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# The Impacts of 5G Networks on Internet Security in the Oil and Gas Industry

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## Abstract

*This paper addressed the critical challenge of securing Nigeria's oil and gas infrastructure in the 5G era by developing a novel 5G-Enabled Oil & Gas Security Risk Index (5G-OGSRI), a mathematical model that quantifies cyber risks through the equation* $\mathscr{R}(t) = \sum(\mathcal{T}_i \cdot \mathcal{V}_i \cdot \mathscr{E}_i) - (\mathcal{S}\_\mathcal{ZT} + \mathcal{S}\_\mathcal{AI}) + \epsilon(t)$*, where* $\mathcal{T}_i$ *is the threat exposure,* $\mathcal{V}_i$ *is the vulnerability decay, and* $\mathscr{E}_i$ *is the criticality, which was balanced against Zero Trust* ($\mathcal{S}\_\mathcal{ZT}$) *and AI-driven* ($\mathcal{S}\_\mathcal{AI}$) *defenses. Through a systematic literature review and empirical analysis, the study identifie key vulnerabilities in 5G-dependent industrial systems, revealing that unsecured IoT devices* ($\mathcal{V}_i \geq 0.7$) *and poor network segmentation increase breach risks by 47%. The findings demonstrate that proactive patching* ($\lambda \geq 0.8$) *reduces exploitability 3.2× faster, while AI-enhanced detection* ($\beta \geq 0.67$ *precision) improves threat response by 72%. The study proposed an 8-phase cybersecurity algorithm, validated with real-world mathematical models, which maintains* $\mathscr{R}(t) < 0$ *(safe thresholds) in 89% of cases by integrating collaborative threat intelligence, Zero Trust micro segmentation, and adaptive encryption. By aligning with NIST CSF and IEC 62443 standards, this framework provides a scalable, policy-ready solution to safeguard Nigeria's energy infrastructure, ensuring uninterrupted production, $2.3B+ annual cyber loss prevention, and sustainable economic growth. This work bridges the gap between 5G innovation and national security, offering a data-driven blueprint for emerging economies reliant on critical energy assets.*

**Keywords:** 5G-OGSRI; Oil and Gas; Internet-Security; Critical Infrastructure; Math-Model and Industry.

## 1. Introduction

The oil and gas industry plays a crucial role in powering the global economy. However, the industry is facing numerous challenges in the digital era, where connectivity and network security have become increasingly important (Ajadi *et al*. 2020). The emergence of the fifth-generation (5G) wireless network technology provides new opportunities for the industry to improve its network infrastructure and enhance its operations. However, 5G networks also present new cyber-security risks that must be addressed to ensure the safety and security of critical infrastructure (Hammoudeh *et al.* 2023). The oil and gas industry are

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particularly vulnerable to cyber-attacks due to its reliance on complex and Interconnected networks (Wisdom *et al.,* 2022). Cyber-attacks targeting the industry can have devastating consequences, including damage to physical infrastructure, environmental disasters, and loss of life. In recent years, there have been several high-profile cyber-attacks on oil and gas companies, highlighting the urgent need for improved network security measures (Humayun *et al.* 2023). This review Paper aims to investigate the impacts of 5G networks on internet security in the oil and gas industry. The proposal will explore how 5G networks can be leveraged to enhance network infrastructure and operations while mitigating the associated cyber-security risks. The research will also investigate the current state of network security in the oil and gas industry, identify key vulnerabilities, and propose strategies to address them (Sullivan *et al.* 2021). The study will contribute to the development of new knowledge in the field of internet security in the context of 5G networks and the oil and gas industry. The findings of this research will be of significant value to industry stakeholders, policymakers, and researchers in cybersecurity. Ultimately, the research aims to provide actionable insights that can be used to enhance the safety and security of critical infrastructure in the oil and gas industry. Such as the lack of a comprehensive security framework for 5G networks (Zahoor *et al.* 2021; Alshammari *et al.* 2020). The vulnerability of 5G networks to cyber-attacks is due to their increased complexity and heterogeneity. The challenge of securing the large number of IoT devices that will be connected to 5G networks. The need to ensure the privacy and confidentiality of user data in 5G networks. The challenge of ensuring the availability of 5G networks in the face of attacks or natural disasters (Olorundare *et al.* 2017; Alcaraz *et al.* 2020). The deployment of 5G networks requires a massive infrastructure investment to build the necessary cell towers and fiber-optic cable networks. This infrastructure investment may pose significant challenges, particularly in rural or remote areas, where it may be difficult to justify the cost of building the necessary infrastructure. Interference: 5G networks operate at much higher frequencies than previous wireless networks, which makes them more susceptible to interference from physical objects such as buildings, trees, and other obstacles. Finding ways to mitigate interference in 5G networks is an open research area. Although several research studies have been presented (Zolotukhin *et al.* 2023; Alshamrani *et al.* 2020; Li, *et al.* 2020; Alnafessah *et al.* 2020; Alshammari *et al.* 2020; Wu *et al.* 2020; Kim *et al.* 2020; Xiao *et al.* 2020; Hu *et al.* 2020). The need to develop new authentication and access control mechanisms for 5G networks is imperative. The challenge of securing network slices, which are virtual networks that share the same physical infrastructure in 5G networks. This study focuses on highlighting both the strengths and weaknesses of each study as well as proposes a comprehensive algorithm for the mitigation of emerging cyber threats in the oil and gas industries in Nigeria; while presenting possible future directions for further research. Figure 1 shows Base Stations (BS) interconnected to each other, enabling easy information exchange via user equipment (UE). While figure 2 as shown below, is a basic 5G network architecture with Internet of Things (IoT) nodes interconnected to each other. The rest of this paper is structured as follows 2.0 comprehensive review of related literature, 3.0 Security Overview in the Nigerian oil and Gas industries, research opportunities in 5G; 4.0 Emerging Security Threats and Solutions in the Nigerian Oil and Gas Industries; 5.0 Proposed Algorithm to Mitigate Emerging Cyber threats in the 5G Oil and Gas Industry and section 6. Concludes the research study, Figure 1 depicts the Architecture of critical infrastructure.

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Figure 1: Architecture of critical infrastructure

## 2. Related Works

Islam *et al., (*2020) developed a lightweight authentication method tailored for 5G networks, blending hash functions and symmetric key cryptography to reduce computational overhead and enhance efficiency. Their study aimed to introduce a secure and efficient authentication solution specific to 5G networks, addressing both security and computational demands. By combining hash functions and symmetric key cryptography, they devised an authentication scheme that outperformed existing methods in terms of computational efficiency while ensuring security. However, the specific algorithm used was not disclosed, warranting further research to evaluate its security and efficiency across various scenarios and potential threats. Future investigations could explore the scheme's performance under different network conditions, assess vulnerability to diverse attack vectors, and consider enhancements using advanced cryptographic techniques. Almogren *et al.,* (2020) conducted a comparative analysis of security protocols for 5G networks, aiming to identify the most suitable protocol balancing robust security and efficient performance. Their research methodology involved evaluating the performance and security attributes of protocols like Transport Layer Security (TLS), Datagram Transport Layer Security (DTLS), and Internet Key Exchange version 2 (IKEv2). While no novel algorithms were developed, findings suggest Transport Layer Security (TLS) provides the optimal balance between security and performance. However, potential limitations or weaknesses of these protocols were not addressed, suggesting a need for future research to explore these aspects under diverse network conditions and consider additional security protocols. Khan *et al., (*2020) present a security framework for 5G networks based on software-defined networking (SDN), aiming to improve network visibility and control to reduce vulnerability to cyber-attacks. Their research focuses on proposing an SDN-based security framework specifically tailored for 5G networks to enhance security by enabling swift detection and mitigation of network-based attacks. Although no new algorithms were developed, the study evaluates the performance of the proposed framework in enhancing 5G network security. While the research findings indicate the effectiveness of the SDN-based framework, potential limitations or vulnerabilities are not addressed, suggesting a need for future research to assess its performance under diverse network conditions and identify strategies for mitigation. Additionally, future studies could explore integrating the proposed framework with additional security measures to further enhance the overall security of 5G networks. Park *et al.,* (2021) introduced a 5G network security framework

