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Original Article

AI-Powered Networked Management: The Future of MVNOs and MVNAs

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Abstract - *The changes that networked management system with AI brings to Mobile Virtual Network Operators (MVNOs) and Mobile Virtual Network Aggregators (MVNAs) signify a leap in the telecommunications business. The major use of artificial intelligence within the MVNO and the MVNA environment is in the machine learning and deep learning models that can be used to design the subsequent network efficiency, customer experience, and operation efficiency. AI figures within traffic predictability assist such entities to anticipate the degree of network density and allocate relevant resources to ensure that users do not encounter hitches. Fault management receives significant enhancements through artificial intelligence, especially when it imparts predictions for preventing network problems and their ultimate impacts on service continuity with minimal disruptions. Thirdly, of the invasive services based on artificial intelligence algorithms, the improvement in such indexes as customer satisfaction is high due to distinguishing between preferences and application patterns. This paper focuses on critical outcomes as it reveals how AI is embedded into the structure of operations in MVNOs and MVNAs, which briefly enables data evaluation and decision-making. Thus, the interaction between AI and network management introduces new opportunities for differentiation and the development of telecommunications technologies.*

Keywords - *AI-powered network management, Mobile Virtual Network Operators (MVNOs), Mobile Virtual Network Aggregators (MVNAs), Machine learning, Deep learning, Network optimization*.

1. Introduction

Mobile Virtual Network Operators (MVNOs) and Mobile Virtual Network Aggregators (MVNAs) are now relevant actors in telecommunications. [1] MVNOs are different from traditional mobile network operators since the latter do not directly own the wireless infrastructure that they use to offer services to their clients. However, they purchase capacity from the mobile network operators (MNOs) and generally target specific segments providing specific services with actionable prices. An MVNA, however, essentially lies between the MNOs and MVNOs and pools network resources for provision to MVNOs on a wholesale basis.

1.1. Evolution of MVNOs and MVNAs

- MVNO (Mobile Virtual Network Operator): A mobile virtual network operator is an entity that offers mobile services by partnering with conventional mobile network operators to purchase space without involving infrastructure establishment.
- MVNA (Mobile Virtual Network Aggregator): An organization that buys the means of providing network services from one or several MNOs to resell them to various MVNOs; this company can also offer these MNOs technical, material and administrative support.

1.1.1. Historical Development

- Early 1990s: The idea of MVNOs arose to introduce competition and expand the opportunities to provide services.
- 2000s: The opportunities for considering the expansion of MVNOs were due to the liberalization of legislation, the development of new technology, and the higher consumer requirements.
- 2010s: Coming up with MVNAs which would work to ensure the efficient organization of MVNOs and cut down their expenses. Flooding of new MVNOs in the emerging markets.
- 2020s: Application of higher levels of technology, including AI, IoT and other related innovations in improving perks in MVNO and MVNA.

The requests levied by the mobile services, which include calls, data usage, and other IoT gadgets due to enhanced proportional usage of smartphones, have led to increased pressure on the MVNOs and MVNAs to deploy and utilize the network's resources optimally. They must again guarantee that they are providing high-quality service, have effective infrastructure and management of resources, and are economically viable in a liberalized market environment.

2. Relevance of AI

The ability to implement the new technologies of Artificial Intelligence turned out to be useful and powerful for achieving the goals of MVNOs and MVNAs to tackle numerous and extensive problems. Prospective operators that integrate the use of AI into their network management shall be able to enhance their efficiency in service delivery, quality, and customer satisfaction.

