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A Critical Review of Network Management Tools and Technologies in the Digital Age

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Abstract: **Every network has network devices that are linked together and entirely in charge of making important network management (NM) choices. IT professionals and network managers handle the devices in this conventional setup. Because of the heterogeneous design of various devices and services, manual setup is laborious and complex due to the continually increasing number of devices linked to the networks. An essential component of NM is tracking, controlling, and monitoring the network, which helps to visualize network performance in real time. Device technology administration, provisioning, setting, tracking, routing, and authentication are all made possible by NM. NM is also necessary for making decisions in quality of service, control of traffic, heterogeneity, and identification of anomalies. This study intends to showcase the state of the art in monitoring and managing techniques, applications, and solutions while also analysing their benefits and highlighting unresolved NM difficulties.**

Keywords: **IoT, ML, SDN, Network, Management.**

1. INTRODUCTION

Computer networks are composed of a broad range of technologies. Their aim is to promote conversation and the exchange of information. The efficiency of the systems within a network is closely correlated with the effectiveness of the products and services offered. The rapid development of network technology and the corresponding decline in the price of hardware and software gave rise to the management of computer networks [1]. Networks are essential to corporate activities in the age of digital transformation because they enable an ever-expanding range of offerings and technologies. But with their hardware dependent activities & static settings, conventional network architectures are becoming more and more inefficient for the flexibility and effectiveness that organizations need. Networks have become considerably more complicated, heterogeneous, and large-scale than could ever be managed manually. Moreover, in many network setups, error by humans is the primary source of outages [2].

The networks used to be too little. In addition, manually maintaining the networks was simple. When the number of connections in a subnetwork increases, the area of the network steadily grows. Maintaining big networks like WAN is difficult. Network management (NM) was created as a solution to this issue. There is more to network administration than simply network management. By the 1920s, AT&T had built its network to accommodate customers' needs for rapid, effective service during regular business day peak times [3]. The goal of NM system (NMS) architecture has shifted as a result, with a reduced emphasis on human intervention in the control loop. IBM introduced the project for autonomic computing in 2001 [4]. The goal was to develop methods for IT systems that could self-configure, self-heal, self-optimize, & self-protect. With the emergence of bigger and more sophisticated networks, the significance of distributed processing systems as well as network in businesses is increasing daily. The more the network expands, the more significant the dispersed services and related resources emerge. The efficiency of networks may be negatively impacted by network

instability, which rises with network size and raises the likelihood that problems may arise. Given the complexity of massive networks, human effort alone cannot handle them; so, automated network management technologies are becoming more and more necessary. These technologies have been more and more popular over the past decade as the decentralization of network services is making network manager jobs more complicated. This is because in several networked information systems, resources requiring to be controlled are located distant from NM professionals [5].

In order to guarantee computer networks' effectiveness, dependability, & security, NM entails their thorough management, functioning, and support. This sector includes maintaining network security, setting network devices, keeping an eye on efficiency, and resolving problems to keep functioning at its best [6]. In order to reduce downtime, maximize efficiency, protect against cyberattacks, and guarantee smooth data flow and communication within a company, effective network NM is essential. NM provides the foundation required for both corporate operations and technology advancement by combining specialist tools with industry best principles [7]. More adaptable and flexible networks are required due to the varied range of network traffic needs brought about by the internet's as well as mobile phones' exponential expansion. SDN (software-defined-networking) is a novel network paradigm that has arisen to fulfill this demand. It allows networks to be more flexible by separating the NM layer from the information processing layer [8].

The needs, features, current network management techniques, and future developments for network management systems are covered in this research. Understanding both the existing functioning of a network and its needs is essential for efficient network management.

2. LITERATURE REVIEW

Features including authentication, supplies, establishing, tracking, routing, & device software control are made possible by NM. Various publications in the literature have examined network management solutions from various angles. Benefits and drawbacks of needs of NMS in different area and field is written in table 1.

In Gholami et al.'s [9] explanation of the Adhoc-Distributed-System (ADS) method for industry WSN leadership, they provide ADS approach for industrial WSN maintenance and evaluate it based on how well it tracks and uses network resources. This method can follow mobile nodes and adjust to modifications in the production environment. More precisely, the performance of the mobile node tracking was little impacted by modifications to the network configuration, despite the fact that they increased network traffic.

Ayoubi et al. [10] provided an explanation of the way machine learning (ML) enables cognitive NM by expanding the Monitor-Analyze-Plan-Execute (MAPE) management loop. They provide an actual application example for a cognitive security administrator and offer potential research areas that may be pursued to develop a comprehensive structure for cognitive NM.

