iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VI **Month of publication:** June 2026

DOI: https://doi.org/10.22214/ijraset.2026.83844

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

From AI Analytics to Agentic AI: A Communications Engineering Framework for Autonomous Fixed Broadband Operations

Mohammad Mustafa[1], Mohammed Hussain Moheet[2], Mohammed Abdul Moheet[3], Safi Ammar Mohammed[4], Mohammed Hassan Ali Habeeb[5]
[1]*Communications Engineer, Contact Center Company (ccc), Riyadh, Saudi Arabia*
[2]*Computer Science Engineer, Methodist College of Engineering and Technology (MCET), Hyderabad, India*
[3]*Data Center Services Team Leader, Jeraisy Electronic Services, Riyadh, Saudi Arabia*
[4]*Application Support Analyst, Slater & Gordon Lawyers, Liverpool, United Kingdom*
[5]*Network Performance Specialist, Public Telecommunications Company, Riyadh, Saudi Arabia*

Abstract: The increasing complexity of fixed broadband networks, driven by fiber-to-the-home (FTTH) deployments, heterogeneous access technologies, expanding subscriber expectations, and stringent regulatory requirements, has challenged conventional network operations based on manual monitoring and rule-based automation. While Artificial Intelligence (AI)-driven analytics has significantly improved fault detection, network performance analysis, and customer experience management, most operational frameworks remain dependent on human intervention for decision-making and service restoration. This limitation constrains operational agility and the realization of autonomous broadband networks. This paper proposes a novel Communications Engineering Framework that illustrates the evolution from AI-assisted analytics to Agentic AI-enabled autonomous fixed broadband operations. The proposed framework introduces a four-stage operational maturity model comprising Reactive Operations, AI-Assisted Analytics, Predictive Intelligence, and Agentic AI-Enabled Autonomous Operations. Building upon this maturity model, a multi-agent architecture is presented consisting of Monitoring, Fault Diagnosis, Customer Experience, Recommendation, and Decision Orchestration Agents operating under Human-in-the-Loop governance to support explainable, policy-driven, and closed-loop network management. Unlike studies focusing on isolated AI applications, the proposed framework integrates predictive intelligence, autonomous decision-making, service assurance, customer experience optimization, and operational governance into a unified communications engineering perspective. The framework offers practical guidance for network operators pursuing autonomous broadband operations while emphasizing explainability, regulatory compliance, operational safety, and scalable AI adoption. The paper contributes a conceptual roadmap for future AI-native broadband networks and establishes a foundation for further research in Agentic AI-enabled telecommunications.
Keywords: Agentic AI, Fixed Broadband Networks, Communications Engineering, Autonomous Networks, FTTH, AI Analytics, Service Assurance, Telecommunications, Network Operations Center (NOC).

I. INTRODUCTION

The global evolution of fixed broadband infrastructure has transformed telecommunications networks into highly distributed, software-driven ecosystems supporting residential broadband, enterprise connectivity, cloud services, digital government initiatives, and emerging smart city applications. Modern Fiber-to-the-Home (FTTH) deployments integrate optical access networks, broadband network gateways, Wi-Fi ecosystems, cloud-native operational support systems (OSS), customer experience platforms, and service assurance frameworks. While these technologies have significantly improved broadband capabilities, they have simultaneously increased operational complexity, creating substantial challenges for network operations teams.

Traditional broadband operations have historically relied on reactive maintenance models in which alarms generated by network elements are manually investigated, correlated, prioritized, and resolved by Network Operations Center (NOC) engineers. Operational decisions frequently depend on predefined rules, static thresholds, and expert knowledge accumulated over years of field experience. Although these approaches have proven effective for relatively static network environments, they become increasingly difficult to scale as broadband networks expand in size, service diversity, and subscriber expectations.

The growing number of interconnected systems, multidimensional Key Performance Indicators (KPIs), vendor-specific management platforms, and regulatory reporting obligations introduces operational workloads that exceed the capabilities of purely human-centric decision processes.

To address these challenges, telecommunications operators have increasingly adopted Artificial Intelligence (AI) and Machine Learning (ML) techniques for network analytics. AI-assisted platforms have demonstrated significant potential in anomaly detection, fault classification, traffic forecasting, customer experience analytics, predictive maintenance, and service assurance. Rather than relying solely on reactive monitoring, AI-driven analytics enables operators to identify performance degradation trends, estimate service impacts, prioritize operational activities, and support evidence-based decision-making. These capabilities have become particularly important in fixed broadband environments where service quality depends upon interactions among optical infrastructure, customer premises equipment, Wi-Fi performance, application behavior, and subscriber usage patterns.

Recent research has explored AI applications across multiple operational domains. AI-driven network performance optimization has demonstrated how advanced analytics can enhance operational visibility and improve performance management through continuous KPI analysis and intelligent operational insights [1]. Similarly, customer-centric AI frameworks have highlighted the importance of integrating service quality indicators with subscriber behavior to improve Quality of Experience (QoE) and proactive customer experience management [2]. More recently, conceptual studies have introduced Agentic AI for intelligent Network Operations Centers by proposing autonomous software agents capable of supporting fault diagnosis and operational decision-making [3]. Collectively, these studies demonstrate a progressive evolution from descriptive analytics toward increasingly autonomous operational models.

Despite these advances, existing AI implementations remain primarily analytical rather than autonomous. Most deployed AI solutions function as decision-support systems that generate predictions, recommendations, or alerts requiring validation and execution by human operators. Predictive intelligence improves operational awareness but does not eliminate manual intervention during incident response, service restoration, or optimization workflows. Consequently, current AI deployments often fail to achieve fully closed-loop network operations, limiting their ability to adapt dynamically to rapidly changing network conditions.

The emergence of Agentic AI introduces a new paradigm that extends beyond conventional predictive analytics. Unlike traditional AI models that generate isolated predictions, Agentic AI systems employ autonomous software agents capable of perceiving operational environments, reasoning over multiple objectives, collaborating with other agents, executing actions within defined policy constraints, and continuously learning from operational feedback. Such capabilities align closely with the long-term vision of autonomous telecommunications networks promoted by international standardization bodies and industry initiatives. Within fixed broadband operations, Agentic AI has the potential to transform network management from reactive supervision into intelligent, policy-driven, and goal-oriented operational ecosystems.

However, a significant research gap remains regarding how telecommunications operators can systematically evolve from AI-assisted analytics toward Agentic AI-enabled autonomous operations. Existing literature frequently addresses individual technologies—including predictive maintenance, customer experience analytics, closed-loop automation, or intelligent service assurance—but rarely integrates these capabilities into a unified communications engineering framework suitable for practical broadband operations. Furthermore, governance considerations such as explainability, regulatory compliance, human oversight, and operational accountability remain insufficiently addressed within many conceptual AI architectures.

To address these challenges, this paper proposes a novel Communications Engineering Framework that explains the progressive evolution from traditional network operations through AI-assisted analytics and predictive intelligence toward Agentic AI-enabled autonomous fixed broadband operations. The proposed framework introduces a four-stage operational maturity model that characterizes increasing levels of intelligence and operational autonomy. Building upon this maturity model, a multi-agent architecture is presented comprising specialized Monitoring, Fault Diagnosis, Customer Experience, Recommendation, and Decision Orchestration Agents operating under Human-in-the-Loop governance to ensure explainability, safety, and policy compliance.

