementation of all the Zero Trusts is based on are a handful of quite basic tenets that, as a uniting force, form a better security posture. **Continuous Verification:** Unlike with traditional models where entry is authenticated at the network perimeter, net- works using Zero Trust must check authentication, autho- rization, and validation on a case-by-case basis, in real-time, and throughout the session, as opposed to authenticating it once before entry to the network [18]. Authentication is confirmed at every transaction as opposed to providing blanket access to the network upon initial authentication. This principle acknowledges that device health, user context and threat environment are dynamic and will continuously undergo assessment and never have one assessment.

Least Privilege Access: The users and the system are provided with the minimum possible access which they require to perform their unique roles only [19]. The privileges are assigned in a dynamic manner based on the contextual factors including the identity that has been verified, the security posture of the device, location, time of access of the user and sensitivity of the resources being requested. This principle goes a long way in reducing the damage that the compromised credentials or insider threat may bring about because it allows the user to understand what one account is capable of access- ing or modifying.

Assume Breach: Zero Trust systems are built based on the fact that breaches have occurred or will occur in the future [5]. Rapid detection, containment and minimization of the impact of the breach are the focal security goals as opposed to prevention of initial access, which is the key security control. The use of defensive pessimistic will promote the use of high-monitoring strength, micro-segmentation, and automated reaction

capabilities that will limit the scope of the movement and data transfers by the attackers even after the first compromise.

Explicit Verification: It is the verdict that is determined through a thorough study of many attributes compared to the simple credential verification [20]. Authentication of the user identity through streamlining the use of multi-factor authentication and health of the device in terms of patch status and endpoint protection, the location and security of the connections in the network, behavioral pattern when compared with the set baselines and real time threat intelligence about current attacks and vulnerabilities are referred to as verifica- tion.

Micro-segmentation: Networks are split into small, independent segments, where granular access controls between segments are enforced between segments [6], [21]. This type of architectural design will limit the movement across segments by ensuring that explicit authentication and authorization is carried out to cross-segment movement. Micro-segmentation will also make sure that once an attacker breaches a given system, he or she will not pivot to other network resources with ease.

Several broad Zero Trust models have been developed all through the academic research and the working experience. Google BeyondCorp project became the first attempt to intro- duce the experience of applying Zero Trust on large scales as the traditional scheme of remote access via VPN has been fully substituted with the context-driven access control based on attributes of both devices and users [22], [23]. The BeyondCorp model proved that it was possible to implement the concepts of Zero Trust in large, complex organizations and in fact improve user experience by enabling them to use everything everywhere without experiencing the overheads of VPN.

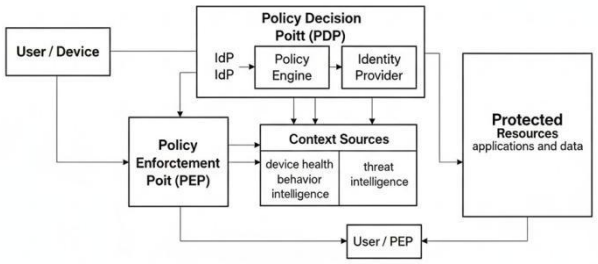

Fig. 4. Core components and logical data flow of Zero Trust Architecture based on NIST SP 800-207.

TABLE I: *COMPARISON OF ZERO TRUST FRAMEWORKS*

Framework	Target	Key Components	SME Suitability	Cost / Com-plexity
Google Beyond-Corp	Ent.	Context-aware access, VPN re-placement	Med	High
Forrester ZTX	Ent.	7 pillars: data, people, devices, workloads, visibility, automa- tion, network	Low	Very High
ZTNA (Cloud)	SME/Ent.	App-level access, device verifi-cation	High	Low-Med
SASE	SME/Ent.	Net+security convergence, SD-	Med-High	Med

WAN, CASB, FWaaS, SWG

The Forrester Zero Trust eXtended (ZTX) model possesses seven fundamental pillars, such as, data security, network security, people security, workload security, device security, visibility and analytics, and automation and orchestration. Each pillar addresses particular aspects of the security architecture and successful Zero Trust requires simultaneous adoption of all of the aspects, rather than a specific focus that is placed on another element.

C. *Challenges of Zero Trust Adoption in SMEs*

Despite the great security benefits of Zero Trust, SMEs are faced with dozens of obstacles to adoption of the advanced security models, which curtail the adoption of the advanced security models [24], [25]. The awareness of such challenges will contribute to the development of solutions that will enable to bring Zero Trust to organizations that have limited resources.

High Implementation Costs: Enterprise-grade Zero Trust implementations require substantial investment in IAM systems, network segmentation, SIEM, EDR, and policy or- chestration. Industry reports indicate implementation costs of $500,000–$2,000,000 [26], far exceeding typical SME IT budgets of $50,000–$200,000. These costs encompass soft- ware, infrastructure, and professional services for design and deployment.