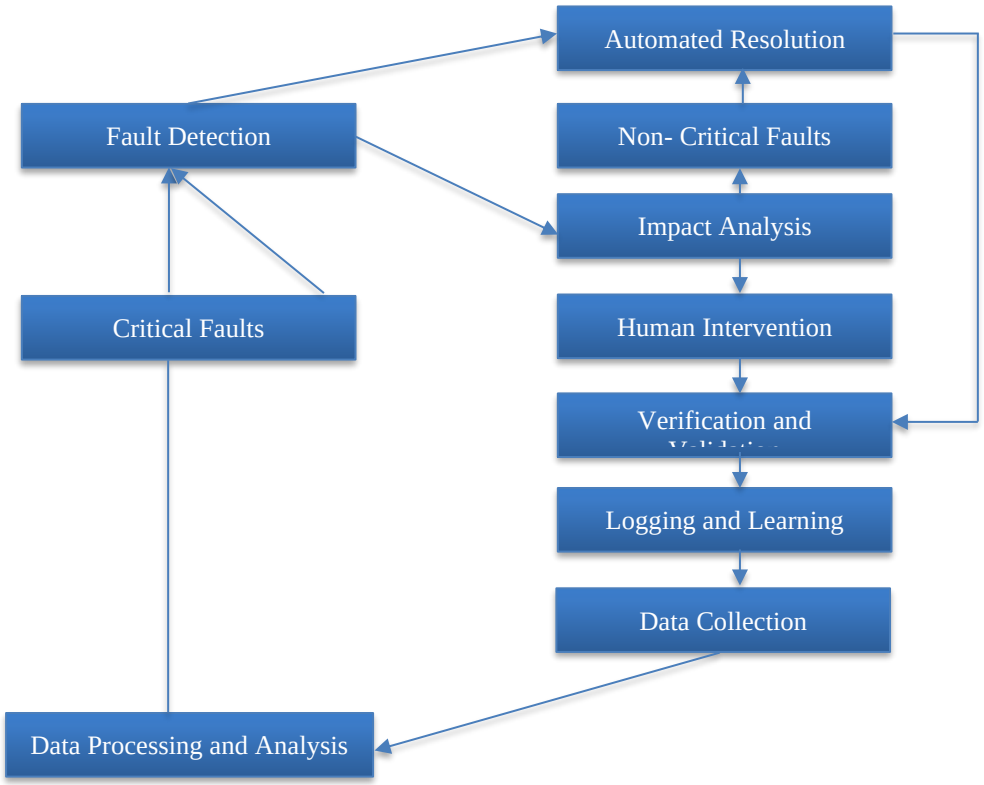

Fig. 1 AI-Powered Network Management Framework

2.1. AI-Powered Network Management Framework

The AI-Powered Network Management [2] Framework is basically aimed at effectively managing and improving network performance by utilizing AI technologies. This is made up of several related parts and procedures that make it possible to achieve sound network performance, rapid detection of faults and problem-solving in Figure 1.

The first step of the presented framework is data collection, which is when data is collected from network devices, fetched from users, and taken from performance logs. This information is then passed to the Data Processing and Analysis component, where such techniques as machine learning are used to scan for patterns, inconsistencies, and performance indicators.

Data processing is the next step of the algorithm, and after that, the application uses the Fault Detection component. This module employs the analyzed data to find out possible faults or a problem that may exist on the network. The Impact Analysis component checks whether a fault is present and, if it is, assesses the level and extensiveness of the fault's influence on the related network and users.

According to the impact, the suggested framework would follow the actions. Typically, for non-critical faults, the Automated Resolution component tries to suggest a set of solutions that are designed to be solved by Artificial Intelligence. In the cases where the fault is severe, the client is forwarded to the Human Intervention, where the experts diagnose and clear the fault.

In this case, the Verification and Validation component is critical after the resolution of an issue in that it guarantees a proper resolution. Finally, the Logging and Learning components record the incident and the subsequent actions taken and feedback the data to the system to enhance the system's fault detection and problem-solving process.

2.2. Intelligent Network Management

AI facilitates networking tasks that can be conducted automatically [3] with the help of intelligent algorithms suitable for perceiving the data and making decisions in real time. This results in anticipative network maintenance to avoid disruption, hence enhancing the network's effectiveness.

2.2.1 Traffic Prediction:

The frequency of traffic patterns is analyzed with the help of an AI model, and the information retrieved from it permits identifying traffic increases and effectively allocating the network for that.

2.2.2 Fault Detection and Resolution:

The applications of machine learning in this area can help predict issues concerning the network infrastructure and identify areas that need to be addressed before they pose more significant problems.

2.3. AI Fault Detection and Resolution Process

The process starts with the constant scanning of the networks in the organization. [4] Network performance is monitored by an AI algorithm that looks for such things as irregularities or poor performance. Such a careful approach is important to achieve the highest availability of the

network and ensure that potential slips become identified at the earliest stage (Figure 2).

If there is a potential fault, then the system must decide whether there is a fault or not. Should no fault be found, it just goes on carrying out its monitoring functions all the time. However, if a fault is detected, the process continues to identify the fault type. This classification is important as it facilitates the determination of the likelihood and possible root causes of the fault, which forms the basis of the resolution process.

Based on the identified fault type, the effect of the fault on the network and, subsequently, the customers is evaluated. It is one of the most important steps of this process since it channels the general priority level of the problem and the necessary steps towards its solution. In case the fault is considered non-critical, automated procedures for their resolution occur. These are automated solutions which are instituted by artificial intelligence to tackle minor frequent problems.