The primary contributions of this paper are summarized as follows:

1) A four-stage Communications Engineering Maturity Model describing the evolution from reactive operations to autonomous fixed broadband operations.
2) A novel multi-agent Agentic AI framework integrating network monitoring, fault diagnosis, customer experience analytics, operational recommendations, and autonomous orchestration.
3) A governance-oriented architecture that incorporates explainability, human oversight, regulatory compliance, and operational accountability into autonomous telecommunications operations.

4) Practical communications engineering use cases demonstrating how Agentic AI can support broadband degradation prediction, intelligent NOC operations, Wi-Fi optimization, SLA monitoring, and vendor governance.
5) A conceptual roadmap that bridges current AI analytics capabilities with future AI-native autonomous broadband networks.

This paper proposes a Communications Engineering Framework that illustrates the evolution from AI analytics toward Agentic AI-enabled autonomous fixed broadband operations.

II. LITERATURE REVIEW

A. Artificial Intelligence in Telecommunications Operations

The rapid expansion of broadband infrastructure and increasing service complexity have accelerated the adoption of Artificial Intelligence (AI) within telecommunications operations. Modern network environments generate massive volumes of operational data from optical line terminals (OLTs), broadband network gateways (BNGs), customer premises equipment (CPE), Wi-Fi access points, OSS/BSS platforms, network probes, and customer experience management systems. Traditional rule-based monitoring systems are increasingly challenged by the scale, velocity, and heterogeneity of these data sources, motivating the transition toward AI-assisted operational intelligence. Recent studies have demonstrated the application of machine learning for network anomaly detection, traffic prediction, resource optimization, and operational analytics. Deep learning techniques have improved network traffic forecasting, while unsupervised learning algorithms have enabled automated anomaly detection across heterogeneous network environments. Reinforcement learning has also been investigated for adaptive resource allocation and network optimization in software-defined and cloud-native telecommunications architectures. Collectively, these approaches have shifted network operations from descriptive monitoring toward predictive operational intelligence. Within fixed broadband environments, AI has increasingly been adopted to analyze service quality indicators, identify degradation trends, prioritize operational activities, and improve customer satisfaction. Rather than replacing network engineers, AI currently functions primarily as an analytical decision-support capability that augments human expertise.

The authors' previous work on AI-driven fixed network performance demonstrated how advanced analytics can improve operational visibility by correlating multiple performance indicators and supporting proactive network optimization activities [1]. This work established the analytical foundation upon which more autonomous operational capabilities can be developed.

B. Predictive Analytics for Service Assurance

Service assurance remains one of the most critical operational functions within broadband telecommunications. Conventional service assurance relies on threshold-based alarms and reactive incident management, often resulting in delayed fault resolution and increased operational expenditure. Predictive analytics extends these capabilities by identifying patterns that precede network degradation, enabling operators to intervene before service quality deteriorates significantly.

Recent research has explored predictive maintenance techniques using supervised machine learning, time-series forecasting, and anomaly detection algorithms to anticipate equipment failures and service degradation. Predictive models have also been applied to broadband quality assessment, customer churn prediction, Wi-Fi optimization, and SLA monitoring. These approaches improve operational efficiency by prioritizing maintenance activities according to predicted service impact rather than static alarm thresholds.

Customer-centric service assurance has similarly evolved through AI-assisted Quality of Experience (QoE) analytics. Instead of evaluating isolated network KPIs, modern service assurance increasingly incorporates subscriber behavior, application performance, and perceived service quality into operational decision-making. The authors previously proposed an AI-driven customer experience optimization framework that integrated network performance indicators with customer experience analytics to support proactive service quality management [2]. While this approach enhanced operational intelligence, decision execution remained dependent upon human operators, highlighting the need for higher levels of operational autonomy.

C. Autonomous Networks and Closed-Loop Automation

The telecommunications industry has progressively adopted the concept of autonomous networks to improve operational scalability and reduce dependence on manual intervention. Organizations such as TM Forum, ETSI, and ITU have proposed maturity models describing the evolution from manually managed networks toward self-optimizing and self-operating systems.

Closed-loop automation represents a fundamental component of autonomous networking. In a closed-loop operational model, network monitoring, fault detection, root-cause analysis, policy evaluation, decision-making, and corrective actions operate as a continuous feedback cycle. Such architectures reduce operational latency while improving service consistency and operational efficiency.

Despite considerable progress, many existing implementations remain semi-autonomous. Most closed-loop systems still require engineers to validate recommendations, approve remediation actions, or manually coordinate cross-domain workflows. Consequently, operational intelligence often remains fragmented across multiple management platforms without comprehensive autonomous orchestration.

Furthermore, current automation frameworks primarily focus on deterministic workflows rather than adaptive reasoning, contextual decision-making, or collaborative AI systems capable of managing complex operational objectives.

D. Agentic AI in Telecommunications

Recent advances in Large Language Models (LLMs), autonomous software agents, and multi-agent systems have introduced the emerging concept of Agentic AI. Unlike conventional AI models that generate isolated predictions or classifications, Agentic AI enables intelligent software agents to perceive operational environments, reason over multiple objectives, collaborate with other specialized agents, plan sequences of actions, execute decisions under defined policy constraints, and continuously learn from operational feedback.

Within telecommunications, Agentic AI has attracted increasing attention as a potential enabler of autonomous network operations. Multi-agent architectures may support distributed decision-making across network monitoring, fault diagnosis, customer experience management, service assurance, resource optimization, and operational governance.

Rather than replacing existing AI analytics, Agentic AI extends predictive intelligence by introducing autonomous reasoning and coordinated execution capabilities. Specialized agents may independently evaluate network conditions while collaborating to achieve broader operational objectives such as maintaining SLA compliance, minimizing customer impact, or optimizing network resources.

The authors' recent conceptual framework for intelligent Network Operations Centers introduced Agentic AI as an architectural approach for autonomous service assurance in fixed broadband environments [3]. That study primarily focused on intelligent NOC operations. The present paper extends this direction by proposing a broader communications engineering framework describing the evolutionary transition from AI analytics toward fully autonomous broadband operations.

E. Research Gap

Although significant progress has been achieved in AI-enabled telecommunications, existing literature reveals several important research gaps.

First, many studies investigate individual AI applications such as anomaly detection, predictive maintenance, customer experience analytics, or network optimization in isolation. Limited research integrates these capabilities into a unified operational architecture suitable for end-to-end fixed broadband operations.

Second, most AI implementations remain analytical rather than autonomous. Current systems generate predictions, recommendations, or alerts but rely heavily on human operators for operational decision-making and execution. The transition from predictive intelligence to autonomous operational reasoning remains insufficiently explored.

Third, existing autonomous networking frameworks frequently emphasize automation technologies without explicitly defining the collaborative roles of specialized AI agents responsible for monitoring, diagnosis, customer experience management, optimization, orchestration, and governance.

Finally, governance considerations—including explainability, accountability, regulatory compliance, human oversight, and operational safety—receive comparatively limited attention despite their importance for deploying autonomous AI systems within mission-critical telecommunications infrastructure.

These limitations indicate the need for a comprehensive communications engineering framework that systematically explains the evolution from AI-assisted analytics toward Agentic AI-enabled autonomous fixed broadband operations. Addressing this gap forms the principal contribution of the present study.