The idea of Zero-touch network & Service Management (ZSM) was first presented by Chafika Benza¨ıd and Tarik Taleb [11]. they demonstrated how AI methods are essential to achieving ZSM. In addition, they highlighted the drawbacks and security issues that might prevent ZSM from the Artificial-Intelligence (AI) approaches.

Muhammad [12] explores how centralizing control, improving security, streamlining operations, and promoting network innovation and flexibility are some of the ways that SDN transforms NM. Organizations may greatly enhance their network management procedures and better meet the needs of the modern digital environment by using SDN.

Kazeem et al [13] discussed about leak monitoring and water quality tracking by the uses of loT enabled technique in Smart-Water-Network-Management (SWNM). In terms of managing water networks, loT enabled technique has a promising potential. To improve system performance and application issues, however, further research is required. Primarily, all loT-based SWNM applications need to use a long-range sensing, low-power & connectivity.

At the level of energy distribution, Davarzani et al. [14] discussed about experimental projects aimed at activating home demand response (DR) as well as its uses. As a significant source of elastic needs, DR plays an essential part in Active-Distribution NM (ADNM). The limitations as well as possible next steps of this technique are analyzed and classified together with DR activation mechanisms for consumer response at the network level.

Saadon et al. [15] emphasized the application layer orchestration & demonstrate the way it affects the function and company assistance systems of future NM in conjunction with SDN & networking Service Virtualization. They are examined the supervisor's responsibilities and duties in relation to higher leadership as well as the many unresolved issues in this field.

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In order to handle the issue in chain networks while minimizing the quantity of utilized channels and the NM overhead, Leng et al. [16] created a unique LRTree Scheduler. To verify the multicluster RT-WiFi network's architecture and assess how well the suggested algorithms for scheduling function in contrast to contention-based techniques in conventional WiFi systems, an experiment for the system is set up.

Udo et al. [17] created a new network framework using SDN for NM. His framework makes use of extra controller to more effectively manage the variegated nature of the contemporary campus environment. These controllers are used to handle clients and operations appropriately, as well as to distribute various network tasks across various resources based on predetermined principles. It is obvious that implementing their recommended framework would guarantee the growth of networks, facilitate NM, and increase network effectiveness and security.

Wang et al. [18] presented a 5G Radio-Access-Network (RAN) NMS structure concept. The RAN structure as specified by the RAN Association is compatible with the suggested NMS. The NMS offers a number of administrative features to make an RAN's processes, management, and repair easier.

Table 1: Comparison between different field-based NMS

Fields	Using NM	Advantages	Drawbacks	References
Vehicular Network	Every network unit has an embedded wireless connection that manages its condition and makes utilization of the SNMP protocol to enable the device operator to apply various administration features.	It is permissible for managers to raise the privacy standards of their personal vulnerability assessment. .	Since most network nodes must function with limited resources, dealing with connectivity, along information, and resources management is a difficult problem.	[26]
IoT	In order to maximize network efficiency while utilizing minimal energy for NM tasks, NM strategies for IoT low-energy networking have been developed.	NM results develop efficient approaches to management that enable flexibility, effective resource usage, and the ability to regulate the heterogeneity of IoT networks while preserving confidentiality and safety.	Heterogeneity, fluctuating network configurations, limited resources, and connection performance, make developing an IoT NM tool a difficult undertaking.	[24]
SDN	All activities and administration tasks inside the network are organized by the administration plane, & the administration gateways offer the appropriate exchange of data between from administration plane to other planes and vice-versa.	Flexible network administration and problem-solving, effective data transfer, enhanced network efficiency, decreased administrative costs and overhead, introduction of novel methods and concepts, and improved security of the network	Interoperability is the main problem with SDN. Its controller features and how they affect complicated, difficult decision-making technologies. Variable load balancing as well as congested load conditions.	[22]
5G	Processes related to NM can be automated, called smart-network-management-automation (SNMA). It offers a framework for NM automation, enabling operators to effectively and dependably monitor their networks.	It covers a wide range of areas, such as digitization, QoS, administration, network segmentation, allocation of resources, and privacy.	When there are a lot of customers, the network has to be well controlled. There might have a negative impact on the efficiency.	[23]

3. TRADITIONAL NETWORK MANAGEMENT SYSTEM

The platform independence, portability, scalability, ease of configuration, and automated upkeep of current and correct use for clients characterize the NMS. The NMS framework's elements offer a connection between protocols specifications and OSS uses, such as APP servers and.net server uses, which are executed through their respective language programs. OSS

needs determine whether to update the protocol's functionality. GUI elements will give the user a way to administer panels that are simple to comprehend, problem browsers, visualization, and evaluations for efficiency charts [19].

Network structure determines an element of NMS. Nodes can grow or shrink inside the network as well as the network's structure must identify and modify newly added nodes. The process of configuring the elements of network involves finding the elements and preserving their structure by adding, changing, and removing elements from the design. Typically, fault elements handle both physical and virtual network element failures, notify fault information, restore services, and troubleshoot issues. Efficiency of elements involve employing metrics to gauge the efficiency of networks. In order to connect with the elements of network element, mediation elements provide certain protocol interface functions [20]. Fundamental system functions comprising determination, logging, and safety are provided via structure elements.

4. NETWORK MANAGEMENT FUNCTIONS

Five functional domains of NM are defined by the International Organization for Standardization (ISO) NM model shown in figure 1 [20-21].

(a) Fault Management: This includes all NMS operations pertaining to defects or issues that arise between the different network elements under management. These features involve the ability to identify and notify users of network failures as well as compile inferences and connections and perhaps automating the process to correct them.

(b) Configuration Management: This includes features related to the setup data connected to the network components and their connections amongst them. Management might involve tasks like keeping an eye on a resource's setup status, offering tools through which authorized administrators can modify the resource's setup, and recording as well as monitoring the setup modifications.

(c) Accounting Management: This measures how different network settings are used in relation to specific individuals or groups of people. By tracking and evaluating the information, the NM can charge the consumer and get insight about the ability of the network usage.

(d) Performance Management: This pertains to the assessment, compilation, evaluation, and documentation of diverse facets of network efficacy. Both proactive and reactive repairs are made possible by the examination of such information.

(e) Security Management: In order to avoid unwanted accessibility, this manages accessibility to all network assets through the use of established policies and procedures. This includes client and company authorization and identification, which confirms login information and allows access to multiple assets.

5. NETWORK MANAGEMENT BASED ON SDM

The fundamental concepts of SDN, an innovative network design, are to isolate the data routing layer from the network control layer, achieve centrally managed NM as well as tracking via open API interfaces and programs definitions, implement dynamic real-time network efficiency and tracking across the globe, and adjust to unified, versatile, and seamless networks for interaction. The system's design concept is to provide centralized data collecting of dispersed equipment or networks by extracting the administration layer to the overall control framework and using a single abstract interface technique. The new NMS uses a visual operating interface that is both versatile and user-friendly to handle, track, and assign services to network parts. It also leverages business-oriented processing to enable the building of pertinent control and administration. Table 2 displays the primary distinctions between the three NMS [17].

Table 2: Comparison Between the Different types of NM

NM Type	Equipment NM	Traditional NM	NM based ON SDM	Refrences
Advantages	Excellent equipment setup and management	centralized oversight of the whole apparatus used for NM. Checking a network issue is simple.	Hardware and system tracking are done centrally. Broad perspective feature. Perception of the network's status in real time. Recognize the network service configuration	[17]
Shortcomings	Information Island	It has a lot of modifications to data as well as is dependent on data maintenance. World optimization a network structure that is dynamic	The programming interface, also known as the data interface, must be opened by the original setup in order to access the initial equipment NM. Connect probe plugs to a select few equipment.	

The two primary categories of the system's global NM are: for conventional network devices, the integrated NMS's role is broadened to include the system's basic capabilities. The new NMS restructures and unifies the administration interface of several NMS into a single, standard administration platform. By using the functionality of the probe component, the other mode depends on an initial hardware or software. The primary purposes of the probe are meta-data collecting and company monitoring. to maintain the system's functionality as well as the purpose of the data of the global view. This architecture leverages the concept of SDN to provide global network visibility & central administration over a dispersed, multi-layer heterogeneous network. The optical network, IP NM, and associated hardware make up the administrative elements in the framework. In addition to maintaining the high level of dependability of the initial structure, the latest version implements a multi-layer energy communication network framework, which enables the network to maintain both dispersed and centralized administration capabilities. The framework's global view component performs a number of tasks, including table element distribution, topology maintenance, connection detection, and policy development. The control system primarily uses link identification and topology control between them to consistently manage equipment [22].

6. MACHINE LEARNING ENABLED NETWORK MANAGEMENT

Novel software technological developments will be essential to the 5G revolution, particularly in terms of NM. With the introduction of such software developments and previously unheard-of processing capacities, the concept of autonomous NM may be realized by using interdisciplinary knowledge advances in ML. The Self-Organizing-Network (SON) is often used to describe the automation of wireless networks as well as the reduction of user involvement in cellular networks. In wireless networks, SON plays a crucial role in maximizing overall effectiveness. The major goal is to increase the efficiency of networks in regards to coverage, and quality of service (QoS) while instilling awareness and autonomous adaptation in them via a reduction in user participation. The main objective of analyzing wireless networks with the right technologies is to make better judgments about how best to handle the whole 4G or 5G network. Wireless networks are a vast collection of data. In this situation, ML presents an excellent possibility since it can analyze data that operators already have access to and provide meaningful information that can be utilized to make adjustments or enhancements. We concentrate on the particular applications of ML to innovative network management ideas including SON. It starts by listing every relevant data source that may be gleaned from a wireless network. Operators have access to all of this data, some of which may be sensitive information pertaining to user confidentiality. Still, databases that are accessible and unencrypted control lines may provide some intriguing information. ML approaches have been used, and the present research has been categorized according to the intended use case, the particular high-level issue that has to be solved, and the ML methodology that the authors choose to handle the issue for NM [23].

7. IOT BASED NETWORK MANAGEMENT

IoT developments in particular sectors of the economy, like as healthcare, housing, and transport, have led to the development of diverse framework and administration strategies composed of methods, protocols, and regulations. NMS is developed with the 3 elements of the computing designs are IoT devices, IoT gateways, and the cloud. The creation of this framework necessitates a description of certain features pertaining to the data of the IoT devices that need to be handled, specifically their characteristics. Because the SNMP specification is simple and uses less storage and resources than the CMIP protocol employed in the ITU as well as OSI management models, the 2 key features of IoT devices, it was chosen to employ the IoT NMS [24].

IoT has the ability to drastically change how public entities gather information by fusing the three primary technological and industrial revolutions of movement, technology, and data processing. IoT links physical item networks through actuators, embedded sensors and various other devices that record and transfer data on network activities in real time. This study presents the architecture of an edge-computing model-based NMS for an IoT network. This concept depends on the Internet administration paradigm, which communicates between controlled devices via the SNMP protocol and a gateway that connects to a manager service using the SOAP protocol. Through this study, the primary NMS efforts for Internet of Things networks were identified and analysed. It was discovered that supplying and verification, setup and surveillance, tracking and testing, and programs changes and repair are the four essential device administration needs for any IoT device implementation. The framework of the information object paradigm makes it simple to handle information gathered by IoT device [25].

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8. ISSUES IN NETWORK MANAGEMENT SYSTEM

NM must adjust since the epidemic has fundamentally altered NM practices. Effective network administration has grown more difficult than with networks now stretching over on-premises facilities, IT surroundings, information centres throughout the globe, virtual networks, and cloud-based systems. Network managers must continue, however, maintain constant availability, high efficiency, and excellent QoS while also keeping up with the rapidly evolving networking requirements and technology. These are the top five issues that NM are now dealing with are given below [27-28]:

(a) Adjusting to the needs of hybrid networking: The use of hybrid networking by several enterprises has grown rapidly due to its versatility, robustness, and flexibility. Emerging networking approaches, such as cloud-based services, are becoming an essential part of company networks because of it. Without the appropriate NM solutions in place, meeting the demands and difficulties of various types of networking can be challenging.

(b) Planning strategically while being aware of network constraints and loads: Although more modern innovations, including virtualisation and SD-WAN, provide excellent flexibility along with additional sophisticated features, wrong deployment might have unfavourable effects. This involves the depletion of assets in one area of the network as assets remain idle in another.

(c) Enhancing dynamic networks' dependability and privacy: In order to operate networks more efficiently, various company have decreased their reliance on old technologies and processes. Networks are dynamic now, always changing to suit the demands of enterprises. Security of the network has grown to be a main issue even if this provides the IT sector with many advantages and innovative features.

(d) Automated, connected, and integrated approach to NM: The rise in tedious manual operations has made automation of networks necessary. Manual labour is still used to begin and complete periodic duties that follow scheduled occurrences and processing. Time of IT team of any company is heavily invested in this. IT sectors may prevent this by selecting a trustworthy network monitor which supports automated network features like processes, handling configurations etc.

(e) Visibility of IT infrastructure and the removal of blind spots in network: Networks for businesses cover cloud infrastructures. Centralized access is necessary to manage such networks successfully, but this presents a hurdle. Using a centralized system, NM must be allowed to establish, add, visualize, and troubleshoot such network elements. Mismanagement as well as blind spots in the network are only made more likely by dividing the NMS.

9. CONCLUSION

The term "NMS" describes a program or collection of programs intended to help network administrators keep an eye on and guarantee the stability of their networks. NMS will keep an eye on the network's hardware and software elements. To demonstrate the range of domains in which managing takes place, we have compiled a brief overview of some of the NM applications and difficulties in this research. These domains include SDN, IoT, 5G networks, AI, ML, and more. In order to analyse every aspect of the network in an effective manner, minimize overhead and latency, maximize precision rate, minimize error rate, and provide service competently and economically, it additionally emphasizes reviewing a variety of applications, approaches, technologies, and frameworks.

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