The flow checks if the automated resolution has solved the problem and terminates or redirects the process if the problem has not been resolved. In the event that the process leading the resolution results in effectiveness, it proceeds with logging the details of the resolution as well as any lessons learnt. It is useful for future reviews and improvement of the fault detection and resolution method used in the organization.

When the impact of the fault is of a critical level, the process needs to be controlled by a human. A human specialist is involved in cases when a machine cannot detect the error; he/she takes responsibility for diagnosing the fault. This escalation makes sure complicated and serious cases get the necessary attention and experience to solve the problem. Afterwards, interaction with human operators or auto-resolve, the system verifies the fault has been cleared. When the fault is still undiagnosed, the process comes back to repeat the evaluation and possible escalation. This approach also guarantees that any issue that may have developed a perennial nature is dealt with until all its facets are rooted out.

Last of all, after the fault has been rectified automatically or manually, the details of the resolution and the things learnt are recorded. This procedure aids in constructing the background data that will aid the system in addressing other faults in the future. It then ends with the continuous current monitoring of the network by the system.

2.4. Predictive Analytics

Data analytics derived from [5] AI assists MVNOs and MVNAs in decision-making to improve the strategic MVNE business planning and operations.

2.4.1. Customer Behavior Analysis

Another advantage is that it applies analysis algorithms on customers to identify their usage and preference for specific services that can help in marketing and delivering services specific to customers' needs.

2.4.2 Capacity Planning

Forecasting facilities help to predict the further demand for the network capacity and increase the infrastructure, providing operators with services correspondingly.

2.5. Automated Decision-Making

With the increasing use of technology, mostly in AI analysis, many decisions are made automatically, [7] there is minimal interference from employees, and response is faster.

2.5.1. Resource Allocation

AI systems also control the resources of the network by allocating unwanted network resources based on real-time usage to improve the quality and reduce the cost.

2.5.2. Customer Support

Chatbots and virtual assistants are AI that offer round-the-clock customer support to address customers' concerns and problems and improve customer satisfaction.

3. Literature Review

3.1. Overview of Existing Research

Current research reveals the increasing focus on the use of AI in network management which this paper comes to embrace. [8,9] The investigations with AI on the networks have shown that there are possibilities to enhance the efficiency of the networks while increasing the level of client satisfaction.

3.1.1. AI in Telecommunications

- Network Optimization: Network resources have been utilized through the application of AI algorithms in organizations to enhance efficiency.
- Predictive Maintenance: Using AI in the predictive analytics of the network, failures in the network can be foreseen, therefore cutting on the expenses incurred in maintenance and high chances of network downtime.
- Customer Experience: The implementation of AI solutions in banking helps to increase the effectiveness of customer support services, including chatbots and individualized services, where the favourability index increases.

3.1.2. Machine Learning Algorithms

- Supervised Learning: Applied in traffic forecasting and intrusion detection in network functionality.
- Unsupervised Learning: Used in clustering processes as well as in the identification of patterns in a network's data.
- Reinforcement Learning: Used for the dynamic allocation of resources and the network slicing.

3.2. Existing Research on MVNOs and MVNAs

Literature reviews concerning MVNOs and MVNAs have mainly targeted business models and market strategies, but there is a poor provision for technological innovation.

3.2.1. Organization Forms and Market Patterns

- Market Penetration: Research has investigated how MVNOs enter markets with unique strategies in terms of a business model.
- Cost Management: Dissection of the cost models and realization of the profit-making strategies by MVNOs.

3.2.2. Technological Adoption

- Virtualization Technologies: Only a few studies are available concerning the manner in which MVNOs deploy virtualization for the purpose of managing networks.
- Service Innovation: An assessment of the services that MVNAs provide and advancement in technology.

3.3. Gaps and Limitations

Nevertheless, it is an addendum that there is a void within the extant literature when it comes to the systematic review of the concept of AI in the context of MVNO and MVNA, and mostly in realistic settings.

