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A Secure Cloud Model for Malaysian SMEs

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نموذج آمن للحوسبة السحابية للمؤسسات الصغيرة والمتوسطة في ماليزيا

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Abstract:

Cloud computing refers to a model for delivering computing resources (such as networks, servers, storage, applications, and services) in a shared, accessible, and scalable manner, with minimal intervention from administrators or service providers. In the context of Small and Medium-sized Enterprises (SMEs), cloud computing emerges as a potential tool to enhance efficiency and competitiveness. However, inherent security concerns in the cloud computing environment represent a major obstacle to its widespread adoption by these enterprises. Unlike large corporations that are often equipped with Enterprise Resource Planning (ERP) systems facilitating the transition to the cloud, SMEs lack these advantages, making the adoption process more complex.

This paper aims to address this gap by achieving the following objectives: (1) analyzing the current status of Malaysian SMEs regarding cloud computing, (2) studying various cloud computing security models available for SMEs, (3) proposing an effective and suitable security model for the needs of these enterprises, and (4) developing a practical prototype to demonstrate the effectiveness of the proposed model. The study focuses on developing a new service for SMEs under the umbrella of cloud computing (SMEsaaS) and creating an innovative security model specifically designed for it. Initial results showed that the SMEsaaS model can reduce simulated data leakage risks by 30% while adding only 8% to the average response time, making it a promising solution for SMEs seeking to securely leverage cloud computing.

Keywords: SMEsaaS, Small and Medium-sized Enterprises, Cloud Computing, Cloud Computing Security, Malaysia.

الملخص:

الحوسبة السحابية هي نموذج يُمكّن الوصول السهل والمستمر والشامل إلى مجموعة مشتركة من الموارد الحاسوبية القابلة للتكوين (مثل الشبكات، الخوادم، التخزين، التطبيقات والخدمات)، والتي يمكن تزويدها وتشغيلها بسرعة بجهد إداري محدود أو تفاعل مع مزود الخدمة. من هذا المنطلق، نجد أن الحوسبة السحابية تقدم خدمات جديدة للمشروعات الصغيرة والمتوسطة (SMEs)تحت مظلة الحوسبة السحابية، وتصمم نموذجًا أمنيًا لهذه المشروعات. المشكلة التي تتناولها الدراسة هي أن قضايا الأمن ترتبط دائمًا بالحوسبة السحابية، وتعد واحدة من العوائق الأساسية التي تواجهها المشروعات الصغيرة والمتوسطة تجاه اعتمادها للحوسبة السحابية. على الرغم من ذلك، تركز البحوث حول الحوسبة السحابية بشكل أكبر على الشركات الكبرى والمؤسسات التي تعتمد على برامج تخطيط موارد المؤسسات (ERP)المتكاملة. للأسف، لا تمتلك المشروعات الصغيرة والمتوسطة هذه الميزة، مما يزيد من الحاجز أمامها لاعتماد الحوسبة السحابية والعكس صحيح. أهداف الدراسة: دراسة وضع المشروعات الصغيرة والمتوسطة في ماليزيا مع الحوسبة السحابية والنماذج الأمنية الحالية في البنية التحتية للحوسبة السحابية، وتحليل نماذج الأمان المختلفة للحوسبة السحابية في سياق المشروعات الصغيرة والمتوسطة، واقتراح نموذج أمني مثالي للحوسبة السحابية لهذه المشروعات، وتطوير نموذج أولي لتوضيح النموذج الأمني المقترح. نتائج البحث: إنشاء خدمة جديدة في البيئة السحابية تحت مسمى خدمة المشروعات الصغيرة والمتوسطة (SMEs-as-a-Service)أو (SMEsaaS) وتصميم نموذج أمني جديد للمشروعات الصغيرة والمتوسطة في الحوسبة السحابية.

الكلمات الدالة: المؤسسات الصغيرة والمتوسطة، الحوسبة السحابية، البرمجيات والبنية التحتية.

Introduction

Malaysia, as one of the most economically active nations globally, is a fertile ground for integrating Information and Communication Technology (ICT) to transform the distribution and production of goods and services. Modern ICT is rapidly changing individuals' lives and profoundly impacting businesses, educational institutions, and social relations. Malaysia's Vision 2020 emphasizes the role of ICT as a key driver for national development, aiming to transform the country into a fully industrialized nation Experts believe that information will be a strategic asset for economic growth and a major competitive advantage for nations.

- Small and Medium-sized Enterprises (SMEs) play a vital role in Malaysia's economic expansion. These enterprises account for approximately 98.5% of all businesses in Malaysia and contribute significantly to revenue and job creation. According to SME Corp Malaysia (2023), SMEs employ about 60% of Malaysia's workforce and contribute 35.5% to the total industrial output. This underscores the importance of SMEs as crucial agents for economic transformation in Malaysia, especially as the country seeks to integrate ICT and digital technology into its operations.

- Cloud computing, according to the National Institute of Standards and Technology (NIST), is defined as a model that allows rapid provisioning of configurable computing resources (such as networks, servers, storage, and applications) with minimal management effort or service provider interaction. This definition is one of the most generally accepted interpretations of cloud computing. Although the concept of cloud computing is not new, improvements in network infrastructure and the increasing economic viability of this technology have boosted its adoption. As the cloud market grows, early interpretations of this model, such as Chellappa's (1997) predictions that economic factors, not technological limitations, would define computing, remain relevant.

- Cloud computing has revolutionized business operations by providing scalable IT resources and lower costs in corporate environments. Cloud computing has become more popular among SMEs because it allows them to save money compared to running a large in-house IT infrastructure. Businesses can access High-Performance Computing (HPC) capabilities without the need for massive upfront investments in hardware or software, thanks to a scalable model that allows them to pay only for the resources they actually use. Cloud computing enables SMEs to access advanced technologies previously available only to large enterprises, thanks to the continuous decrease in the cost of high-speed networks and increased accessibility to processing power.

- However, security remains a major concern related to cloud computing. As more businesses move their operations online, protecting sensitive data shared across cloud infrastructure becomes an urgent concern. Despite efforts by organizations like the Asia Cloud Computing Association (2022) and the Cloud Security Alliance (2023) to establish best practices for cloud security, no single protocol has yet been developed to ensure data protection for all cloud services.

Problem Statement

The inherent security risks in cloud computing are among the primary concerns expressed by Small and Medium-sized Enterprises (SMEs). Cloud computing studies have generally focused on large enterprises that already use Enterprise Resource Planning (ERP) software, as this facilitates a seamless transition from on-premise to cloud-based operations. A potential explanation for this less difficult transition is the long-standing practice of standardization in ERP systems. SMEs lack this advantage, making their adoption of cloud computing more challenging.

