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Current Trends in Computer Networking and Management in the Era of AI, ML and DS

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Abstract

The field of computer networking and management is witnessing rapid evolution and innovation driven by emerging technologies and the growing demands of modern applications. This review explores current trends in computer networking and management, encompassing a wide array of topics ranging from software-defined networking (SDN) and network virtualization to edge computing, Internet of Things (IoT), and artificial intelligence (AI)-based network management. The review investigates the transformative impact of these trends on network architectures, protocols, and management paradigms. It examines how SDN, and network virtualization are revolutionizing traditional networking by centralizing network control and enhancing flexibility and scalability. Moreover, it discusses the pivotal role of edge computing and IoT in enabling distributed and low-latency network services, driving the need for efficient network management solutions. Furthermore, the study sheds light on the integration of AI and machine learning (ML) techniques into network management processes, facilitating proactive monitoring, predictive analytics, and automated decision-making. By synthesizing insights from recent research and industry developments, this review paper provides a comprehensive overview of the current landscape of computer networking and management, offering valuable perspectives for researchers, practitioners, and decision-makers navigating this dynamic domain.

Keywords: Computer Networks, Artificial Intelligence, Software-Defined Networking, Internet of Things, Network Management

1. Introduction

Computer management along with networking are the processes and tools that are utilized to successfully link and manage many computer systems to enable them to communicate with one another and share information [1]. The topic of information technology encompasses a multitude of concepts, protocols, hardware, and software components that enable the transmission and reception of data and information across a wide range of networks, including those that are local, large, and global in scope [2]. The construction of connections between various devices, including computers, servers, switches, routers, and other network-enabled devices, is the fundamental component of computer networking [3]. Ethernet, wireless internet, and Bluetooth are examples of some of the networking technologies that are frequently used to support these connections, which might be wireless or wired [4]. As a result of these connections, users can communicate with other devices and users on the network, as well as access shared resources such as files, printers, as well as internet connections. The administration of computer networks is an essential component in maintaining the smooth operation of these networks as well as their safety [5]. Among the responsibilities that are involved include monitoring the functioning of the network, configuring network devices, resolving connectivity issues, putting security measures into place, and properly allocating network resources [6]. Network administrators and other professionals working in information technology make use of specialized tools and software programs to carry out these responsibilities and guarantee the reliability and accessibility of network services [7].

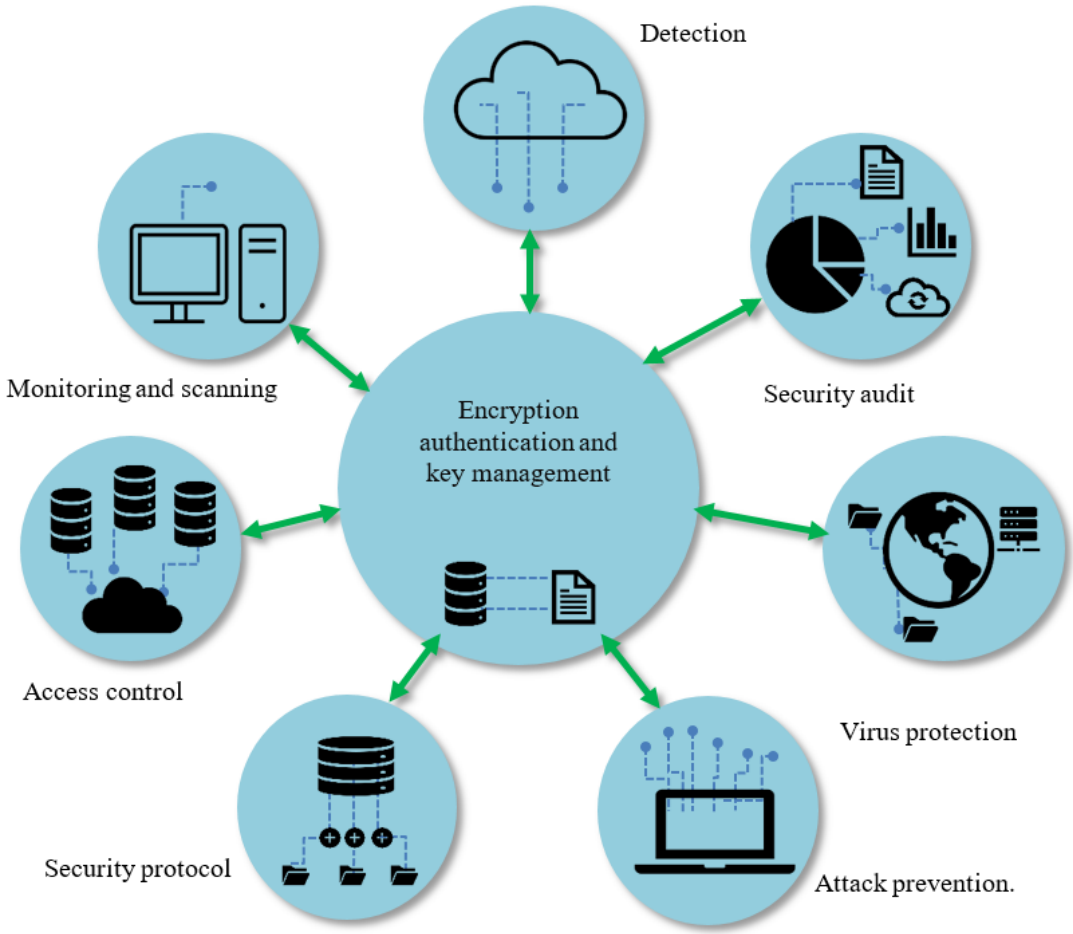

Figure 1: Architecture of Computer Network Management [10]

1.1 Key components of network management

A representation of the architecture for the protection of computer networks can be seen in Figure 1. Based on the two features of encryption cognition and key management, it is evident from the figure that users contribute to the enhancement of the stability, dependability, and security of computer network communication [8]. There are some key components of network management which are discussed below here [9]:

1. **Network Monitoring:** Constantly observing network traffic, device status, and performance metrics to identify and address any anomalies or issues promptly.
2. **Configuration Management:** Managing the settings and configurations of network devices such as firewalls routers, and switches to optimize performance and confirm compatibility and security.
3. **Security Management:** Protecting the network from risks like malware, illegal access, and intrusion requires security measures like firewalls, encryption, access restrictions, and intrusion detection systems.
4. **Performance Management:** Analyzing network performance metrics such as bandwidth utilization, latency, and packet loss to identify bottlenecks and optimize network efficiency.
5. **Fault Management:** Detecting and resolving network faults and errors to minimize downtime and ensure continuous operation.
6. **Capacity Planning:** Forecasting future network requirements and scaling network resources accordingly to accommodate growth and changing demands.

Overall, computer networking and management are essential aspects of modern information technology (IT) infrastructure, enabling organizations and individuals to connect, communicate, and collaborate effectively in an increasingly interconnected world [11].

1.2 Trends in Computer Network

Computer networking is a rapidly evolving field, driven by technological advancements, changing user demands, and emerging trends [12]. Some of the key trends in computer networking include:

1. **5G Technology:** The deployment of 5G networks brings the promise of much improved data rates, reduced latency, and more capacity as compared to earlier generations. Autonomous cars augmented and virtual reality, the Internet of Things (IoT), and other applications that rely on fast, low-latency connections are made possible by 5G technology [13].
2. **Software-Defined Networking (SDN):** SDN enables software controllers to centrally manage and design the network infrastructure by decoupling the data plane from the control plane in network devices. More efficient and nimble networks are the result of SDN's automation, scalability, and flexibility in network provisioning and administration [14].
3. **Network Function Virtualization (NFV):** NFV is the process of replacing specialized appliances with software instances operating on commodity hardware. This technology is used to virtualize network services including firewalls, load balancers, and routers. Faster deployment of network services, lower hardware costs, and on-demand scalability are all made possible by NFV [15].
4. **Edge Computing:** The goal of edge computing is to process data closer to its point of origin, rather than transmitting it to distant cloud data centers, thereby lowering latency and bandwidth consumption. Things like the IoT, real-time analytics, and immersive media rely heavily on edge computing because of the latency it provides [16].
5. **Internet of Things (IoT):** The need for secure and scalable networking solutions is being driven by the raising IoT devices, such as smart sensors, actuators, connected appliances, and wearables, which produce vast amounts of data [17]. Message Queuing Telemetry Transport (MQTT) and Low-Power Wide-Area Network (LPWAN) are affordable and power-efficient connection alternatives that are often used by IoT networks [18].
6. **AI in Networking:** Network management activities including automated optimization, anomaly detection, and predictive maintenance are seeing a rise in the use of AI and ML approaches. Intelligent judgments made to improve performance and security by analyzing massive volumes of network

data in real-time using AI-driven networking solutions [19].

7. **Zero Trust Security:** Companies are embracing a Zero Trust security approach, which states that no entity, whether within or outside the network perimeter, should be trusted by default, in response to the increasing complexity and sophistication of cyber threats. To prevent attackers from gaining unauthorized access or moving laterally, zero trust networking designs include stringent access restrictions, constant authentication, and micro-segmentation [20].

2. Current Research On Computer Networking

Improving network speed, scalability, and resilience in the face of changing technical and use patterns is the goal of current computer networking research. Topics being investigated include security protocols, IoT connectivity, edge computing, and SDN. The previous studies of several authors are discussed below:

1. Ajani et al. (2024) [21] explored the intersection of emerging digital fields with state-of-the-art computers. In the context of cybersecurity in computer science, the findings emphasized the need for education, employment growth, scalability, effective management of data, and interdisciplinary collaboration. Authors also emphasized the fundamental significance of cybersecurity, the ever-evolving threat landscape, and best practices.
2. Ahmadi (2024) [22] focused on developing zero-trust security measures and adaptable security frameworks for edge devices. Improving edge computing calls for robust data security measures, threat intelligence, and continuous monitoring. The development and improvement of edge computing are increasingly dependent on the integration of security solutions. The results demonstrated that cloud networks can now provide secure, efficient, and scalable collaborative computing thanks to the reliability of edge environments.
3. Ramadass et al. (2023) [23] presented the Application Reliable Traffic Control (ARTC) approach which depended on the application's need for minimal and maximum service data distribution. Processes for traffic forwarding and infrastructure allocation were carried out to ensure continuous data dissemination, depending on the needs of the application. Linear dissemination analysis, by using a regressive learning model, helped strike a balance between the application's requirements. The suggested method's performance was evaluated based on parameters like backlogs, latency, and dissemination loss.
4. Gill et al. (2022) [24] explored the potential of combining ML and AI to improve resource independence and performance on a large scale is an essential but challenging undertaking. The authors had laid up a plan and researched several new developments in AI and ML for various types of computing, including cloud, fog, edge, server-free, and quantum computing.
5. Khan et al. (2022) [25] provided the essential specifications for 6G to be enabled using digital twin technology, firstly. Then, the next section delved into the architectural components and trends which included edge-cloud-based doubles, cloud-based doubles, and other similar concepts. Findings demonstrated that that 6G services would rely heavily on digital twins.
6. Strinati et al. (2021) [26] recommended that semantic and goal-oriented components be included into 6G networks via the use of knowledge representation, reasoning tools, and machine learning. Consequently, this improved the capacities of interpretation, discovered information that was relevant, and increased efficiency while also defending against adversary attacks.
7. Stergiou et al. (2020) [27] devised a strategy with the intention of constructing a smart and safe environment by merging the capabilities of the Internet of Things with those of Cloud Computing, Edge Computing, and Big Data. The method that had been proposed demonstrated high levels of security, efficiency, transmission speed, performance, energy efficiency, and connectivity.
8. Huang et al. (2019) [28] suggested Deep Reinforcement learning-based Online Offloading (DROO), a process that can adapt to changing conditions by dynamically adjusting algorithm's

parameters. The suggested technique outperformed state-of-the-art optimization methods numerically while cutting computation time by almost an order of magnitude, achieving near-optimal performance. In a 30-user network, for instance, DROO's central processing unit (CPU) execution latency was under 0.1 second, proving that optimum offloading in real-time was possible even in a fast-fading environment.

9. Yaqoob et al. (2019) [29] examined the innovative aspects that the Internet of Things brought to the field of conventional computer forensics via investigation. IoT forensics studies were analyzed for strengths and weaknesses and classified using a taxonomy based on phases, enablers, networks, sources of evidence, investigation modes, models, layers, tools, and data processing. As a result of that, the inclusion of forensic solutions into the architecture of the Internet of Things allowed for the assurance of a secure environment, which was necessary for the maintenance of user trust in IoT systems.
10. Saad et al. (2019) [30] proposed an extensive and future-oriented concept that outlined the principles of a 6G system. Authors argued that 6G would not only focus on expanding spectrum in high-frequency bands, but instead it would integrate emerging technical trends driven by innovative underlying services. As a result, the proposed work offered specific suggestions for the plan to achieve 6G.

3. Conclusion

This study has explored several current trends in computer networking and management, highlighting the significant advancements and challenges within the field. From the rise of SDN and NFV to the increasing adoption of cloud-based networking solutions, the landscape of computer networking is continually evolving to meet the demands of modern applications and infrastructures. Additionally, the integration of AI and machine learning ML techniques into network management processes promises to revolutionize network optimization, security, and troubleshooting. Looking ahead, future research in computer networking and management should focus on enhancing the scalability, reliability, and security of emerging technologies, as well as addressing the complexities introduced by the proliferation of IoT devices and the evolution towards 5G and beyond. Moreover, interdisciplinary collaboration between networking experts, data scientists, and cyber security professionals would be essential to harness the full potential of innovative approaches and ensure the seamless operation of next-generation networks in an increasingly connected world. In future, as the demand for high-performance, reliable, and secure networks continues to grow, it would be imperative for researchers in the field to stay well-informed of these trends and develop innovative solutions to address the evolving challenges in computer networking and management.

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