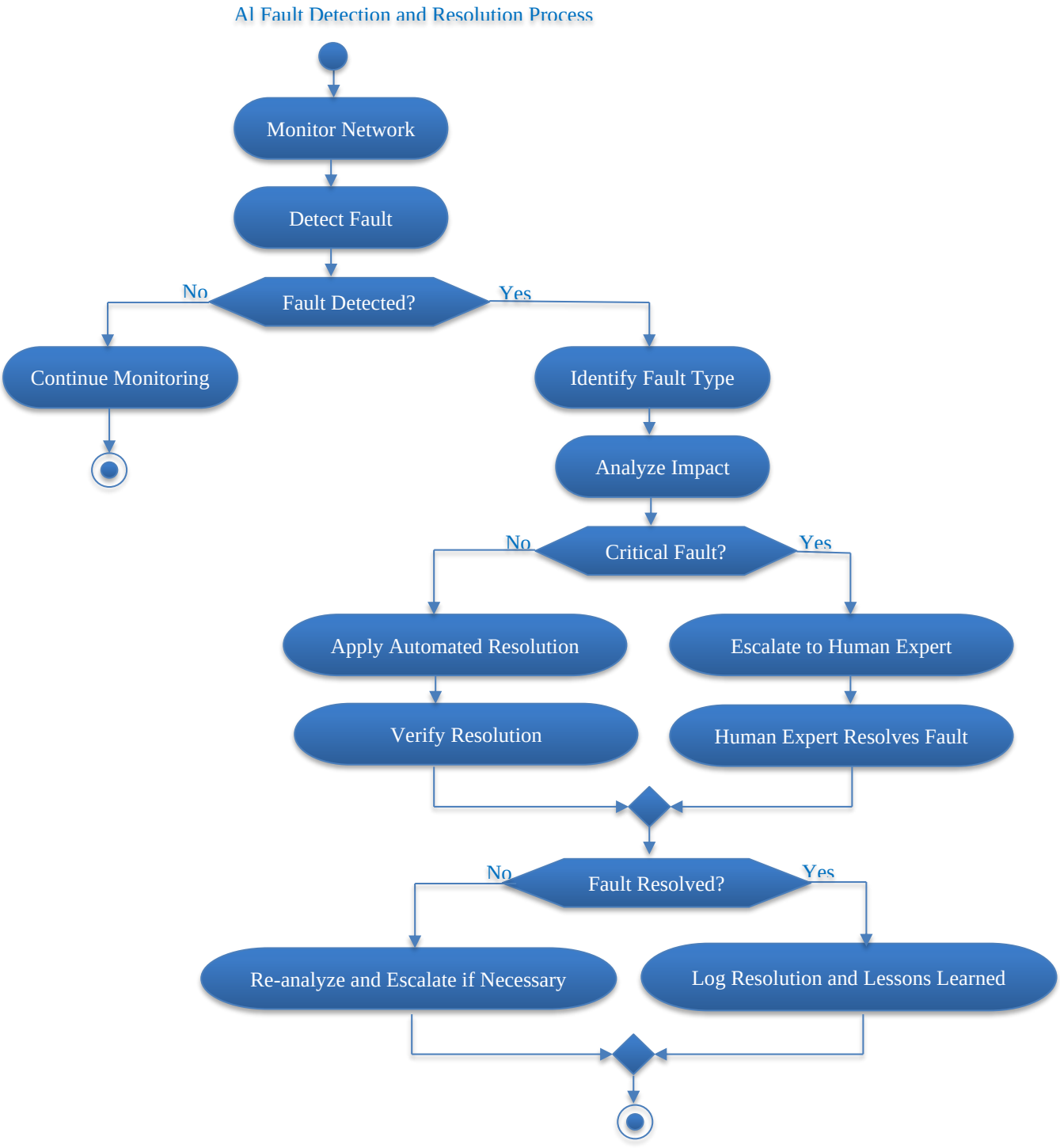

Fig. 2 AI Fault Detection and Resolution Process

3.3.1. Real-life cases are usually scarce in this case

- Empirical Evidence: Significantly, most of the research is at the conceptual level, and there is little documentation of the actual AI use in the case of MVNOs and MVNAs.
- Scalability Issues: There is not enough literature on aspects such as the possibilities of applying AI solutions at the large-scale network level.

3.3.2. Integration Challenges

- System Integration: Despite pressing issues of effectively incorporating AI with conventional network management systems, the literature lacks sufficient discussion.
- Interoperability: Challenges that exist in regard to the integration of AI solutions within the context of network management and its inherent instruments.

3.4. Future Trends of AI Monopoly in Network Management

- AI and 5G: Studies on how the application of AI can be of help in managing 5G are also coming up.
- Edge Computing: Exploration of AI in edge computing for real-time network management.
- IoT Integration: Some works related to the integration of AI with the IoT networks for better control and security.

4. AI in Networked Management

4.1. Overview of AI Techniques

Thus, AI techniques can be seen as the enablers of the improvement of effective capabilities [10,11] of network management for MVNOs and MVNAs. Described below are the detailed descriptions of the major AI methods and their uses.