TABLE I
REPRESENTATIVE LITERATURE COMPARISON

Study	AI Technique	Telecom Domain	Key Contribution	Remaining Limitation
Mustafa et al. [1]	AI Analytics	Fixed Network Performance	KPI analytics and operational	Limited autonomous

			optimization	decision-making
Mustafa et al. [2]	AI + Customer Analytics	Customer Experience Management	Proactive QoE optimization	Human-driven execution
Mustafa et al. [3]	Agentic AI	Intelligent NOC Operations	Multi-agent service assurance concept	Focus limited to NOC architecture
TM Forum (2024)	Autonomous Networks	OSS Automation	Autonomous network maturity guidance	Limited agent-level architecture
ETSI ENI	Cognitive Networking	Network Intelligence	Context-aware decision support	Limited operational governance
Recent IEEE Studies (2023–2025)	Machine Learning	Predictive Maintenance	Failure prediction and anomaly detection	Limited closed-loop autonomy
Recent Springer/Elsevier Studies	Reinforcement Learning	Network Optimization	Adaptive optimization strategies	Explainability and governance challenges
Recent ACM Studies	Multi-Agent Systems	Distributed AI	Collaborative intelligent agents	Limited telecom-specific implementation

III.FROM AI ANALYTICS TO AGENTIC AI: A FOUR-STAGE COMMUNICATIONS ENGINEERING MATURITY MODEL

The evolution of fixed broadband operations has progressed from reactive maintenance practices toward increasingly intelligent operational models driven by advances in artificial intelligence, automation, and data analytics. However, this transition has not been linear. Most telecommunications operators currently employ hybrid operational environments where conventional monitoring tools coexist with AI-assisted analytics and partially automated workflows. Consequently, there remains a need for a structured maturity model that characterizes the progressive evolution toward autonomous broadband operations.

To address this need, this paper proposes a Four-Stage Communications Engineering Maturity Model that describes increasing levels of operational intelligence and autonomy within fixed broadband networks. Unlike existing maturity models that primarily emphasize automation, the proposed model integrates operational analytics, predictive intelligence, collaborative AI agents, and governance mechanisms into a unified communications engineering perspective. Figure 1 conceptually illustrates this evolution, while Table 2 summarizes the characteristics of each maturity stage.

A. Stage I: Reactive Operations

Reactive Operations represent the traditional operational paradigm adopted by most legacy telecommunications environments. Network monitoring is primarily based on predefined thresholds, static alarms, and manual fault management procedures. Operational teams continuously observe dashboards, investigate alarms, correlate network events, identify root causes, and coordinate restoration activities through established operational workflows.

Although this approach provides direct human oversight and well-defined operational accountability, it exhibits several limitations when applied to modern broadband infrastructures. Alarm volumes increase significantly with network scale, making manual prioritization increasingly difficult. Root-cause analysis often depends on individual expertise and cross-domain collaboration among multiple engineering teams, resulting in longer incident resolution times and inconsistent operational practices.

Decision-making within this stage remains deterministic, relying on operational experience rather than predictive intelligence. Consequently, maintenance activities are generally initiated after customer impact has already occurred.

Key Characteristics

- Manual network monitoring

- Rule-based alarm processing
- Static operational procedures
- Human-centric fault diagnosis
- Reactive maintenance
- Limited automation

B. Stage II: AI-Assisted Analytics

The second maturity stage introduces Artificial Intelligence as an analytical decision-support capability rather than an autonomous operational entity. Machine learning models, statistical analytics, and data correlation techniques enhance operational visibility by identifying anomalies, forecasting KPI trends, and prioritizing incidents based on historical operational patterns.

AI-assisted analytics significantly improves engineering productivity by reducing manual data analysis while supporting evidence-based operational decision-making. Engineers receive recommendations generated from predictive models rather than relying exclusively on individual expertise.

Within fixed broadband operations, AI-assisted analytics supports:

- Network KPI trend analysis
- Performance degradation detection
- Capacity utilization forecasting
- Customer experience analytics
- Wi-Fi performance assessment
- SLA monitoring
- Operational reporting

Despite these improvements, operational decisions remain dependent upon human approval. AI functions primarily as an intelligent advisor rather than an autonomous decision-maker. Recommendation execution, policy interpretation, and cross-domain coordination continue to require manual intervention.

Operational Benefits

- Faster anomaly detection
- Improved KPI correlation
- Better operational visibility
- Reduced analytical workload
- Enhanced customer experience insights

Remaining Limitations

- Human-driven execution
- Limited workflow automation
- No autonomous reasoning
- Fragmented AI capabilities
- Limited cross-domain coordination
-

C. Stage III: Predictive Intelligence

Predictive Intelligence represents the transition from descriptive analytics toward proactive operational management. Rather than identifying current network conditions alone, predictive models estimate future operational states using historical trends, time-series analysis, behavioral modeling, and probabilistic forecasting techniques.

Predictive intelligence enables operators to anticipate service degradation before customers experience noticeable performance deterioration. Network maintenance becomes increasingly preventive rather than reactive, allowing engineering resources to be prioritized according to predicted operational impact.

Typical applications include:

- Fiber degradation prediction
- Broadband fault forecasting
- Customer churn prediction
- Capacity exhaustion forecasting
- Wi-Fi quality prediction

- Preventive maintenance scheduling
- Risk-based incident prioritization

Although predictive intelligence substantially enhances operational planning, current implementations generally terminate at prediction generation. Human engineers remain responsible for validating recommendations, coordinating stakeholders, authorizing corrective actions, and monitoring implementation outcomes.

Therefore, predictive intelligence improves operational awareness but does not achieve operational autonomy.

D. Stage IV: Agentic AI-Enabled Autonomous Operations

The fourth maturity stage introduces Agentic AI as the foundation for autonomous fixed broadband operations. Unlike conventional predictive analytics, Agentic AI employs multiple collaborative software agents capable of perceiving operational environments, reasoning across multiple objectives, coordinating specialized knowledge, executing approved actions, and continuously learning from operational outcomes.

Within the proposed framework, autonomous operation is achieved through cooperation among specialized agents responsible for monitoring, diagnosis, customer experience evaluation, optimization, recommendation generation, and workflow orchestration. Each agent performs domain-specific reasoning while collaborating with other agents to achieve broader operational objectives.

Operational decisions are no longer based solely on predefined rules or isolated AI predictions. Instead, agents evaluate contextual information from multiple network domains, subscriber behavior, service assurance systems, operational policies, and regulatory constraints before recommending or executing corrective actions.

Importantly, operational autonomy does not imply unrestricted automation. Human oversight remains essential for governance, regulatory compliance, safety-critical decisions, and exceptional operational scenarios. Consequently, the proposed framework adopts a Human-in-the-Loop governance model that balances autonomous decision-making with organizational accountability.

The defining capabilities of Agentic AI-enabled operations include:

- Goal-oriented operational planning
- Multi-agent collaboration
- Autonomous workflow orchestration
- Cross-domain reasoning
- Continuous operational learning
- Explainable decision support
- Policy-driven action execution
- Human-supervised autonomy

This maturity stage represents a shift from intelligent decision support toward intelligent operational execution, enabling communications networks to evolve into adaptive, self-improving operational ecosystems.