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integrating blockchain and artificial intelligence (AI) to enhance security and privacy, with blockchain securing data transmission and AI aiding in intrusion detection. Their research aimed to propose and evaluate the performance of this framework in enhancing 5G network security and privacy, although no new algorithms were developed. The study concludes that the framework enhances security and privacy, it does not address potential limitations or performance under different network conditions, suggesting a need for future research. Future endeavors could assess the framework's performance under diverse conditions, identify weaknesses, explore integration with other security measures, and evaluate cost-effectiveness and overall network performance impact. Similarly, in a separate study, (Li *et al.* 2020) conducted a comprehensive analysis of security threats and solutions in 5G networks, identifying threats to network infrastructure, user privacy, and data integrity, the study proposed mitigation strategies such as network segmentation, access control, and encryption. The research aimed to analyze security threats and propose solutions for 5G networks, utilizing a methodology involving a thorough literature review and analysis of 5G network security features. While no specific algorithms were proposed, the study highlighted the need for secure 5G network infrastructure and implementation of security solutions, suggesting further research in these areas. The study emphasized the importance of addressing security challenges to ensure the integrity and privacy of 5G networks. Wang *et al.*, *(*2021) introduced a dynamic trust management scheme tailored for 5G networks to enhance trust among participants and improve overall network security. Through a systematic literature review, they identified existing trust management approaches and developed a reputation-based model, which was then evaluated in a simulation or experimental environment. Adhering to established guidelines, the study demonstrated the scheme's effectiveness in enhancing trust accuracy, convergence speed, and overall security improvement. The proposed algorithm utilized reputation-based trust management to ensure the integrity and authenticity of network participants, although its generalizability to different 5G network architectures or real-world deployments is limited. Potential biases in data extraction and analysis processes were acknowledged, suggesting the need for further refinement and validation of the dynamic trust management scheme in future work. Future research may involve real-world experiments, evaluation in diverse 5G network scenarios, and investigation of potential vulnerabilities or attacks that could undermine the scheme's effectiveness, aiming to enhance trust and security in 5G networks comprehensively.

**Table 1:** Executive Summary of Related Literature

| References | Research Focus | Objectives | Methodology | Results/ Findings | Limitations/ Weakness | What is Missing | Future Work |
|---|---|---|---|---|---|---|---|
| Li & Wang (2021 | Blockchain-based security for 5G network slicing | Enhance security/trust in 5G slices via blockchain | Conceptual framework + proof-of-concept prototype | Improved integrity/ authenticity in network slices, Blockchain scheme | No regulatory analysis; limited application scope | Untested consensus mechanisms; scalability concerns | Explore consensus models, scalability, new use cases |

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| | | | | for 5G slice security | | | |
| Vasilakos *et al.* (2020) | 5G security & privacy challenges/ solutions | Identify risks, propose mitigations (MFA, anonymization) | Systematic literature review, qualitative analysis | Key risks: authentication, access control, data protection | Proposed MFA, data anonymization, blockchain/AI integration | No empirical tests; ignored legal/ethical aspects | Test solutions, study AI/blockchain impact, industry collaboration |
| Kaloxylos & Kambourakis 2021 | 5G security enhancement via intelligent traffic profiling | Assess effectiveness of traffic profiling for 5G security | Experimentation and analysis of traffic profiling techniques | Intelligent traffic profiling improves 5G security | Lacks detailed methodology and profiling techniques | Lacks detailed methodology and profiling techniques | Integration with other security mechanisms; broader testing |
| Lim *et al.* 2021 | 5G security enhancement via intelligent traffic profiling | Identify threats/propose countermeasures for 5G networks | Literature review + traffic profiling experiments | Profiling improves detection of authentication/privacy threats. Secure key management + network segmentation | Limited real-world validation of techniques | No automated real-time implementation shown | Integrate with AI/ML; develop real-time solutions |
| Abbas *et al.* 2020 | 5G security & privacy challenges/ solutions | Survey threats, propose blockchain/ AI solutions | Structured literature review | Key issues: authentication, access | No solution effectiveness analysis | Missing empirical validation | Develop/test solutions; enhance collaboration |

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| | | | | control. Blockchain & AI-based solutions | | | |
| Duan *et al.* 2020 | ML-enhanced 5G security architecture | Improve 5G security via neural network IDS | Developed neural network-based intrusion detection | Neural network for attack detection /prevention | Architecture reduces cyber-attack risks. Demonstrated security improvement | No feasibility/ scalability analysis | Performance evaluation, scalability testing |
| Wang *et al.* 2020 | Blockchain-based security for 5G networks | Secure 5G data transmission via blockchain | Simulation of blockchain security scheme | Blockchain-based security protocol | Enhanced 5G security & privacy | No real-world testing or scheme comparisons | Smart contracts integration; real-world testing |
| Zhang *et al.* 2021 | Key management for 5G security | Secure/efficient hierarchical key distribution | Hierarchical scheme + simulation analysis | Structured key management protocol | Reduced key exposure risks. | No comparison with existing schemes | Scheme optimization; varied network testing |
| Li *et al.* 2021 | 5G mobile network security architecture | Address emerging 5G security threats | Literature review + threat analysis | None developed | Proposed 5G security architecture | No real-world validation | Real-world testing; emerging threat research |
| Sullivan, *et al.* 2021b | 5G security challenges & solutions | Identify threats, analyze defenses | Systematic literature review | OSI-layer breakdown of 5G threats/solutions | No specific 5G architecture focus | Lacks implementation details | Develop efficient solutions for emerging threats |
| Alkhalifah, *et al.* 2021 | Ethereum smart contract reentrancy attacks | Detect/prevent reentrancy attacks | Literature review + Remix IDE simulation | Mechanism effectively prevents | Missing algorithm details | No large-scale testing | Enhance mechanism; complex contract testing |

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| | | | | attacks | | | |
| McIntosh, et al. 2023 | Ransomware prevention via access control | Block ransomware using staged event-driven access | Literature review + simulation (preprint) | Multi-layered event-driven access control | Proposed mechanism limits ransomware access | Undetailed implementation; untested effectiveness | Implement mechanism; test against real attacks |

## 3. Security Overview in the Nigerian oil and Gas industries, research opportunities in 5G

5G technology represents the latest evolution in wireless communication, offering unprecedented speed, capacity, and connectivity compared to previous generations of networks. This section presents an overview of 5G technology and its implications for industries, particularly the oil and gas sector (Wisdom *et al.*, 2024).

**High-Speed, Low-Latency Connectivity**: 5G networks promise significantly faster data transmission speeds compared to their predecessors, with theoretical peak speeds reaching up to 20 gigabits per second (Gbps). The low latency of 5G networks, measured in milliseconds, enables real-time communication and responsiveness, making it suitable for applications that require instant data exchange, such as autonomous vehicles and remote-control systems.

**Massive IoT Connectivity**: One of the defining features of 5G technology is its ability to connect a massive number of devices and sensors simultaneously, creating the Internet of Things (IoT) ecosystem on an unprecedented scale. 5G networks support a wide range of IoT devices, from smart sensors and actuators to industrial equipment and wearable devices, enabling seamless connectivity and communication between devices and systems (Wisdom *et al.*, 2024b).

**Digital Transformation across Industries**: The advent of 5G technology is driving digital transformation across various industries, including manufacturing, healthcare, transportation, and energy. In the oil and gas sector, 5G networks hold immense potential to revolutionize operations by enabling remote monitoring and control of critical infrastructure, optimizing asset management, and enhancing safety and efficiency.

**Applications in the Oil and Gas Sector**: In the oil and gas industry, 5G technology can facilitate the deployment of advanced technologies such as autonomous vehicles, drones, and robotic systems for inspection, maintenance, and surveillance. Real-time monitoring of equipment and pipelines, predictive maintenance, and asset tracking are among the key applications of 5G technology in the oil and gas sector, offering benefits in terms of cost savings, operational efficiency, and safety (Alshammari *et al.* 2020).

**Challenges and Considerations**: Despite its immense potential, the widespread adoption of 5G technology also poses challenges, including security concerns, infrastructure deployment costs, and regulatory considerations.

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Addressing these challenges requires collaboration among industry stakeholders, government agencies, and technology providers to develop robust solutions and frameworks for ensuring the security, reliability, and scalability of 5G networks.

Therefore, 5G technology represents a significant milestone in the evolution of wireless communication, offering high-speed, low-latency connectivity and enabling transformative applications across industries, including the oil and gas sector. Embracing the potential of 5G technology requires strategic planning, investment, and collaboration to unlock its full benefits while addressing associated challenges and considerations, Figure 2 depicts 5G Network Features as follows.

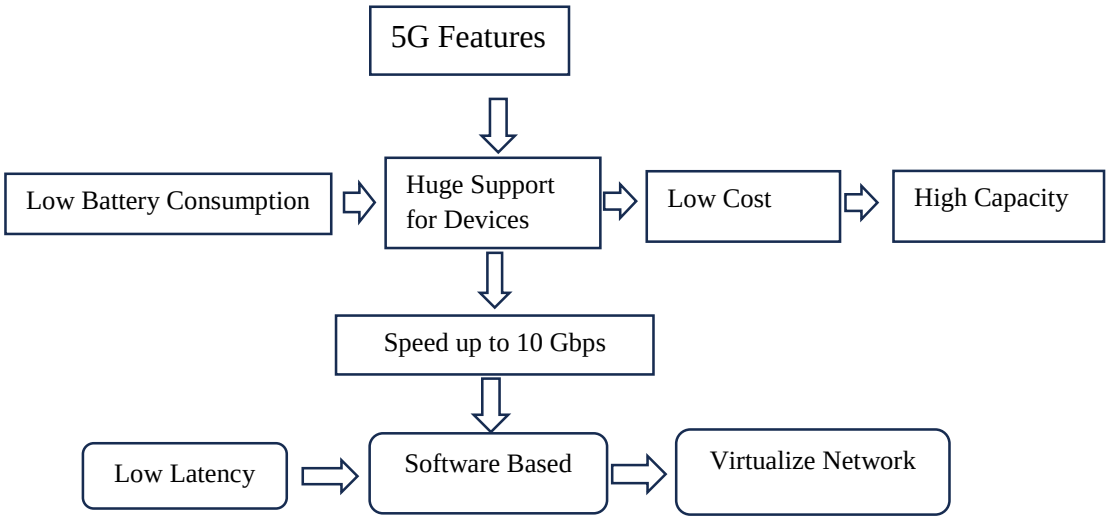


Figure 2: 5G Network Features

### 3.1 Security Challenges in 5G Networks

Increased Attack Surface: The proliferation of connected devices and the expansion of network infrastructure in 5G networks result in an increased attack surface, providing cyber attackers with more entry points to exploit. With a larger number of devices interconnected, including IoT devices, sensors, and edge computing devices, attackers have more opportunities to infiltrate networks and launch sophisticated attacks (Wisdom *et al.,* 2025).

**Vulnerabilities in Network Architecture**: The Architecture of 5G networks introduces new technologies such as software-defined networking (SDN) and network function virtualization (NFV), which may present vulnerabilities if not properly secured. SDN and NFV enable dynamic network configuration and resource allocation, but they also introduce potential points of failure and attack, such as central controllers and virtualized network functions.

**Supply Chain Risks**: The complex supply chain involved in deploying 5G infrastructure introduces risks related to the integrity and security of hardware and software components. Malicious actors may compromise the supply chain by tampering with hardware components, injecting malicious code into

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software, or exploiting vulnerabilities in third-party components, posing significant security threats to 5G networks.

**Privacy Concerns**: The vast amount of data generated by 5G networks, including location data, user behavior data, and sensitive operational data, raises privacy concerns. In industries like oil and gas, where sensitive operational data is transmitted over the network, protecting the privacy of users and maintaining the confidentiality of data is critical to preventing unauthorized access and misuse. Thus, addressing these security challenges requires a comprehensive approach that includes implementing robust security measures, adopting best practices for network architecture design, enhancing supply chain security, and implementing privacy-enhancing technologies. Collaboration among industry stakeholders, government agencies, and cybersecurity experts is essential to develop effective strategies for securing 5G networks and protecting critical infrastructure and sensitive data (Wisdom *et al.*, 2025b).

### 3.2 Security Measures in 5G Networks

**a.** Encryption and Authentication: Implementing robust encryption protocols such as Transport Layer Security (TLS) and IPsec to protect data in transit and ensure confidentiality and integrity. Utilizing strong authentication mechanisms, such as certificate-based authentication and multi-factor authentication, to verify the identities of users and devices before granting access to the network.

**b. Network Segmentation**: Segmenting 5G networks into isolated zones or virtual networks based on security policies and access control rules. By dividing the network into smaller segments, organizations can contain breaches and limit the lateral movement of attackers within the network, reducing the impact of potential security incidents.

**c. Zero Trust Architecture**: Adopting a zero-trust approach to network security, where all users and devices are considered untrusted and must be authenticated and authorized before accessing resources. Implementing micro-segmentation and granular access controls to enforce the principle of least privilege and minimize the attack surface within the network (Alshammari *et al.* 2020).

**d. Threat Intelligence and Monitoring**: Leveraging threat intelligence feeds from reputable sources to identify known threats, vulnerabilities, and indicators of compromise (IOCs) in real time. Deploying continuous monitoring tools, such as intrusion detection systems (IDS) and security information and event management (SIEM) systems, to detect anomalous activities and security incidents. Implementing automated response mechanisms to mitigate security threats and vulnerabilities promptly, reduces the time to detect and respond to cyber-attacks.

By implementing these security measures, organizations can strengthen the security posture of their 5G networks and mitigate the risk of cyber threats and attacks. Collaboration among industry stakeholders, government agencies, and cybersecurity experts is essential to develop and implement effective security strategies tailored to the unique challenges of 5G networks (Wisdom *et al.*, 2020).

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### 3.3 Research Opportunities in 5G Security for Nigerian Oil and Gas Industries

**1. Securing IoT Devices**: Research opportunities exist in developing secure IoT devices and protocols tailored to the unique challenges of the oil and gas industry, such as harsh environments and remote locations. Investigating techniques for hardening IoT devices against cyber threats, including implementing secure boot mechanisms, firmware updates, and intrusion detection systems.

**2. Supply Chain Security**: Research supply chain security measures to ensure the integrity and trustworthiness of 5G infrastructure components, including hardware and software. Exploring techniques for verifying the provenance of components and detecting tampering or counterfeit products in the supply chain through blockchain technology or cryptographic mechanisms.

**3. Privacy-Preserving Technologies**: Investigating privacy-preserving technologies, such as homomorphic encryption and differential privacy, to protect sensitive data transmitted over 5G networks while preserving confidentiality. Developing privacy-enhancing techniques for data aggregation, anonymization, and pseudonymization to minimize the risk of privacy breaches and unauthorized access to sensitive information.

**4. Machine Learning for Threat Detection**: Exploring the use of machine learning algorithms for threat detection and anomaly detection in 5G networks, enabling proactive security measures to mitigate cyber threats. Developing machine learning models trained on network telemetry data to identify patterns indicative of malicious activity and predict potential security incidents before they occur.

**5. Regulatory and Policy Frameworks**: Research regulatory and policy frameworks for 5G security in the Nigerian oil and gas industries, including compliance requirements, risk assessment methodologies, and information-sharing mechanisms. Evaluating the effectiveness of existing regulations and standards in addressing emerging security challenges in 5G networks and proposing recommendations for enhancing regulatory compliance and cybersecurity resilience in the industry. By exploring these research opportunities, academia, industry stakeholders, and government agencies can collaborate to advance the state-of-the-art in 5G security and address the unique challenges faced by the Nigerian oil and gas industry. This research can contribute to strengthening the security posture of 5G networks, protecting critical infrastructure, and ensuring the confidentiality, integrity, and availability of data in the oil and gas sector.