4.1.1. Machine Learning

Machine learning is a technique that involves the use of a set of processes by which a specific kind of program can learn from the data and, in turn, make the right kind of predictions. In network management, the deployment of machine learning can be applied to different areas like Traffic forecasting, activity monitoring, and resource allocation, among others.

- Supervised Learning: They are learned through labeled data to produce outputs and discern network occurrences.
- Unsupervised Learning: Machine learning can work on the free form of text or data and is good at finding irregular traffic patterns for the network.
- Semi-supervised Learning: It involves the use of both labeled and unlabeled data in the generation of the final output and becomes particularly important since a large volume of unlabeled data may be available, whereas the number of labeled data is somewhat limited.

4.1.2. Deep Learning

Neural networks with multiple layers are used in deep learning and can be thought of as a sub-area of machine learning. It is particularly efficient at the analysis of large amounts of unstructured data for which examples are logs and network traffic data.

- Convolutional Neural Networks (CNNs): Specifically designed for image and spatial data, CNNs are effective in identifying the patterns of network traffic, too.
- Recurrent Neural Networks (RNNs): Used in time series-based prediction in network traffic, RNNs are suitable for sequential data.
- Autoencoders: Used for anomaly detection by learning the efficient representations of data and analysis of the data samples against the learned representations.

4.1.3. Reinforcement Learning

Reinforcement learning-based training is done to achieve a sequence of decisions by encouraging positively desired actions and penalizing negatively desired ones. They apply especially well when the situations in an environment are ever-changing and diverse.

- Q-Learning: Agent-free reinforcement learning is used when making decisions concerning the allocation of resources in the network.
- Deep Q-Networks (DQNs): The reinforcement learning Q-variants are integrated with Deep learning to work under higher dimensional space, which is useful for network environments.
- Policy Gradient Methods: Directly optimize the policy (strategy) for decision-making, suitable for continuous action spaces in network control.

Table 1. AI Algorithms for network optimization

Algorithm	Application	Benefits
Machine Learning	Traffic prediction	Improved network efficiency
Deep Learning	Fault detection	Reduced downtime
Reinforcement Learning	Resource allocation	Optimized service quality

4.2. AI Applications in Network Management

The application of AI in network management is diverse, profoundly impacting the overall functionality of the MVNE and the MVNA.

4.2.1. Traffic Prediction and Optimization

Machine learning [12] algorithms monitor past and current patterns of traffic in the networks to foresee future bottlenecks to help control network traffic for the required levels of functionality.

- Short-term Traffic Prediction: By applying machine learning techniques to the current traffic condition, the traffic in the near future (minutes to hours) can be forecasted, and thus, action can be taken instantly.
- Long-term Traffic Forecasting: Thus, the use of deep learning methods to predict long timeframes of traffic (from days to months) helps present additional capacities and construct more infrastructures.

- Real-time Traffic Optimization: Applying reinforcement learning to select the best possible traffic flow at any given moment, depending on the general networks.

4.2.2. Fault Detection and Resolution

It is the use of machine learning where the algorithm is set to analyze the network and send out automatic resolution procedures for problems that it finds as they occur so that disruptions are reduced in the network and services.

- Anomaly Detection: In this case, they made use of unsupervised learning to recognize out-of-the-ordinary behaviors that might point to faults or security compromises.
- Predictive Maintenance: Supervised learning for detecting possible faults that are likely to occur soon, thereby scheduling for repairs.
- Automated Resolution: Using AI and machine learning concepts to integrate automation processes that help solve the issues detected with minimal human interference.

4.2.3. Quality of Service (QoS) Management

Thus, AI makes it possible to achieve the desired QoS by adjusting the appropriate network parameters based on the users' needs.

- Dynamic QoS Adjustment: Applying the concepts of machine learning for real-time analyzation and fine-tuning of QoS parameters ongoing.
- User Experience Optimization: Utilizing AI to detect patterns of users' activity and network characteristics to improve the level of user satisfaction.
- Service Level Agreement (SLA) Management: Utilizing predictive analytics to ensure compliance with SLAs by forecasting potential breaches and taking preemptive actions.

5. The Role of AI in MVNOs and MVNAs

5.1. Current Challenges

AI can solve several tough issues that new and existing MVNOs and MVNAs [13,19] experience in present and future telecommunication markets.