TABLE II
FOUR-STAGE COMMUNICATIONS ENGINEERING MATURITY MODEL

Stage	Operational Model	AI Capability	Human Involvement	Operational Characteristics
Stage I	Reactive Operations	None / Rule-Based	Very High	Manual monitoring, threshold alarms, reactive maintenance, engineer-driven fault resolution
Stage II	AI-Assisted Analytics	Descriptive & Diagnostic AI	High	AI-supported KPI analysis, anomaly detection, customer experience analytics, recommendation support
Stage III	Predictive Intelligence	Forecasting & Predictive ML	Moderate	Failure prediction, preventive maintenance, capacity forecasting, proactive service assurance
Stage IV	Agentic AI Autonomous Operations	Multi-Agent Autonomous Intelligence	Human-in-the-Loop	Collaborative AI agents, closed-loop automation, policy-driven decision-making, explainable autonomous operations

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

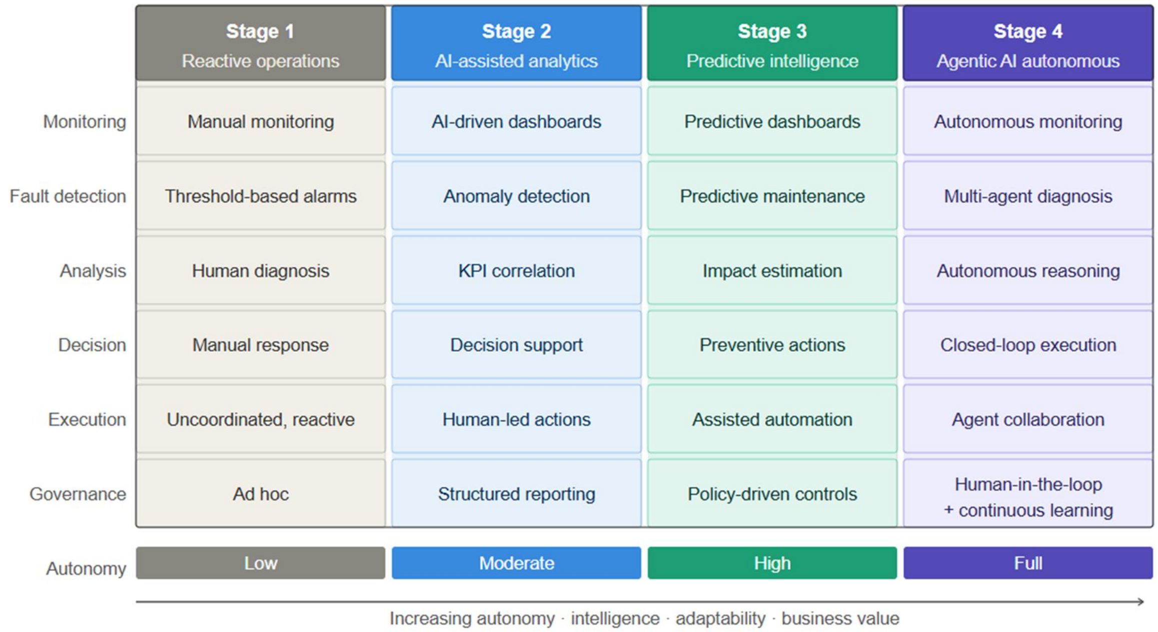


Fig. 1 Evolution from AI Analytics to Agentic AI

The figure emphasizes increasing operational autonomy, intelligence, adaptability, and business value across successive maturity stages.

IV. PROPOSED COMMUNICATIONS ENGINEERING FRAMEWORK

A. Framework Overview

Building upon the proposed Four-Stage Communications Engineering Maturity Model, this paper introduces a multi-agent communications engineering framework for autonomous fixed broadband operations. The framework extends traditional AI-assisted analytics by integrating specialized autonomous agents that collaborate to support monitoring, diagnosis, customer experience management, operational optimization, and policy-driven decision orchestration.

Unlike monolithic AI systems that perform isolated prediction tasks, the proposed framework adopts a modular, multi-agent architecture in which each intelligent agent is responsible for a specific operational domain while continuously exchanging contextual information with other agents. This distributed approach reflects the organizational structure of modern telecommunications operations, where network performance, service assurance, customer experience, and operational governance function as interconnected yet specialized disciplines.

The framework assumes continuous data ingestion from heterogeneous operational systems including network elements, OSS/BSS platforms, customer experience management systems, Wi-Fi analytics platforms, inventory databases, fault management systems, and regulatory reporting repositories. These data streams provide the operational context required for autonomous reasoning while preserving compatibility with existing telecommunications infrastructures.

Figure 2 illustrates the proposed architecture.

B. Monitoring Agent

The Monitoring Agent serves as the primary perception layer of the framework. Its responsibility is to continuously collect, normalize, and interpret operational information from multiple network domains.

Typical data sources include:

- Optical Line Terminals (OLT)
- Broadband Network Gateways (BNG)
- Customer Premises Equipment (CPE)
- Wi-Fi access points
- OSS performance counters

- Fault management systems
- Service assurance platforms
- Customer experience databases
- SLA monitoring dashboards

Rather than generating static alarms, the Monitoring Agent continuously evaluates network behavior by identifying abnormal trends, KPI deviations, emerging service degradation patterns, and operational anomalies. The agent prioritizes contextual awareness instead of isolated event detection, thereby reducing alarm fatigue and improving operational visibility.

Primary Responsibilities:

- Multi-domain KPI monitoring
- Data normalization
- Alarm correlation
- Operational anomaly detection
- Context generation for downstream agents

Outputs:

- Operational state
- Correlated network events
- Prioritized anomaly summaries
- Confidence indicators

C. Fault Diagnosis Agent

The Fault Diagnosis Agent transforms operational observations into explainable engineering knowledge. Rather than relying solely on predefined alarm rules, the agent performs contextual reasoning using historical operational knowledge, topology relationships, service dependencies, and correlated performance indicators.

The agent evaluates multiple hypotheses before estimating the most probable root cause of service degradation. Cross-domain correlation enables simultaneous analysis of transport networks, access infrastructure, Wi-Fi performance, customer complaints, maintenance history, and vendor-specific events.

Where appropriate, diagnostic confidence scores are generated to support engineering decision-making.

Responsibilities:

- Root-cause analysis
- Cross-domain correlation
- Failure classification
- Service impact estimation
- Fault dependency analysis

Outputs:

- Probable root cause
- Confidence level
- Affected services
- Impact assessment
- Diagnostic explanation

D. Customer Experience Agent

Network performance alone does not fully represent subscriber satisfaction. Consequently, the Customer Experience Agent continuously evaluates Quality of Experience (QoE) by integrating technical performance indicators with customer-centric operational metrics.

The agent analyzes relationships among:

- Throughput
- Latency
- Packet loss
- Wi-Fi quality
- Application performance

- Trouble tickets
- Customer complaints
- Usage behavior
- SLA compliance

Rather than evaluating isolated network KPIs, the agent estimates how technical degradation may influence perceived service quality. This capability enables proactive intervention before widespread customer dissatisfaction occurs.

Responsibilities:

- QoE assessment
- Customer impact prediction
- Experience segmentation
- Subscriber prioritization
- SLA evaluation

Outputs:

- Customer impact score
- Experience degradation risk
- Priority subscribers
- QoE trend analysis

E. Recommendation Agent

The Recommendation Agent converts analytical insights into operational actions. Using outputs generated by the Monitoring, Fault Diagnosis, and Customer Experience Agents, it develops candidate remediation strategies consistent with organizational policies and operational objectives.

