Network Security Governance Policy and Risk Management: Research on Challenges and Coping Strategies

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Abstract – Cybersecurity is a big issue for major multinational corporations in today's lightning-fast digital world. Risk management and Network Security Governance (NSG) are complex, and this paper discusses the challenges and strategies needed to protect digital assets in a more vulnerable cyber environment. Cyber threats are constantly changing, technological integration is complex, and regulatory compliance is severe, all of which make it more challenging to maintain robust network security. NSG requires strong security rules and standards, which this conversation must address. The ever-changing threat environment demands that these regulations be open, accurate, and flexible. Risk management identifying, assessing, and mitigating threats—is essential to regulatory compliance and organizational reputation, according to the article. Risk mitigation methods like proactive, investigative, and remedial approaches are examined, along with cybersecurity advancements like Artificial Intelligence (AI) and Machine Learning (ML). In solving network security issues, the text emphasizes continuous learning, collaboration, and information sharing. Network Security Governance and Risk Management (NSGRM) is complex and dynamic, and this study covers its challenges and strategies.

Keywords – Risk Management, Network Security, Governance Policy and Standards, Risk Mitigation Strategies, Artificial Intelligence.

I. INTRODUCTION

The current digital transformation age is causing an extraordinary evolution in the technical landscape. This evolution presents numerous prospects for improved connectivity and innovation but poses several challenging cybersecurity issues [1]. Organizations worldwide are becoming more dependent on digital infrastructures, making them more susceptible to various cyberthreats. These threats not only endanger sensitive data but also pose severe risks to the continuity of business operations [2]. Thus, the digital age is characterized by a paradox: it offers significant potential for growth and operational efficiency, yet it is accompanied by notable cybersecurity risks. The cybersecurity landscape is dynamic and ever-changing, with new threats emerging constantly. Organizations, irrespective of their size or industry, are compelled to confront the challenge of protecting sensitive information and ensuring uninterrupted business operations amidst these evolving threats [3]. This situation necessitates a proactive and flexible approach to network security that effectively addresses current threats while remaining agile enough to adapt to future challenges. Effective Network Security Governance (NSG) is anchored in well-crafted policies and standards establishing a comprehensive framework for safeguarding digital assets [4]. These policies cover various security aspects, including user authentication, data encryption, network access control, and incident response protocols. The creation and implementation of these policies demand a collaborative approach, leveraging expertise from various organizational departments [5].

At the core of NSG lies the critical practice of risk management. This involves the systematic identification, evaluation, and mitigation of risks to an organization's network infrastructure [6]. A tactical approach to risk management is crucial for defending against potential threats, maintaining adherence to regulatory norms, and safeguarding the organization's standing. The urgency to explore Network Security Governance and Risk Management (NSGRM) arises from the necessity to protect digital assets, which are becoming more susceptible to security breaches [7]. Cyber incidents, such as data breaches and advanced cyber-attacks, are now frequent threats that carry far-reaching repercussions. These incidents often result in substantial financial losses, harm to an organization's reputation, and erosion of customer confidence. In light of this, setting up and enforcing strong network security measures goes beyond a mere technical necessity; it becomes a strategic necessity critical for ensuring the organization's resilience [8]. The increasing complexity and sophistication of cyber threats, coupled with strict regulatory demands, underscore the vital importance of thorough security governance and the implementation of effective risk management strategies [9].

This paper endeavors to unravel and comprehend the intricate field of NSGRM. A basic overview of NSG, which includes security standards and regulations, is provided. Risk management—identifying, assessing, and mitigating network infrastructure risks—is stressed in the discussion. The study discusses cloud-based solutions for scalability, Artificial Intelligence (AI) and Machine Learning (ML) for predictive threat analysis, and regular technological audits to ensure system integrity and security as techniques to improve network security. The paper aims to provide a comprehensive review of NSGRM as it is today. It aims to shed light on the difficulties businesses encounter in this dynamic field and the solutions they may use to overcome them. The ultimate goal is to provide companies with the information and resources to protect themselves from threats and prepare for upcoming cybersecurity problems.

The article's structure is as follows: Section 2 introduces the concept and necessity of NSG. Section 3 covers the Policies and Standards relevant to NSG. Section 4 delves into Risk Assessment within NSG. Section 5 discusses the Challenges encountered in NSGRM. Section 6 outlines various Coping Strategies for NSGRM. Finally, Section 7 provides the conclusion of the article.

II. DEFINITION AND NEED FOR NSG

Definition

NSG, in line with industry standards and best practices, refers to a holistic and strategic framework adopted by an organization to maintain the security and integrity of its network infrastructure [10]. This framework forms a crucial part of the more comprehensive organizational security strategy, positioning network security as a key element in business operations and decision-making processes.

Key Components of NSG include:

- Policy Development and Enforcement: NSG entails developing, implementing, and upholding policies that govern network usage, data management, and security protocols. These policies are crafted to align with industry norms and regulatory mandates, including standards like ISO/IEC 27001 and frameworks established by NIST.
- Risk Management and Compliance: Fundamentally, NSG is centered on identifying, evaluating, and mitigating risks to network infrastructure. It ensures adherence to legal and regulatory requirements, thus protecting the organization from potential legal and financial repercussions.
- Access Control and Identity Management: Strong administration of identity verification procedures and access restrictions is essential for the effectiveness of NSG since these measures stop unwanted access and protect sensitive data.
- Continuous Monitoring and Improvement: The process of NSG is dynamic rather than static. It necessitates ongoing assessment, evaluation, and adjustment to handle emerging risks and stay current with technology developments.
- Stakeholder Engagement and Training: In order to make sure that everyone is aware of and follows security measures, NSG highlights the significance of involving all stakeholders in security practices and the necessity of frequent training.

Need for Network Security Governance

NSG is more important than ever in the present digital world. It is the cornerstone of a company's defense against different cyberthreats, shielding confidential and valuable information from breaches and illegal access. Organizations may safeguard their data's availability, confidentiality, and integrity by implementing a robust governance framework. This is important because it helps to maintain confidence with stakeholders, clients, and regulatory bodies [11]. Furthermore, risk management plans and security event responses depend on efficient governance to ensure business continuity. NSG is more than just a defensive mechanism when cyber threats are growing more sophisticated and pervasive; it is a strategic requirement that supports and aligns with an organization's larger goals, assuring its long-term resilience and success [12].

Protection of Sensitive Data: Protecting sensitive and private information within a company is primarily made possible by NSG. This includes financial information, trade secrets, other sensitive information, and the private information of clients and staff. Good governance ensures that this data is protected against cyberattacks, unwanted access, and unintentional disclosures. Organizations can prevent the abuse, loss, or leakage of critical information by implementing strict encryption, access restrictions, and data integrity safeguards. This is crucial for maintaining consumer trust and safeguarding the organization's reputation.

Compliance with Regulations: NSG is crucial to guaranteeing that a company complies with legal and regulatory requirements of cybersecurity and data protection in an increasingly regulated digital world. Compliance is essential to avoid legal issues like steep fines. For example, regulations like the General Data Protection Regulation (GDPR) in the European Union set stringent data handling and privacy guidelines. Failing to comply with these regulations can lead to severe financial penalties [13]. A well-organized governance framework is key in aligning network security protocols with these regulatory requirements, ensuring that the organization operates within the confines of the law.