5.1.1. Scalability Issues

- Data Volume Management: As the amount of mobile data grows day by day, MVNOs and MVNAs find themselves overwhelmed by huge volumes of data. [14] Big data can be readily handled, stored and analyzed using AI, therefore being a major advantage in the management of big data.
- User Demand Fluctuations: Specifically, scalability is needed to provide a constant stream of service at a specific quality while the user load fluctuates, for instance, in peak and off-peak periods. AI applications for demand pattern forecasting can make appropriate modifications to the network resources at any given time.
- Infrastructure Expansion: It is very hard to scale up infrastructure to accommodate more users. It shows that the use of AI in the infrastructure can support the automation of infrastructure construction and further enhancement of the processes.

5.1.2. Resource Allocation

- Dynamic Resource Allocation: The conventional approaches of resource management make arrangements that cause the wastage of resources. Distributed AI can proactively assign resources depending on the status of the network and the users' needs.
- Load Balancing: When AI algorithms are available to manage the network traffic flow, traffic distribution to the resources is well managed; hence, the smooth flow of service provision is achieved.
- Energy Efficiency: This shows that AI can help reduce energy usage within its networks as it adapts to the usage trends, hence acting sustainability and reducing costs.

5.1.3. Customer Experience

- Service Quality Monitoring: It also means that there are always AI-assisted tools that can constantly scan service delivery to check for any possible concern and address it before the user is affected.
- Personalization: AI makes it easy to provide targeted services and suggestions to the users, hence improving their experience.
- Proactive Customer Support: Self-service is anticipated through AI to minimize the cases where the user will need to seek assistance from the firm.

5.2. AI Solutions for MVNOs

AI offers several solutions tailored to the unique needs of MVNOs.

5.2.1. Intelligent Resource Management

- Traffic Prediction: Using the analysis of big data, AI models can predict the flow of the traffic in the network and help the MVNOs manage their resources.
- Network Optimization: AI may help to learn network topologies and fine-tune them for the best throughput and minimal delays.
- Predictive Maintenance: AI can identify the wear and tear of equipment and plan for repairs and replacements, hence minimize on operational costs.

5.2.2. Automated Customer Service

- AI-driven Chatbots: With the help of NLP, the chatbots can respond to frequently asked questions, thus offering some form of assistance.
- Virtual Assistants: Virtual assistants can help users with composite operations, including problem-solving and account operations.
- 24/7 Availability: Automated customer service technology guarantees customers continuous support hence increasing the satisfaction levels among customers.

5.2.3. Personalized Services

- Recommendation Engines: The use of artificial neural networks involves mining the users' activities to present to them content and services of their interest.

- Dynamic Pricing: Prices can be changed according to the user's use of the application, needs and market offers; AI provides customized solutions.
- Content Personalization: AI, in relation to users, presents relevant content that depends on the users' habits and choices, increasing their loyalty.

5.3. AI solutions for MVNAs

As illustrated above, MVNAs leverage AI to deal with sophisticated, accumulated networks in several MVNOs.

5.3.1. Aggregated Network Management

- Unified Management Platforms: Using AI, it can be easier to operate several MVNO networks on a single interface.
- Resource Pooling: Regarding MVNOs, AI enables the exchange of resources, hence enhancing the MVNOs network performance.
- Centralized Monitoring: Monitoring using AI-driven analytics ensures proper monitoring of the network, and it is easier to troubleshoot in case of a problem.

5.3.2. Enhanced Interoperability

- Protocol Translation: AI can work as an interface, converting protocols from a network system into another system's protocols for easy communication.
- System Integration: With AI tools, the incorporation of new systems and technologies can be accelerated since it will eliminate the human contribution, which is full of errors.
- Compatibility Testing: AI performs compatibility testing automatically, so it can be confidently said that new elements of the system are compatible with the existing ones.

5.3.3. Advanced Analytics for Decision-Making

- Data-driven Insights: Increased use of AI solutions: Networks can generate huge amounts of data, and AI-based analytics can provide the necessary recommendations for network development and strategic planning.
- Predictive Analytics: AI capability to predict possible characteristics of the network and behavior of the users, which helps to make decisions in advance.
- Performance Benchmarking: AI tools can analyze the operational performance of networks compared to standards that exist in the marketplace to help solve the network problem.

6. Case Studies

6.1. Real-time Case Study: AI-Powered Networked Management for MVNOs and MVNAs

6.1.1. Case Study: Plintron's AI-Driven MVNA Solution

Overview: Plintron is the world's largest cloud-communication solution provider and provides AI-enabled Network Management solutions exclusively for MVNOs and MVNAs. Their solution is a Telecom as a Service (TaaS) that includes all of the services that will enable the management and operation of the MVNOs without their own networks [6].

6.2. Challenges Addressed

6.2. 1. Scalability:

Indeed, with the growth of MVNOs, the amount of data and user requirements also rises. The scalability is managed efficiently in Plintron's AI systems resources, which automatically allocate and optimize the performance of the network.

6.2.2. Resource Allocation

AI algorithms are used to distribute the available networks efficiently depending on the requirements of users in the network, thus making the networks more efficient.

6.2.3. Customer Experience

Thus, they enhance client satisfaction through the organization of AI-driven analytics to offer individual services and successful customer support.

6.3. AI Solutions Implemented

6.3.1. Intelligent Resource Management

AI models, including predictive analysis on the usage of the network and self-provisioning to utilize resources efficiently and effectively.

6.3.2. Automated Customer Service

AI chatbots and virtual assistants are available 24/7 to assist customers and deal with most problems automatically.

6.3.3. Predictive Maintenance

The system uses intelligent fault detection mechanisms to detect potential problems in a network before the user encounters them so that the problems may be solved at their source.

6.4. Benefits for MVNOs and MVNAs

6.4.1. Cost Efficiency

The TaaS model does not require high levels of Capex and Opex because Plintron bears all the costs of the required infrastructure.

6.4.2. Rapid Deployment

These solutions help MVNOs to come up with their services within the shortest possible time span, with time to market averaging below a week.

6.4.3. Regulatory Compliance

Plintron takes care of legal and regulatory issues, which, in turn, makes MVNOs and MVNAs' work easier.

6.4. Success Metrics

6.4.1. Improved Network Performance

Networking reliability is enhanced, along with the rates achieved due to optimal use of the available resources.

6.4.2. Increased Customer Satisfaction

Better services and enhanced customer care services, hence improved customer loyalty and good remarks.

6.4.3. Scalable Growth

The management company, Plintron, has been highly recommended because the responding MVNOs opined that

it has been easy for them to add more subscribers and offer qualitative services.

7. Future Directions and Trends

7.1. Emerging AI Technologies

7.1.1. AI-driven Network Slicing

Network Slicing is an innovative tool in which artificial intelligence controls the availability of virtual networks on the physical network platform [15] to increase the performance and adaptability of the network. Every slice is designed for a specific application or service type, like the Internet of Things, high-speed data, or low latency.

- Dynamic Slicing: Self-organizing network management can also be deployed where AI algorithms map the network slices dynamically with the need and performance characteristics of the slices.
- Quality of Service (QoS) Assurance: AI means that every network slice maintains its QoS parameters to the intended level based on the offered resources.

7.1.2. Edge computing and AI

Edge computing always works hand in hand with AI to accelerate the processing of the data at the edge level, hence reducing the latency. Combined, such a mechanism is even more beneficial for real-time computing and IoT devices.

- Latency Reduction: To be specific, by carrying out computations close to the sources of data, AI algorithms take milliseconds to analyze and respond to data, which is ideal for self-driving cars and smart factories.
- Data Privacy: Edge computing improves data privacy because, instead of transferring data to remote data centers, computations are made at the edge, hence minimizing the susceptibility to data theft.

7.2. Possible Effects on MVNOs and MVNAs

7.2.1. Shifts of Business Models

New technologies based on artificial intelligence are in line to change the existing business models of some players, such as MVNOs and MVNAs, by creating possibilities for delivering new services and improving operation plans.

- Service Customization: In a way, options enabled by AI can allow the services and pricing of an MVNO to be tailored to the individual needs of the client base, thus improving the levels of customer satisfaction and loyalty to the company.
- Operational Efficiency: Through AI, routine processes are done, and resources are used efficiently to minimize costs and increase profits.

7.2.2. Impact on the Market Forces

The application of smart networks based on AI technologies will have a strong impact on competition in the field and the customer base.

- Competitive Advantage: MVNOs and MVNAs utilizing AI should be able to provide better services, launch new services, and respond to clients' requests much faster compared to their competitors.
- Customer Expectations: Because more service providers use AI technologies and as speech recognition and natural language processing improve, customers will expect tailored, trustworthy, and speedy services, forcing operators to integrate AI into their services.

7.2.3. Building Regulatory Awareness

In the application of AI in network management, significant concerns are presented about legal frameworks to follow regarding the technology as well as factors involving the realization of its operations.

- Data Protection Regulations: MVNOs and MVNAs are bound by the rules and regulations of data protection laws such as GDPR and CCPA concerning users' data collection, processing, and storage.
- AI Ethics and Bias: The main constraints on how to make AI systems legal are to guarantee that AI systems are transparent, accurate, and non-discriminatory.
- Not applicable
- Telecom Regulations: Spectrum issues, allocation, and licensing are crucial areas that define the legal and legitimate functioning of telecoms and AI-enhanced networks.

8. Challenges and Limitations

8.1. Technical Challenges

8.1.1. Complexity in Integrating AI with Existing Network Infrastructure

Integrating AI into existing network [16] infrastructures presents several challenges:

- System Compatibility: It has always been the case that there is a problem of integrating new series of AI to be in synchrony with the current network products. Interoperability testing issues may arise when there are other vendors or other generations of equipment that are hard interfaced.
- Data Management: AI systems rely on big data for learning and for the intended activities as well. The acts of collection, processing and proper storage of this data are activities that ought to be done securely, and this is a task that requires proper solutions in data management.
- Scalability: The scalability process of the AI-based solutions for crashing the increasing demand for network traffic and data can be especially technically challenging. The status of AI models should be scalable to avert possible performance issues.

8.1.2. Ensuring the Reliability and Accuracy of AI Algorithms

The reliability and accuracy of AI algorithms are critical for effective network management:

- Model Training and Validation: Current generative AI models then need certain training and validation, which includes not only a view of the specific variational distribution in the external space. Some of the developments entail altering models often to reflect data as and when it comes in.
- Error Handling: As a result, it becomes pertinent to have methods of detecting errors and remedies for

graceful failure in the instance that an error occurs to avoid detrimental outcomes such as offline networks.

- Performance Metrics: Hence, there is a need to define and measure by quantitating the KPIs to get the required normalized performances of the AI systems for the above-mentioned networks.

8.2. Ethical and Privacy Concerns

8.2.1. Addressing Data Privacy Issues and Ethical Considerations

Deploying AI in network management raises [17] significant ethical and privacy concerns:

- Data Privacy Regulations: GDPR and CCPA are the current requirements of data privacy regulations that organizations cannot avoid observing. Implementations of AI systems are required to safeguard the user's data and be very open about how they are processed.
- Ethical AI: Making AI ethical requires fixing the biases in the data and the models, making it possible to explain the decisions of the system and making everyone answer for their actions. Ethical measures in Artificial Intelligence define the strategy on how best to build and deploy impartial AI.
- User Consent: Getting clear consent from the users, on collection and processing of their data is also an important thing. They should be told how their data is used and be able to deny the use of their information.

8.3. Integration with Legacy Systems

8.3.1. Overcoming Challenges in Integrating AI Solutions with Legacy Network Systems

Integrating AI solutions with [18] legacy systems involves several challenges:

- Interoperability Issues: Many existing solutions have not been implemented with modern AI technologies and, therefore, experience integration problems. Some possible solutions are to work through a set of middleware that lies between the old and the new system.
- Cost Considerations: Integration of AI intelligence requires a better system; this means that upgrading or acquiring a new system is costly. Economical approaches include gradual changes and the usage of as many already-in-place resources as possible.
- Technical Debt: Legacy systems often come with accumulated technical debt, making integration more challenging. Addressing technical debt involves refactoring code, updating outdated components, and improving documentation.

9. Conclusion

The incorporation of AI in network management in MVNOs and MVNAs has been incredibly beneficial as it has unlocked considerable improvements in the operations and experiences of consumers. Thus, using machine learning for traffic prediction, deep learning for fault identification or reinforcement learning for resource management, these operators can obtain the maximum network performance. This not only decreases the duration of time required for the services but also decreases the operating expenses for the same while providing a more efficient and effective service to the ultimate consumers. In this research, concrete evidence and cases support the effectiveness of AI in improving profits and efficiency of MVNOs and MVNAs' decision-making concerning the networks and immediate issues.

Nevertheless, the process towards the realization of fully supervised network management through artificial Intelligence comes with its barriers. Concerning its challenges, one can identify the questions of data protection, the human resource requirement for artificial intelligence specialists, and risks associated with dependency on AI systems. To proceed with these issues, stakeholders should make an investment in the AI training of employees and address the question of the data management system. Still, the current and future AI-based solutions in network management of MVNOs and MVNAs seem to further expand with new possibilities due to increasing effectiveness. Such a conclusion drawn from this research work lays a strong platform for further research to ensure a new telecom ecosystem that is intelligent, responsive and robust.

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