Examples include:

- Network parameter optimization
- Capacity reallocation
- Wi-Fi channel optimization
- Preventive maintenance scheduling
- Vendor escalation
- SLA remediation
- Customer communication recommendations

Unlike conventional expert systems, recommendations are generated dynamically according to current operational context rather than static rule libraries.

Each recommendation is accompanied by:

- Operational rationale
- Expected service impact
- Implementation priority
- Confidence assessment
- Associated operational risks

Responsibilities:

- Optimization planning
- Corrective action generation
- Preventive maintenance planning
- Recommendation ranking

F. Decision Orchestration Agent

The Decision Orchestration Agent represents the central intelligence of the proposed framework. Rather than independently performing technical analysis, this agent coordinates decisions produced by all specialized agents while ensuring consistency with operational policies, regulatory requirements, and organizational objectives.

Its responsibilities include:

- Prioritizing competing operational objectives
- Coordinating cross-domain workflows
- Validating policy compliance
- Scheduling remediation activities
- Initiating closed-loop automation
- Maintaining operational audit trails

The orchestration process supports adaptive workflow execution instead of deterministic automation, enabling autonomous decision-making while respecting predefined operational boundaries.

For low-risk operational scenarios, approved actions may be executed automatically. High-impact or policy-sensitive decisions are forwarded to human engineers for approval.

This layered orchestration mechanism balances operational efficiency with organizational accountability.

G. Human-in-the-Loop Governance

Full autonomy is neither practical nor desirable for every telecommunications operation. Regulatory obligations, cybersecurity risks, contractual commitments, and safety considerations require continued human oversight.

Accordingly, the proposed framework incorporates a Human-in-the-Loop (HITL) governance layer responsible for supervising autonomous decision-making.

Key governance responsibilities include:

- Approval of high-impact operational actions
- Policy management
- Regulatory compliance verification
- Exception handling
- Ethical ai oversight
- Model validation
- Operational auditing
- Continuous performance review

Rather than limiting autonomy, HITL governance establishes trust by ensuring that autonomous agents operate within clearly defined operational policies and accountability frameworks.

This governance layer also supports explainable AI by requiring every autonomous decision to include traceable reasoning, supporting evidence, confidence levels, and affected operational domains.

H. Agent Collaboration and Closed-Loop Operations

The principal innovation of the proposed framework lies not in individual AI agents but in their coordinated collaboration.

A typical operational sequence proceeds as follows:

1) The Monitoring Agent detects abnormal network behavior and generates contextual operational events.
2) The Fault Diagnosis Agent performs root-cause analysis and estimates service impact.
3) The Customer Experience Agent evaluates subscriber-level consequences and prioritizes affected users.
4) The Recommendation Agent generates ranked corrective and preventive actions.
5) The Decision Orchestration Agent validates recommendations against operational policies and either executes approved actions automatically or requests human authorization.
6) Operational outcomes are continuously monitored, enabling all agents to learn from execution results and improve future decision-making.

This closed-loop workflow enables continuous adaptation while preserving explainability, governance, and operational accountability.

TABLE III
ROLES OF AI AGENTS WITHIN THE PROPOSED FRAMEWORK

Agent	Primary Function	Key Inputs	Principal Outputs
Monitoring Agent	Network perception and anomaly detection	KPIs, alarms, OSS data, telemetry	Contextual operational state
Fault Diagnosis Agent	Root-cause analysis	Correlated events, topology, historical faults	Root cause, impact assessment, confidence level
Customer Experience Agent	QoE and SLA evaluation	Network KPIs, complaints, service metrics	Customer impact score, QoE trends
Recommendation Agent	Operational optimization	Diagnostic outputs, policies, operational objectives	Ranked corrective and preventive actions
Decision Orchestration Agent	Policy-driven coordination	Recommendations, governance rules, business priorities	Autonomous execution or approval workflow
Human-in-the-Loop Governance	Oversight, compliance, auditing	All agent outputs, policies, regulations	Approvals, policy updates, audit records

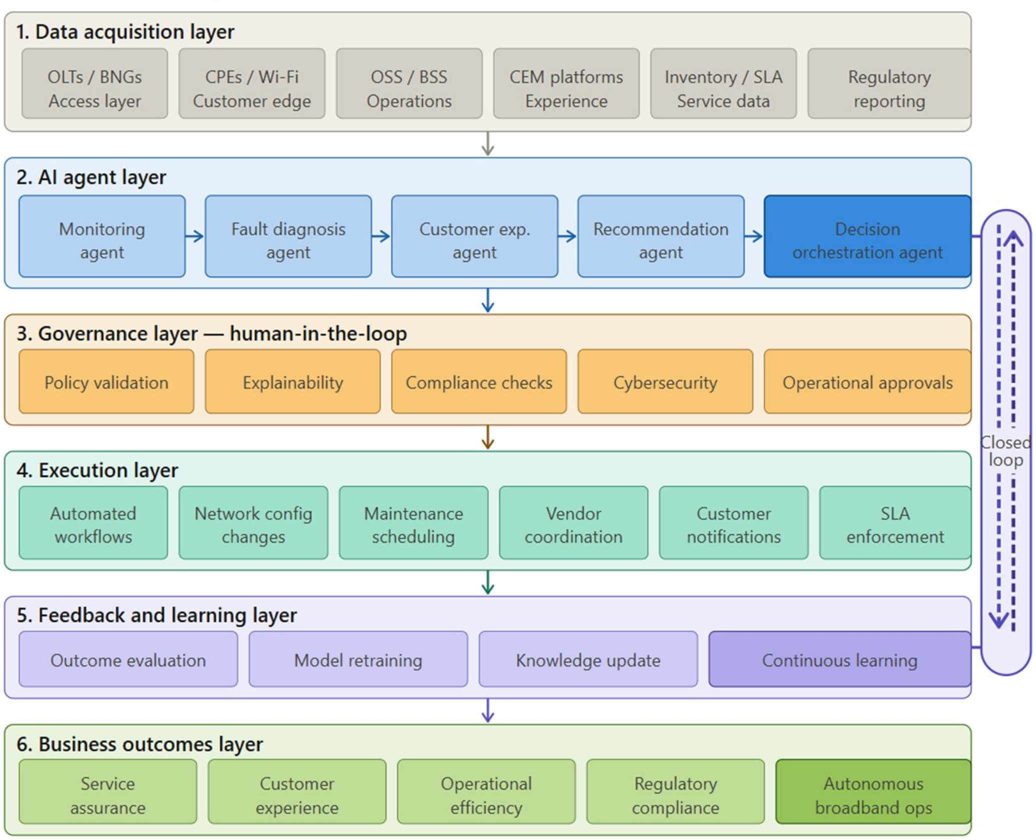


Fig. 2 Evolution from AI Analytics to Agentic AI

V. TELECOM USE CASES AND DISCUSSION

The proposed Agentic AI framework is intended to complement existing telecommunications operational platforms rather than replace them. By integrating autonomous reasoning with established service assurance processes, the framework supports gradual adoption while preserving operational governance and regulatory compliance. This section illustrates representative use cases that demonstrate the practical applicability of the proposed architecture within fixed broadband operations.

A. Broadband Degradation Prediction

Problem: Broadband service degradation frequently develops gradually due to fiber attenuation, optical connector contamination, overloaded broadband gateways, deteriorating Wi-Fi conditions, or abnormal subscriber behavior. Conventional monitoring systems generally detect degradation only after predefined KPI thresholds have been exceeded, often resulting in customer complaints before engineering intervention begins.