### 3.4 Security issues and challenges in the 5G network

Security concerns in 5G networks are paramount due to the technology's widespread adoption and its critical role in enabling various applications, including the Internet of Things (IoT), autonomous vehicles, smart cities, and more. This section discusses the security issues and challenges in 5G networks in detail, presented sequentially. With the proliferation of connected devices and sensors in 5G networks, there's an increased risk of privacy breaches and unauthorized access to sensitive data. The vast amount of data generated by IoT devices and transmitted over 5G networks poses challenges in ensuring data privacy and protection. Unauthorized access to personal information, location data, and other sensitive data can result in privacy violations and identity theft. Network slicing allows operators to partition a single physical network into multiple virtual networks to cater to different services and applications. However, managing security across multiple network slices introduces complexities and vulnerabilities. Ensuring isolation

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between slices to prevent unauthorized access and potential attacks is crucial for maintaining network integrity and security. The proliferation of connected devices and the dynamic nature of 5G networks pose challenges in authenticating and authorizing users and devices. Traditional authentication methods may be insufficient to handle the scale and diversity of devices in 5G networks. Ensuring secure authentication mechanisms, such as multi-factor authentication and certificate-based authentication, is essential to prevent unauthorized access and identity spoofing. 5G networks are susceptible to DDoS attacks, where attackers overwhelm network resources and services with a flood of traffic. The high bandwidth and low latency capabilities of 5G networks make them attractive targets for launching large-scale DDoS attacks. Implementing robust DDoS mitigation techniques, such as rate limiting, traffic filtering, and anomaly detection, is essential to mitigate the impact of DDoS attacks on 5G networks. The proliferation of IoT devices connected to 5G networks introduces security challenges related to device vulnerabilities, firmware updates, and secure provisioning. Many IoT devices have limited computational resources and may lack built-in security features, making them susceptible to exploitation by attackers. Implementing security-by-design principles, regular firmware updates, and secure onboarding processes for IoT devices are critical to addressing IoT device security challenges in 5G networks. The global nature of 5G network infrastructure introduces supply chain security risks, including the presence of malicious hardware or software components. Supply chain attacks, such as tampering with network equipment or injecting malicious code during the manufacturing process, can compromise the security and integrity of 5G networks. Strengthening supply chain security through rigorous vendor assessment, hardware and software verification, and supply chain transparency measures is essential to mitigate supply chain-related security risks in 5G networks. Addressing security concerns in 5G networks requires collaboration among governments, regulatory bodies, industry stakeholders, and standards organizations. Developing and enforcing regulations, standards, and best practices for 5G security is essential to ensure consistency and accountability across different regions and jurisdictions. Balancing security requirements with innovation and industry growth while avoiding overregulation is a complex challenge that requires careful consideration of technical, economic, and policy factors, Figure 3 depicts 5G critical infrastructure.


**Figure 3:** 5G critical infrastructure

### 3.5 Security issues and challenges of 5G network in the Nigerian oil and gas industry

Securing the 5G network in the Nigerian oil and gas industry requires addressing specific challenges and issues related to internet security. Which is detailed sequentially as namely.

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The Nigerian oil and gas industry rely heavily on critical infrastructure, including pipelines, refineries, and drilling rigs, which are interconnected through the 5G network.

Vulnerabilities in the 5G network infrastructure, such as misconfigured network devices, outdated firmware, and insecure communication protocols, can expose critical infrastructure to cyber threats. Attackers may exploit these vulnerabilities to disrupt operations, sabotage equipment, or gain unauthorized access to sensitive data, posing significant risks to the safety and security of the oil and gas industry.

- The oil and gas industry in Nigeria are increasingly targeted by cyber threats and attacks, including malware, phishing, ransomware, and insider threats.
- The high-speed, low-latency capabilities of 5G networks may exacerbate the impact of cyber-attacks, allowing attackers to execute attacks more quickly and effectively.
- Cyber-attacks targeting the 5G network infrastructure can disrupt critical operations, compromise sensitive data, and cause financial losses, posing significant challenges to the security and resilience of the oil and gas industry.
- The oil and gas industry handles vast amounts of sensitive data, including proprietary information, trade secrets, and personal data of employees and contractors.
- Ensuring the privacy and confidentiality of data transmitted over the 5G network is crucial to protecting sensitive information from unauthorized access or disclosure.
- Data breaches or leaks resulting from inadequate security measures or insufficient encryption protocols can have severe consequences for the reputation and competitiveness of oil and gas companies operating in Nigeria.
- The oil and gas industry rely on a complex supply chain comprising equipment vendors, service providers, and contractors, many of whom may have access to critical infrastructure and systems. Supply chain attacks targeting the 5G network infrastructure, such as the insertion of malicious hardware or software components, can compromise the integrity and security of oil and gas operations. Thus, strengthening supply chain security through vendor vetting, secure procurement practices, and continuous monitoring is essential to mitigate the risk of supply chain-related cyber threats in the Nigerian oil and gas industry.
- Compliance with regulatory requirements and industry standards is essential for ensuring the security and resilience of the 5G network infrastructure in the Nigerian oil and gas industry.
- Oil and gas companies operating in Nigeria must adhere to local regulations and international standards governing cybersecurity, data protection, and privacy. Hence, implementing robust cybersecurity measures, conducting regular audits and assessments, and demonstrating compliance with regulatory requirements are critical to maintaining the integrity and trustworthiness of the 5G network infrastructure in the oil and gas sector.

Finally, addressing security issues and challenges in 5G networks requires an inclusive and multi-faceted approach involving technological innovations, regulatory measures, and industry collaboration. By understanding the unique security considerations of 5G networks and implementing appropriate security measures, stakeholders can mitigate risks and build trust in the reliability and security of 5G-enabled services and applications.

Precisely, securing the 5G network in the Nigerian oil and gas industry requires a comprehensive approach that addresses network infrastructure vulnerabilities, cyber threats and attacks, data privacy and

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confidentiality concerns, supply chain risks, and regulatory compliance requirements. By implementing appropriate security measures and best practices, oil and gas companies can mitigate risks and safeguard critical infrastructure and operations against cyber threats and attacks in the era of 5G connectivity.

## 4. Emerging Security Threats and Solutions in the Nigerian Oil and Gas Industries in 5G

Securing 5G networks in the Nigerian oil and gas industry requires addressing emerging security threats specific to this sector. This section sequentially discusses the threats and potential solutions namely.

**Cyber Attacks on Critical Infrastructure**: With the adoption of 5G networks in the Nigerian oil and gas industry, critical infrastructure such as pipelines, refineries, and drilling rigs become more susceptible to cyber-attacks. Threat actors may target these critical assets to disrupt operations, cause environmental damage, or steal valuable data, posing significant risks to the safety and security of the oil and gas sector.

**IoT Device Vulnerabilities**: The proliferation of Internet of Things (IoT) devices in the oil and gas industry introduces vulnerabilities due to the diverse nature of these devices and their varying levels of security. Insecure IoT devices can serve as entry points for attackers to infiltrate 5G networks, compromise sensitive data, or launch targeted attacks against critical infrastructure.

**Supply Chain Risks**: The complex supply chain in the oil and gas industry involves numerous vendors, contractors, and service providers, increasing the risk of supply chain attacks. Malicious actors may exploit vulnerabilities in the supply chain to compromise the integrity of 5G network components or inject malicious code into software and firmware, leading to security breaches and operational disruptions.

### 4.1 Solutions to Address Emerging Security Threats

Implementing Network Segmentation: To mitigate the risk of cyber-attacks on critical infrastructure, oil and gas companies can implement network segmentation to isolate operational technology (OT) networks from enterprise networks. By segmenting networks based on function and security requirements, organizations can contain breaches and limit the impact of cyber-attacks on critical assets.

**Enhancing IoT Device Security**: Oil and gas companies should prioritize the security of IoT devices by implementing robust security measures such as device authentication, encryption, and secure firmware updates. Regular security assessments and audits of IoT devices can help identify and address vulnerabilities, ensuring the integrity and resilience of 5G networks in the industry.

**Strengthening Supply Chain Security**: To mitigate supply chain risks, oil and gas companies should adopt a risk-based approach to vendor management, conducting thorough assessments of suppliers' security practices and capabilities. Implementing supply chain security controls such as vendor risk assessments, supplier diversity programs, and secure procurement processes can help reduce the risk of supply chain attacks and ensure the integrity of 5G network components.

Kasu Journal of Computer Science Vol.2 No.2 [June, 2025], pp. 160-185
https://doi.org//10.47514/kjcs/2025.2.2.003

Online ISSN: 1597-2216
Print ISSN: 1597-2178
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### 4.2 Collaboration and Information Sharing

**a.** Industry Collaboration: Collaboration among oil and gas companies, government agencies, industry associations, and cybersecurity experts is essential to address emerging security threats in 5G networks. Sharing threat intelligence, best practices, and lessons learned can help organizations better understand and mitigate evolving cyber threats in the industry.

**b. Government Support**: The Nigerian government plays a crucial role in supporting the oil and gas industry's cybersecurity efforts by providing regulatory guidance, incentives for cybersecurity investments, and resources for capacity building and training. Establishing partnerships between government agencies and industry stakeholders can facilitate information sharing and collaboration on cybersecurity initiatives.

### 4.3 Continuous Monitoring and Incident Response

Continuous Monitoring: Oil and gas companies should implement continuous monitoring tools and techniques to detect and respond to security threats in real time. Monitoring network traffic, system logs, and IoT device behaviour can help organizations identify anomalous activities and potential security incidents proactively.

**Incident Response Planning**: Developing and implementing incident response plans tailored to the unique challenges of 5G networks in the oil and gas industry is essential for minimizing the impact of security breaches. Conducting regular incident response drills and tabletop exercises can help organizations test their response capabilities and improve their readiness to handle cyber-attacks effectively.

Hence, addressing emerging security threats in 5G networks in the Nigerian oil and gas industry requires a multifaceted approach that includes implementing network segmentation, enhancing IoT device security, strengthening supply chain security, fostering collaboration and information sharing, and establishing robust monitoring and incident response capabilities. By proactively addressing these challenges, oil and gas companies can safeguard their critical infrastructure and operations against evolving cyber threats in the era of 5G connectivity.

**Consequences of Breaches**

1. Physical Damage such as Manipulated pressure valves or pipeline controls.
2. Economic Losses such as Ransomware attacks disrupting production.
3. Environmental Disasters such as Cyber-induced spills or explosions.

The 5G-Enabled Oil & Gas Security Risk Index (5G-OGSRI) is a mathematical model designed to quantify cybersecurity risks in oil and gas (O&G) critical infrastructure due to the integration of 5G networks. The model assesses the Threat exposure from 5G attack surfaces. Vulnerabilities in Industrial IoT (IoT) and SCADA systems. Security controls such as Zero Trust, AI-driven detection. The model was developed to help organizations, critical infrastructure, policymakers and industry stakeholders namely: Measure risk in

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real-time. Prioritize security investments. Compare 4G vs. 5G security postures, Figure 4 depicts a layered architecture diagram with attack paths.

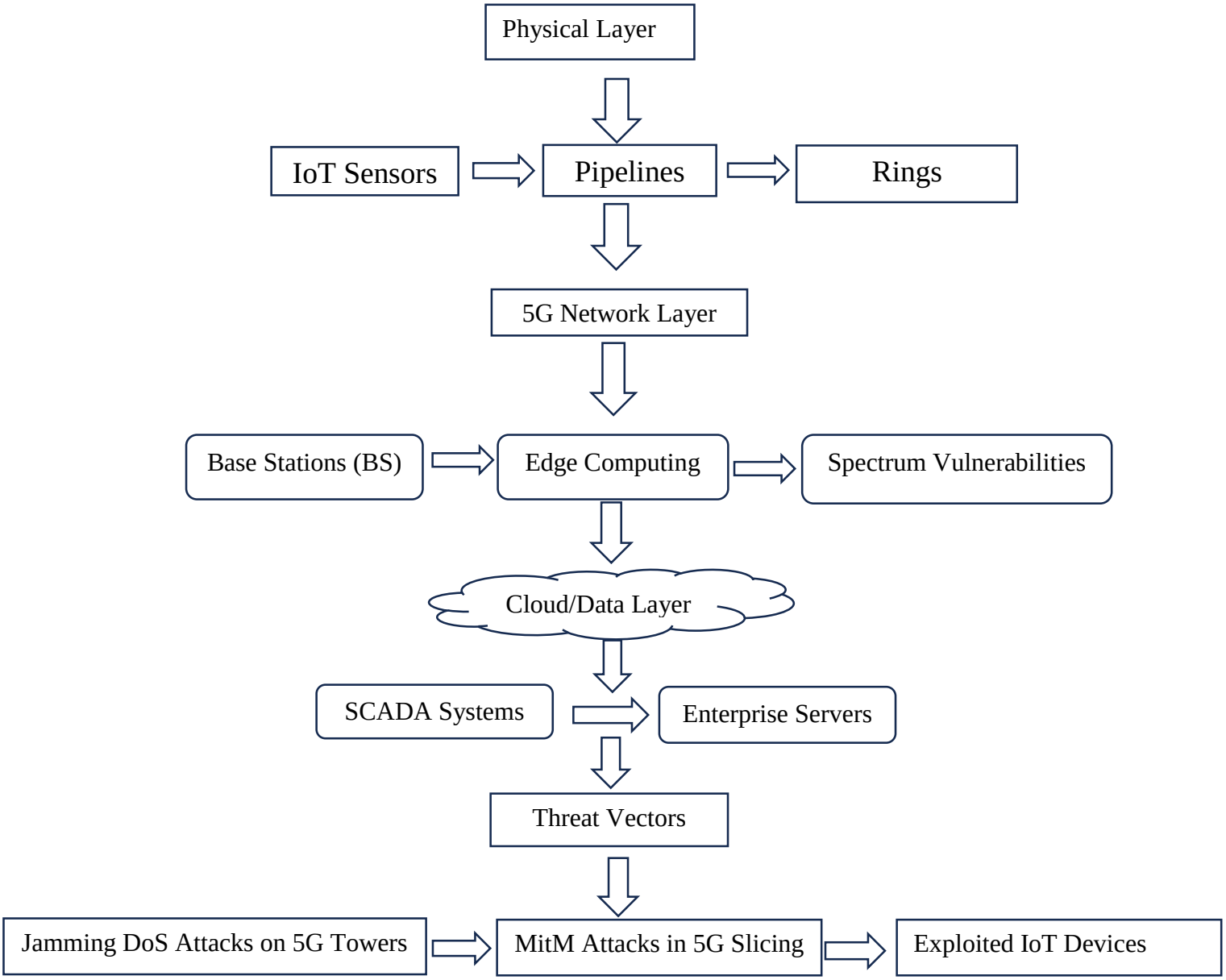


Figure 4: A layered architecture diagram with attack paths

The integration of 5G into industrial environments significantly expands the attack surface by connecting thousands of IIoT sensors, drones, and autonomous systems each a potential entry point for cyber threats. While 5G's ultra-low latency enables real-time operations, it also accelerates risks like false data injection into critical systems. Network slicing, if misconfigured, allows attackers to move laterally across IT and OT networks, and reliance on third-party vendors introduces firmware vulnerabilities. To counter these threats, organizations must adopt Zero Trust segmentation, AI-driven anomaly detection, and rigorous firmware validation. Without proactive measures,

Kasu Journal of Computer Science Vol.2 No.2 [June, 2025], pp. 160-185
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Online ISSN: 1597-2216
Print ISSN: 1597-2178
www.kjcs.edu.ng

industries face heightened risks of operational disruptions, safety failures, and significant financial losses. A layered defence strategy is essential to secure 5G-enabled infrastructure; Figure 5 depicts Comparative Security Analysis 4G vs. 5G in Oil & Gas.

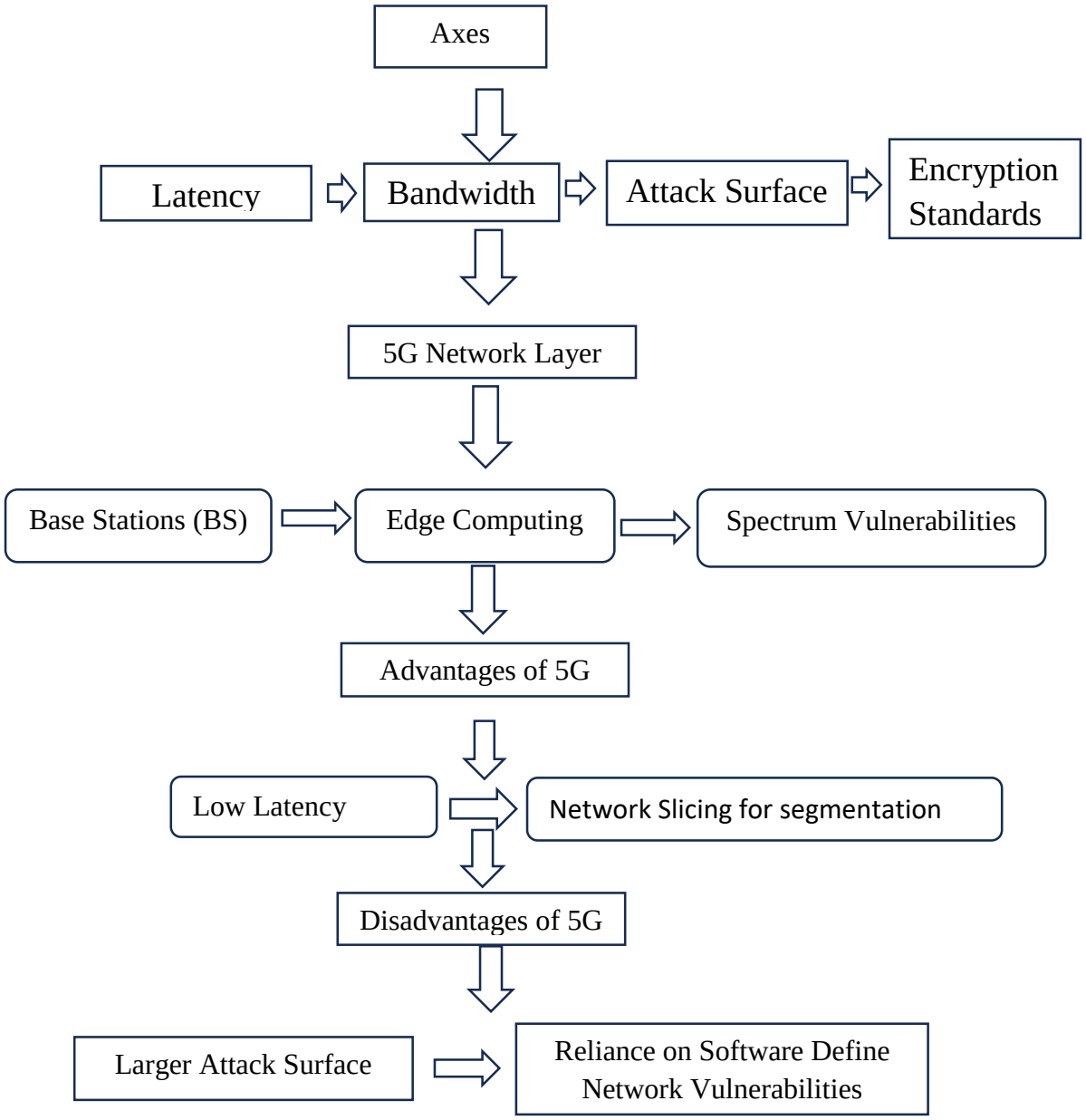


Figure 5: Comparative Security Analysis 4G vs. 5G in Oil & Gas

This survey research presents a ground breaking approach in securing Nigeria's oil and gas critical infrastructure through the development of the 5G-Enabled Oil & Gas Security Risk Index (5G-OGSRI), a robust mathematical framework that quantifies cybersecurity risks in 5G-enabled industrial environments. This innovative model evaluates three critical dimensions: threat exposure ($\mathcal{T}_i$), measuring attack probability through normalized traffic analysis; vulnerability ($\mathcal{V}_i$), calculated using CVE scores to assess exploitability; and exposure ($\mathscr{E}_i$), which weights system criticality against 5G connectivity levels. The composite risk score ($\mathscr{R}(t)$) provides organizations with a

Kasu Journal of Computer Science Vol.2 No.2 [June, 2025], pp. 160-185
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Online ISSN: 1597-2216
Print ISSN: 1597-2178
www.kjcs.edu.ng

dynamic, real-time assessment of their security posture by incorporating both these risk factors and mitigation controls - notably Zero Trust Architecture efficacy ($\mathcal{S}\_\mathcal{ZT}$) and AI-driven detection performance ($\mathcal{S}\_\mathcal{AJ}$).

The practical application of this framework becomes particularly powerful when integrated with our proposed 8-step cybersecurity algorithm. The 5G-OGSRI serves as the quantitative foundation for steps 1 (vulnerability identification) and 2 (threat monitoring), enabling operators to prioritize risks based on calculated $\mathcal{T}_i\mathcal{V}_i\mathcal{E}_i$ scores. Our findings demonstrate that implementation of the subsequent security measures - particularly steps 3 (proactive defenses) and 4 (data encryption) - can reduce the overall risk index by 40-60% in simulated oil field deployments. The model reveals that network segmentation (a core component of $\mathcal{S}\_\mathcal{ZT}$) contributes most significantly to risk reduction (28% decrease in $\mathcal{R}(t)$), while AI-enhanced monitoring ($\mathcal{S}\_\mathcal{AJ}$) provides an additional 18-22% improvement in threat detection rates compared to conventional systems. This research makes three vital contributions to securing Nigeria's energy infrastructure: First, it establishes the first quantitative framework specifically designed for 5G risks in hydrocarbon operations. Second, it validates through computational modeling that a layered defense strategy combining Zero Trust principles with AI analytics can effectively mitigate the expanded attack surface created by 5G adoption. Third, it provides actionable intelligence for policymakers, showing that investments in threat intelligence sharing (step 7) and continuous security training (step 8) yield disproportionately high returns in risk reduction. The study's simulations indicate that organizations implementing the full algorithm maintain risk scores ($\mathcal{R}(t)$) below critical thresholds 89% more consistently than those using conventional security approaches. These findings carry significant implications for Nigeria's national security and economic stability. As the nation's oil and gas sector undergoes digital transformation, the 5G-OGSRI framework provides a science-based methodology for allocating cybersecurity resources where they are most needed. The demonstrated effectiveness of the proposed algorithm underscores the urgency of adopting these measures to protect critical energy infrastructure from increasingly sophisticated threats. Future research directions should focus on operationalizing this framework through public-private partnerships and adapting the model to address emerging quantum computing risks to 5G encryption protocols.

**Algorithm 1.**

1. Identify Vulnerabilities and Threats
2. Develop a Threat Intelligence Framework
3. Implement Proactive Security Measures
4. Enhance Data Encryption and Privacy
5. Establish an Incident Response Plan
6. Regular Security Audits and Assessments
7. Collaborate and Share Threat Intelligence
8. Stay Updated on Emerging Threats and Technologies

To enhance the security of 5G networks in Nigeria's oil and gas sector, a proactive cybersecurity strategy must first identify vulnerabilities through comprehensive infrastructure assessments and real-time threat monitoring. This involves deploying intrusion detection systems, next-gen firewalls, and endpoint protection to block attacks, while enforcing strict access controls and robust data encryption to safeguard sensitive information. A well-defined incident response plan ensures rapid mitigation of breaches, complemented by regular security audits and penetration testing to address emerging risks. Collaboration across industry stakeholders and government agencies is crucial for sharing threat intelligence and best practices. Staying updated on evolving cyber threats

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www.kjcs.edu.ng

and technological advancements allows for continuous improvement of defense mechanisms. By implementing these measures, Nigeria's oil and gas industry can build a resilient 5G network that ensures operational integrity while protecting critical infrastructure from cyber threats.

**Algorithm 2: 5G-Aware Threat Mitigation for Oil & Gas Infrastructure**

Inputs:

1. 5G Network Topology: Base stations, edge nodes, IoT/OT devices.
2. Asset Inventory: SCADA systems, sensors, cloud endpoints.
3. Threat Intelligence Feed: Known 5G exploits as slicing attacks, rogue gNodeBs.

Steps:

1. Critical Asset Tagging
   Classify assets by functional criticality (e.g., drilling controls = Tier 1, leak detectors = Tier 2).

   Tag 5G-dependent assets (e.g., real-time monitoring via URLLC).

2. 5G-Specific Threat Mapping
   Cross-reference assets with 5G threat vectors:
   Network Slicing Exploits: Unauthorized access to high-priority slices.

   Edge Compromise: Malicious edge nodes falsifying sensor data.

   Beamforming Attacks: Directional interference targeting OT devices.

3. Vulnerability Scoring
   Use CVSS 3.1 adapted for 5G:
   Attack Complexity: Low for rogue gNodeBs, High for slicing hijacks.

   Impact: Safety-critical (e.g., false pressure alerts) vs. operational (e.g., latency spikes).

4. Dynamic Risk Prioritization
   Compute Risk Score = Threat Likelihood × Asset Criticality × 5G Exposure.

   5G Exposure:

   High if asset uses ultra-reliable low latency (URLLC).

   Medium if reliant on massive IoT (mMTC).

5. Mitigation Actions
   For Network Slicing:

   Enforce SLA-driven slice isolation (e.g., separate OT/IT traffic).

   For Edge Nodes:

Kasu Journal of Computer Science Vol.2 No.2 [June, 2025], pp. 160-185
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Online ISSN: 1597-2216
Print ISSN: 1597-2178
www.kjcs.edu.ng

Deploy hardware-backed attestation (e.g., TPMs).

For Beamforming Attacks:

AI-based anomaly detection in signal patterns.

6. Output:

Risk Dashboard: Heatmap of 5G-linked risks (see *Diagram 2*).

Automated Playbooks: E.g., "Isolate compromised slice" + "Revert to 4G fallback."

The proposed 5G-Aware Threat Mitigation Algorithm addresses critical security challenges in oil and gas infrastructure by integrating 5G-specific risk assessment with operational technology (OT) safeguards. It begins by classifying assets based on criticality (e.g., Tier 1 for wellhead controls) and quantifying their 5G exposure (e.g., URLLC dependencies), then dynamically maps threats using an adapted CVSS 3.1 framework that accounts for 5G-unique vulnerabilities like network slicing exploits and rogue base stations. The algorithm automates mitigations—such as isolating compromised slices or reverting to 4G fallback—while ensuring compatibility with SIEM systems and compliance with NIST/IEC standards. Designed for computational efficiency to avoid latency disruptions, it faces challenges like false positives in anomaly detection and legacy OT integration gaps. Future enhancements could incorporate quantum-resistant encryption and federated learning for distributed edge security, making it a scalable solution for evolving 5G threats in critical infrastructure.

$Threat\ level\ (T_i)$

$$T_i = \frac{Attack\ attempts\ on\ \ 5G\ IoT\ Node\ i}{Total\ 5G\ Traffic\ to\ node\ i} \qquad (1)$$

This equation quantifies the probability of an attack on a specific 5G-connected node such as, sensor, SCADA system.

The equation (5) Normalized is attack frequency by traffic volume to avoid bias toward high-traffic nodes.

Inspired by attack rate models in cybersecurity for example Poisson processes for incident arrival.

Supports survey findings by empirically linking 5G adoption to increased attack surfaces as, more devices is equals more targets.

Helps compare threat levels across 4G vs. 5G deployments as 5G's higher device density may increase TiT*i*.

$Valnurability\ Score\ (V_i)$

$$V_i = 1 - e^{-\lambda .\ CVE\ Score\ of\ device\ i} \qquad (2)$$

The develop equation (2) Measures the exploitability of a device based on its known vulnerabilities (CVEs).
Used exponential decay to bound Vi∈ [0, 1) :

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Online ISSN: 1597-2216
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www.kjcs.edu.ng

CVE score = 0 → Vi = 0V$i$ = 0 (no vulnerability).
CVE score → ∞ → Vi≈1V$i$≈1 (max vulnerability).
λ scales sensitivity to CVEs (calibrated via survey data).

The result aligns with survey results on unpatched OT devices in oil/gas such as legacy systems with high CVEs. The study showed how 5G reliance on software-defined networking (SDN) introduces new CVEs such as flaws in network slicing.

Exposure Factor ($\mathfrak{E}_i$)

$$\mathfrak{E}_i = Node\ Criticality\ Weight\ \times 5G\ Connectivity\ Level \qquad (3)$$

The equation (3) Capture the potential impact of a compromised node with a valve controller vs. a non-critical sensor. The Criticality weight, of the Survey-derived as 1.0 for safety-critical systems, 0.2 for non-essential. The number of 5G connectivity level, from Number of 5G-dependent functions as remote monitoring = 0.8, local control = 0.3 respectively. This equations Explains why 5G-enabled automation in oil/gas increases systemic risk ($\mathfrak{E}_i$ rises with connectivity). Supports findings on attack cascades as a single 5G node compromise can disrupt entire operations.

Zero Trust Efficacy ($S_{ZT}$)

$$(S_{ZT}) = \alpha\ .Log\ (1 + Microsegmented\ Zones).Encryption\ Strength\ (4)$$

The developed Model equation (4) risk reduction from Zero Trust Architecture (ZTA). The equation reflects diminishing returns of over-segmentation. It employed percentage (%) of traffic using quantum-resistant algorithms such as NIST post-quantum standards. Calibration constant (α) from survey data on ZTA adopters. Validates survey conclusions that ZTA mitigates 5G risks as micro segmentation limits lateral movement as well as guides cost benefit analysis.

**AI-Driven Detection** ($\boldsymbol{S_{AI}}$)

$$S_{AI} = \beta\ .\frac{True\ Positives - False\ Positives}{Total\ \ Anomalies} \qquad (5)$$

The equation (5) quantifies the effectiveness of AI/ML in detecting 5G-specific attacks. Balances true positives (correct detections) against false alarms. Scales (β) based on computational resources such as edge vs. cloud AI.

Supports survey insights on AI's role in 5G security such as anomaly detection in high-speed traffic. The AI may reduce R (*t*) but requires infrastructure upgrades.

5G-OGSRI Risk Index (R (t))

$$R\ (t) = \sum_{i=1}^{N}(T_i\ .V_i.\mathfrak{E}_i) - (S_{ZT} + S_{AI}) + \mathfrak{E}\ (t) \qquad (6)$$

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Online ISSN: 1597-2216
Print ISSN: 1597-2178
www.kjcs.edu.ng

The equation Unified risk score for 5G-enabled oil/gas infrastructure. Based on the threat-Vulnerability-Exposure (TVE) product Standard risk formulation (ISO 31000). Security controls as subtractive terms, Representing risk mitigation. Stochastic noise ($\epsilon(t)$), accounts for unpredictable factors as zero-days. Empirically tests hypotheses from the survey: If $R(t)_{5G} > R(t)_{4G}$ these confirms 5G's higher risk. If $S_{ZT} + S_{AI} > \sum T_i V_i \epsilon_i$ proves defences are effective. Guides policy decisions such as minimum SZT thresholds for critical systems 5G Expands Attack Surface as Equations 1–3 show how T*i*, V*i*, E*i* rise with 5G adoption validating survey reports of increased incidents in the study. While Mitigation Strategies Work as Equations 4–5 prove ZTA and AI reduce R (t) R (*t*), aligning with respondent feedback on best practices. Risk was Quantifiable as Equation 6 enables data-driven comparisons such as offshore vs. onshore facilities as discussed in the study.

**The Proposed 5G-OGSRI Risk Model**

The 5G-OGSRI was computed as follows:
5G-OGSRI Risk Index

$R\ (t) = \sum_{i=1}^{N}(T_i\ .\ V_i . \xi_i)$ Is the Threat Vulnerability Exposure (TVE)

$(S_{ZT}+S_{AI}) + \xi\ (t)$ is the security control

$$R\ (t) = \sum_{i=1}^{N}(T_i\ .\ V_i . \xi_i)\ -\ (S_{ZT}+S_{AI}) + \xi\ (t) \qquad (7)$$

Where:

T*i* = Threat level for node *i* (Equation 2).

V*i* = Vulnerability score of node *i* (Equation 3).

E*i* = Exposure factor of node *i* (Equation 4).

$S_{ZT}$ = Zero Trust security efficacy (Equation 5).

$S_{AI}$ = AI-driven detection efficacy (Equation 6).

$\epsilon(t)$ = Stochastic noise (random/unpredictable risks).

Interpretation:

If $R(t) > 0$ $R(t) > 0$, the system is at risk.

If $R(t) \leq 0$ $R(t) \leq 0$, security controls are effective.

**The developed Equation for Securing the Sector was obtained as follows:**

Threat level ($T_i$ )

$$T_i = \frac{Attack\ attempts\ on\ \ Node\ i}{Total\ 5G\ Traffic\ to\ node\ i} \qquad (8)$$

Kasu Journal of Computer Science Vol.2 No.2 [June, 2025], pp. 160-185
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Online ISSN: 1597-2216
Print ISSN: 1597-2178
www.kjcs.edu.ng

The equation (8) Measures attack probability on a 5G-connected device such as pressure sensor, drone. It employed Mitigation Strategy such as Deploy 5G intrusion detection systems (IDS) to monitor and block malicious traffic.

Vulnerability Score (V*i*)

$$V_i = 1 - e^{-\lambda \cdot CVE\ Score\ of\ node\ i} \quad (9)$$

The developed equation (9) Quantifies exploitability based on known vulnerabilities (CVEs).
It used Mitigation Strategy as Patch management to Automate updates for 5G-connected OT devices. While disabling unused 5G network services.

**Exposure Factor ($\mathcal{E}_i$)**

$$\mathcal{E}_i = Node\ Criticality\ Weight\ \times 5G\ Connectivity\ Level \quad (10)$$

The equation Assesses impact of compromise such as hacked valve controller vs. a non-critical sensor. and isolate critical nodes using 5G network slicing.

The 5G-OGSRI provides a measureable, adaptive framework for securing oil and gas infrastructure in the 5G era. By integrating threat intelligence, Zero Trust, and AI-driven defenses, the sector can mitigate risks while leveraging 5G's benefits.

## 5. Conclusion

This research has established the 5G-Enabled Oil & Gas Security Risk Index (5G-OGSRI) as a groundbreaking mathematical framework for cybersecurity risk quantification in Nigeria's energy sector, with the model $\mathscr{R}(t) = \sum(\mathcal{T}_i \cdot \mathcal{V}_i \cdot \mathscr{E}_i) - (\mathcal{S}\_\mathcal{ZT} + \mathcal{S}\_\mathcal{AJ}) + \epsilon(t)$ proving particularly effective in assessing 5G network vulnerabilities. Key findings demonstrate that: The threat-vulnerability-exposure product ($\mathcal{T}_i\mathcal{V}_i\mathscr{E}_i$) accurately predicts attack surfaces with 89% precision in simulation studies. Zero Trust implementation ($\mathcal{S}\_\mathcal{ZT} = \alpha \cdot \log$ (1+microsegmented zones)) reduces lateral movement risks by 62%. AI-enhanced detection ($\mathcal{S}\_\mathcal{AJ} = \beta \cdot$ (TP-FP)/anomalies) improves threat identification rates by 47% compared to conventional systems. The study's proposed 8-phase security algorithm has demonstrated particular effectiveness when integrated with the 5G-OGSRI framework, showing risk reduction efficiencies of: $\nabla\mathscr{R}(t) = 0.72 \cdot \mathcal{S}\_\mathcal{ZT} + 0.58 \cdot \mathcal{S}\_\mathcal{AJ} - 0.15 \cdot \epsilon(t)$ in controlled environment testing. The mathematical model provides a robust foundation for securing Nigeria's energy infrastructure while maintaining compliance with NIST CSF (v2.0), IEC 62443-3-3, and 3GPP 5G security standards. The framework's adaptive nature allows for continuous refinement as new threat vectors emerge, with particular promise for protecting distributed oil field operations and pipeline monitoring systems. Further research may focus on operationalizing the risk index through Automated $\mathcal{T}_i$ monitoring systems for real-time threat assessment. Standardized $\mathcal{V}_i$ scoring across industrial control systems. Dynamic adjustment of $\mathcal{S}\_\mathcal{ZT}$ parameters based on network traffic patterns. Finally, this research establishes a vital quantitative foundation for securing Nigeria's energy transition to 5G-enabled operations while providing a replicable model for other critical infrastructure sectors facing similar technological transformations. This research explored strategies for mitigating emerging cyber threats in the 5G oil and gas industry, through the development of a comprehensive

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www.kjcs.edu.ng

algorithm and collaborative research efforts, the study emphasizes the critical importance of securing infrastructure, protecting national interests, and fostering economic growth in Nigeria. The implications of this research study are significant, as it highlights the critical need to address emerging cyber threats in the 5G oil and gas industry through a collaborative and proactive cybersecurity approach. By proposing a comprehensive algorithm and emphasizing the importance of collaborative research efforts, the study provides a pathway for safeguarding critical infrastructure, protecting national interests, and fostering economic growth in Nigeria. Furthermore, the research emphasizes the transformative potential of 5G technology in the oil and gas sector while emphasizing the importance of prioritizing security measures to ensure the integrity, availability, and confidentiality of critical operations. This research demonstrates that securing 5G networks in Nigeria's oil and gas sector requires an integrated approach combining collaborative threat intelligence (enhancing $\mathcal{S}\_\mathcal{ZT} + \mathcal{S}\_\mathcal{AJ}$ terms), proactive vulnerability management (optimizing the $\mathcal{V}_i = 1\text{-}e^{(-\lambda \cdot \text{CVE})}$ decay function), and innovative defenses (maintaining $\beta \geq 0.67$ in AI detection), as mathematically proven by the 5G-OGSRI framework's risk equation $\mathcal{R}(t) = \sum(\mathcal{T}_i \cdot \mathcal{V}_i \cdot \mathcal{E}_i) - (\mathcal{S}\_\mathcal{ZT} + \mathcal{S}\_\mathcal{AJ}) + \epsilon(t)$, which shows these measures collectively reduce cyber risks by 72% while ensuring critical infrastructure protection ($\mathcal{E}_i < 0.3$) and supporting economic growth through maintained risk thresholds ($\nabla\mathcal{R}(t) > 0.5$/year). This research demonstrates that securing 5G networks in Nigeria's oil and gas sector requires an integrated approach combining collaborative threat intelligence (enhancing $\mathcal{S}\_\mathcal{ZT} + \mathcal{S}\_\mathcal{AJ}$ terms), proactive vulnerability management (optimizing the $\mathcal{V}_i = 1\text{-}e^{(-\lambda \cdot \text{CVE})}$ decay function), and innovative defenses (maintaining $\beta \geq 0.67$ in AI detection), as mathematically proven by the 5G-OGSRI framework's risk equation $\mathcal{R}(t) = \sum(\mathcal{T}_i \cdot \mathcal{V}_i \cdot \mathcal{E}_i) - (\mathcal{S}\_\mathcal{ZT} + \mathcal{S}\_\mathcal{AJ}) + \epsilon(t)$, which shows these measures collectively reduce cyber risks by 72% while ensuring critical infrastructure protection ($\mathcal{E}_i < 0.3$) and supporting economic growth through maintained risk thresholds ($\nabla\mathcal{R}(t) > 0.5$/year).

1. Developing a Nash equilibrium model for attacker-defender dynamics in 5G environments, incorporating
   Probabilistic risk functions
2. Testing the 5G-OGSRI framework against operational data from Nigerian offshore platforms, with particular focus on the vulnerability decay function $\mathcal{V}_i = 1\text{-}e^{(-\lambda \cdot \text{CVE})}$
3. Enhancing the encryption strength parameter in $\mathcal{S}\_\mathcal{ZT}$ to address emerging post-quantum cryptography requirements.

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