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Original Research Article

AI-Driven Automation and Self-Healing Mechanisms in 5G Core Networks for Reliable Telecom Operations under Vision 2030

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Abstract: The study presents an overview of automation technologies that are self-healing methods applied in stand-alone 5G Core telecommunications systems required for providing reliable communications in Saudi Vision 2030 conditions. Literature surveys covering the period 2020-2025 have been done in research domains like cloud-native 5G Core design, SBA, NDAF roles, closed-loop assurance, AI-based anomalies detection and localization, root cause analysis, policy management, edge computing, and automation. It is shown in the paper that the 5G Core is much more than a pure packet router and, in fact, represents a state-of-the-art platform which allows predicting network performance degradation, localize faults, and execute repair processes without any impact on user services and industrial operations. The focus of the review is on Saudi Arabia, where the country's oil and gas industry, mining sector, transport, manufacturing industries, smart city initiatives, and giga projects require reliable connectivity, deterministic performance, and secure digital infrastructure. Based on the findings of the literature survey, it is possible to conclude that the self-healing feature of stand-alone 5G Core can be achieved with the help of the following three capabilities being implemented jointly: telemetry trustworthiness, explainable AI for decision-making, and automation policies enforcement. In the proposed Saudi Arabia-specific solution, the relationship between NWDAF, cloud-native NFs, MEC, slicing assurance, and operation management will be discussed.

Keywords: Stand-Alone 5G Core (SA-5GC), Self-Healing Networks, Saudi Vision 2030, Network Data Analytics Function (NWDAF), Explainable AI (XAI), Closed-Loop Assurance.

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1. INTRODUCTION

The study presents an overview of automation technologies that are self-healing methods applied in stand-alone 5G Core telecommunications systems required for providing reliable communications in Saudi Vision 2030 conditions. Literature surveys covering the period 2020-2025 have been done in research domains like cloud-native 5G Core design, SBA, NDAF roles, closed-loop assurance, AI-based anomalies detection and localization, root cause analysis, policy management, edge computing, and automation. It is shown in the paper that the 5G Core is much more than a pure packet router and, in fact, represents a state-of-the-art platform which allows predicting network performance degradation, localize faults, and execute repair processes without any impact on user services and industrial operations. The focus of the review is on Saudi Arabia, where the country's oil and gas industry, mining sector, transport, manufacturing industries, smart city initiatives, and giga projects require reliable connectivity, deterministic performance, and secure digital infrastructure. Based on the findings of the literature survey, it is possible to conclude that the self-healing feature of stand-alone 5G Core can be achieved with the help of the following three capabilities being implemented jointly: telemetry trustworthiness, explainable AI for decision-making, and automation policies enforcement. In the proposed Saudi Arabia-specific solution, the relationship between NWDAF, cloud-native NFs, MEC, slicing assurance, and operation management will be discussed.

2. Aim and Objectives of the Study

The aim of this review is to evaluate how AI-driven automation and self-healing mechanisms can be integrated into 5G Core standalone networks to enhance operational reliability for Saudi telecom and industrial environments. The first objective is to explain the architectural features of 5G Core SA that enable automation, especially service-based interfaces, cloud-native deployment and analytics functions. The second objective is to review AI techniques used for anomaly detection, prediction, root-cause analysis and closed-loop orchestration. The third objective is to identify sector-specific reliability needs in oil and gas, mining, logistics, manufacturing and smart city platforms. The fourth objective is to propose a Vision 2030-aligned framework for governed self-healing operations. The final objective is to highlight research gaps related to explainability, data quality, interoperability, cybersecurity and performance validation. These objectives allow the paper to move beyond a general discussion of AI and focus on the operational mechanisms needed for resilient Saudi digital infrastructure.

3. METHODOLOGY

This paper follows the structure of a narrative review methodology, appropriate for technologies that are still developing simultaneously with the emergence of architectural, standardization and industrial practices around them. This review includes literature from peer-reviewed journals, conferences, standards and industry papers dated from 2020 to 2025. The keywords used include 5G Core standalone, NWDAF, zero-touch network, AI network automation, self-healing networks, closed-loop assurance, network slicing, MEC, telecom anomaly detection and Vision 2030 digital infrastructure. Papers were selected in case at least one of four factors was relevant: 5G Core architecture; AI or ML applications within telecommunication networks; automated healing or assurance; or industrial private network. This review was carried out in four analytical stages. First, technical literature was reviewed, extracting knowledge on 5G Core functions, cloud-native orchestration and network analytics. Second, AI techniques were categorized into predictive, diagnostic, prescriptive, and autonomous control. Third, the cases were matched to sectors of Saudi Arabia economy requiring reliable network connectivity. Fourth, results were organized in a conceptual framework that shows how different layers such as telemetry, intelligence, policy and execution cooperate. Given the speed of development of this area, it should be noted that the aim of this work is not to identify a single universal model of self-healing network but to describe convergence between standardization, prototyping and application requirements for it. In addition, a conceptual model similar to the one provided by Springer (2020) was used for structuring the literature review, identifying use cases and formulating future research directions.

4. 5G Core SA as an Automation-Ready Platform

One of the critical innovations in terms of architectural design in 5G Core SA comes down to transitioning from monolithic nodes to modular network functions communicating via service-based interfaces. The modularity means that each function operates independently and can expose its data, process policy information and scale. Among these functions are AMF for access and mobility, SMF for session management, UPF for user plane forwarding, PCF for policy and NWDAF for supporting analytics. As one can easily notice, such modularity is an important pre-requisite for closed-loop automation since the collected telemetry data can be processed by AI models in order to turn them into controlled actions (3GPP, 2020; Khan *et al*., 2020; Polese *et al*., 2021). Another factor which improves automation capabilities and makes the network flexible comes down to its cloud-native deployment. With containerized services deployed on Kubernetes-like infrastructure, operation teams have more tools at their disposal to keep everything functioning. If one function degrades, it can be replaced, scaled up or relocated without having to change physical appliances. While this approach will not reduce the importance of telecom engineering in terms of latency, state management, lawful interception requirements and the like, but it will allow the network to react similarly to biological organisms and adapt to challenges. In the case of industrial networks, it becomes crucial since they cannot afford any downtime (Taleb *et al*., 2021; ETSI, 2021; Bega *et al*., 2020). One last element which can make the network intelligent is network slicing. Thanks to network slicing, a physical network can serve several logical slices providing enhanced broadband, massive Internet of Things and ultra-reliable low-latency communication services respectively. While each slice has its own characteristics and SLAs, some of them require different thresholds, alerts and healing actions to be applied. One of them might tolerate throughput changes while another will immediately require rerouting in case of additional latency. Thus, AI-based assurance can help in distinguishing between normal changes and actual deviations (Barakabitze *et al*., 2020; Foukas *et al*., 2021; O-RAN Alliance, 2022).

5. AI-Driven Automation and Self-Healing Mechanisms

AI-driven self-healing begins with observability. The network must collect counters, logs, alarms, traces, packet metrics, resource usage and service-quality indicators from core, transport, radio and edge layers. Traditional threshold alarms are insufficient because they often trigger too late or create alarm storms. Machine learning models can learn normal behavior patterns and detect deviations before outages become visible. Time-series models, autoencoders, clustering and graph neural networks can identify abnormal latency, authentication failures, signaling overload, session establishment delays, UPF congestion or abnormal slice behavior. These methods transform operations from reactive monitoring into predictive assurance (Moysen and Giupponi, 2020; Moubayed *et al*., 2022; Abayo *et al*., 2025).

After anomaly detection, the next requirement is root-cause analysis. In a distributed 5G Core, one symptom may have several causes. Increased latency may result from user-plane congestion, misconfigured policy rules, DNS delays, fronthaul issues, overloaded edge nodes or software defects. AI can support correlation by learning relationships among network functions, dependency graphs and historical incidents. Probabilistic models and knowledge graphs are especially useful because they can represent causal links and explain why a model recommends a specific cause. Explainability is not optional in telecom operations; engineers must understand whether the model is identifying a real risk or simply reacting to noisy data (Cheng *et al*., 2021; Boutaba *et al*., 2021; Moubayed *et al*., 2022).

Prescriptive automation converts diagnosis into action. Potential self-healing actions include horizontal scaling of AMF or SMF instances, rerouting user-plane traffic to a healthier UPF, changing slice resource allocation, restarting a failing container, rolling back a configuration, prioritizing emergency traffic or moving workloads closer to a MEC node. Reinforcement learning is useful for policy optimization, but production networks normally require guardrails, simulation and approval levels. Therefore, mature self-healing designs often use a human-on-the-loop model for high-risk actions and full automation only for well-tested low-risk actions. This balance helps operators gain reliability benefits without exposing national infrastructure to uncontrolled AI behavior (ETSI, 2021; Sun *et al*., 2021; O-RAN Alliance, 2022).

Table 1: AI-driven self-healing mechanisms for 5G Core SA operations

Mechanism	5G Core function involved	AI technique	Self-healing action	Saudi relevance
Anomaly detection	AMF, SMF, UPF, NWDAF	Autoencoders, time-series forecasting	Early warning and alarm enrichment	Reduces downtime in industrial networks
Root-cause analysis	NRF, PCF, UDM, cloud platform	Knowledge graphs, Bayesian reasoning	Fault localization and ranked causes	Improves response in carrier NOC/SOC teams
Slice assurance	NSSF, PCF, SMF, UPF	Reinforcement learning, policy analytics	Dynamic slice scaling or prioritization	Supports robotics, ports and smart-city services
User-plane healing	UPF and MEC	Prediction and optimization models	Rerouting, workload migration, local breakout	Improves latency for factories and remote sites
Cloud-native recovery	Containerized core functions	Health analytics and orchestration rules	Restart, scale, rollback and redeploy	Strengthens resilience of national digital infrastructure

6. Operational Relevance for Saudi Vision 2030 Sectors

First, one can note that there are numerous Saudi Arabia's economic sectors where reliable 5G Core operation can produce economic gains directly related to business performance. For example, oil and gas facilities are required to operate safely through connectivity used for remote monitoring, worker safety, autonomous inspection, and preventive maintenance. Similarly, mining operations should be supported by low latency communication capabilities for automated machinery and remote sites. Logistics industry requires fast data transfer in order to monitor assets, automate ports and warehouses, and provide secure cross-border operations. Lastly, manufacturing sector requires a wireless network for robotics, quality control, digital twin creation, and IoT devices. In all of these cases, 5G Core operation will have to ensure continuity of service, not just high speeds (Alsharif *et al*., 2021; Akhtar *et al.,* 2020; ITU, 2020).

Secondly, Vision 2030 highlights the importance of diversifying economy, developing locally advanced technologies, and establishing a digital government. Self-healing mechanisms powered by AI can help to achieve those aims by increasing overall efficiency of these systems. Outages caused by disruptions can negatively impact the productivity of businesses operating in industrial zones, interfere with logistics, diminish security measures, and reduce consumer's confidence in the digital transformation. In addition, self-healing will help to predict any issues that might arise, thus ensuring that the advanced services would become more reliable for consumers. In other words, self-healing will improve Saudi Arabia's competitiveness in offering advanced services to private enterprises (Saudi Vision 2030, 2021; CST, 2022; GSMA, 2022). Lastly, from the perspective of sustainability, automated processes in self-healing networks will help to reduce unnecessary truck rolls and optimize energy consumption in cloud facilities. At the same time, AI algorithms will be able to predict load and scale down the number of resources used in low demand periods but still provide a high level of service availability for critical slices. Moreover, edge computing will be helpful for reducing backhaul traffic. Thus, self-healing is also an opportunity to improve the sustainability of networks and increase their energy efficiency.

Table 2: Saudi sector requirements and self-healing value

Vision 2030 sector	**Reliability requirement**	**5G Core SA dependency**	**Self-healing value**
Oil and gas	Continuous monitoring and safety visibility	UPF, MEC, private slices	Maintains sensor and inspection connectivity
Mining	Remote operations and autonomous assets	Low-latency slice and edge analytics	Reduces operational interruption in remote sites
Logistics and ports	Real-time tracking and automation	Session continuity and local breakout	Improves throughput and asset visibility
Manufacturing	Robotics, quality control and digital twins	URLLC-like slice assurance	Protects production continuity
Smart cities	Command-center integration	Massive IoT, analytics and policy control	Supports responsive urban governance

7. Governance, Security and Implementation Challenges

However, AI-based self-healing also comes with some challenges. First is data quality issues. Telemetry could be incomplete, inconsistent or spread across different vendors and domains. Poor training data will result in flawed automated recommendations. The second issue is interoperability. In most cases, the operator will have devices from different suppliers who offer their own telemetry and control APIs. Thirdly is explainability. Telecom engineers and the regulator will want to understand how the model came up with a particular recommendation, especially when the model wants to execute an action that could affect critical services. The fourth issue is cybersecurity since automation interfaces become easy targets for attacks (Boutaba *et al*., 2021; Abayo *et al*., 2025; ETSI, 2022). There is a need to ensure that cybersecurity is embedded into self-healing. Security of AI solutions can be achieved through identity management, secure APIs, signing of model artifacts, logging, access control, and continuous validation. In instances where two or more operators need to collaborate to build a model but without revealing sensitive information, federated learning could be used. Nevertheless, federated learning poses new risks of poisoning the model and exposing private data. Zero-trust principles could also be applied since there is nothing to trust indefinitely in the entire network. Verification is necessary throughout the process, from ingestion of telemetry through orchestration execution of actions (Moubayed *et al*., 2022; O-RAN Alliance, 2022; NIST, 2023). Implementation should follow a phased approach. First is assisted intelligence, where AI identifies abnormal situations and recommends actions. Second is partial automation, where the automated solution executes low-risk actions such as scaling or enriching alerts. Third is governed closed-loop control, whereby the system executes healing actions within the bounds of policy constraints. Last is autonomous optimization across slices, edge sites and industrial service requirements. For Saudi operators to implement the self-healing framework, they should start from non-critical slices. Also, they should consider building digital twins for simulations, define rollback mechanisms and create joint governance across telecom, cybersecurity, enterprise IT, and industrial operations.

8. Proposed Framework

The proposed framework contains five layers. The telemetry layer collects metrics from

AMF, SMF, UPF, PCF, NRF, NSSF, NWDAF, Kubernetes clusters, MEC platforms and industrial applications. The intelligence layer applies anomaly detection, forecasting, root-cause analysis and risk scoring. The policy layer defines allowable actions, approval thresholds, SLA priorities and regulatory constraints. The orchestration layer executes healing through scaling, rerouting, configuration rollback, slice adjustment or workload migration. The validation layer confirms whether the action restored performance and records evidence for audit and model improvement. Figure 1 presents this closed-loop logic in a simplified form.

In Saudi industrial environments, the framework should be connected to business outcomes. For oil and gas, the main outcome may be safety and production continuity. For logistics, it may be asset visibility and port throughput. For manufacturing, it may be robotic uptime and quality control. For smart cities, it may be public-service continuity and command-center responsiveness. Figure 2 maps these vertical needs to 5G Core functions, AI automation and operational outcomes. The value of self-healing increases when telecom indicators are linked to sector-specific performance indicators rather than treated as isolated network counters.

The framework also recommends a governance board for AI-enabled telecom operations. This board should include network engineering, data science, cybersecurity, compliance and business representatives. Its role is to define automation policies, approve model updates, review incidents and ensure that self-healing supports Vision 2030 priorities. Such governance is important because advanced automation affects critical infrastructure. A technically powerful model may still be unsuitable if it cannot be audited, explained or aligned with service obligations.

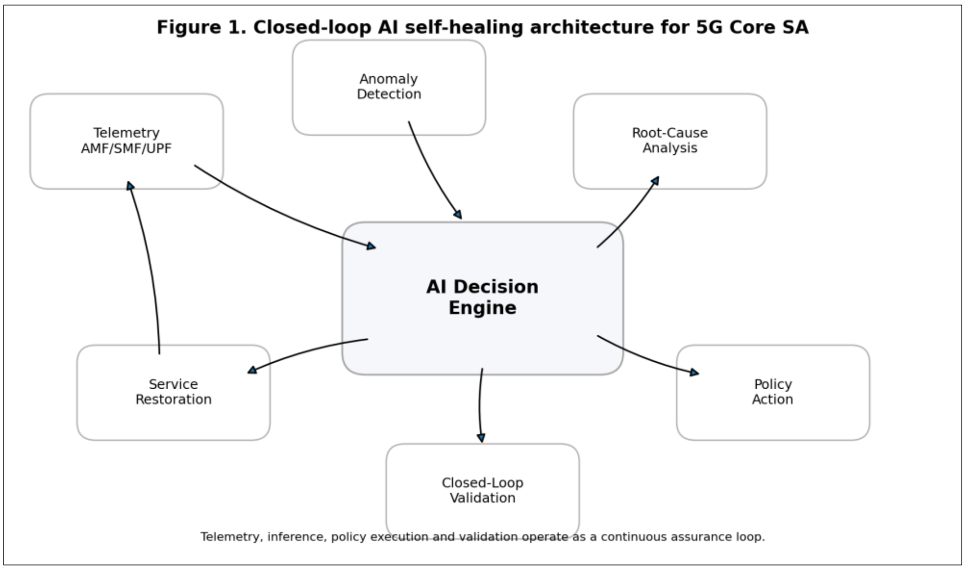

Figure 1: Closed-loop AI self-healing architecture for 5G Core SA

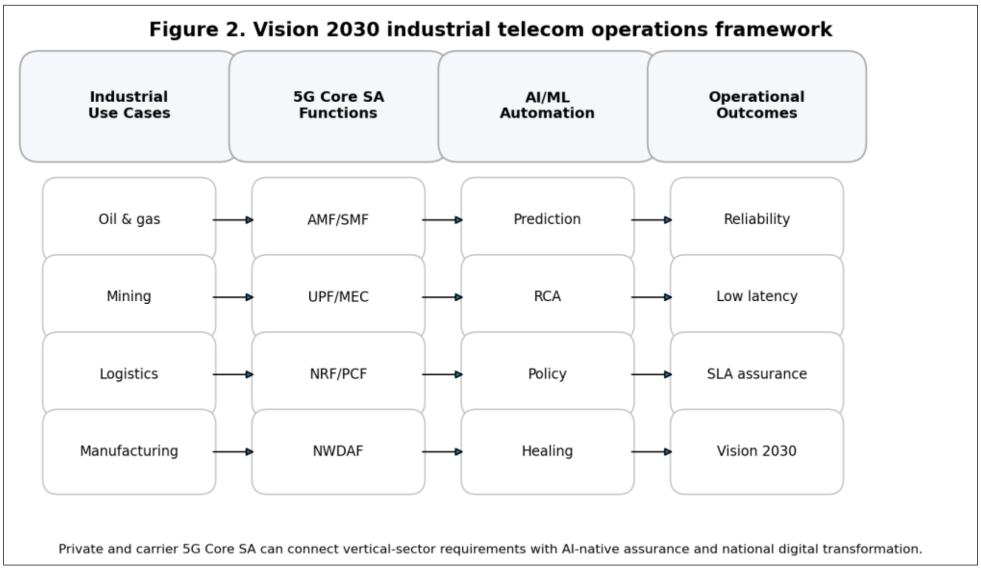

Figure 2: Vision 2030 industrial telecom operations framework

9. DISCUSSION

According to the literature review, AI-driven self-healing has progressed beyond theoretical ideas. With the growing use of 5G Core SA in private networks and industrial sectors, the number of slices, services, and edge locations will become too much to handle through manual operation. However, it is not necessarily the capability for full autonomy that makes the use of AI so valuable. Engineers will benefit significantly by being able to detect and diagnose an issue within just a few seconds instead of a couple of hours. The second major insight that emerges from the literature is that self-healing needs to be cross-domain. Purely core-network analysis cannot provide a solution for all problems because some issues might have originated at the radio, transport, cloud, applications, or devices level. Therefore, future studies might look into cross-domain analysis models incorporating data from 5G Core SA telemetry and industrial applications. It would be particularly interesting to investigate how such models could be used in the context of Saudi sectors embedding connectivity within their production flows. Thirdly, research needs to pay attention to evaluation methods for self-healing processes that go beyond technical indicators and incorporate economic criteria as well. Such parameters as packet loss, latency, and session success rate are important, yet they need to be complemented with information about whether AI-powered automation has reduced downtime, helped achieve compliance with SLAs, reduced costs on energy usage, or increased overall operational productivity. The proposed research methodology would help demonstrate how AI network automation connects with Vision 2030 and its goals.

10. CONCLUSION

AI-driven automation and self-healing mechanisms can significantly improve the reliability of 5G Core SA networks when they are implemented through governed closed-loop architectures. The 5G Core provides an automation-ready foundation through service-based architecture, cloud-native deployment, network slicing and analytics functions such as NWDAF. AI methods can detect anomalies, forecast congestion, diagnose faults and recommend or execute corrective actions. For Saudi Arabia, these capabilities are directly relevant to Vision 2030 sectors including oil and gas, mining, logistics, manufacturing, smart cities and giga-project digital infrastructure.

The review also shows that self-healing is not simply a technical feature. It requires high-quality telemetry, explainable models, secure automation interfaces, phased implementation and governance aligned with national priorities. Uncontrolled AI could introduce operational risk, but policy-bound automation can improve resilience and service assurance. Future research should focus on cross-domain datasets, digital twins for telecom operations, trustworthy AI, slice-specific healing models, energy-aware automation and real-world validation in industrial private networks. If these challenges are addressed, AI-enabled 5G Core self-healing can become a key enabler of reliable, secure and sustainable telecom operations in Saudi Arabia's knowledge-based digital economy.

11. Future Research Directions

Future research should shift focus from algorithmic tests towards end-to-end validation in realistic 5G Core environments. Many publications report impressive accuracy in anomaly detection or resource prediction, yet few researches validate model behaviors in connection with live orchestration systems. Researchers should develop testbeds based on virtualization techniques that create exact copies of the entire environment consisting of AMF, SMF, UPF, PCF, NWDAF, MEC and cloud platform interactions. This will allow safe and repeatable evaluation of healing actions before they are applied to the actual environment. Universities, operators and industrial enterprises in Saudi Arabia can utilize such setups for private-network testbeds for refineries, mines, ports and manufacturing plants.

The second area of future research is trustworthy AI for telecom operations. Self-healing models need to explain decision-making process, measure uncertainty and log evidence. Future research should address explainable root-cause analysis, policy-aware reinforcement learning, model validation under rare conditions and other challenges. Outages happen too seldom to be captured by any reasonable dataset, so researchers need to explore synthetic data, simulation and fault injection in generating realistic training scenarios. This is particularly important in the context of critical national infrastructure, where experiments cannot interfere with operational systems.

Third, future research should investigate how telecom indicators translate into national goals set out in the Vision 2030. Most global research focuses on technical metrics, such as accuracy, latency and throughput. However, Saudi Arabia's digital transformation depends on evidence proving that AI-driven automation increases economic efficiency, safety, sustainability and service confidence. Future studies should map telecom indicators to specific business value, such as downtime avoided, truck rolls reduced, energy saved, service-level agreements achieved and industrial operations fulfilled without disruptions. In this way, research would allow Saudi authorities to compare economic impact of various automation solutions.

Lastly, future research should focus on human capital development and governance. Future self-healing systems will require professionals with a combination of expertise in networking, data science, cloud platforms, cybersecurity and industrial processes. Consequently, research programs should incorporate training models, operational playbooks and governance templates in addition to pure technical algorithms. This multidisciplinary approach may help develop local expertise while maintaining security and alignment of automation systems with national priorities.

Researchers should investigate ways how the self-healing system interacts with O-RAN and cloud native near-real-time control plane and data-plane components such as NWDAF, near-real-time radio, near-real-time transport and other analytics and control components in edge, core and enterprise environments. In many cases, telemetry, analytics and recommendations might be available at all these components. It is possible that the recommendations are conflicting. This is a research area related to coordination and prioritization of decisions by different domains. This is important for private-industrial networks in Saudi Arabia because near-real-time controllers in edge environments might emphasize low latency and local processing, whereas similar controllers in core network might seek optimal use of resources.

Data sovereignty and privacy is another area related to telemetry required for self-healing. Some telemetry data might disclose user behavior, enterprise application usage or sensitive information about industrial processes. Future research should identify privacy-preserving data analytics techniques and approaches to data sovereignty in 5G Core environments. This includes such approaches as federated learning, anonymization, secure aggregation and restricted access to results of telemetry and analytics. Data sovereignty in Saudi Arabia may have its specifics as multiple parties, including operators, cloud platforms, enterprises and even government bodies, could participate in telecom operations. It is crucial to determine ownership of operational data, location of storage and processing of data as well as data retention periods.

Energy aware self-healing is another research area where current literature offers little contribution. Many self-healing models aim to maximize performance, yet they do not optimize energy consumption. On one hand, self-healing actions may scale multiple functions and recover lost performance at the cost of increased energy consumption. On another hand, excessive saving of energy may sacrifice reliability and resilience. Self-healing needs to balance reliability, latency, cost and energy consumption. This is a topic of great interest in Saudi Arabia, as large-scale self-healing is expected in the country. It is necessary to develop self-healing models capable of managing performance-energy trade-off.

Empirical investigation of human-AI collaboration in NOC is a promising area to explore further. Self-healing will likely require a sophisticated dashboard showing engineers information on detected issues, root cause analysis, recommended actions, risk associated with an issue and network status after an action. Human factors in telecommunications research would be useful to ensure proper human-AI interaction and avoid alert fatigue. At early stages, the most practical model might be collaborative intelligence in which a self-healing system continuously monitors the system and detects issues while engineers evaluate them and perform complex actions. Over time, accumulated evidence allows moving toward complete closed-loop automation.

Resilience of self-healing system in the case of compound failures is another research area worth exploring. Typically, incidents are rare events, and there is a small number of them in history that a model can learn from. However, incidents rarely happen in isolation from one another; e.g., they may take place simultaneously with large public event, natural catastrophe, or a cybersecurity attack. Future research needs to generate compound failure scenarios and determine whether a self-healing system can handle such conditions. In particular, such a system should demonstrate its ability to prioritize services provided for emergency response, secure critical industrial slices and provide basic connectivity for public safety. These capabilities may be useful in the context of Saudi Arabia.

Lifecycle management for models used in automation is another research topic to consider. When software upgrades, new slices are deployed, traffic moves to new locations or industrial enterprise introduces new devices, network characteristics are changing. This may lead to gradual deviation of a model from reality. It may be necessary to retrain and approve such models at regular intervals and implement rollback when something goes wrong with the latest update. Lifecycle view on self-healing becomes important because it is not a one-time task; rather, it is an ongoing operation that evolves over time.

Research program focused on interoperability of multi-vendor and private industrial environments is another promising avenue. Many systems today consist of multiple vendors' solutions or integrate various elements, including telecom infrastructure, cloud computing platforms, IoT devices, enterprise applications and cybersecurity solutions. Future research might look at standardizing interfaces for telemetry, implementing standardized telemetry models and establishing intent-based management. These measures will improve interoperability, which is critical for self-healing. Otherwise, such systems would be limited by vendor boundaries, which makes it difficult to achieve national scalability.

Researchers also should address ethical and accountability aspects of autonomous AI in telecommunications operations. Whenever the autonomous self-healing system takes any action impacting network behavior, it is necessary to establish responsibility for this action. There should be policies defining whether a given action can be automated or requires approval, what evidence to log, and how to inform users or other parties of major events that occurred. Such an accountability framework helps promote confidence in self-healing systems and encourages its deployment.

From methodological perspective, future reviews and empirical studies should distinguish between three concepts: automation, autonomic management and self-healing. While automation simply executes predefined workflows and autonomic management adapts workflows according to network conditions, self-healing should prove detection of performance degradation, treatment and validation with minimum human intervention. Such distinctions can increase scientific validity of publications in the field. Authors need to publish information on datasets, modeling assumptions, rate of false positives, recovery time, rollback success and operational constraints.

Further research should focus on localized telecom intelligence in Saudi Arabia. Self-healing system might rely on generic datasets, yet it might be beneficial to generate and train models using localized data that reflects unique conditions of Saudi Arabia, including traffic patterns, Arabic-speaking service environment, industrial operations schedules and others. Localization is important for technical and socio-economic reasons. On the one hand, a model that considers unique national circumstances will likely perform better. On the other hand, localized training will allow developing local skills for telecom and IT professionals.

Cost model for deploying self-healing systems is another interesting topic to study. For an operator, it is important to estimate expenses required to deploy self-healing solutions, such as data pipeline, model management, cloud resources, integration testing, cybersecurity measures, etc. However, there is also an opportunity to save costs by reducing network outages, minimizing time and efforts to recover network, and improving the quality of enterprise services. Thus, a cost-benefit perspective will help Saudi decision-makers choose most promising automation projects.

In summary, research related to telecom self-healing should adopt a socio-technical perspective on the problem. Strong systems combine advanced algorithms with robust engineering, sound governance, professional skills and continuous validation in Saudi environment. Responsible self-healing research should combine reliable telemetry, transparent models, domain expertise, secure policies, continuous validation, local datasets, national skills, energy awareness, measurable impacts and more.

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