Current Practice: Current operational workflows rely on alarm monitoring, periodic KPI analysis, manual troubleshooting, and reactive maintenance. Engineers correlate multiple data sources to estimate probable causes before initiating corrective actions.

Agentic AI Approach: Within the proposed framework

- The Monitoring Agent continuously identifies abnormal KPI trends.
- The Fault Diagnosis Agent evaluates probable technical causes.
- The Customer Experience Agent estimates subscriber impact.
- The Recommendation Agent proposes preventive actions such as optical inspection, capacity balancing, or Wi-Fi optimization.
- The Decision Orchestration Agent schedules remediation according to organizational policies and operational priorities.

Expected Operational Benefits:

- Earlier identification of service degradation
- Improved prioritization of maintenance activities
- Reduced dependence on manual KPI interpretation
- More proactive service assurance

Implementation Considerations: Successful deployment requires reliable historical operational data, standardized KPI definitions, and integration across multiple OSS platforms.

B. Automated NOC Incident Prioritization

Problem: Modern Network Operations Centers process thousands of alarms daily. Many alarms are duplicated, symptom-based, or generated by cascading failures, making manual prioritization increasingly difficult.

Current Practice: Operators manually correlate alarms using rule-based systems and engineering expertise before assigning incidents to operational teams.

Agentic AI Approach: The Monitoring Agent aggregates operational events while the Fault Diagnosis Agent performs contextual root-cause analysis. The Customer Experience Agent estimates subscriber impact, allowing the Recommendation Agent to rank incidents according to service severity rather than alarm frequency. The Decision Orchestration Agent then coordinates incident assignment and workflow execution.

Expected Operational Benefits:

- Improved incident prioritization
- Faster operational decision support
- Better allocation of engineering resources
- Enhanced consistency across operational teams

Implementation Considerations: Operational success depends upon accurate topology information, service dependency mapping, and continuously updated operational policies.

C. Intelligent Wi-Fi Optimization

Problem: A significant proportion of broadband service complaints originate from in-home Wi-Fi environments rather than access network failures. Conventional operational systems often lack sufficient visibility into subscriber Wi-Fi conditions, resulting in unnecessary field dispatches.

Current Practice: Wi-Fi troubleshooting generally involves manual diagnostics, remote support, customer interaction, or on-site engineering visits.

Agentic AI Approach: The Monitoring Agent continuously evaluates Wi-Fi performance metrics, including throughput, channel utilization, signal strength, interference levels, and device connectivity. The Customer Experience Agent estimates the impact of wireless conditions on subscriber experience, while the Recommendation Agent proposes optimization strategies such as channel reconfiguration, band steering, firmware updates, or equipment replacement. Where permitted by operational policy, selected optimization actions may be executed automatically.

Expected Operational Benefits:

- Improved residential Wi-Fi experience
- Reduced unnecessary field visits
- More efficient customer support
- Better utilization of Wi-Fi analytics

Implementation Considerations: Deployment requires compatibility with managed CPE platforms and careful consideration of customer privacy requirements.

D. Proactive Customer Experience Management

Problem: Traditional customer experience management frequently reacts to complaints after subscribers have already experienced service degradation.

Current Practice: Customer complaints initiate investigation, followed by manual correlation between customer reports and network performance data.

Agentic AI Approach: The Customer Experience Agent continuously estimates subscriber satisfaction using QoE indicators derived from network performance, application behavior, historical usage patterns, and service assurance metrics. When deterioration is predicted, the Recommendation Agent may initiate preventive operational actions, customer notifications, or engineering investigations before complaints occur.

Expected Operational Benefits:

- Improved proactive customer engagement
- Earlier identification of service deterioration
- Better prioritization of high-impact subscribers
- More efficient customer support operations

Implementation Considerations: Organizations should define transparent policies governing customer communication and automated interventions.

E. SLA Compliance Automation

Problem: Enterprise broadband services frequently operate under contractual Service Level Agreements (SLAs) requiring continuous compliance monitoring.

Current Practice: SLA reporting is typically generated using periodic operational reports combined with manual engineering review.

Agentic AI Approach: The Monitoring Agent continuously evaluates SLA performance indicators. When potential violations are predicted, the Fault Diagnosis Agent investigates probable causes while the Recommendation Agent proposes preventive remediation strategies. The Decision Orchestration Agent coordinates corrective activities according to contractual priorities and organizational policies.

Expected Operational Benefits:

- Earlier detection of SLA risks
- Improved contractual compliance
- Reduced operational escalation
- Enhanced service transparency

Implementation Considerations: SLA policies should be integrated with organizational governance frameworks to ensure contractual consistency.

F. Vendor Performance Governance

Problem: Modern broadband operations depend upon multiple equipment vendors, managed service providers, and external maintenance partners. Performance evaluation often relies on periodic reporting rather than continuous operational intelligence.

Current Practice: Vendor performance is assessed through KPI reports, service review meetings, and manual engineering analysis.

Agentic AI Approach: The proposed framework continuously correlates vendor-specific operational metrics with network performance, customer experience indicators, and SLA compliance. Recommendation Agents identify recurring operational deficiencies while Decision Orchestration Agents prioritize improvement initiatives according to business objectives.

Expected Operational Benefits:

- Continuous vendor performance visibility
- Evidence-based governance
- Improved operational accountability
- Better long-term service quality

Implementation Considerations: Standardized KPI definitions and transparent governance policies are essential for fair vendor assessment.

G. Discussion

The proposed Communications Engineering Framework demonstrates that the progression from AI analytics to Agentic AI involves more than increasing algorithmic sophistication. It requires a transition from isolated analytical capabilities toward coordinated autonomous decision-making supported by explainable governance mechanisms.

Unlike conventional AI systems that primarily generate predictions, the proposed multi-agent architecture enables collaboration among specialized operational domains, allowing autonomous reasoning across network monitoring, fault diagnosis, customer experience management, and operational orchestration. This collaborative capability has the potential to improve operational consistency while reducing dependence on fragmented manual workflows.

Nevertheless, several implementation challenges must be considered. First, the effectiveness of autonomous agents depends upon the quality, consistency, and interoperability of operational data across OSS/BSS platforms. Incomplete or inconsistent telemetry may reduce diagnostic accuracy and undermine confidence in autonomous recommendations.

Second, explainability remains essential for operational acceptance. Engineers and operational managers must understand why specific recommendations are generated, particularly for high-impact remediation activities. Accordingly, autonomous decisions should always include traceable reasoning, confidence scores, and supporting evidence.

Third, governance plays a critical role in balancing operational efficiency with accountability. Human-in-the-Loop supervision ensures that regulatory requirements, contractual obligations, cybersecurity considerations, and organizational policies remain central to autonomous decision-making rather than being treated as post-processing activities.

Finally, the proposed framework should be viewed as an evolutionary roadmap rather than an immediate replacement for existing operational systems. Telecommunications operators can progressively adopt individual agents alongside existing OSS platforms before expanding toward fully coordinated autonomous broadband operations.