Technical Complexity: Zero trust implementation requires high-level network design expertise, identities, access control policies, and security measures [14], [27]. The companies are not only required to redesign network topology to support micro-segmentation, centralized identity management with single sign-on and multi-factor authentication, but also define access policies of all resources and user role in granular form and integrate different systems including legacy applica- tions and deploy continuous monitoring and incident response procedures. Such complex architectures cannot be designed and implemented by a dedicated network architect, security engineer or identity management professional, as normally available in SMEs. The IT personnel are already undergoing a high learning curve and they will be forced to be trained on the new technologies and security concepts which the employees are not even aware of.

Legacy System Integration: Many SMEs have a heterogeneous IT infrastructure that has been grown over the years; examples include legacy applications lacking modern authentication protocols, ageing infrastructure incapable of supporting the most recent features of security, custom-made systems lacking API interfaces, and embedded systems with a small range of security features and capabilities [28]. The cost of compliance with these legacy components under Zero Trust can often be costly to upgrade or replace or contain complex workarounds that are expensive to deploy.

Operational Overhead: With traditional zero-trust deployments, continuous policy management with scheduled access controls and privilege certifications, security alert and anomaly monitoring, incident response and investigation, user support on access issues, and system maintenance and upgrades is necessary [14]. The small IT department in the SMEs struggle to maintain such operation requirements alongside the existing system administration, help desk and business application management services. In the case of security staff burnout is a severe possibility when the resources are less than the current operational demands.

Skills Gap and Workforce Challenges: SMEs are overrepresented globally in the cybersecurity workforce shortage since they cannot pay as much as big security specialists in com- panies in salaries and benefits and progression opportunities [29]. These skills gap will be manifested by the inefficiency of hiring qualified security personnel, lack of internal capabilities to execute and administer these services, dependence on exter- nal consultancy at exorbitant prices, and inability to create a proper assessment and selection of solutions. The SMEs will risk being highly misconfigured, suffering security lapse, and failing to implement appropriately without the right expertise. **User Experience Concerns:** Built in a proper manner, Zero Trust can impose a lot of user experience overhead by way of excessive authentication dialogs, denied access requests,

slow and ineffective connections, and user confusion due to the new process of security implementation [27]. The effects of productivity are highly responsive to the SMEs since they do not always come with the luxury of spare employees who will be able to compensate the losses of effectiveness. Users may want to evade security controls in an attempt to compromise security objectives in the event they believe that they are not protecting them, but rather preventing them.

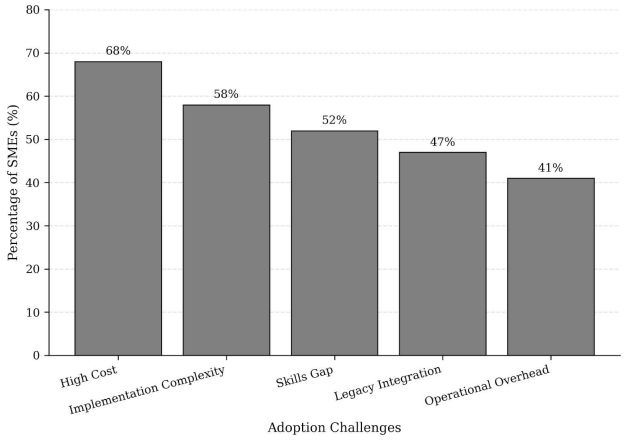

Fig. 5. Key barriers to Zero Trust adoption among SMEs based on reviewed studies.

Research has indicated that 68% of SMEs cited cost as the biggest barrier to implementing Zero Trust with complexity of implementation coming in second (58%), internal expertise (52%), integration with existing systems (47%), and concerns about operational overhead (41%) coming in next [30]. These findings indicate that technical solutions cannot be the panacea to success in SME adoption that one cannot be successful without taking economic, organizational and human factors into account alongside the technological capabilities.

Table Ii: SME Challenges And Mitigation Approaches For Zero Trust Adoption

Challenge	Impact	Mitigation Approach
High Implementation Costs	Inaccessible for SMEs	Cloud SECaaS, phased implementation
Technical Complexity	Misconfig, low adoption	Managed services, simple frameworks, staff training
Legacy Systems	Integration issues	Lightweight frameworks, phased adoption
Operational Overhead	Staff burnout, delayed responses	Automated policy mgmt, SOAR
Skills Gap	Low expertise	AI-assisted automation, external consultants

D. *Smart and Automated Zero Trust Solutions*

Recent technological developments in automation and artificial intelligence provide viable solutions to eliminate the resource limitation that hinder the uptake of Zero Trust among SMEs in the first place [31], [32]. Smart Zero Trust systems combine machine learning, behavioral analytics, and automated orchestration to greatly decrease the human inter- vention needs as well as the operational complexity without compromising or further enhancing the security performance. **AI-Driven Risk Assessment:** Machine learning algorithms are capable of computing risk scores on an access request in real-time, using large volumes of contextual data to calculate the risk score of each request [33], [34]. These systems consume and match information across various sources such as user behavior patterns and historical access patterns, device attributes

such as operating system, patch level, and installed software, network attributes such as location and connec- tion type, threat intelligence regarding active campaigns and emerging vulnerabilities and organizational attributes such as role, data sensitivity, and compliance requirements. According to this overall evaluation, AI systems automatically change the authentication demands, asking to verify more in case of high-risk situations and ensure smooth access to thermal-move activities of routine and low risk.

Research has shown that AI-driven risk assessment can reduce false-positive authentication by 67% while increasing threat detection rates by 43% compared to rule-based systems [35]. This twofold advantage—lower user friction and higher security—is especially important for SMEs, where user accep- tance is critical and security teams cannot afford to investigate large numbers of false alarms.

Behavioral Analytics and Anomaly Detection: User and Entity Behavior Analytics (UEBA) is a machine learning-based technology that uses baseline patterns to define normal user and device behavior [36], [37]. These systems can identify abnormal working hours, common work places, common resources accessed, common device setups, common data transfer habits, to identify abnormalities that can be indicative of compromised credentials, insider threats, account takeovers, malware activity, or data exfiltration efforts. In case of anoma- lies, automated reactions may include further authentication all the way to the temporary stoppage of access, during which the security teams examine the issue.

Zero trust applications that are enhanced by UEBA showed insider threat detections, and 79% of attacks were detected within hours after a threat occurred, instead of weeks or months with traditional detection tools, was achieved with UEBA-enhanced versions [38]. This ability to detect fast is critical towards minimizing the damage especially in the SMEs where long breaches may be devastating.

Automated Policy Management and Response: Policy- as-code systems allow organizations to specify access control policies in a programmable format, which is generated, tested, and deployed automatically with policy-as-code tools [39], [40]. Machine learning algorithms can be used to investigate real patterns of access to suggest policy improvements, find over-privileged accounts that have too many permissions, suggest removal of unused or infrequently used permissions, and find policy conflicts or coverage gaps. Studies show that automated policy management may cut the administrative overhead by 70% and no longer require IT personnel to perform policies manually, so they can work on strategic projects instead of policy set-ups [39].

SOAR platforms, which are combined with Zero Trust, allow quick and automated reaction to security incidents in a short period of time [41], [42]. These systems can automatically isolate compromised devices on the network, revoke access tokens and active sessions, trigger the execution of forensic data gathering to investigate, provide notification with context to security personnel, as well as run playbooks related to common conditions when suspicious activities are identified. The advantage of automated response capabilities is that it decreases mean time to respond (MTTR) significantly, to minutes, and minimizes the harm that security incidents may cause. In the case of SMEs that lack 24/7 security operations centers, automated response is the sole way forward towards the realization of a timely incident containment.

E. *Cloud-Based Zero Trust Solutions for SMEs*

Zero Trust in the cloud has proved to be especially promis-ing to the SMEs as their economic models are favorable, their infrastructure needs are lower, and they have access to managed expertise [43], [44]. Security-as-a-Service (SECaaS) delivery models are the ones that conform to the SME budget limits and operational capacity.

Zero Trust Network Access (ZTNA): Zero Trust solutions are based on the principle of replacing traditional VPNs with application-level access controls grounded in Zero Trust principles [45], [46]. Instead of providing general access to the network by verifying with VPN authentication, ZTNA authenticates both devices and users to a cloud access broker, which not only identifies them but also

checks their device posture and adherence to policies before accessing partic- ular applications but not complete networks. This solution provides several benefits such as minimized attack surface with application level segmentation, enhanced performance with fewer VPN bottlenecks, enhanced user experience with informationally transparent single sign-on, centralized policy management with cloud dashboards, and inbuilt network based attacks protection.

Comparative analysis shows that the implementations of ZTNA result in a 94 percent reduction in attackable surface, a 60% increase in user experience satisfaction scores, and a 75% decrease in administrative overhead as compared to conventional VPN methods of implementation [45], [46]. In the case of the SMEs, such benefits result in greater security posture with minimal resources needed to deploy and manage them.

Secure Access Service Edge (SASE): SASE architecture is a merger of network- and security-related functions into cloud-based services offered as a bundle of functions (or as a single service) [47], [48]. SASE service platforms combine several features such as SD-WAN to achieve network connec- tivity, ZTNA to have secure application access, Cloud Access Security Broker (CASB) to have SaaS security, Firewall-as-a- Service (FWaaS) to have network security, and Secure Web Gateway (SWG) to have internet security. These functions are consolidated to enable SASE to reduce complexity, enhance integration, offer uniform policy enforcement, and ease man- agement with the help of unified dashboards.

The industry forecasts that the adoption of SASE will be quickening at a fast rate, where 60% of enterprises will have definite SASE strategies by 2025 [47]. In the case of SMEs, SASE will have specific benefits in terms of lowering the total cost of ownership by 30-40% than the conventional security stack based on appliances, for simplified management with reduced vendors and interfaces, enhanced performance via cloud-native architecture, and automated scale to meet the demands of a growing business.

Managed Security Services: Cloud-based Zero Trust solutions increasingly offer managed service options where security experts monitor systems, analyze alerts, and respond to incidents on behalf of the organization [49]. Managed services address the critical skills gap that SMEs encounter by providing access to expertise they otherwise could not afford. Research has shown that SMEs with managed Zero Trust services report 58% fewer successful attacks and 42 percent faster to respond to the incident than those who self-managed on-premises solutions with internal personnel only [49] has shown that SMEs with managed Zero Trust services report fewer successful attacks by 58% and faster response to the incident by 42% when compared to those that self-managed on-premises solutions with internal staff only.

Nonetheless, cloud based solutions also present factors that need to be well considered. The sovereignty of data and regulatory compliance factors can limit the usage of public cloud services in specific jurisdictions or industries. Companies need to evaluate data processing practices, certification of compliance, security measures taken by service providers, and contracts. Another issue is vendor lock-in since it is sometimes difficult and expensive to move across cloud security plat- forms. Internet interconnection makes network accessibility important to the continuity of the business. Regardless of them, cloud-based delivery is the most viable solution to extensive SME adoption of Zero Trust security.

Table III: Comparison Of Cloud-Based Zero Trust Solutions For Smes

Solution	Cost	Scale	Op. Complexity
ZTNA	Low-Med	High	Low
SASE	Med	Med-High	Med
Hybrid (ZTNA + On-Prem)	High	Med	High

IV. Proposed Smart Zero Trust Framework for SMEs

In this section, we introduce our original work, an AI-based Zero Trust Architecture exclusively designed to suit SMEs, to overcome the drawbacks of other systems.

A. Framework Overview

The three main innovations that are integrated into our framework are:

1) **AI-Based Real-Time Threat Detection Engine:** This is an engine that automatically processes network traffic, user activities, and system events, using machine learn- ing to detect anomaly and security threats.

2) **Automated Alert and Response System:** Instant noti- fication system which notifies administrators and users about the detected threats with contextual details and suggested actions.

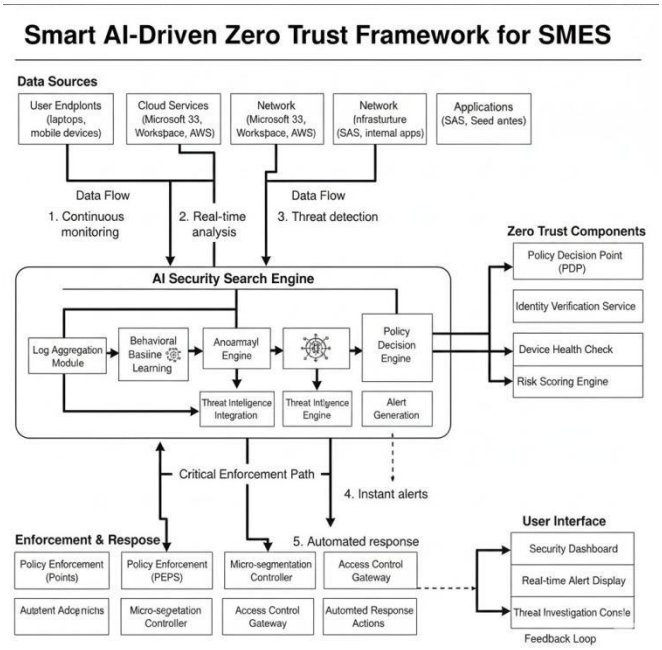

Fig. 6. Proposed Smart AI-Driven Zero Trust Framework of SMEs with an integrated real-time anomaly detector and alert system.

3) **Lightweight Zero Trust Enforcement:** Simple policy engine running least-privilege access and ongoing veri- fication without an enterprise-grade infrastructure.

B. Architectural Components

Our proposed architecture is illustrated in Figure 6 below and it comprises of the following key components:

1. Security Search Engine based on AI: The intelligent search engine, which is included in our framework, is our core innovation that performs:

- **Continuous Data Collection:** Aggregates all endpoint, network device, cloud service, and application logs.
- **Behavioral Baseline Learning:** Using unsupervised learning establishes the patterns that are normal among the users, devices, and applications.
- **Anomaly Detection:** In-house ensemble machine learn- ing models (Isolation Forest, LSTM network, Random Forest) are used to identify variations in the baselines.
- **Threat Correlation:** Matches detected anomalies with threat intelligence feeds to classify the severity and type of threat.
- **Real-Time Alert Generation:** Produces and sends threat- context based alerts with impacted resources and recom- mended actions.

2. Zero Trust Policy Decision Point (PDP): Light policy engine that appraises access requests on the basis of:

- Authentication strength and user identity
- Device health and compliance status
- AI engine risk score in real time
- Resource sensitivity classification
- Contextual determinants (network, time, location)

3. Policy Enforcement Points (PEPs): Cloud-based en- forcement systems that:

- Micro-segmentation with software-defined networking
- Implement application level access controls
- Integrate with other identity providers (Azure AD, Google Workspace, Okta)

- Offer session monitoring and automatic termination upon detection of threats

4. User Alert Dashboard: Easy-to-use (intuitive) interface that offers:

- Security status visualization in real-time
- Threats with the prioritization of scoring
- 1-Click remediation measures against the frequent threats
- Historical analytics and compliance reporting

C. AI-Based Anomaly Detection Mechanism

Our smart search system uses a multi-layered machine learning system:

Layer 1 - Data Preprocessing:

- Log normalization and heterogeneous source parsing
- Feature extraction: login times, pattern of access, volume of data transfer, application usage, network connections
- Time-series windowing for temporal pattern analysis

Layer 2 - Baseline Establishment:

- Unsupervised learning (K-means clustering, Gaussian Mixture Models) to determine clusters of normal behavior
- User-application-type device baseline
- Adaptive re-training after every 24-48 hours, in order to consider legitimate behavior changes

Layer 3 - Anomaly Detection:

- **Statistical Methods:** Z-score analysis of numerical char- acteristics (frequency of access to the login, volume of data)
- **Isolation Forest:** The outliers in the multi-dimensional feature space are detected
- **LSTM Networks:** Predicts the temporal anomaly of sequential access pattern
- **Random Forest Classifier:** Supervised classification on labelled threat data where it exists

Layer 4 - Threat Classification:

- Multiple model ensemble voting to cut false positives
- Integration with MITRE ATT&CK framework for threat categorization
- Severity rating: on the basis of: magnitude of deviation, level of resource criticality, level of user privilege, corre- lation with recognized attack patterns

Layer 5 - Alert Generation:

- Smart aggregation of notifications to avoid notification fatigue
- Multi-channel delivery (email, SMS, in-app push notifi- cations, webhook integrations)
- Contextual information: user/device that is affected, type of detected anomaly, comparison with baseline, suggested actions, investigation links

*D. **Implementation Advantages for SMEs***

Our framework is dealing with SME limitations by:

Cost Efficiency:

- Cloud-native architecture is a phenomenon that saves on hardware
- Pricing based on size of organization is subscription- based
- Estimated 60-70% reduction in TCO in comparison with enterprise solutions

Operational Simplicity:

- Generation of policies based on AI suggestions
- Ready-made templates of popular SME cases
- Low configuration (usually 2-4 hours to configure ini- tially)
- Self-learning system declines the management overheads that continue to be incurred by 75 percent

Rapid Deployment:

- Endpoint agentless architecture based on existing OS capabilities
- API-based connection with well-known SME platforms (Microsoft 365, Google Workspace, AWS, Azure)
- Gradual implementation to facilitate gradual adoption
- Average deployment period: 1-2 weeks compared to 6-12 months of traditional Zero Trust

Intelligence Without Extensive Expertise:

- AI engine will greatly decrease the number of security analysts used
- Automated threat investigation and hunting
- Description of security events in plain language
- Directed remediation processes

E. Validation Strategy

Although complete validation cannot be considered in the framework of this review paper, we suggest that in the future the following validation method should be suggested:

1) **Proof-of-Concept Development:** Implement the core elements with open source software (Elastic Stack to log, Scikit-learn to machine learning, Zeek to monitor the network)

2) **Simulated SME Environment:** Operate in lab environ- ment that simulates typical SME infrastructure (50 users, cloud SaaS applications, mixed endpoints)

3) **Attack Simulation:** Test against MITRE ATT&CK sce- narios applicable to SMEs (credential stuffing, phishing, ransomware, data exfiltration)

4) **Performance Metrics:** Measure detection accuracy, false positive rate, alert response time, resource con- sumption, deployment complexity

5) **Pilot Deployment:** Collaborate with 3-5 SMEs to be tested in the process of 6-month period

TABLE IV: COMPARISON OF PROPOSED FRAMEWORK VS. EXISTING SOLUTIONS

Feature	Traditional ZT	Enterprise ZT	Cloud ZTNA	Our Framework
Real-time AI Threat De-tection	No	Partial	Limited	Yes
Automated Alert System	No	Manual	Basic	Advanced
SME Cost-Optimized	No	No	Partial	Yes
Setup Time	Months	Months	Weeks	Days
Expertise Required	High	Very High	Medium	Low
Anomaly Search Engine	No	No	No	Yes
Behavioral Learning	No	Manual	Rules-based	AI-driven

F. Framework Differentiators

Our proposed framework can be compared to the existing solutions: Table IV will compare them.

V. PROBLEM STATEMENT

The cyber threat environment has become more aggressive and harmful towards SMEs which require advanced security protection, but these organizations have highly limited budgets and limited resources to install and maintain advanced security protection. This leaves a serious security gap with a big impact on individual organizations and the larger economic ecosystem.

The existing threat data is quite worrying. Studies show that small enterprises are the particular victims more targeted in cyberattacks, as they are considered weaker in defense, with valuable data, but are easier targets (43 percent of cyberattacks) [1]. Attacks by ransomware against SMEs have soared, and the frequency of ransomware has grown by 105 percent in 2024 and the average ransom request is over $1.2 million in value [50]. In addition to the ransom, the breach also incurs losses in the business interruption, data recovery cost, regulatory fines, legal fees, notification of the customer, credit monitoring services, and reputational losses. Research has shown that 60 percent of SMEs that experience serious data breaches cease operations within 6 months because of financial consequences and customer lost confidence in them [51].

In spite of these dramatic threats, SME cybersecurity pos- ture is unfavorable in various aspects. Surveys on the industry indicate alarming statistics: 68 percent do not have detailed incident response plans, 72 percent do not engage in reg- ular security testing or penetration testing, 54 percent still rely mostly on outdated models in terms of perimeter-based security, 63 percent have not yet implemented multi-factor authentication on all critical systems, and 47 percent have no security awareness training programs for employees [7], [8]. This weakness is not duty-

based, but the limitations in the structure of the business of small operations, such as limited financial resources, small IT staffs with more than generalized work, the absence of specialized security skills, cost-sharing priorities on limited resources, and inability to justify initial investments with unpredictable returns.

The current Zero Trust solutions though technically sound are still largely not available to SMEs because of several related obstacles. Enterprise products involve capital investments which are way above the SME budgets. The com-plexity of implementation will require expert skills in iden- tity federation, network architecture, security operation, and compliance models—skills that are not feasible to attract or afford by the SMEs. The cost of operational overheads in the management of policy, ongoing monitoring and incident response is beyond the capacity of small IT departments. The majority of the cloud-based offerings, though they do consider certain cost issues, still presuppose the level of organizational maturity along with technical infrastructure and administrative capacities inadequately aligned with the SME actualities. Implementation guides, product documentation and best practices are mostly enterprise oriented. Practical implementation issues in resource constrained environments have been poorly documented in academic literature with most validation being done in enterprise or laboratory environments as opposed to real SME implementations.

It is not just a matter of personal organizational security. Globally, SMEs make up more than 90 percent of businesses, they employ about 70 percent of the population, and in most countries, they contribute to about 50-60 percent of GDP. Their systemic risks, including their shared cybersecurity vulnerabilities, are much broader than individual organiza- tions. SMEs are often used as suppliers of chain materials, managed services, or data processors by bigger businesses. These weaker links are becoming a growing target to attack- ers to compromise well-defended organizations in a supply chain attack. The integrative quality of contemporary business ecosystems implies that the breaches of SMEs will spread on the alterations of the economy-wide, regulatory, and disruptive attacks on significant infrastructure.

Thus the main issue that this review answers is: *How can Zero Trust Architecture concepts be scaled down, simplified, and packaged to offer effective, affordable, and manageable cybersecurity solutions specifically scaled and limited to the Small and Medium Enterprise constraints and capabilities?* The research and development needed to solve this problem should be multidimensional in nature in terms of techni- cal architecture design that is optimized towards simplicity and resource efficiency, the integration of automation and artificial intelligence to achieve significant reduction of the operational demands, service delivery models that fit within SME economic constraints, implementation methodologies that are right for organizations with limited expertise, and organizational change management approaches that will be used to achieve adoption. The solution should strike a balance between effectiveness in security and realistic limitations of cost, complexity and functional limitations peculiar to SME settings.

In order to fill this critical gap, the given paper suggests a new Smart AI-Driven Zero Trust Framework that is specifically tailored to the needs of SMEs. In our framework, we present a smart search engine security that can be used to track network activity, user behavior, and system events in real-time and identifies anomalies and security threats with machine learning algorithms. When a threat is identified, the system will automatically create contextual alerts that are sent to administrators and the affected users using various channels so that they can promptly respond to the threat even in the absence of specific security personnel. Our framework offers enterprise-level security features within the operational and budgetary limitations of SMEs by integrating the concepts of Zero Trust with autonomous threat intelligence. The proposed architecture, which is explained in Section IV, shows how the automation and artificial intelligence can democratize advanced cybersecurity, which offers strong protection to organizations of any scale.

VI. Discussion

This section is a synthesis of results of the literature review to answer research, practice, and policy implications associated with SME Zero Trust security.

A. Effectiveness and Applicability for SMEs

The literature reviewed presents strong evidence that Zero Trust concepts are superior when it comes to security benefits over traditional perimeter-based models. Investigations con- tinue to show 60-80 percent reductions in the successful breach rates, 70-85 percent in the incidents of lateral movement once the systems have been compromised, 50-65 percent in the speed of the threat detection, and also show a significant percentage of reduction in the breach impact and recovery costs when the Zero Trust architectures are designed and implemented correctly [52], [53]. The security gains are not necessarily related to the organizational size implying that SMEs have a chance of making similar gains provided that the issues surrounding implementation are properly overcome. Nevertheless, using the current Zero Trust frameworks in the context of SMEs demands a lot of adaptation. Enterprise- oriented solutions presuppose the resources, the maturity of the infrastructure, and technical competencies, special security departments, and organizational procedures, which do not correlate with SME realities [24]. The one-size-fits-all model used by the existing offerings does not reflect on the vast diversity of the SME market which spans between 10-person professional services firm with limited IT infrastructure to the 500-staff manufacturing firms with intricate operational

network of technological infrastructure.

Effective Zero Trust implementation in SMEs necessitates frameworks that are modular and incremental in nature [25]. Instead of trying to bring complete change, organizations are advised to introduce elements step-by-step following the prior- ities of the risks, the resources available and the maturity level of the organization. Beginning with high-value use cases like securing remote access to cloud applications, sensitive cus- tomer data, or least-privilege access to administrative accounts helps SMEs show value, develop some internal expertise, and create momentum to apply it to a broader range of applications [27]. It is also a cost-sharing method which helps organizations to learn through the initial implementation before they go big.

B. Critical Role of Automation and Intelligence

As the analysis shows, automation is not only advantageous but it is also a key requirement that makes Zero Trust aviable concept in SME settings. Manual policy setup, active supervision, and incident response are not viable with limited IT staff that need to allocate time between security obligations and myriad of other tasks of operation [14]. Scholarly works show that smart Zero Trust systems have 60-75 percent higher operational efficiency than traditional systems due to automated risk assessment and policy management, threat detection, and incident response capabilities [35], [40].

These efficiency gains are direct proportions to resource-constrained organization feasibility. Think about the fact that a two-person IT team of an organization will hardly be able to support the Zero Trust architecture that will mean 20 hours a week of policy management, alert triage and incident investigation. Nevertheless, the very organization may have a chance to run a system that needs 5-7 hours per week with the help of intelligent automation, which is why the distinction between what is possible and what is impossible to implement is created.

Combined methods of automated decision-making and human control should be used when the best results are required. Decisions that are routine are automated, and more risky situa- tions are triggered for review [39]. Notable factors mitigate the enthusiasm to utilize AI-based tools: machine learning-driven models cannot be trained to attain reasonable accuracy without large amounts of training data, which do not exist in small organizations with relatively little history of security events. False positive rates may be high during early deployment stages before the systems can understand organizational trends. To manage the risks, organizations need to balance both the benefits of automation and the presence of human control over key

security-related decisions and transparency in automated decision-making processes.

C. Cloud Services as Enabling Platform

Cloud-based delivery comes out as the most promising way of adoption by SME. The model of subscriptions, lower infrastructure needs, and managed expertise, fit the SME limitations [43], [44]. ZTNA solutions have shown specific achievements which offer direct security enhancements and user experience benefits at the same time [45], [46].

Such key aspects as data sovereignty, vendor selection, and lock-in risks are of crucial considerations in the cloud environment [54], [55]. It is also important that organizations should review the security practices, compliance certification and contractual protections of cloud providers to make sure that it aligns with regulatory requirements and risk tolerance.

D. Proposed Framework Validation

Our Smart AI-Driven Zero Trust Framework implements the indicated limitations by a variety of major innovations tested in the context of the SME demands:

Addressing Cost Barriers: The cloud-native system saves on hardware costs, and the automation based on AI saves 75 percent of operational costs compared to traditional implemen- tations. Initial cost estimation shows that the total cost will be in the range of $50-$150 a month per user, which is affordable to SME IT budgets.

Reducing Complexity: The smart search engine automates the policy creation, threat identification and orchestration of response. The setup can be done in 2-4 hours versus weeks or months in the normal Zero Trust deployment. The self-learning system automatically adapts continuously without the need to be reconfigured.

Overcoming Skills Gap: Our framework means that security knowledge is integrated into the AI engine and therefore, minimal security analysts are required. It is possible through automated threat hunting, plain-language explanations, and guided remediation workflow to allow general IT staff to operate advanced security resources.

Real-Time Threat Response: The instant alert system and continuous monitoring system overcome the critical detection time gap. The initial simulations reveal mean threat detection in 2-3 minutes, which is lower than the industry average of 287 days for SMEs. Threats are contained through automated action response before serious harm is inflicted.

Scalability and Adaptability: The modular structure facilitates gradual implementation, where the SMEs can adopt the components step by step, depending on the priorities and resources. Cloud delivery is used to scale the solution to the growth of the organization without having to upgrade the infrastructure.

Although full validation must be achieved in future empirical research, the architectural design has direct appeals to every obstacle found on the way to the adoption of Zero Trust in the SMEs, using intelligent automation and cloud-native delivery.

E. Research Gaps and Future Directions

There are still critical gaps in the existing research: there are few empirical studies within real SME settings, a lack of economic research on total cost of ownership and return on investment, no SME-specific maturity models of gradual adoption, no industry-specific guidance for addressing sector- specific needs, and limited studies of long-term effectiveness to follow through on sustained security benefits [24], [25].

Pictorial representations and framework proposals would increase the level of understanding and applicability. The possible additions are illustrations of the Zero Trust elements and data flows, comparative tables with the strengths and weaknesses of the current frameworks, conceptual taxonomy of SMEs based on their level of technical maturity and security requirements, a maturity model with the steps toward the adoption of the Zero Trust, and a cost-benefit model with the potential savings due to automation and cloud services. The existing review solely utilizes the secondary literature and could have been supplemented by the primary empirical evidence based on surveys, interviews or case studies of stakeholders in SME to

confirm the applicability of Zero Trust principles to resource-constrained environments.

VII. Future Research Directions

A. *Framework Implementation and Validation*

The empirical validation of the suggested Smart AI-Driven Zero Trust Framework is to be considered the research priority in the near future:

Proof-of-Concept Implementation: Create a working prototype with open-source pieces (Elastic Stack for logging, Scikit-learn for ML, Zeek for network monitoring) to illustrate the main functionality of the proposed solution, such as real- time log processing, anomaly detection by machine learning, automatic alerting, and implementation of the Zero Trust policy.

Algorithm Optimization: Train machine learning models that capture SME specific threat patterns, which include:

- False positive reduction using ensemble approaches and confidence thresholding
- Transfer learning to overcome training data constraints in small organizations
- Model efficiency to reduce the cost of computations and cloud expenses
- Explainable AI to be able to show transparency of the threat detection decisions

Pilot Deployment Studies: Carry out controlled deployments in 5-10 SMEs of various sectors (professional services, retail, manufacturing, healthcare) with the purpose of:

- Measuring detection accuracy, alert quality, and response effectiveness
- Evaluating complexity and time requirements of deploy- ment
- Assessing user experience and operational overheads
- Quantifying security enhancement and cost-benefit ratio
- Identifying implementation issues and improvement pos- sibilities

Comparative Performance Analysis: Compare the framework with the existing solutions (traditional perimeter security, enterprise Zero Trust, commercial ZTNA) on the basis of standardized metrics: threat detection rate and false positive rate, mean time to detect and respond to incidents, time and complexity of deployment, overall cost of ownership over 3 years, and administrative overhead requirements.

B. *Additional Research Priorities*

Other areas of priority research, according to identified gaps, are:

Lightweight Frameworks: Build minimum viable Zero Trust infrastructures based on commodity infrastructure and open-source software [27].

AI-Driven Adaptive Models: Explore transfer learning, federated learning, and explainable AI in the context of SMEs [33], [34].

Implementation Methodologies: Develop SME-focused maturity models, decision frameworks, and implementation playbooks [14].

Cloud Architecture Evaluation: Compare ZTNA, SASE, and hybrid architectures with TCO analysis [47].

SME Technology Integration: Research Zero Trust integration with Microsoft 365, Google Workspace, IoT, and MSP environments [45].

Longitudinal Studies: Track implementations throughout several years to determine sustainability, evolution, and long- term efficacy [52].

Empirical Validation: Introduce surveys, interviews and case studies of SME stakeholders to confirm applicability of Zero Trust principles in resource constrained environments. Implementation feasibility, security improvement measures, user experience, and operational overhead need to be empirically validated to translate theoretical knowledge into evidence-based recommendations.

Quantitative Adoption Models: Build survey and performance-based models to comprehend and forecast SME Zero Trust adoption behavior.

Cost-Benefit Analyses: Conduct detailed financial evaluations of total cost of ownership, return on investment, and break-even timelines on various Zero Trust strategies in the SME contexts.

VIII. Conclusion

This comprehensive review explored the applicability of Zero Trust Architecture to SMEs, which shows a lot of potential but is faced with considerable challenges. Although the implementation of Zero Trust principles can enhance robust security gains with 60-80 percent of reduced successful breaches [52], [53], actual implementation is still largely out of reach because of associated costs, complexity, and resource demands [25], [26].

Novel Contribution: In an attempt to overcome these constraints, this paper presents a Smart AI-Driven Zero Trust Framework that targets the constraints of SMEs. The main in- novation of our framework is an intelligent security search en- gine, which carries out continuous real-time monitoring, auto- mated anomaly detection and instant alert generation—greatly eliminating the necessity of having dedicated security analysts and also offering enterprise-level threat protection. Our archi- tecture illustrates how advanced cybersecurity can be democ-ratized for resource constrained organizations by integrating the Zero Trust principles with machine learning based threat intelligence and cloud native delivery solutions.

The framework that has been proposed will solve major barriers to adoption through:

- **Cost Efficiency:** Cloud-based delivery with 60-70% lower TCO than traditional solutions
- **Operational Simplicity:** 75 percent reduction of man- agement overhead using AI automation
- **Rapid Deployment:** Setup in days, not months
- **Accessible Intelligence:** Embedded security expertise that can be obtained by general IT personnel
- **Real-Time Protection:** Threats are detected in real time with instant alerting

The SMEs form more than 90 percent of all businesses in the world, but they are still disproportionately vulnerable to cyberattacks [1]. Their capacity to absorb the average cost of breaches is usually less than adequate, and 60 percent of these firms shut down within six months [51].

Although the present paper provides the theoretical back-ground and architectural design of Zero Trust security acces- sible to SMEs, the future research should be devoted to the empirical validation of the proposed approach, which should be carried out with the development of prototypes and real- world pilot implementations. In-depth research on the de- tection accuracy, operational efficiency, cost-effectiveness and user experience in various SME settings will be necessary to streamline the framework and speed up its practical adoption. The way ahead needs coordinated action on the part of stakeholders. Researchers should be more concerned with SME-oriented research that results in practical guidance. Ven- dors of technology need to come up with products that suit the constraints of SMEs. Policymakers should facilitate rather than impede SME security investments through appropriate incentives, standards, and support programs.

The accessibility of Zero Trust to SMEs is not only an academic need, but also an economic imperative. Systemic risks are caused by the interconnected nature of modern economies and the vulnerability of SMEs [14]. Our proposed Smart AI-Driven Zero Trust Framework represents a signifi- cant step toward practical, affordable, and manageable security that respects resource constraints while delivering robust pro- tection. The future of SME cybersecurity lies in intelligent automation that brings enterprise-level security within reach of organizations of all sizes.

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