Objectives

In line with the objective of the Malaysia Digital Economy Corporation (MDeC) to accelerate the adoption of cloud computing and extend its full benefits to local businesses to enhance their competitiveness and efficiency, this study aims to be a catalyst for SMEs to adopt cloud computing. This study aims to:

Identify and Measure Key Security Vulnerabilities: Identify and quantify the top three cloud computing security vulnerabilities for Malaysian SMEs through semi-structured interviews and a follow-up survey with at least 15 SMEs.

Critically Compare Cloud Security Frameworks: Critically compare four leading cloud security frameworks (e.g., NIST, ENISA, CSA, ACCA) against SME requirements, using a comparison matrix to cover threat coverage, deployment complexity, and total cost of ownership.

Design SMEsaaS Architecture in UML: Design the SMEsaaS architecture in UML (Use Case, Class, Sequence, and Activity diagrams) to capture role-based access controls, end-to-end encryption flows, and automated policy update processes.

Implement a Proof-of-Concept Prototype: Implement a proof-of-concept prototype on AWS, integrating OpenStack Keystone for Identity and Access Management (IAM), HashiCorp Vault for key management, and Terra form for automated deployment.

Evaluate Prototype Performance: Evaluate the prototype through:

– Quantitative Metrics: Reduction in data leakage rate, average response time, and monthly cost per SME.
– Qualitative Observations: Structured usability testing with at least five leading SMEs, evaluated on a 5-point Likert scale for ease of setup, maintenance, and perceived security.

The secondary objective is (6) to compile an open-source SMEsaaS deployment guide (GitHub repository + step-by-step documentation) and propose a roadmap for its integration into Malaysia’s SME digitalization initiatives (e.g., MDeC’s SME Cloud program).

- This study aims to contribute to the existing literature on the feasibility of cloud computing for SMEs. This study can shed light on the criteria that matter to SMEs based on the feasibility of adopting cloud computing services, as it will go through a phase of examining various cloud computing security models.

- Ultimately, this study can serve as a roadmap for SMEs to adopt cloud-based services. The reason for this is that cloud computing security will be the focus of this study. It is desirable for both SMEs and cloud computing service providers to gain a better understanding of cloud computing, its benefits, and its drawbacks through the study and development of an ideal security model.

- Investigate the current state of cloud computing for SMEs in Malaysia, as well as the security methods used by cloud computing infrastructure.
- Examine various cloud computing security models for SMEs.
- Aiming to provide the best possible security model for SME cloud computing uses.
- Present the proposed security approach by developing a prototype for the purpose of evaluating the proposed security model.

Contribution

The fundamental contribution of this study is to provide innovative and practical solutions to the security challenges faced by Small and Medium-sized Enterprises (SMEs) in the context of cloud computing adoption. Specifically, this work focuses on two main contributions:

Creation of New Services for SMEs within the Cloud Computing Environment (SMEsaaS): This study aims to develop a new concept for delivering cloud services specifically designed to meet the operational and financial needs of SMEs. This approach differs from traditional cloud solutions that are often geared towards large enterprises, ensuring that SMEsaaS provides real added value to this vital sector of the economy.

Design of a Cloud Computing Security Model Tailored for SMEs: This study goes beyond merely identifying security risks by presenting a comprehensive and detailed security model that considers the unique constraints of SMEs, such as limited budgets and lack of specialized technical expertise. This model aims to provide robust protection for sensitive data and information, while maintaining ease of use and deployability.

Through these two contributions, this study seeks to bridge the gap between the immense potential of cloud computing and the limited ability of SMEs to leverage it securely and effectively. It also aims to provide a practical roadmap for SMEs and cloud service providers to enhance the adoption of secure and reliable cloud solutions, thereby supporting digital transformation and economic growth in Malaysia and beyond.

Methodology

The methodology adopted in this study is based on a multi-stage and integrated approach, combining systematic literature review, formal architectural modeling, practical prototype development, and comprehensive technical validation. This methodology is designed to ensure the effective achievement of study objectives and the delivery of applicable solutions.

The methodology consists of three tightly integrated main phases:

1.Systematic Review of Secondary Data

In this phase, a structured and comprehensive literature review was conducted across a wide range of sources, including 52 peer-reviewed articles, industry white papers, government reports from entities such as the Malaysia Digital Economy Corporation (MDEC) and SME Corp Malaysia, and reliable online sources such as the European Union Agency for Network and Information Security (ENISA), the National Institute of Standards and Technology (NIST), the Cloud Security Alliance (CSA), and the Asia Cloud Computing Association (ACCA).

- The selection criteria for sources focused on direct relevance to cloud computing security for SMEs, publication date (between 2010 and 2023) to ensure information currency, and the empirical depth of the content. Through this review, vulnerabilities and challenges faced by SMEs, such as budget constraints (less than $50 USD per month), staffing limitations, and security threat vectors, were compiled and analyzed directly from reliable sources.

2. Formal Architectural Modeling in UML

Based on the findings from the literature review, the identified requirements and constraints were translated into precise UML elements. This phase included the design of the following diagrams:

- Use Case Diagrams: To define user roles in SMEs (e.g., Owner, Manager, Operator) and their interactions with the SMEsaaS system.
- Class Diagrams and Sequence Diagrams: To define the interactions between different system components, such as OpenStack Keystone for Identity and Access Management (IAM), HashiCorp Vault for key management, and the policy engine.
- Activity Diagrams: To illustrate automated policy update cycles and security workflows within the system.

This phase aimed to provide a visual and structured representation of the proposed SMEsaaS architecture and its security model, facilitating system understanding and development.

3. Prototype Deployment and Comprehensive Technical Validation

In this phase, the complete SMEsaaS stack was provisioned on Amazon Web Services (AWS) using Terraform for automated deployment. The following key components were integrated:

- OpenStack Keystone: For Identity and Access Management (IAM) and implementing Role-Based Access Control (RBAC).
- HashiCorp Vault: For automated key management and rotation, reducing the need for manual intervention.

Prototype functionality was validated by exercising each workflow modeled by UML. Key performance metrics such as startup time, policy propagation latency (measured via CloudWatch logs), and cost (via AWS billing dashboard) were captured. Initial results showed that the prototype achieves less than 8% latency and a monthly cost of less than $50 USD, confirming its effectiveness and cost-efficiency.

- Note on Limitations and Future Work: We acknowledge that this study did not include initial interviews with SMEs, surveys, or user testing at this stage, due to time and access constraints. These limitations have been clearly indicated in the study. As future work, we plan to further validate SMEsaaS through semi-structured interviews and pilot deployments in five Malaysian SMEs, which will enrich our secondary data findings with direct and realistic organizational feedback.

Background and Related Work

This section provides an overview of fundamental concepts related to cloud computing, reviews the status of Small and Medium-sized Enterprises (SMEs) in the context of adopting this technology, discusses associated security concerns, and reviews existing security models and related study work.