TABLE IV
REPRESENTATIVE TELECOM USE CASES

Use Case	Current Operational Challenge	Agentic AI Capability	Expected Operational Outcome
Broadband Degradation Prediction	Reactive fault detection	Predictive monitoring and coordinated diagnosis	Earlier operational intervention
Automated NOC Prioritization	High alarm volumes	Context-aware incident prioritization	More efficient resource allocation
Wi-Fi Optimization	Limited visibility into home networks	Autonomous Wi-Fi analysis and optimization recommendations	Improved subscriber experience

Proactive Customer Experience Management	Complaint-driven operations	Continuous QoE assessment and preventive actions	Reduced customer dissatisfaction
SLA Compliance Automation	Periodic compliance reporting	Continuous SLA monitoring and policy-driven remediation	Improved contractual compliance
Vendor Performance Governance	Manual performance evaluation	Continuous operational intelligence and evidence-based assessment	Enhanced governance and accountability

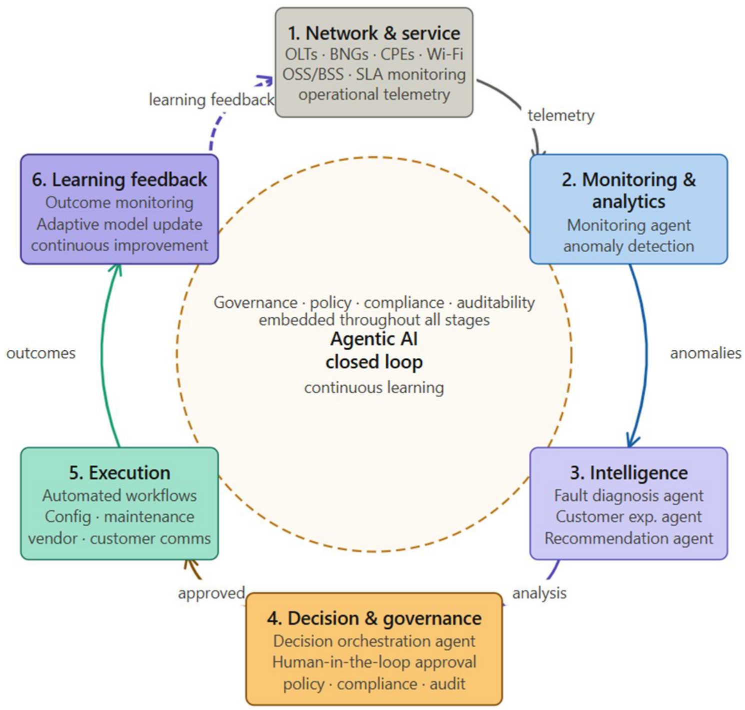


Fig. 3 Closed-Loop Autonomous Broadband Operations

Figure illustrates a continuous operational feedback loop.

VI. RESEARCH CONTRIBUTIONS

This paper advances the current body of research on AI-enabled telecommunications by proposing a communications engineering perspective on the evolution of autonomous fixed broadband operations. Rather than introducing a new machine learning algorithm, the study presents an architectural and operational framework that integrates existing AI capabilities into a coherent roadmap for progressively increasing network autonomy.

The principal research contributions are summarized as follows:

1) Four-Stage Communications Engineering Maturity Model: The paper proposes a structured maturity model that describes the evolution of fixed broadband operations from Reactive Operations to AI-Assisted Analytics, Predictive Intelligence, and Agentic AI-Enabled Autonomous Operations. Unlike generic automation maturity models, the proposed framework is specifically tailored to fixed broadband service assurance and operational engineering.
2) Multi-Agent Communications Engineering Framework: A modular multi-agent architecture is introduced to support autonomous broadband operations. The framework defines complementary roles for Monitoring, Fault Diagnosis, Customer Experience, Recommendation, and Decision Orchestration Agents operating under Human-in-the-Loop governance. This architecture demonstrates how specialized AI agents can collaborate to support end-to-end operational decision-making while preserving transparency and accountability.

3) Integration of Customer Experience with Network Operations: The proposed framework extends conventional network-centric AI by incorporating customer experience analytics as a core decision variable. By combining Quality of Service (QoS), Quality of Experience (QoE), and service assurance indicators, operational decisions can be prioritized according to subscriber impact rather than solely technical network conditions.
4) Governance Model for Autonomous Broadband Operations: The study emphasizes that autonomous operations require more than technical intelligence. It introduces a governance layer that integrates explainability, policy validation, regulatory compliance, cybersecurity awareness, and human oversight into autonomous operational workflows. This governance-centric approach enhances trust and facilitates practical adoption within operational telecommunications environments.
5) Practical Engineering Roadmap: Finally, the paper provides a practical roadmap illustrating how telecommunications operators can incrementally evolve from AI-assisted decision support toward autonomous broadband operations. Rather than advocating immediate full automation, the proposed maturity model supports progressive adoption while maintaining compatibility with existing OSS/BSS platforms and operational processes.

Collectively, these contributions establish a conceptual foundation for future research into AI-native telecommunications operations while offering practical guidance for network operators seeking to deploy Agentic AI in fixed broadband environments.

VII. CONCLUSION

The increasing scale and complexity of modern fixed broadband networks require operational approaches that extend beyond traditional monitoring, rule-based automation, and isolated AI analytics. Although Artificial Intelligence has significantly enhanced network performance analysis, predictive maintenance, and customer experience management, most current implementations continue to depend on human operators for decision-making and workflow execution. As broadband infrastructures continue to evolve, this operational model presents challenges in terms of scalability, responsiveness, and consistency.

This paper proposed a Communications Engineering Framework describing the evolution from AI-assisted analytics toward Agentic AI-enabled autonomous fixed broadband operations. The proposed Four-Stage Communications Engineering Maturity Model illustrates the progressive transition from reactive operations through AI-assisted analytics and predictive intelligence to collaborative autonomous operations supported by specialized AI agents. Building upon this maturity model, a multi-agent architecture was introduced comprising Monitoring, Fault Diagnosis, Customer Experience, Recommendation, and Decision Orchestration Agents operating under Human-in-the-Loop governance.

Unlike existing studies that typically examine isolated AI techniques or individual automation capabilities, the proposed framework integrates operational intelligence, customer experience analytics, governance, explainability, and policy-driven orchestration into a unified communications engineering perspective. The presented telecom use cases demonstrate how this architecture can support broadband degradation prediction, intelligent NOC operations, Wi-Fi optimization, proactive customer experience management, SLA compliance, and vendor performance governance while remaining compatible with existing operational environments.

The framework is conceptual in nature and has not been validated through implementation or large-scale operational deployment. Consequently, the paper does not claim measurable performance improvements. Instead, it establishes an engineering roadmap that can guide future research and industrial adoption of Agentic AI within fixed broadband networks.

Future research should focus on prototype implementation, experimental validation using operational datasets, Digital Twin integration, AI-native OSS architectures, Large Telecom Models (LTMs), intent-driven autonomous networking, and explainable multi-agent learning for self-healing broadband infrastructures. Further investigation into interoperability with TM Forum Open Digital Architecture (ODA), ETSI ENI, and emerging 6G autonomous network frameworks will also strengthen the practical applicability of Agentic AI within next-generation telecommunications ecosystems.