Risk Management and Mitigation: Efficient NSG includes identifying, assessing, and mitigating risks that might jeopardize network security. This involves conducting regular risk assessments to comprehend the potential threats and vulnerabilities present in the network infrastructure [14]. Organizations can enhance their resource allocation by prioritizing risks according to their potential impact, enabling them to focus on addressing the most critical vulnerabilities first. Mitigation strategies may encompass deploying firewall intrusion detection systems, ensuring regular software updates, and conducting employee training programs. Adopting this proactive approach to risk management is essential in reducing the probability and the severity of security incidents.

Ensuring Business Continuity: When protecting an organization's operations from cyber-attacks and guaranteeing minimal disruptions, NSG is essential. In order to effectively handle and recover from various network security incidents, a comprehensive business continuity plan must be developed and maintained. Organizations can enhance consumer trust and operational stability by minimizing downtime and sustaining important activities in the case of incidents such as ransomware infections, DDoS attacks, or data breaches. [15].

Building Customer Trust and Reputation: In today's digital era, how an organization handles network security greatly impacts its reputation and the trust it earns from customers and partners. Protecting sensitive data and guaranteeing a secure operating environment are the goals of a robust NSG [16]. When choosing which businesses to deal with, customers and business partners are placing an increasing weight on this dedication to network security. Organizations may create and maintain a reputation for dependability and trustworthiness by maintaining high network security standards, which is crucial in today's competitive market.

Adaptation to Evolving Threats: Cyber threats constantly evolve, with new dangers and weaknesses appearing regularly. A methodical strategy for keeping up with these advancements and modifying security protocols as necessary is provided by NSG. This adaptability is required to defend against both current and potential dangers. It entails keeping personnel knowledgeable about emerging cyber threats, being prepared to manage them, and updating technology and procedures. Considering the rapidly changing landscape of cyber threats, an organization's network security must be maintained via a flexible governance approach.

III. POLICIES AND STANDARDS IN NETWORK SECURITY GOVERNANCE

Standards and policies are essential resources in the organization's toolbox for network security, not merely piles of paper papers. They ensure that all organization members have a uniform approach to network security by providing explicit standards and processes for safeguarding the network and sensitive data. By regularly reviewing and updating these documents and ensuring that they are effectively communicated and enforced, organizations can create a strong foundation for their NSG efforts.

The Essence of Security Policies

Security policies are theoretical documents and the foundation of an organization's network security. These comprehensive documents articulate an organization's stance on network security, tailored to its unique needs, risks, and objectives. For instance, a financial institution might prioritize data encryption and transaction security due to the sensitive nature of economic data, while a healthcare provider would focus on compliance with HIPAA regulations to protect patient information [17]. These policies cover a broad spectrum of topics, from user authentication, which could involve multi-factor authentication methods as seen in companies like Google and Microsoft, to data encryption, mirroring practices used by organizations like Apple to secure user data. Network access control is another critical area, akin to the systems used by Amazon Web Services to manage and monitor access to its cloud resources [18]. Incident response protocols are also integral, similar to the rapid response measures employed by Facebook during data breach incidents [19].

The collaborative development of these policies is a key factor in their effectiveness. For example, when a major cyber-attack hit Sony in 2014, it led to a significant overhaul of its security policies, involving multiple departments to address the diverse nature of the threats faced [20]. This collaborative approach, involving Information Technology (IT), legal, and executive management, ensures that the policies are comprehensive, realistic, and aligned with the organization's overall goals. The clarity and relevance of these policies are paramount. They must be written in a language easily understandable by all employees, not just the IT staff. For instance, IBM's security policies are known for their clarity and accessibility, making them effective across the organization [21]. Regular reviews and updates are also crucial, as the cyber threat landscape constantly evolves. The infamous WannaCry ransomware attack in 2017, which affected organizations globally, highlighted the need for regular updates to security policies and systems to guard against emerging threats [22].

The Role of Security Standards

Security standards in NSG are theoretical guidelines and practical, actionable directives that have proven their worth in the real world. These standards translate the broad demands of security policies into specific technical actions and requirements, ensuring a uniform application of security measures across an organization.

- ISO/IEC 27001 is a widely recognized standard for Information Security Management Systems (ISMS) used by companies like Microsoft and IBM to protect assets like financial information, intellectual property, employee details, and third-party information. By adhering to such standards, these companies demonstrate their commitment to high security, which is crucial for customer trust and business continuity.
- The Payment Card Industry Data Security Standard (PCI-DSS) is another crucial example for businesses processing credit card transactions. Visa and Mastercard enforce stringent security standards that include specifications for security management, policies, procedures, network architecture, and software design. Complying with PCI-DSS is essential for stopping credit card fraud and protecting cardholder data, which is vital for major online retailers like Amazon.
- Network architecture and data transmission management in enterprises heavily depend on security standards. A prime example is Google's implementation of secure data transmission technologies, such as SSL/TLS and HTTPS. These protocols ensure that the transferred data is secured and protected from eavesdropping [23]. The industry has adopted this technique as a benchmark, highlighting the significance of strong standards for data transfer.
- Moreover, the application of security standards is dynamic rather than static. These guidelines must be updated often due to the dynamic nature of cyber threats. The 2014 Heartbleed bug, which exploited flaws in the OpenSSL cryptographic software library, had a significant impact and is a vivid example of the continuous necessity for attention and frequent changes to security standards [24].

Respecting security requirements shows that a company is dedicated to maintaining a safe and reliable network environment. Industry best practices, legal requirements, and knowledge from past security incidents influence these standards. These standards are crucial in mitigating risks and fostering a consistent approach to network security across different sectors and industries by providing explicit guidelines and technical specifications.

Implementation and Compliance

The effectiveness of these policies and standards is determined by their implementation and enforcement. These guidelines must be not merely documented but actively applied. This requires ongoing monitoring to ensure compliance, performing security audits, and making certain that everyone, including third-party vendors and partners, follows these standards consistently [25]. It's important to address non-compliance with well-defined processes for managing violations swiftly. The practical application and adherence to network security policies and standards are pivotal elements that transform theoretical models into tangible, efficacious security measures. This phase marks the transition of guidelines and standards from theory to practice within an organization, with their effectiveness ultimately being measured by their real-world implementation and impact.

Real-World Implementation: In the implementation context, corporations such as Cisco and IBM exemplify excellence. They craft detailed network security policies and standards and stringently enforce these guidelines. Their implementation strategies include deploying sophisticated security technologies, regular network evaluations, and ensuring compliance of all network elements with established standards. For example, Cisco's application of network segmentation and Access Control Lists (ACLs) demonstrates a practical enactment of its network security policies, effectively reducing the risk of unauthorized access and data breaches [26].

Monitoring and Compliance: Compliance monitoring stands out as a key facet, with companies like Amazon and Google setting prime examples. These organizations use ongoing monitoring systems to guarantee compliance with network security policies and standards. They leverage automated tools to oversee adherence, spot inconsistencies, and take swift corrective measures. For instance, Amazon's deployment of AWS CloudTrail for auditing and monitoring its cloud environment ensures rapid detection and rectification of any deviations from security standards. [27].

Enforcement and Regular Updates: The effectiveness of policies and standards heavily relies on their enforcement. In the wake of the 2013 Target data breach, which occurred due to insufficient security measures, numerous organizations, including Target, have substantially strengthened their enforcement protocols [28]. This includes regular security audits, employee training programs, and strict disciplinary actions for non-compliance. Regular updates to policies and standards are also crucial, as seen in the aftermath of the GDPR implementation in 2018 [29].

Corporations like Facebook and Apple had to extensively revise their data privacy and security policies in response to these evolving regulations, illustrating the necessity for guidelines and standards to adapt to the shifting legal and technological environments.

Employee Training and Awareness: Corporations like Facebook and Apple had to extensively revise their data privacy and security policies in response to these evolving regulations, illustrating the necessity for guidelines and standards to adapt to the shifting legal and technological environments. [30]. This training is essential for preventing security breaches, often resulting from human error or lack of awareness.

IV. RISK ASSESSMENT IN NETWORK SECURITY GOVERNANCE

A fundamental element of NSG is risk assessment, which is necessary for identifying and managing possible threats to a company's network infrastructure. This meticulous process includes several essential phases, as shown in the flowchart that goes with it, to examine the network, identify weaknesses, assess risks, and create risk-reduction plans.

Cataloging Assets: Security begins with an inventory of an organization's data, hardware, software, and network to determine the need for security and assess security breach consequences.

Identifying Potential Threats and Vulnerabilities: Staff errors, system failures, malware, and hackers are identified as weaknesses and threats by the company.

Assessing Potential Impact of Threats: Once threats have been identified, the organization considers how they might affect its operations, standing, and financial health. For example, a data breach may have serious negative effects on one's reputation and legal repercussions.

Determining Likelihood of Threats Occurring: The organization then assesses the probability that each threat will materialize. This step entails reviewing industry trends, historical data, and the efficacy of the security measures that are currently in place.

Developing a Risk Management Plan: The organization creates a thorough plan after identifying and ranking the risks. This strategy outlines the tactics and actions to be taken in order to mitigate the risks that have been placed successfully.

Implementing Mitigation Strategies: The strategy is implemented by putting the chosen mitigation methods into practice. These could be improving security procedures, regularly providing staff with security training, or doing other pertinent actions to manage the risks successfully.

Regular Review and Update of the Plan: Because the risk management plan is dynamic, it must be reviewed and updated frequently. This continuous update makes sure that, despite constantly changing cyberthreats, the objective remains applicable and efficient.

Fig 1 below visually represents this process, providing a clear and structured approach to risk assessment in NSG.

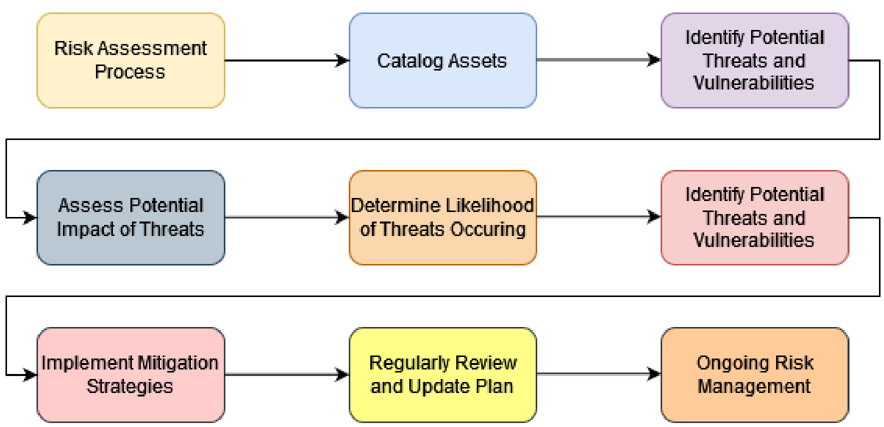

Fig 1. Risk Assessment Process flow

Security Architecture in NSG

NSG relies heavily on security architecture, which provides an organized and strategic framework for protecting an organization's IT infrastructure. This component includes the planning, carrying out, and overseeing of diverse technologies and security measures. These are necessary to defend the company's network and data from various attacks and weaknesses.

Designing the Security Architecture

Understanding the organization's business goals, IT environment, and potential security threats is the first step in designing the security architecture. This involves mapping the network infrastructure, including servers, endpoints, and network devices, and identifying critical assets requiring protection. The architecture must be resilient, scalable, and adaptable to changing business needs and evolving cyber threats. Key components of security architecture design include network segmentation, which isolates distinct parts of the network to contain potential breaches; firewalls and Intrusion Detection/Prevention Systems (IDPS) that monitor and control incoming and outgoing network traffic; and data encryption methods to protect sensitive information both in transit and at rest.

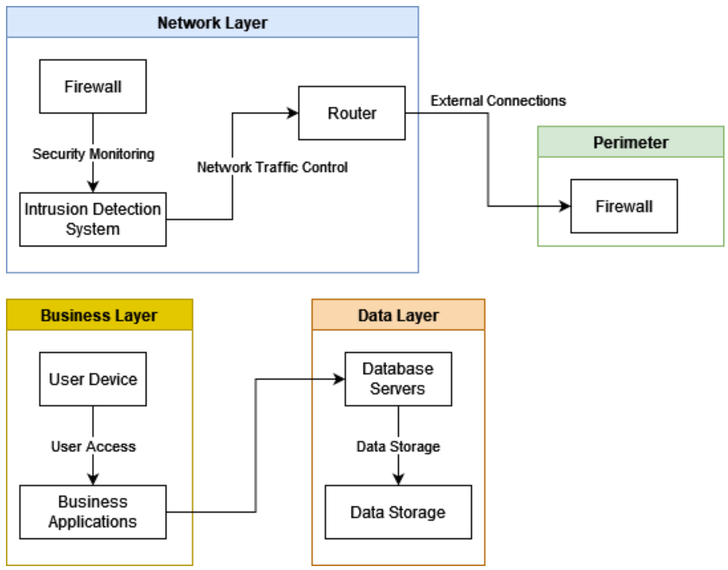

Fig 2. Security Architecture Design

The network layer and business layer representation as independent blocks in the network security architecture diagram (**Fig 2**) reflect the layered approach to network security. This approach segregates different functional areas of an organization's IT infrastructure for better clarity, management, and security. Here's why they are depicted as separate entities:

- Distinct Functions and Objectives: At the network layer, the emphasis is on connecting, communicating, and safeguarding the network infrastructure. This layer incorporates routers, firewalls, and intrusion detection systems, which are crucial for defending against external threats and regulating data flow. Conversely, the business layer focuses on applications and services facilitating business operations and user interactions. It encompasses user devices and business applications, addressing the needs at the application and service level.
- Security Management: Separating these layers allows organizations to tailor security policies and controls to each layer. At the network layer, robust security measures can be implemented to block unauthorized access and monitor network traffic. Meanwhile, the business layer can concentrate on securing applications, maintaining data integrity, and verifying user authentication. This layered approach enables more focused and effective security management for several aspects of the IT infrastructure.
- Risk Mitigation: This segregation helps in risk management. If a security breach occurs in one layer, the impact can be contained within that layer, preventing or minimizing the spread to other areas of the IT infrastructure.
- Simplified Troubleshooting and Maintenance: With a layered architecture, it's easier to identify, isolate, and resolve issues within a specific layer without affecting the entire network. This approach simplifies maintenance and troubleshooting processes.
- Scalability and Flexibility: Independent blocks allow scalability and flexibility within each layer. For example, the business layer can be scaled to add more applications or services without significantly impacting the network layer's structure.

Implementation of security architecture involves deploying various technologies and controls. This includes advanced threat protection systems, Secure Access Service Edge (SASE) models for secure and fast cloud access, and Zero-Trust Network Access (ZTNA) principles, which assume no user or device is trustworthy until verified [31]. These technologies are integrated into the IT infrastructure to create multiple layers of defense, often called defense in depth. Effective security architecture is not static; it requires ongoing management and evolution to remain effective. This involves regular security assessments to identify new vulnerabilities, continuous monitoring for threats, and periodic updates to security policies and technologies. For example, after the widespread adoption of remote work, many organizations had to update their security architecture to accommodate the increased use of cloud services and remote access technologies. The security architecture must also align with industry best practices and applicable compliance standards.

Compliance with industry-specific laws like HIPAA for healthcare and PCI-DSS for credit card processing, ISO/IEC 27001 for information security management, and the National Institute of Standards and Technology (NIST) framework is required [32].

Monitoring and Reporting in Network Security Governance

Monitoring and reporting are crucial elements of NSG to maintain the integrity and security of a company's network infrastructure. This entails closely monitoring network activity and frequent security audits to identify and address potential risks or weaknesses.

- Continuous Monitoring of Network Activities: Continuous monitoring examines network operations to spot any oddities or irregularities that can point to a security breach. Advanced technologies and techniques are used in this process to monitor user activity, system logs, performance metrics, and network traffic. For example, network data is examined for signs of malicious activity or policy violations using IDPS. Likewise, Security Information and Event Management (SIEM) systems collect and review network log data from many sources, providing instantaneous security alert analysis of network hardware and applications. Events such as the 2020 SolarWinds Orion platform breach, when early discovery of abnormal network activity may have mitigated the impact, were a stark reminder of the importance of continual monitoring [33]. Organizations can minimize possible damage by promptly detecting and responding to such risks through continuous monitoring.
- Regular Security Audits: A crucial component of the monitoring and reporting procedure is conducting regular security audits. These audits entail carefully examining a company's network security policies, practices, and controls to confirm their efficacy and adherence to laws and industry standards. Security audits can be carried out outside by unbiased security specialists or internally by the company's security team. These audits usually include examining access controls in detail, evaluating the effectiveness of security policies and procedures, assessing the security of virtual and physical environments, and verifying the resilience of incident response plans. To make sure it complies with the PCI-DSS regulations, for instance, a financial institution could conduct routine audits.
- Reporting and Analysis: Regular audits and monitoring produce detailed reports on an organization's security, highlighting strengths and weaknesses. These reports help inform security investments and strategic planning by describing network security conditions.

Impact Analysis in NSG

NSG must analyze the impact of security incidents on an organization's operations, reputation, and finances to develop risk mitigation and business continuity strategies.

- Understanding the Scope of Impact: As a data breach could result in fines and damage, impact analysis begins by identifying organizational segments affected by network security incidents, such as customer service, legal compliance, operational procedures, financial stability, and reputation. One such instance is the 2017 Equifax data breach, which was among the biggest in history and revealed the personal data of more than 147 million customers. Equifax suffered a significant financial setback due to the hack, paying over $1.4 billion in settlements, legal fees, and infrastructure upgrades. [34].
- Evaluating the Severity of Potential Incidents: The assessment of potential security incidents' severity considers several factors, including the sensitivity of the data involved, the importance of the affected systems, and the likelihood of operational disruption. For instance, an attack on a crucial server holding sensitive customer information is deemed more severe than an incident impacting a non-critical system. The 2017 WannaCry ransomware attack is a notable example, wreaking havoc globally by affecting over 200,000 computers in 150 countries. This attack caused significant disruptions across different sectors, notably healthcare, where UK hospitals had to redirect emergency patients because they couldn't access medical records. [35].
- Quantifying the Impact: Quantifying the impact involves estimating the potential financial costs, such as loss of revenue, legal fines, and costs associated with incident response and recovery. It also includes assessing intangible costs like customer trust and brand reputation damage. Tools like Business Impact Analysis (BIA) are often used to quantify these impacts systematically. The Yahoo data breaches disclosed in 2016, which occurred in 2013 and 2014, affected all 3 billion Yahoo accounts. This massive breach resulted in a $350 million reduction in the sale price to Verizon and severely damaged Yahoo's reputation, highlighting the long-term reputational impact of security incidents [36].

- Prioritizing Risks Based on Impact: Impact analysis helps prioritize risks based on their potential impact. This prioritization is crucial for allocating resources effectively and focusing on the most significant threats. High-impact risks are addressed with more urgency and robust countermeasures.
- IBM's 2020 Cost of a Data Breach Report: It estimates a data breach's average total cost of $3.86 million, with healthcare breaches costing the most at $7.13 million per incident [37]. Gartner's report estimates IT downtime at $5,600 per minute, over $300,000 per hour [38].

Based on the impact analysis, organizations develop mitigation and response strategies. This includes implementing more robust security measures for high-risk areas, developing incident response plans, and establishing business continuity and disaster recovery plans.

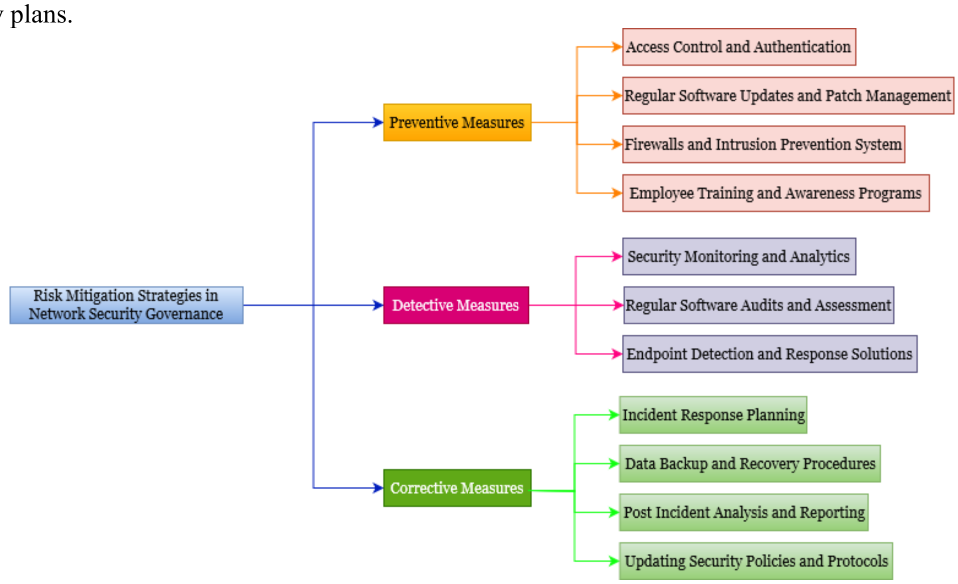

Fig 3. Risk Mitigation Strategies

Risk Mitigation Strategies in NSG

Risk mitigation is essential to NSG, preventing, detecting, and correcting security threats to build a resilient security posture that can adapt to changing cyber threats (**Fig 3**).

Preventive Measures: A strong cybersecurity strategy requires preventive security measures.

- Access Control and Authentication: Only authorized users can access sensitive systems and data with multi-factor authentication and least privilege access.
- Regular Software Updates and Patch Management: Software and systems need the latest patches to prevent attackers from exploiting vulnerabilities.
- Firewalls and Intrusion Prevention Systems: Monitor and regulate network traffic with firewalls and intrusion prevention systems to follow security rules.
- Employee Training and Awareness Programs: Educating employees on cybersecurity best practices, including identifying phishing emails and adhering to secure password protocols, is crucial for preventing security breaches that stem from human error.

Detective Measures: Detective measures are implemented to spot and alert about potential security incidents in real-time. These measures are essential for quickly identifying threats, enabling a rapid response.

- Security Monitoring and Analytics: Deploying sophisticated monitoring tools that scrutinize network traffic and user behavior is effective in detecting irregularities that could signal a security breach.
- Regular Security Audits and Assessments: Regular security audits and vulnerability assessments are crucial in identifying potential vulnerabilities in the network infrastructure.
- Endpoint Detection and Response (EDR) Solutions: For endpoint threat detection and isolation, EDR solutions provide real-time monitoring and automated response.

Corrective Measures: Corrective measures are actions taken post-security incidents to contain and improve the situation, thereby reducing the impact of security breaches.

- Incident Response Planning: A security breach must be handled quickly and effectively by a company with a clear incident response strategy.
- Data Backup and Recovery Procedures: Having robust recovery protocols in place and regularly backing up important data are essential for a prompt resumption of activities after a security incident.
- Post-Incident Analysis and Reporting: Performing comprehensive post-incident analysis and reporting is crucial for understanding the cause of the breach and devising strategies to prevent similar incidents.
- Updating Security Policies and Protocols: It's crucial to assess and revise current security policies and procedures following a security incident to fix any weaknesses.

V. CHALLENGES IN NSGRM

NSGRM plays a vital role in safeguarding an organization's digital assets. Nonetheless, various challenges can hinder these processes, complicating the maintenance of strong security. Recognizing these obstacles is fundamental to formulating effective strategies to surmount them.

Evolving Threat Landscape

The cybersecurity threat landscape is in constant flux, with new varieties of attacks surfacing continually. Cybercriminals increasingly use more sophisticated methods, employing advanced technologies like artificial intelligence and machine learning to circumvent conventional security defenses. For example, the rise of ransomware attacks, such as the WannaCry and NotPetya incidents, has shown how quickly new threats can emerge and spread globally [39], causing severe damage to unprepared organizations.

- Advanced Ransomware Tactics: Beyond the widely known WannaCry and NotPetya incidents, recent years have seen a surge in more sophisticated ransomware attacks. For instance, the Ryuk ransomware, active since 2018, targets large, high-value organizations with carefully planned attacks, leading to substantial ransom demands [40]. These attacks often involve extensive network penetration and lay dormant until activated, making them harder to detect and counter.
- State-Sponsored Cyber Attacks: There has been a notable increase in state-sponsored cyber activities. These attacks are often highly sophisticated and can target critical national infrastructure. The SolarWinds Orion breach in 2020, attributed to a Russian cyber espionage group, compromised numerous US government agencies and major corporations [41], highlighting the scale and sophistication of state-sponsored cyber threats.
- AI-Powered Attacks: The use of AI by attackers is a growing concern. AI can be used to automate the generation of phishing emails that are more convincing and targeted, making them harder to distinguish from legitimate communications. AI can also be used to develop malware that adapts to defenses in real-time, posing a significant challenge to traditional security measures.
- Supply Chain Attacks: Cybercriminals increasingly target supply chains to infiltrate multiple organizations through a single breach. These attacks exploit vulnerabilities in third-party vendors or software suppliers to gain access to their customers' networks. A notable example is the 2020 Kaseya VSA ransomware attack, where attackers exploited a vulnerability in Kaseya's remote monitoring and management software to deploy ransomware across multiple managed service providers and their clients [42].
- IoT Device Vulnerabilities: The proliferation of Internet of Things (IoT) devices has introduced new vulnerabilities into network environments. Many IoT devices lack robust security features, making them easy targets for attackers. The Mirai botnet, which first appeared in 2016, demonstrated how easily IoT devices could be compromised and used for large-scale network attacks [43].
- Cryptojacking: Cryptojacking, a method where attackers exploit a victim's computing resources to mine cryptocurrency, has become a covert and profitable activity. Unlike ransomware, cryptojacking can operate unnoticed for extended periods, discreetly draining resources potentially leading to performance degradation and escalated operational costs.

In response to these ever-changing threats, organizations must persistently revise their security approaches. This involves investing in *state-of-the-art* threat detection and response systems, regularly conducting security audits, and keeping abreast of the latest cyber threats. Furthermore, cultivating a culture of security awareness among employees and establishing strong incident response plans are essential measures to mitigate the effects of these sophisticated attacks.

Technology Complexity

IT settings are becoming more complex as technology advances. These days, managing a combination of mobile, cloud, IoT, and legacy systems presents unique security problems for organizations. The complexity of these systems increases risks by making management and security more difficult. Integrating innovative technologies into outdated infrastructures is more complicated, mainly when legacy systems don't work with the security measures in place.

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- Cloud Services: The transition towards cloud computing has brought fresh security challenges. Although cloud service providers typically offer comprehensive security features, the onus of securing assets hosted on the cloud remains with the organization. Numerous high-profile data breaches have resulted from misconfigurations in cloud services, highlighting the importance of having specialized knowledge and skills in cloud security.
- Mobile and Remote Workforce: The growing reliance on mobile devices and the surge in remote work have broadened the security boundaries of organizations. Mobile devices frequently connect to corporate networks from diverse locations and networks, amplifying the risk of data breaches and other security threats. The COVID-19 pandemic expedited this shift, leading many organizations to swiftly embrace remote work models, often without comprehensively tackling the related security challenges.
- IoT Devices: IoT devices are being adopted at an unprecedented rate in various sectors, from smart home devices to industrial IoT. However, these devices often have inherent security weaknesses, such as default passwords and lack of regular updates, making them prime targets for cyber-attacks. The 2016 Dyn cyberattack, which used a large network of compromised IoT devices, highlighted the potential scale of attacks leveraging IoT vulnerabilities [44].
- Integrating recent technologies with existing infrastructure is a pivotal yet challenging network security task involving compatibility issues, security protocol conflicts, data integration challenges, and resource allocation. Innovative technologies may not align seamlessly with legacy systems, leading to security gaps and operational inefficiencies. Merging data across different systems can also present significant challenges, potentially affecting data integrity and organizational workflows. To effectively navigate these challenges, organizations can adopt strategies like phased integration, which allows for gradual implementation and testing. Upgrading legacy systems to enhance compatibility, conducting interoperability testing, and consulting with IT integration experts are crucial steps. Additionally, training employees on modern technologies and the associated process changes ensures a smoother transition and integration. Collectively, these strategies help minimize disruptions and maintain robust network security while integrating new and existing technologies.

Compliance and Regulatory Challenges

In NSG, organizations face a labyrinth of compliance and regulatory challenges that are both intricate and dynamic. These challenges are confined to local authorities and span international boundaries, making compliance a complex and ongoing task.

- Diverse International Regulations: With regulations like the EU's General Data Protection Regulation (GDPR) and the California Consumer Privacy Act (CCPA) in the US, organizations are required to adhere to stringent data protection and privacy standards [45]. However, the complexity escalates for multinational corporations that must comply with diverse regulations across different regions. For instance, the GDPR imposes strict rules on data handling and grants significant rights to individuals regarding their data, while the CCPA focuses on consumer privacy rights and transparency in data practices.
- Sector-Specific Regulations: Certain industries face additional layers of regulatory requirements. For example, the healthcare sector in the US must comply with the Health Insurance Portability and Accountability Act (HIPAA), which sets standards for protecting sensitive patient data. Similarly, financial institutions are governed by regulations like the Sarbanes-Oxley Act (SOX) [46] and the PCI-DSS, each with its own set of stringent security mandates.
- Emerging Data Sovereignty Laws: The rise of data sovereignty laws in countries like Russia and China requires data about citizens to be stored within national borders. This adds another layer of complexity for global organizations, as they must ensure that their data storage and processing practices comply with these territorial requirements.
- Non-compliance with these regulations can have severe consequences. Financial penalties can be substantial, as seen in cases like Google's €50 million GDPR fine in 2019 [47]. Beyond economic loss, non-compliance can lead to legal battles, operational disruptions, and significant reputational damage, which can have long-term impacts on customer trust and business viability.

Resource Constraints

Resource constraints represent a significant hurdle in implementing robust NSGRM, particularly for Small and Medium-sized Enterprises (SMEs). These constraints manifest in various forms, including financial limitations, time constraints, and a shortage of skilled cybersecurity personnel, each posing unique challenges in maintaining effective security measures.

Financial Limitations

- Budgetary Constraints in SMEs: SMEs often operate with limited financial resources, restricting their ability to invest in advanced security infrastructure and tools. Unlike giant corporations with more substantial budgets, SMEs might struggle to afford comprehensive cybersecurity solutions, leaving gaps in their defense mechanisms.
- Cost of Security Solutions: The high cost of state-of-the-art security technologies and services can be prohibitive for many organizations. This includes expenses for acquiring, implementing, and maintaining sophisticated security systems and the costs associated with ongoing updates and upgrades necessary to combat new threats.

Time Constraints

- Rapidly Evolving Threat Landscape: Keeping pace with the rapidly evolving cyber threat landscape requires continuous monitoring and updating of security protocols. For many organizations, especially those with limited IT staff, dedicating the necessary time to these tasks can be challenging.
- Implementation Time: The time required to implement and integrate new security measures can be substantial. For organizations with limited human resources, this can lead to delays in deployment, during which time the organization remains vulnerable to emerging threats.

Shortage of Skilled Personnel

- Cybersecurity Talent Gap: There is a well-documented shortage of skilled cybersecurity professionals. This talent gap means many organizations, particularly SMEs, struggle to recruit and retain qualified security personnel.
- Training and Development: The cost and time required for training existing staff in cybersecurity can be significant. For smaller organizations, this investment can strain already limited resources, impacting their ability to maintain an adequately trained security team.

Human Factor

The human element in cybersecurity represents a critical and often vulnerable aspect of NSG. Despite advanced technological defenses, human error remains a significant risk factor, often cited as the weakest link in the cybersecurity chain.

Prevalence of Human Error

- Common Mistakes Leading to Breaches: Human errors, such as succumbing to phishing attacks, using weak or reused passwords, or inadvertently misconfiguring security systems, are frequent culprits in security breaches. These mistakes can provide easy entry points for cybercriminals to exploit.
- Statistical Evidence of Risk: The 2017 Verizon Data Breach Investigations Report underscores the magnitude of this issue, revealing that human error was involved in 90% of security incidents [48]. This statistic highlights the critical need for addressing the human factor in cybersecurity strategies.

Challenges in Mitigating Human Risk

- Changing Human Behavior: Altering ingrained behaviors and habits, such as careless password practices or the indiscriminate opening of email attachments, is a significant challenge. People are creatures of habit, and changing these habits requires consistent effort and reinforcement.
- Maintaining Awareness and Vigilance: Keeping cybersecurity at the forefront of employees' minds is an ongoing challenge. As the immediacy of security training fades, so can vigilance, leading to complacency and increased risk of error.

VI. COPING STRATEGIES FOR NSGRM

In the dynamic world of network security, coping strategies are essential for organizations to adapt and stay resilient against evolving threats. These strategies include a variety of approaches, such as creating flexible security architectures, ongoing education, and collaborative initiatives.

Adaptive Security Architecture for Evolving Threat Landscape

The concept of adaptive security architecture (**Fig 4**) embodies a dynamic and proactive approach tailored to evolve alongside the constantly shifting landscape of cyber threats. This strategy goes beyond merely implementing tools; it's about establishing an ecosystem that persistently learns, adapts, and reacts to new and emerging threats. Key components of this approach include:

Layered Defense Mechanisms

- Comprehensive Coverage: The multi-layered defense strategy operates like a security net, incorporating various tools and protocols, including firewalls, IDPS, and Advanced Threat Protection (ATP). This multifaceted strategy ensures that other levels are in place to thwart an attack if one layer is compromised.
- Depth in Defense: Each layer in this defense strategy is tailored to counteract particular threats, establishing a comprehensive defense depth. This depth makes it difficult for cyber threats to penetrate all layers. For example, while

firewalls regulate traffic using security rules, IDS and IPS systems examine the traffic for unusual activities, and ATP systems are designed to neutralize sophisticated threats that might slip through the initial defenses.

Real-Time Threat Intelligence

- Staying Ahead of Threats: Leveraging real-time threat intelligence feeds in cybersecurity is comparable to continuously updating a map. These feeds offer valuable insights into newly discovered vulnerabilities, emerging malware varieties, and the strategies employed by cybercriminals.
- Adaptive Security Posture: Organizations with access to this real-time information can modify their security protocols quickly. This adaptability is essential in an environment where threats change quickly, guaranteeing that defenses stay applicable and valuable.

Automated Response Systems

- Reducing Human Dependency: By incorporating automated response systems, organizations can detect and neutralize threats in real-time. This automation reduces the dependency on manual intervention, which is crucial in scenarios where speed is of the essence.

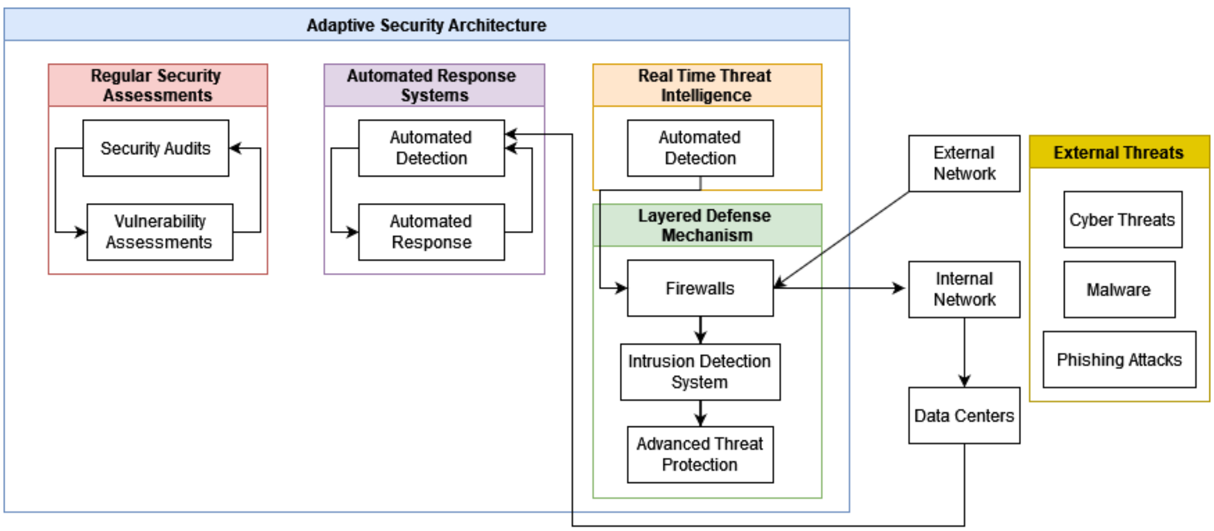

Fig 4. Adaptive Security Architecture

- Enhanced Response Capabilities: These systems are not just reactive but designed to learn from each incident, enhancing their response capabilities over time. This means the system becomes more efficient and effective in identifying and mitigating threats, thereby continuously strengthening the organization's security posture.

Regular Security Assessments

- Proactive Vulnerability Identification: Regular security assessments are vital in identifying vulnerabilities and gaps in the security architecture. These assessments can range from penetration testing to security audits, highlighting potential weaknesses.
- Timely Adjustments and Updates: The insights gained from these assessments enable organizations to adjust their security strategies promptly. This could involve patching vulnerabilities, updating security protocols, or even overhauling certain aspects of the security architecture to address new threats.

Continuous Education and Training

Continuous education and training are pivotal in fortifying an organization's defense mechanisms in the rapidly evolving network security domain. This ongoing process is essential for IT professionals and all employees, as each individual plays a critical role in maintaining the organization's cybersecurity posture. The key aspects of this comprehensive training program include the following:

Regular Cybersecurity Training Sessions

- Up-to-Date Knowledge: To keep the workforce informed about the most recent developments in cybersecurity practices, trends, and threat landscapes, regular training sessions are essential. These seminars should cover various subjects, from sophisticated threat detection strategies to fundamental cybersecurity hygiene.

- Engaging and Relevant Content: Training materials should be interesting, interactive, and customized to various employee groups' unique tasks and responsibilities to enhance their efficacy. This strategy guarantees that the training is instructive, approachable, and helpful for their day-to-day work.

Simulated Cyber Attacks

- Practical Experience: Employees can get valuable experience addressing such dangers by participating in cyberattack exercises that mimic real-world attacks, like phishing simulations or breach scenarios. The knowledge that is taught during training sessions is tested and reinforced with the aid of these simulations.
- Response Evaluation and Improvement: Organizations can analyze employee reactions to these simulations to pinpoint areas of weakness and offer specialized training to close these gaps. Additionally, it aids in improving incident response procedures and plans.

Creating a Security-Conscious Culture

- Beyond Training Sessions: Embedding cybersecurity knowledge into the organization's core is necessary to foster a security-conscious culture that goes beyond training. This entails incorporating security into routine discussions and choices.
- Empowering Employees: Empowering staff members to assume responsibility for their part in cybersecurity is essential. This includes seeing and reporting unusual activity, following security guidelines, and keeping up with best practices.
- Leadership Involvement: Establishing this culture requires strong leadership. Leaders can set the tone for cybersecurity throughout the company by actively participating in training sessions and exhibiting a commitment to the field.

Collaboration and Information Sharing

Network security, cooperation, and information exchange are essential for constructing a stronger defense against cyberattacks. This cooperative strategy encourages a group effort to address cybersecurity issues by bridging organizational boundaries. The major components of this approach comprise:

Participating in Industry Forums and Groups

- Knowledge Exchange Platforms: Industry associations and forums offer firms a great way to share knowledge, expertise, and best practices in cybersecurity. These discussion boards offer chances to pick up knowledge from colleagues, comprehend new dangers, and talk about practical defenses.
- Community Strength: Organizations can access diverse collective knowledge and expertise by engaging with these groups. A more comprehensive awareness of the threat landscape and more potent risk mitigation techniques are made possible by this collaborative approach to security.

Public-Private Partnerships

- Synergizing Efforts: Public-private partnerships are strategic relationships where the business sector and government organizations work to strengthen cybersecurity. These collaborations are vital in sharing threat intelligence, coordinating responses to large-scale cyber threats, and adopting uniform cybersecurity strategies.
- Resource Optimization: By combining resources, knowledge, and information, these collaborations allow for the development of cybersecurity solutions that are more effective and efficient. They also make it easier to comprehend the regulatory environment and assist in coordinating security procedures with legal requirements.

Cross-Industry Collaboration

- Diverse Perspectives Working with companies in various industries provides a special chance to learn about other viewpoints and methods for approaching cybersecurity. This diversity is crucial for comprehending how various industries handle related security concerns.
- Innovative Solutions: Collaboration between different industries can create creative security solutions that are more thorough and efficient. Through assimilating knowledge from diverse industries, enterprises might use optimal methodologies that might not have been contemplated in their field.

Leveraging Technology

In network security, the incorporation of cutting-edge security techniques that use AI, ML, and Deep Learning (DL) has completely changed how enterprises anticipate and counteract cyberattacks. With the help of these advanced technologies, reactive security measures can be replaced with a more proactive, predictive strategy.

Predictive Capabilities with ML/DL Models

- ATD: Massive volumes of network data may be analyzed in real-time by ML/DL models, which can then be used to spot trends and abnormalities that could point to a security risk. For example, models like Recurrent Neural Networks (RNNs) and Convolutional Neural Networks (CNNs) identify anomalous patterns in network traffic that may indicate impending cyberattacks.
- Predictive Analytics: Predictive analytics is used by these tools to anticipate possible security incidents. Organizations can proactively strengthen their defenses by utilizing algorithms like Gradient Boosting Machines, Random Forests, and Decision Trees, which analyze past data and forecast potential attack vectors.

Continuous Learning and Adaptation

- Dynamic Response to Emerging Threats: The strength of ML/DL models is their ongoing learning from fresh data. This is a critical component in the dynamic world of cyber threats, where new attack techniques and malware are constantly being developed. Reinforcement Learning systems, for instance, can adjust to novel threats by gaining knowledge from the results of earlier security occurrences.
- Self-Improving Security Posture: Using these models, security measures are guaranteed to change and adapt over time. The models improve the organization's security posture by improving their predicted accuracy when exposed to fresh data and attack patterns. Strategies such as Transfer Learning work exceptionally well when transferring expertise from one area to another but are related to security problems.

Real-World Applications and Case Studies

- Behavioral Analysis for Anomaly Detection: In real-world applications, ML/DL models have been instrumental in detecting anomalies that deviate from typical user behavior, which could indicate a security breach. For instance, Sequence Models like Long Short-Term Memory (LSTM) networks help identify irregularities over time, providing early warnings of potential violations.
- Automated Threat Intelligence: These models also play a significant role in automated threat intelligence, where they analyze data from various sources to identify emerging threats. By employing Natural Language Processing (NLP), these tools can sift through unstructured data from news feeds, blogs, and reports to extract actionable intelligence.

Cloud-Based Security Solutions

Incorporating cloud-based security solutions into NSG offers a modern approach to managing cybersecurity risks. These solutions, provided by leading cloud platforms like Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP), bring various features and benefits tailored to the needs of diverse organizational structures.

Scalability and Flexibility with Specific Cloud Platforms

- AWS Security: AWS Identity and Access Management (IAM) for safe user access control and AWS Shield for DDoS prevention are only two of the scalable security services that Amazon Web Services provides. Strong security is provided by these systems, which may be expanded to accommodate enormous volumes of data and traffic for both small and large businesses.
- Azure Security Center: Azure Security Center, a unified security management system from Microsoft Azure, improves data centers' security posture. It uses AI to identify and stop complex assaults and provides advanced threat protection for hybrid cloud workloads.
- Google Cloud Security: Advanced security technologies like Cloud Identity for identity management and Google Cloud Armor for network security are included in the Google Cloud Platform. The worldwide infrastructure of GCP enables quick scaling and the deployment of security resources as required.

Centralized Management and Accessibility Across Platforms

- Unified Security Dashboards: Centralized dashboards are available for managing compliance and monitoring security alerts on platforms such as AWS and Azure. These dashboards facilitate prompt response and repair by offering real-time visibility into security issues.
- Accessibility and Control: Security personnel may monitor and react to threats from any location in the world using cloud-based solutions. This is especially advantageous for businesses that employ remote workers or have a global presence.

Platform-Specific Enhanced Security Features

- Automated Security in AWS: Without requiring manual involvement, AWS provides automated patch management and updates to safeguard the infrastructure against known vulnerabilities.
- AI-Driven Threat Detection in Azure: Azure uses ML and AI algorithms for proactive threat detection, offering analytics and insights to anticipate and stop possible security breaches.
- Data Encryption in GCP: With built-in encryption for both in-transit and at-rest data security, the Google Cloud Platform provides crucial data security and privacy.

Real-World Applications and Cloud-Specific Benefits

- Data Protection in Remote Work: Robust solutions for safeguarding remote work environments are provided by platforms such as GCP and Azure, guaranteeing that data is secure no matter where the employee is located.
- Compliance and Regulatory Adherence: These cloud platforms offer comprehensive data protection and privacy features, tools, and services to help organizations comply with legal obligations like GDPR and HIPAA.

Regular Technology Audits

Maintaining a strong NSG structure requires regular technology assessments. These audits accomplish several goals, such as verifying the technological stack's currency and security and coordinating it with the organization's overall security goals.

- Ensuring Up-to-Date and Secure Systems: Regular audits are instrumental in identifying and addressing vulnerabilities within the technology infrastructure. They help pinpoint outdated software, underutilized applications, and potential security gaps that cyber adversaries could exploit. By systematically evaluating the technology stack, organizations can preemptively rectify issues that might otherwise lead to security breaches.
- Alignment with Security Goals: These audits are not just about technical assessment; they also ensure that the technological infrastructure is coordinated with the organization's security goals and strategies. This alignment is crucial for a cohesive and effective security posture. It involves evaluating whether the current technology stack supports the desired level of security and meets the standards set by the organization.
- Role of Third-Party Audit Firms: Often, organizations enlist third-party audit firms to conduct these technology audits. These firms bring an objective and expert perspective, essential for a thorough and unbiased evaluation. They possess specialized knowledge and experience in identifying potential security risks that internal teams might overlook. Third-party auditors can also benchmark an organization's security practices against industry standards and best practices, providing valuable insights into areas of improvement.
- Compliance Verification: Third-party audit firms play a pivotal role in verifying compliance with various regulatory standards such as GDPR, HIPAA, or PCI-DSS. Their expertise ensures that organizations meet the required compliance standards and stay updated with any changes in regulatory requirements.
- Recommendations and Actionable Insights: Post-audit, these firms often provide detailed reports with improvement recommendations. These insights are invaluable for organizations to refine their security strategies and implement best practices. They offer actionable steps organizations can take to enhance security posture and mitigate risks effectively.

Generally, regular technology audits, particularly those conducted by third-party firms, ensure that an organization's technology infrastructure is secure, up-to-date, and aligned with its security objectives. They offer an outside perspective to supplement internal evaluations, resulting in a more thorough comprehension of the cybersecurity readiness of the company.

VII. CONCLUSION

To sum up, this study has explored the complex and dynamic domains of risk management and Network Security Governance (NSG), emphasizing the critical role these fields play in the modern digital environment. Strong and flexible security measures are more important than ever when cyberattacks are becoming more sophisticated and common. This study examines several aspects of NSG, highlighting the foundation of successful cybersecurity: creating and applying all-encompassing policies and standards. Despite having different purviews, these policies aim to protect digital assets from several cyber threats while maintaining adherence to changing legal requirements. The importance of taking a methodical approach to risk management was also emphasized in the report. This strategy entails risk identification, mitigation, proactive threat anticipation, and preparation. Because the cyber landscape is dynamic, risk management must be a continuous process marked by ongoing evaluation and modification. This paper also discussed the difficulties businesses have in this area, such as the always-changing threat landscape, complex technological issues, challenges with compliance, limited resources, and the human element. Due to these difficulties, network security requires a complex, multidimensional strategy that balances technology advancements and human-centered approaches. Advanced technologies like Artificial Intelligence (AI) and machine learning have been emphasized as crucial components in augmenting cybersecurity endeavors. These technologies provide the flexibility and predictive power needed to keep ahead of new threats. Furthermore, the importance of teamwork, ongoing education, and training was stressed, reiterating that cybersecurity is a shared duty.

In conclusion, this article adds to the current Network Security Governance and Risk Management (NSGRM) discussion by providing businesses with techniques and insights to navigate this intricate terrain. These methods for mitigating cyber dangers need to change along with them. Organizations may protect themselves from known threats and strengthen their defenses against new ones by adopting a comprehensive and flexible strategy for cybersecurity.

Data Availability
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests
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