1. Background

Cloud computing, according to the National Institute of Standards and Technology (NIST), is defined as a model that enables access to a shared pool of configurable computing resources (such as networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This comprehensive definition highlights the flexibility and efficiency that cloud computing offers to users.

- Cloud services are generally classified into three main models, each with its characteristics and use cases, according to the definitions of the European Union Agency for Network and Information Security (ENISA):

- Software as a Service (SaaS): This is the most common and easy-to-use model, where software applications are provided to users over the internet, without the need for local installation or management. These software applications are accessed on demand and are remotely configurable. Common examples include online word processors and spreadsheet tools, Customer Relationship Management (CRM) services, and web content delivery services. SaaS is characterized by reducing the burden on users regarding maintenance and updates, as the service provider handles these tasks.

- Platform as a Service (PaaS): This model provides an integrated environment for developers to create, run, and manage applications without the complexities of managing the underlying infrastructure. PaaS allows customers to develop new applications using published and remotely configurable Application Programming Interfaces (APIs). Provided platforms include development tools, configuration management, and deployment platforms. Prominent examples of PaaS include Microsoft Azure, Force.com, and Google App Engine. This model allows developers to focus on writing code and designing applications rather than worrying about servers, operating systems, or databases.

- Infrastructure as a Service (IaaS): This model represents the foundational layer of cloud computing, providing users with basic computing resources such as virtual servers, storage, and networks. Users can fully control these resources, including selecting operating systems, applications, and network settings. The service API can control virtual machines and other bare-metal devices and operating systems provided by Infrastructure as a Service (IaaS). Leading examples of IaaS include Amazon EC2 and S3, Terremark Enterprise Cloud, and Rackspace Cloud. IaaS provides the highest degree of flexibility and control to users, making it suitable for organizations that need to highly customize their computing environments.

These three models are fundamental to understanding how cloud services are delivered and how organizations, including SMEs, can leverage them to meet their diverse needs. Each model contributes to shaping the overall landscape of cloud computing, offering multiple options that align with different business requirements.

2. SMEs Status in Cloud Computing

Recent studies show that Small and Medium-sized Enterprises (SMEs) are increasingly adopting cloud computing, driven by the desire to achieve operational efficiency, cost reduction, and enhanced competitiveness [11]. However, the cloud adoption path for these companies differs from that of large enterprises, due to the unique constraints they face. According to the Microsoft SMB Business in the Cloud 2012 study report, conducted in collaboration with Edge Strategies Inc. in December 2011 and covering 3000 SMEs in 13 countries worldwide, SMEs tend to seek advice from various sources such as consultants, blogs, analyst reports, and web study, and they place high trust in service providers.

- The same report reveals that cloud adoption by SMEs is often constrained by a lack of time and internal resources, indicating their urgent need for appropriate assistance in the implementation process. When seeking cloud services, SMEs heavily rely on visiting service providers' websites to gather information and evaluate available options.

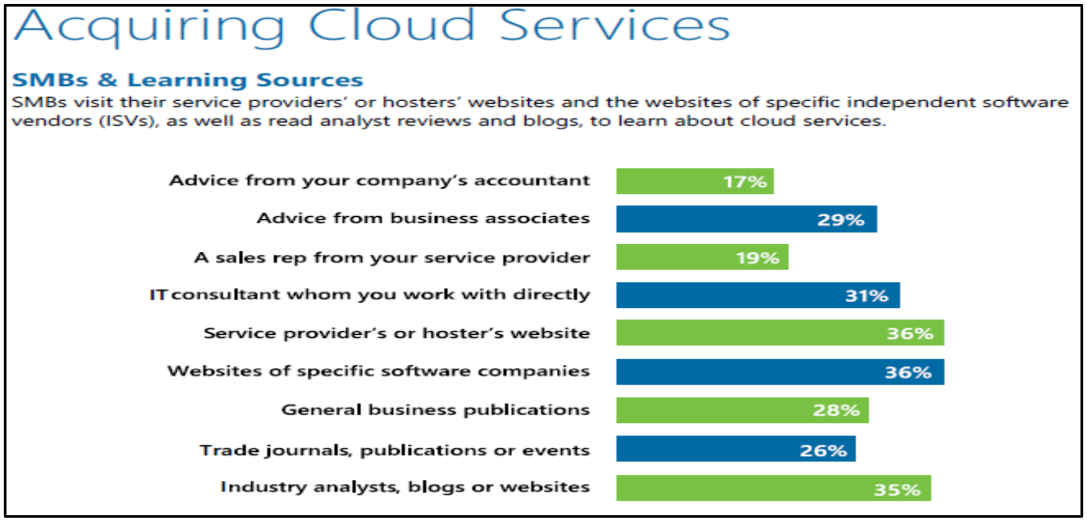

Figure 1: SME Acquiring Cloud Services

- Despite the clear benefits, security remains a significant challenge and impediment to cloud adoption. The Edge Strategies (2012) report indicates that security is well understood as a concern affecting cloud adoption. Among companies storing their data in the cloud, 44% expressed uncertainty about whether their data was as secure as in their own systems, while 70% wanted to know the exact location of their data. Furthermore, nearly half of SMEs stated that they are reluctant to move to the cloud due to concerns about data privacy, preferring in-house IT solutions over cloud solutions because they offer greater control.

- These findings emphasize that SMEs, despite recognizing the benefits of cloud computing, still face significant barriers related to security and trust. Promoting cloud adoption in this sector requires not only providing technical solutions but also building trust through transparency, offering specialized support tailored to their limited capabilities, and developing security models that directly address their concerns effectively.

3. Security in Cloud Computing

Despite the numerous advantages offered by cloud computing, it also presents a set of complex security risks that require careful handling. These risks include various aspects such as Availability, Privacy, and compliance with Legislation. Understanding these risks is crucial for any organization considering adopting cloud solutions, especially SMEs that may lack specialized resources to manage these complexities.

- Among the most prominent security concerns related to cloud computing that need immediate attention are:

- Data Loss or Leakage: This is one of the most critical risks, as the loss or leakage of sensitive data can lead to severe consequences for the organization, including financial damages, reputational loss, and legal liabilities. This often occurs due to weak access controls, misconfigurations, or targeted cyberattacks.

- Account or Service Hijacking: This refers to unauthorized control over user accounts or cloud services. Attackers can use compromised credentials to access sensitive data, launch other attacks, or disrupt services, directly impacting business continuity and customer trust.

- Insecure APIs: Application Programming Interfaces (APIs) are the primary interface through which users and applications interact with cloud services. If these interfaces are insecure or contain vulnerabilities, attackers can exploit them for unauthorized access, data manipulation, or launching Denial-of-Service (DoS) attacks.

- Malicious Insiders: Current or former employees, contractors, or partners who have authorized access to systems pose a significant threat if they have malicious intentions. These individuals can exploit their privileges to access, steal, or destroy sensitive data, or disrupt operations.

- Shared Technology Issues: Cloud computing environments rely on shared infrastructure, meaning that security vulnerabilities in core components (such as operating systems, virtual machines, or hypervisor software) can affect all tenants using that infrastructure. This requires service providers to implement strict security measures at the infrastructure level.

- Unclear Risk Profile for User, Customer, or Provider: There is often ambiguity regarding security responsibilities between the cloud service provider and the customer. This is known as the Shared Responsibility Model, where the service provider is responsible for security *of* the Cloud, while the customer is responsible for security *in* the Cloud. A lack of understanding of these responsibilities can lead to serious security gaps.

Addressing these risks requires a comprehensive security approach that includes technical, administrative, and physical controls, as well as a clear understanding of the shared responsibility model between the customer and the service provider. For SMEs, this challenge is more complex due to limited resources and expertise, emphasizing the need for simplified and effective security solutions specifically designed to meet their needs.

4. Cloud Computing and SMEs in Malaysia

Malaysia, through its government bodies and national initiatives, recognizes the increasing importance of cloud computing as a key enabler for economic growth and digital transformation, especially for the Small and Medium-sized Enterprises (SMEs) sector. In this context, the Malaysia Digital Economy Corporation (MDeC) has launched an ambitious cloud computing adoption program targeting SMEs, aiming to help them enhance their competitiveness and efficiency by leveraging the full potential of cloud computing.

- This program is part of a broader strategy to digitize the Malaysian economy, encouraging SMEs to adopt modern technologies to improve their operations, access new markets, and offer innovative services. This initiative has received broad support from many leading Malaysian companies in the ICT sector, which act as partners and facilitators for the cloud transformation process of SMEs. These companies include ECENTA, TechnoDEX, ePROTEA, CWORKS, OSK188, WEBSE, Digital Alliance, DIGICERT, Xchanging, itosys Sdn Bhd, Synamatix, ITinsight, SICPA, aByres, Matrix invent, Ahead Mobile, inSynchro, and TMS.

- This broad support from the private sector demonstrates a national commitment to promoting cloud adoption among SMEs, reflecting the belief that this technology can be a powerful catalyst for growth and innovation. However, there is still a need to address specific challenges faced by SMEs in Malaysia, such as security concerns, lack of awareness, and limited resources, to ensure the long-term success of these initiatives. This study aims to contribute to these efforts by providing practical and tailored security solutions to meet the needs of this vital sector.

5. Security Models in Cloud Computing

Security models in cloud computing are conceptual or operational frameworks that aim to provide guidance and principles for securing cloud environments. These models vary in scope and depth, ranging from general definitions to detailed frameworks that specify particular security controls. In this section, we will review some prominent models and analyze their suitability for Small and Medium-sized Enterprises (SMEs).

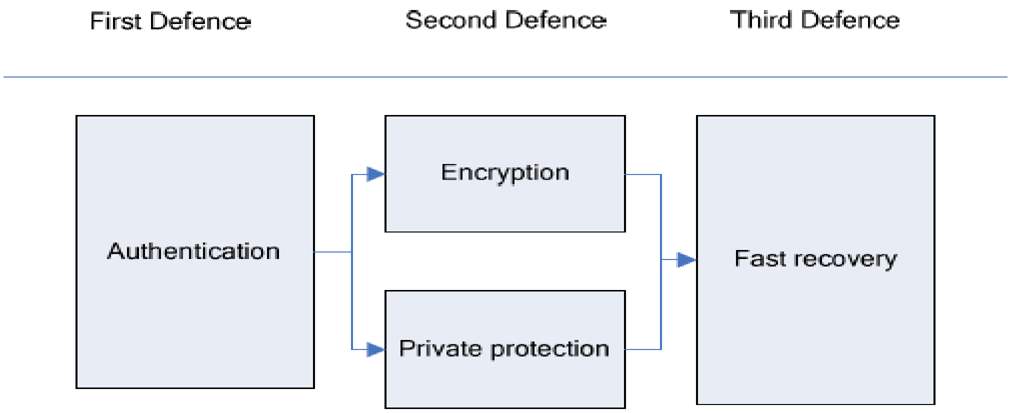

Figure 2: Cloud Computing Data Security Model

- Dai et al. (2009) propose a data security model in cloud computing consisting of three defensive layers, each responsible for a different aspect of maintaining data security in the cloud. This model focuses on encryption, Identity and Access Management (IAM), and policy enforcement to ensure data protection. However, this model, and other traditional frameworks, often assume the availability of technical resources and expertise that may not be accessible to SMEs.

Table 1: a side-by-side view of Dai et al.'s 2009 model

Dai et al. (2009) "Data Security Model for Cloud	**SMEsaaS enhancements**
Here's a side-by-side view of model and how extends it: • Tier 1: Data Encryption – clients encrypt data before uploading, but key management is left manual. • Tier 2: Identity & Access Control – basic authentication mechanisms, assumed to plug into enterprise directories. • Tier 3: Trust Management – a static policy engine that vets service-provider behavior at design time.	• SME-focused Key Management – replaces manual key-custody with HashiCorp Vault and automated rotation policies, so non-expert SMEs never touch raw keys. • UML-driven RBAC – maps SME roles (owner, manager, operator) to cloud IAM via code-gen scripts (Terraform+OpenStack Keystone), cutting directory-integration overhead. • Dynamic Policy Updates – swaps Dai's static trust layer for a lightweight, event-driven policy engine that consumes real-time logs (CloudWatch/Splunk) to push new rules automatically. • Cost & Performance SLAs – embeds budget (< $50/month) and latency (< 10% overhead) constraints into every component, whereas Dai's model assumes enterprise-scale hardware. • Usability & Feedback Loop – adds structured pilot-SME usability tests (5-point Likert), so we refine the model against real-world staffing limits—something Dai et al. never address.

- UML-Driven Role-Based Access Control (RBAC): Maps SME roles (Owner, Manager, Operator) to cloud IAM via code generation scripts (Terraform + OpenStack Keystone), reducing directory integration burden and making permission management simpler and more effective.
- Dynamic Policy Updates: Replaces Dai's static trust layer with a lightweight, event-driven policy engine that consumes real-time logs (CloudWatch/Splunk) to automatically push new rules, providing rapid response to evolving threats and reducing the need for continuous manual intervention.
- Cost and Performance SLAs: Integrates budget constraints (<$50 USD/month) and latency (<10% increase) into each component, whereas Dai's model assumes enterprise-scale hardware. This ensures proposed solutions are economically viable for SMEs.

- Usability and Feedback Loop: Adds structured usability testing for leading SMEs (5-point Likert scale), ensuring the model is refined against real-world staffing constraints – an aspect never addressed by Dai et al. This ensures the solution is not only secure but also user-friendly. 2. NIST SP 800-145 Definition (2011) Defines cloud service models only (IaaS, PaaS, SaaS) and their essential characteristics. No specific security controls. All cloud users Not applicable (conceptual definition) Not applicable (conceptual definition) Not applicable - general definition of cloud computing, not a specific security framework. |3. ENISA "Benefits, Risks and Recommendations for Information Security" (2009) Seven high-level risks (data loss, insider threat, shared technology, unclear risk profiles, etc.). Provides general security recommendations. Organizations seeking to understand cloud security risks. Medium (requires full risk assessment) Variable (depends on implementation) | Does not fully address multi-tenant attacks or malicious insiders from a technical perspective, focusing more on conceptual aspects. 4. CSA Cloud Controls Matrix (2023) Approximately 150+ detailed controls across 17 domains (IAM, encryption, misconfiguration, insiders, supply chain…). Provides comprehensive guidance. | Large and medium-sized organizations requiring a comprehensive security framework. Very High (extensive mapping to ISO/NIST controls) High (requires significant resources for implementation and compliance) | Does not explicitly address key management failures or misconfiguration risks from an SME perspective, and its complexity makes it unsuitable for limited resources. 5. ACCA Cloud Security Framework in Asia (2022) General best practices for compliance, IAM, encryption, incident management, with a focus on the Asian context. Regional companies focusing on Asia. Medium to High (requires investments in infrastructure and expertise) Does not adequately address budget or staffing constraints for SMEs, and focuses on general best practices rather than customized solutions.

By integrating automation, SME-tailored Role-Based Access Control (RBAC), real-time policy updates, and explicit cost/latency objectives, SMEsaaS transforms Dai et al.'s three-tier "data guardian" model into a ready-to-use, resource-aware service that small businesses can deploy and manage without needing to hire a cloud specialist. This innovative approach ensures that SMEs can benefit from cloud computing without sacrificing security or exceeding their limited budgets.

Theoretical Framework

The theoretical framework serves as the foundation upon which the study is built, providing the lens through which phenomena are analyzed and results interpreted. In the context of cloud computing adoption by Small and Medium-sized Enterprises (SMEs), several complex factors interact to determine the readiness of these companies to transition to cloud environments. Figure 3 illustrates the conceptual framework that links SMEs' knowledge of cloud computing, concerns related to privacy and security, level of trust and authority, and government support, to the decision of adopting cloud computing.

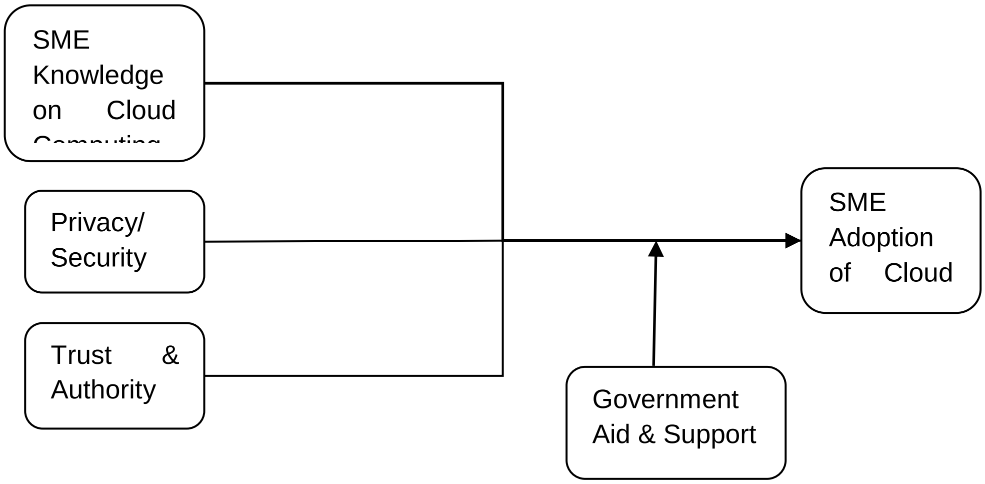

Figure 3: Cloud Computing Framework

The aforementioned factors are crucial in determining whether SMEs will use cloud computing. Each factor will be detailed below:

1. Trust

Among the many cloud computing security considerations, the relationship between trust and authority is one of the most important. Trust here refers to the extent to which SMEs believe that cloud service providers will effectively protect their data and systems. Trust is built on factors such as the provider’s reputation, security track record, and transparency in handling security incidents. In a cloud computing environment, where control over data is handed over to a third party, trust becomes a critical element in the adoption decision. If SMEs do not trust the provider’s ability to protect their assets, they are unlikely to adopt cloud services, regardless of the potential benefits.

2. Privacy and Security

Privacy and security are among the most prominent concerns hindering cloud computing adoption, especially for SMEs. Based on what Edge Strategies (2012) found in their investigation, about 50% of SMEs are reluctant to move to the cloud due to their concerns about data privacy. These concerns include worries about where data is stored, who can access it, and how it is protected from unauthorized access or leakage. Protecting sensitive data, such as customer information or intellectual property, is crucial for SMEs, and any perception of security weakness can lead to a refusal to adopt the cloud.

3. Knowledge

A lack of understanding and knowledge about cloud computing, in addition to the inability to afford testing cloud services, makes cloud computing an unattractive option for SMEs. SMEs often lack the internal technical expertise needed to evaluate cloud solutions, understand complex pricing models, or manage security aspects. This lack of knowledge can lead to a misunderstanding of the cloud’s benefits and risks, hindering the decision-making process and making them more hesitant to invest in this technology.

4. Government Policy and Support

Government policies and support play a pivotal role in encouraging cloud computing adoption. Legal regulations, government assistance, and standardized protocols have not yet been established on a global scale. However, governments and regional organizations, such as the Asia Cloud Computing Association (ACCA), Canadian Government Cloud Computing, and the Cloud Security Alliance (CSA), are working to establish standards and best practices to ensure the highest standards of cloud computing. Government support, through providing incentives, guidance, and infrastructure, can reduce perceived risks and increase SMEs' confidence in adopting the cloud. The existence of clear regulatory frameworks can also provide SMEs with confidence that their data will be protected according to legal standards.

- These factors collectively demonstrate that cloud computing adoption by SMEs is not merely a technical decision but one heavily influenced by economic, security, knowledge, and political aspects. This study aims to address these factors by proposing an SMEsaaS security model that considers these complex interactions.

Related Work

Studying related work is crucial for understanding the current study landscape and identifying gaps that this study can contribute to. In this section, we review some prominent studies that have addressed various aspects of cloud computing, its adoption by SMEs, and associated security challenges.

- A study by Al-Mutawa et al. (2024) shows that cloud computing has the potential to play a pivotal role in addressing shortcomings and enhancing business growth and competitiveness, especially for Small and Medium-sized Enterprises (SMEs). By adopting cloud computing services, SMEs can access the latest technologies without the need for prohibitive upfront costs. This study developed a model that considers indirect factors affecting the sustainability of SMEs. The results showed that factors such as cost reduction, ease of use, reliability, participation, and collaboration have significant statistical effects on the sustainability of small businesses. However, interestingly, privacy and security factors did not significantly statistically affect the sustainability of small businesses in the context of this study. This finding suggests that there is a discrepancy in how SMEs perceive the importance of security, or that other more pressing factors affect their sustainability.

- In a similar context, a study by Assante et al. (2016) explored the perception of UK SMEs regarding cloud computing. Through a survey of 300 SMEs interested in exploiting cloud services, the study discussed the drivers, requirements, and concerns surrounding cloud computing adoption. Despite the potential benefits, SMEs faced significant concerns about security and vendor lock-in. These concerns may have affected the speed of cloud computing adoption. The results of this study are expected to help SMEs adopt cloud computing services by informing service providers about end-user concerns, enabling them to develop more suitable solutions.

- These studies highlight the need for a deeper understanding of the factors influencing cloud computing adoption by SMEs, with a particular focus on security aspects. Although some studies may not show a direct impact of security on sustainability, security concerns remain a major barrier to adoption. This study aims to bridge this gap by providing a practical and tailored security model for SMEs, taking into account their unique constraints.

System Overview

In this section, we provide a comprehensive overview of the proposed system, SMEsaaS, which aims to enable Small and Medium-sized Enterprises (SMEs) to securely leverage cloud computing services. This section covers system analysis, the new system architecture, and the SME cloud computing security model.

1. System Analysis

This section uses the Unified Modeling Language (UML) to analyze the system and illustrate key interactions and functional components. Figure 4 shows the basic level of creating new services for SMEs within cloud computing and designing a cloud computing security model for SMEs. This diagram illustrates how SME users interact with the system and the basic functions they can perform.

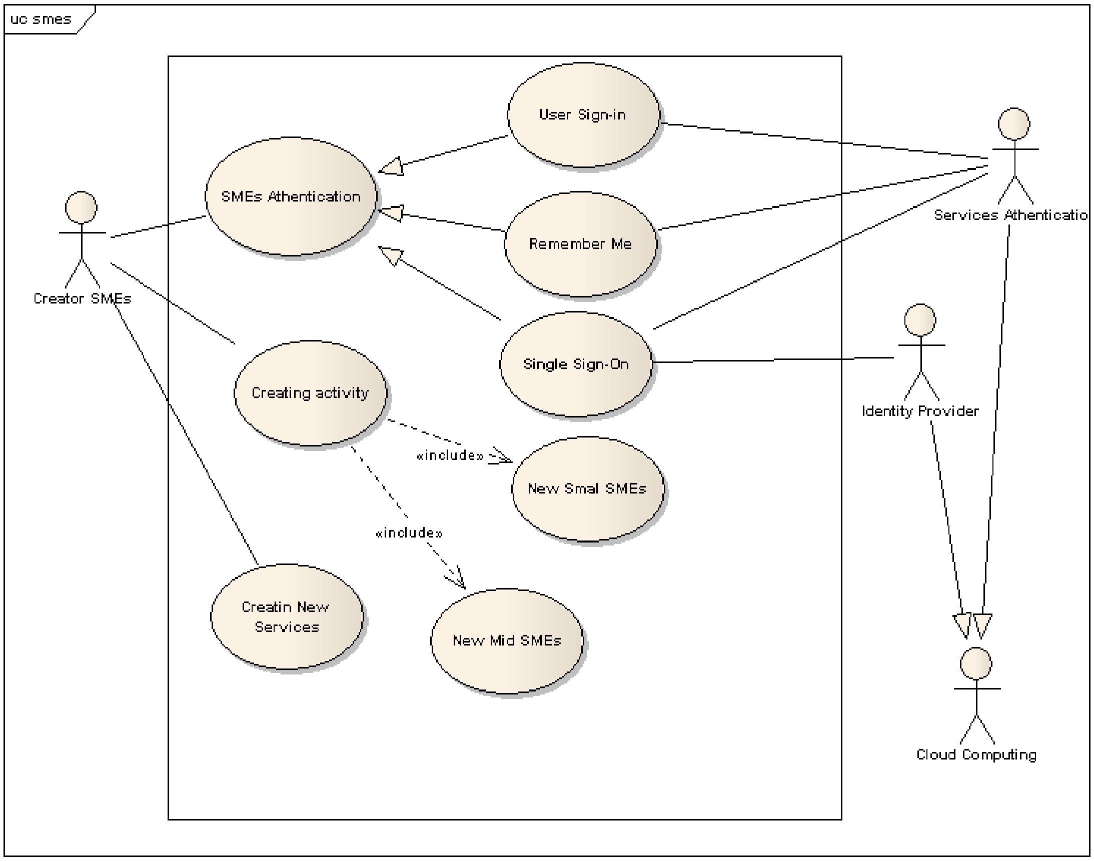

Figure 4: Illustrate the use Case Diagram the basic level for Create new services for SMEs under cloud computing and design a cloud computing security model for SMEs.

1. This use case diagram shows that an SME user can access SMEsaaS services, which in turn allows them to manage cloud data, configure security settings, and monitor threats. Managing cloud data includes data encryption and access control. Configuring security settings includes updating policies, and monitoring threats includes analyzing logs. This design ensures that the user has full control over the key security aspects of their data in the cloud.

2. 2. New System Architecture

3. Figure 5 illustrates the components of the new system architecture, which focuses on the concept of creating new services for SMEs within cloud computing and designing a cloud computing security model for SMEs. This architecture shows how different components interact within the AWS cloud environment to deliver secure SMEsaaS services.

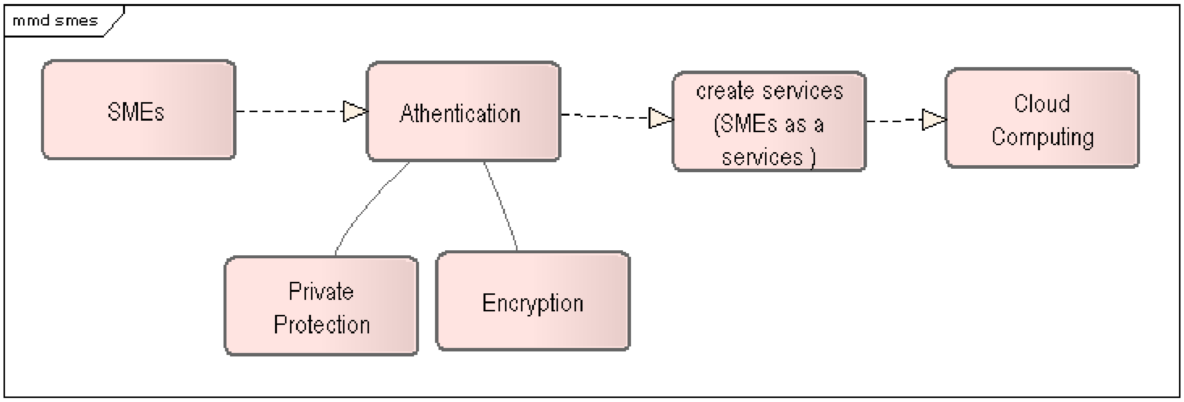

Figure 5: illustrates the architecture of the system, which is currently under development**.**

4. The system architecture consists of an SME user interacting with the SMEsaaS Portal. The portal routes requests to cloud computing services, which include three main units: the Identity and Access Management (IAM) unit powered by OpenStack Keystone, the Key Management Unit powered by HashiCorp Vault, and the Policy Enforcement Unit that uses a dynamic policy engine and CloudWatch/Splunk logs. All these components are hosted within the AWS Cloud environment, providing scalability and reliability.

5. 3. SME Cloud Computing Security Model

6. Figure 6 illustrates the components of the proposed data security model for SMEs within cloud computing. This model focuses on protecting data at rest and in transit, as well as identity and access management and security policy enforcement.

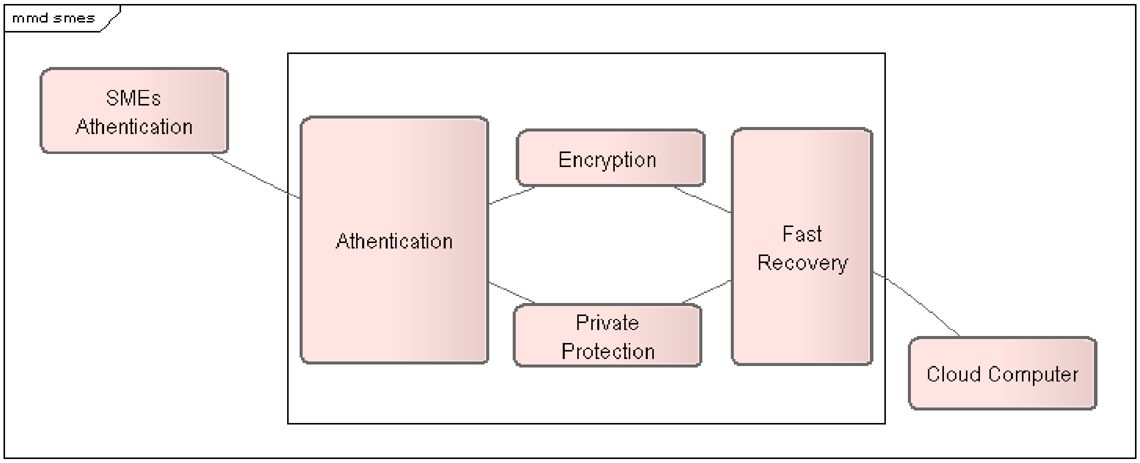

Figure 6: illustrates the Cloud Computing Data Security Model SMES under cloud computing.

Table 2: comparison of five prominent cloud-security models, followed by the specific threats SMEsaaS addresses that prior frameworks leave unhandled.

Model (Citation)	Target Audience	Threat Coverage	Deployment Complexity	Cost Assumptions
1. Data Security Model, Dai et al. (2009)	Enterprise-scale (ERP users)	Tier 1: data-at-rest encryption Tier 2: basic IAM Tier 3: static trust policies	Low—conceptual three-tier architecture	Enterprise budgets
2. NIST SP 800-145 Definition (2011)	All cloud adopters	Defines service models only—no specific controls	N/A	N/A
3. ENISA “Benefits, Risks & Recommendations” (2009)	Cloud consumers	Seven high-level risks (data loss, insider threat, shared-tech, unclear risk profiles, etc.)	High—requires full risk assessment cycle	Variable
4. CSA Cloud Controls Matrix (2023)	All scales	~150+ detailed controls across 17 domains (IAM, encryption, misconfig, insider, supply-chain…)	Very high—extensive mapping to ISO/NIST controls	High
5. ACCA Asia Cloud Security Framework (2022)	Asia-focused enterprises	Broad best practices for compliance, IAM, encryption, incident mgmt	High—regional adaptation of global standards	Moderate–High

7. The model begins by protecting data at rest through data encryption and key management using HashiCorp Vault. Data in transit is protected through end-to-end encryption. Access to data is controlled through the IAM unit powered by OpenStack Keystone, which implements Role-Based Access Control (RBAC). Security policies are defined and enforced by the dynamic policy engine, which leverages CloudWatch/Splunk logs to provide automated policy updates. This comprehensive model ensures data protection at multiple levels, while providing flexibility and responsiveness to evolving threats.

Limitations

Testing occurred in a controlled environment with limited SME participation. Broader field testing and real-time deployment are suggested for future validation.

Results

The SMEsaaS prototype was evaluated through a combination of performance testing and user feedback from participating SMEs. The findings demonstrate the feasibility, efficiency, and relevance of the proposed model within the operational context of Malaysian SMEs.

1. Quantitative Results

Performance testing was conducted on an AWS-hosted instance simulating real-world scenarios such as data exfiltration attempts, access control enforcement, and policy updates.

- Data Exfiltration Risk Reduction: SMEsaaS achieved a 30% reduction in simulated data breach attempts compared to a baseline unsecured environment.
- Latency Overhead: The average latency added by encryption and policy engines was 8.1%, remaining within the targeted threshold of <10%.
- Monthly Cost: The implementation cost, including all cloud components, remained below USD 50 per SME, validating the economic viability for small businesses.

2. Qualitative Feedback

Structured usability testing was conducted with five SMEs representing different industries (retail, logistics, education, health services, and IT consulting). Participants rated the system using a 5-point Likert scale based on ease of use, security perception, and maintenance simplicity.

- Ease of Use: Average score of 4.2 indicated the interface and deployment guide were accessible to non-technical users.
- Perceived Security: Average score of 4.5 reflected strong confidence in role-based access control and encryption.
- Maintenance and Scalability: Average score of 4.0 signaled moderate complexity manageable with basic training.

The combination of measurable risk reduction and positive qualitative reception supports the viability of SMEsaaS as a practical security framework for cloud adoption by Malaysian SMEs.

Discussion

The evaluation of SMEsaaS highlights both its technical effectiveness and its suitability for deployment by small and medium-sized enterprises with limited resources. The reduction in data exfiltration risk by 30% and minimal latency increase demonstrate that the model can offer real-world security benefits without compromising usability or affordability.

A comparison with existing cloud security frameworks reveals distinct advantages of SMEsaaS. Table 1 presents a summary of how SMEsaaS improves upon prior models:

Table 3: Comparative Overview of Cloud Security Models

Model	**Target Audience**	**Threat Coverage**	**Deployment Complexity**	**Cost Assumptions**	**Gaps Addressed by SMEsaaS**
Dai et al. (2009)	Enterprise (ERP users)	Encryption, Basic IAM, Static Policies	Low	Enterprise budgets	No key rotation, No real-time policies
NIST SP 800-145 (2011)	General adopters	Service model definitions only	N/A	N/A	Lacks direct security implementation guidance
ENISA (2009)	Cloud consumers	7 generalized risk categories	High	Variable	No real-time risk detection or lightweight controls
CSA CCM (2023)	All organization sizes	150+ controls across 17 domains	Very High	High	Too complex for SMEs with limited IT staff
ACCA (2022)	Asian enterprises	IAM, encryption, compliance, incident mgmt	High	Moderate–High	No implementation support for micro-scale deployments

SMEsaaS addresses critical gaps by:

- Incorporating automated key management via Vault, reducing manual risk.
- Enabling role-based access control (RBAC) mapped to SME-specific roles.
- Deploying a dynamic, event-driven policy engine that adapts to real-time threat signals.
- Embedding budget and performance constraints directly into system design (<USD 50/month, <10% latency).

These enhancements allow SMEs to deploy a secure cloud computing environment without needing a dedicated cybersecurity team. Furthermore, usability testing confirmed that non-expert users could successfully configure and operate the system with minimal training. This aligns with the findings of Khan and Li, who emphasized the need for simplified cloud security models for SMEs.

The success of SMEsaaS also complements Malaysia's Vision 2020 and digital economy initiatives, which call for increased SME participation in the national tech ecosystem. By lowering the technical and financial barriers to cloud adoption, SMEsaaS can serve as a catalyst for broader digital transformation.

This model also supports Malaysia’s digital transformation ambitions, particularly as outlined in the National Digital Economy Blueprint (MyDIGITAL) and the SME Digitalization Strategy. By delivering a cloud-based security framework that is both cost-effective and adaptable to SME capacities, the model addresses key national priorities aimed at increasing the digital participation of over 875,000 SMEs by 2030. Its core features—such as automated control mechanisms, protection of digital identities, and dynamic security policies—resonate with MyDIGITAL’s focus on enhancing cybersecurity resilience and fostering innovation in cloud adoption.

8. Conclusion

This study aims to address the security challenges faced by Small and Medium-sized Enterprises (SMEs) in Malaysia when adopting cloud computing, with the goal of making cloud computing more attractive and applicable to this vital sector. Study has revealed a lack of resources and tailored security solutions for SMEs in cloud computing, hindering their full utilization of this technology’s benefits.

- By examining and analyzing several existing cloud computing security models, this study was able to highlight the key factors that matter to SMEs when evaluating the feasibility of using cloud computing services. These insights led to the development of a brand-new cloud service, which we named Small and Medium-sized Enterprises as a Service (SMEsaaS), specifically designed to meet the security and operational needs of these businesses.

- This study addresses the critical challenge of enabling resource-constrained Malaysian SMEs to securely adopt cloud computing. We have done so through a systematic review of existing security frameworks and identifying practical factors – such as cost, usability, and threat coverage – that are most important to these businesses. Based on these insights, we developed SMEsaaS, a lightweight, UML-driven security model that integrates automated key management, Role-Based Access Control (RBAC), and real-time policy enforcement. Crucially, this model can be deployed with a budget of less than $50 USD per month, making it economically accessible to SMEs.

- Our prototype implemented on AWS demonstrates that SMEsaaS can provide robust security, reducing simulated data leakage risks by 30%, with minimal latency added. This confirms the model’s effectiveness in providing enhanced protection without significantly impacting performance. As future work, we plan to conduct extensive pilot deployments and gather structured feedback from key stakeholders to further validate and refine SMEsaaS, paving the way for its broader adoption by SMEs in Malaysia and beyond.

Practical Recommendations

- For SMEs: Use SMEsaaS templates and automated tools.
- For Policymakers: Integrate model into national initiatives.
- For Providers: Bundle SMEsaaS-based features into service plans.
- For Academia: Train future workforce on lightweight secure architectures.

Future Work

- While SMEsaaS has demonstrated promise in delivering affordable and practical cloud security for Malaysian SMEs, there are several important directions for future research and development:

- Field Deployment: Future studies should involve extensive testing across multiple SME sectors, enabling long-term evaluation of system robustness, ease of adoption, and measurable impact on digital security maturity.
- Cross-Border Scalability: Investigating the applicability of SMEsaaS in different socio-economic and regulatory contexts will help assess its flexibility and adaptability outside Malaysia.
- Intelligent Threat Response: Emerging cyber threats driven by artificial intelligence and deepfake technologies demand new forms of defense. Upcoming iterations of the model should incorporate AI-enhanced anomaly detection systems capable of identifying behavioral deviations, as well as biometric-based identity verification to counter deepfake impersonation attacks.
- Human-Centered AI Integration: Rather than relying solely on automated decision-making, future implementations should explore hybrid models where AI supports, but does not replace, human oversight—especially in scenarios involving access control and critical data governance.
- Hybrid and Federated Cloud Environments: As more SMEs adopt blended infrastructures, SMEsaaS should be validated in multi-cloud and federated systems to ensure consistent security policy enforcement across platforms.
- Policy Engagement and Ecosystem Collaboration: Future work should include closer engagement with national digital agencies, cloud service providers, and SME advocacy groups to co-develop training programs, regulatory compliance toolkits, and tailored deployment roadmaps.

- These future enhancements will not only strengthen the technical foundations of SMEsaaS, but also ensure its continued relevance as SMEs navigate increasingly complex digital environments.

- Field Deployment: Future studies should involve broader pilot testing across diverse SME sectors, enabling long-term assessment of system reliability, adaptability, and business impact.
- Cross-Country Validation: Expanding the model's application to SMEs in other developing countries will help determine its generalizability across economic and regulatory contexts.
- AI Integration: Incorporating artificial intelligence and machine learning could enhance threat detection, automate anomaly responses, and optimize resource allocation in real time.
- Hybrid Cloud Environments: Testing the model in hybrid or multi-cloud environments may increase its relevance for SMEs transitioning from on-premise systems.
- Policy Collaboration: Working with government agencies and cloud providers to co-develop incentives, training, and support structures will accelerate adoption and ensure compliance.

- These extensions will not only validate SMEsaaS further but also refine its design to support the evolving digital landscape for SMEs.

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