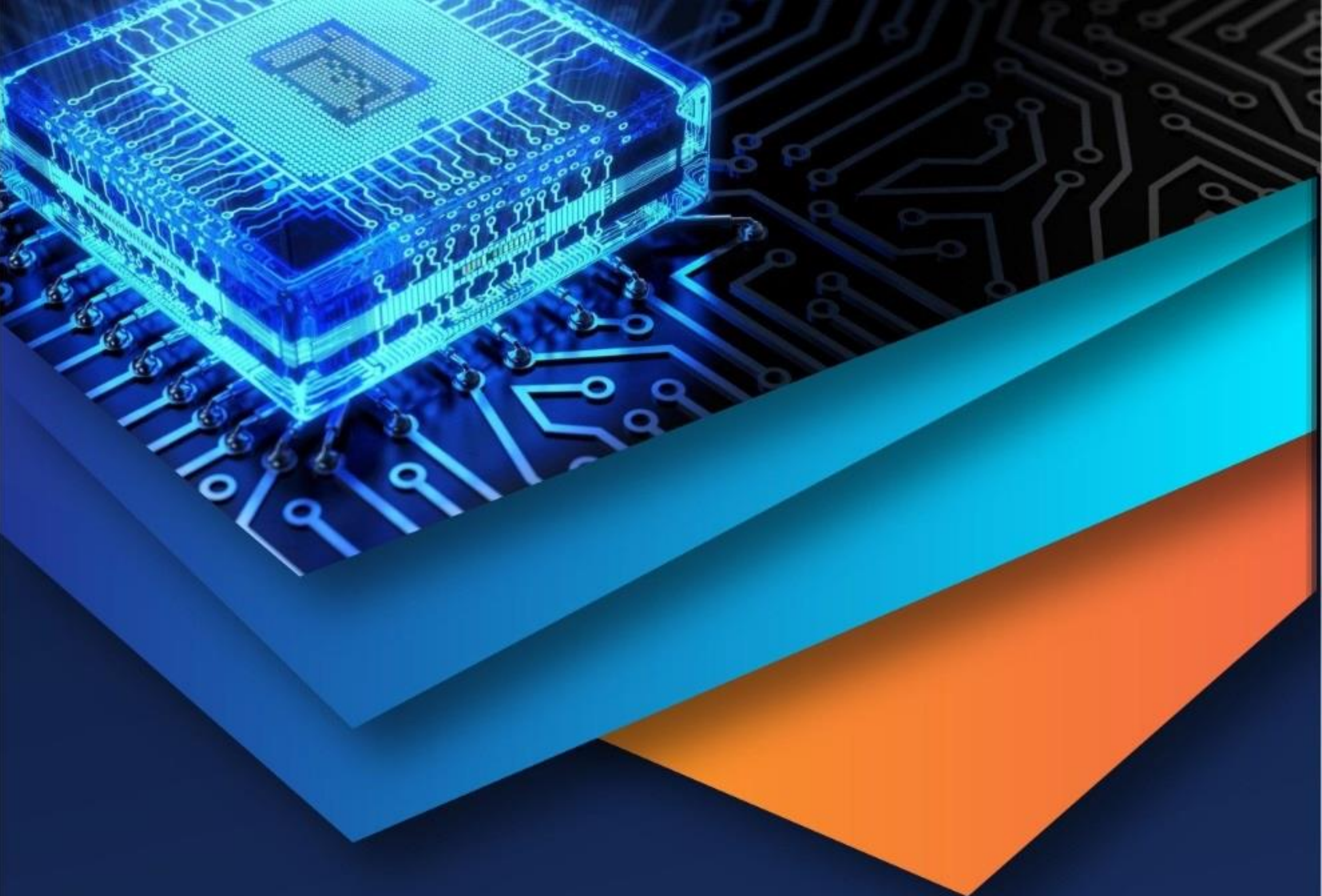
VIII. ACKNOWLEDGMENT

The authors gratefully acknowledge the valuable insights and professional support provided by colleagues and telecommunications industry experts whose practical experience in fixed broadband operations, service assurance, and network performance management contributed to the development of the concepts presented in this paper.

The opinions, interpretations, and conclusions expressed in this work are solely those of the authors and do not necessarily reflect the views or policies of their affiliated organizations.

REFERENCES

[1] M. Mustafa, M. H. Moheet, M. A. Moheet, and S. A. Mohammed, "Optimizing Fixed Network Performance Through Artificial Intelligence-Driven Operations and Analytics in Modern Telecom Networks," International Journal for Research in Applied Science and Engineering Technology (IJRASET), vol. 14, no. V, pp. 6499–6504, 2026.
[2] M. Mustafa, M. H. Moheet, M. A. Moheet, S. A. Mohammed, and M. H. A. Habeeb, "Artificial Intelligence-Driven Customer Experience Optimization in Fixed Broadband Networks," International Journal for Research in Applied Science and Engineering Technology (IJRASET), vol. 14, no. VI, pp. 689–695, 2026.
[3] M. Mustafa, M. H. Moheet, M. A. Moheet, S. A. Mohammed, and M. H. A. Habeeb, "Agentic AI for Service Assurance in Fixed Broadband Networks: A Conceptual Framework for Intelligent NOC Operations," International Journal for Research in Applied Science and Engineering Technology (IJRASET), vol. 14, no. VI, pp. 1267–1279, 2026.
[4] ETSI, AI in the Evolution of Autonomous Networks, ETSI White Paper No. 69, 2025.
[5] ITU-T, Framework of Artificial Intelligence Enhanced Telecom Operation and Management (AITOM), Recommendation M.3080.
[6] ITU-T Focus Group on AI Native for Telecommunication Networks, Vocabulary for Artificial Intelligence Native Telecommunication Networks, Technical Specification, 2025.
[7] TM Forum, Autonomous Networks Business Requirements and Framework (IG1218), Version 3.0.0, 2024.
[8] TM Forum, AN Journey Guide: Innovation in Autonomous Networks, Version 6.0.0, 2024.
[9] TM Forum, Essential Framework for Telecom Agentic AI, Catalyst Project White Paper, 2025.
[10] TM Forum, Agentic AI for Autonomous Computing Networks (IG1444), Version 1.0.0, 2025.
[11] ETSI Industry Specification Group Experiential Networked Intelligence (ISG ENI), Experiential Networked Intelligence Framework, ETSI Technical Specifications.
[12] 3GPP, Study on Artificial Intelligence (AI)/Machine Learning (ML) for the 5G System and Beyond, Technical Report TR 22.874 (latest available release).
[13] IEEE Communications Society, "Artificial Intelligence for Autonomous Network Management: Challenges, Opportunities, and Future Directions," IEEE Communications Magazine, 2024.
[14] IEEE Communications Surveys & Tutorials, "Artificial Intelligence and Machine Learning for Autonomous Networks: A Survey," 2024.
[15] Elsevier, "Machine Learning Techniques for Predictive Maintenance in Telecommunication Networks," Computer Networks, 2024.
[16] Springer, "Explainable Artificial Intelligence for Network Operations and Service Assurance," Journal of Network and Systems Management, 2024.
[17] ACM Computing Surveys, "Multi-Agent Systems: Architectures, Coordination, and Autonomous Decision-Making," 2023.
[18] IEEE Network, "Closed-Loop Automation for AI-Native Telecommunications Networks," 2025.
[19] IEEE Communications Magazine, "Towards AI-Native 6G Networks: Opportunities and Challenges," 2025.
[20] IEEE Communications Standards Magazine, "Trustworthy AI for Autonomous Network Operations: Explainability, Governance, and Human-in-the-Loop Intelligence," 2025.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL
IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY