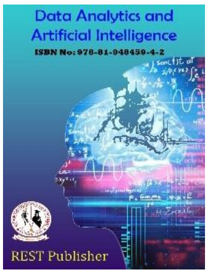
Data Analytics and Artificial Intelligence
Vol: 3(5), 2023
REST Publisher; ISBN: 978-81-948459-4-2
Website: http://restpublisher.com/book-series/daai/
DOI: https://doi.org/10.46632/daai/3/5/3



Enabling Efficient IoT Device Connectivity and Dynamic Network Management through SDN: A Weighted Sum Method Approach

M.Kranthi, E.V.N.Jyothi
Rise krishna Sai Prakasam Group of Institutions Ongole, A. P, India.
Pace Institute of Technology & Sciences, Ongole, A.P, India.
Corresponding Author Email: kranthim_maddala@yahoo.com.

Abstract: *SDN-Enabled IoT Networks bring about a transformative shift in conventional network models by integrating the core principles of Software-Defined Networking (SDN) into the realm of the Internet of Things (IoT). This integration empowers the agile and effective management of IoT devices, facilitating smooth connectivity, optimized distribution of resources, and flexible network setups. Through the consolidation of control and the utilization of virtualization methods, SDN-Enabled IoT Networks amplify scalability, security, and real-time responsiveness. This addresses the obstacles presented by the extensive proliferation of IoT devices. This paradigm transition heralds a fresh era of interconnectedness, where SDN assumes a central role in harmonizing the intricate interplay of IoT devices and services. The rapid expansion of Internet of Things (IoT) devices has introduced unparalleled complexities in overseeing networks and establishing connections. This compels the need for inventive strategies to effectively manage the substantial surge of IoT devices and their ever-changing connectivity prerequisites. Software-Defined Networking (SDN) emerges as a promising approach to tackle these issues by enabling the flexible management of networks and allocation of resources. This study investigates the amalgamation of SDN within the realm of IoT, aiming to streamline device connections, optimize data transmission efficiency, and accommodate adaptable network setups. Introducing an innovative weighted sum technique for resource allocation optimization, this work lays the foundation for a comprehensive framework that bolsters IoT network performance and expandability. Four different SDN implementations are examined, including the Conventional IoT Network, SDN-enabled IoT utilizing Centralized Control, SDN-enabled IoT employing Distributed Control, SDN-enabled IoT with Hierarchical Control, and SDN-enabled IoT utilizing Hybrid Control. The assessment considers various aspects such as Enhanced Scalability, Enhanced Traffic Engineering, Heightened Security, Implementation Complexity, Difficulty of Migration, and Reliance on Vendors. The Conventional IoT Network secures a moderate 3rd position with a Preference Score of 0.56030, while the SDN-enabled IoT with Centralized Control holds the 5th rank at 0.49732, despite excelling in specific domains. The SDN-enabled IoT with Distributed Control achieves the top rank with a notable Preference Score of 0.79414 due to comprehensive performance, followed by the SDN-enabled IoT with Hierarchical Control securing the 2nd spot (Preference Score: 0.57022), and the SDN-enabled IoT with Hybrid Control taking the 4th position (Preference Score: 0.51300), particularly excelling in Traffic Engineering.*

Keywords: *Internet of Things, software-defined networking, application program interfaces, Network Function Virtualization (NFV) and MCDM.*

1. INTRODUCTION

The conventional networking framework comprises various network components like switches, routers, and intermediate gadgets. These devices integrate application-specific integrated circuits for specific functions. As a result, these devices come with fixed sets of intricate rules (protocols) that cannot be altered on the fly to carry out their designated functions. Additionally, these devices lack the capacity to be preloaded with multiple rules due to limited resources, hindering their ability to deliver optimal network services. This inherent limitation of traditional networking technologies renders them unable to dynamically adjust policies in real-time to cater to the specific demands of the Internet of Things (IoT) [1,2]. To overcome the constraints observed in conventional networks, a novel approach termed software-defined networking (SDN) has been put forth. SDN represents an emerging network structure that allows for the detachment of network control from conventional hardware components. In essence, SDN aims to segregate the control plane from the data plane, which encompasses the forwarding apparatus. Consequently, this segregation enables the deployment of appropriate control mechanisms directly onto the physical devices, adapting to the real-time demands of specific applications. Conceptually, SDN can be broken down into three layers—namely, infrastructure, control, and application [3]. Apart from the layered design of SDN, multiple sets of application program interfaces (APIs) also exist—referred to as northbound, southbound, eastbound, and westbound. The northbound API serves as the bridge connecting the application layer to the control layer, facilitating their mutual communication. This API also provides an abstracted perspective of the network to the application layer. On the other hand, the southbound API facilitates interaction between the control and infrastructure layers, enabling controllers to implement diverse regulations within forwarding devices like routers and switches. This communication allows these devices to engage with the controller in real-time. As for the eastbound and westbound APIs, they are tasked with establishing communication between various controllers, enabling them to collaboratively make decisions. Among the protocols used to facilitate communication between the control and data planes, OpenFlow stands out as the most widely adopted [4,5]. Integration stands out as a vital catalyst for the Internet of Things (IoT). Incorporating other technologies into the realm of IoT offers a viable strategy for facilitating extensive implementations while ensuring robust security measures. The adoption of IoT is gaining momentum across industrial and research landscapes, although several challenges must be overcome to achieve prosperous large-scale deployments. Among these challenges, an essential and particularly significant hurdle within the IoT domain pertains to the effective management and provisioning of devices. To achieve successful scalability of IoT deployments, a pivotal factor involves the dynamic provisioning of devices, primarily through automated processes, thereby minimizing the need for extensive administrative intervention [6,7]. The Internet of Things (IoT) employs a layered structure comprising three primary tiers: The Perception layer encompasses physical entities and sensory apparatuses, the Network layer is tasked with transferring data from these physical objects to the network's gateway or edge, while the Application layer focuses on delivering the user-requested applications and services. The proliferation of IoT is broadening the reach of Internet connectivity, encompassing billions of devices. A Cisco report on IoT expansion indicates that the current count of 6.4 billion internet-connected devices is projected to escalate to 50 billion by 2020. This surge in connected devices results in a substantial data influx. For instance, the data produced in the present year (6.2 Exabyte) is estimated to encounter a significant surge of 478% (30.6 Exabyte) by 2020. Such projections, with a 781% increase in connected devices and a 478% surge in data generation by 2020, underscore the anticipation of intelligent network control and management solutions. Numerous approaches have been proposed to tackle prevailing challenges within the IoT paradigm. However, conventional networks are ill-equipped to handle the vast number of interconnected devices and the extensive data manipulation that accompanies them [8,9]. Regarded as a groundbreaking networking innovation, Software Defined Network (SDN) constitutes an advanced network technology that facilitates varied networking environments characterized by swift evolution and dynamic attributes. This is achieved through programmable planes, encompassing the control and data planes as elaborated in Section II. The fusion of SDN and IoT holds the potential to fulfill the requisites of control and management across a wide array of scenarios. A multitude of research papers delve into the comprehension, application, implications, challenges, issues, forecasts, and analyses pertaining to SDN in diverse domains of both IoT and SDN itself [10]. The fog network evolves into a diverse and varied entity, positioned at the network periphery and encompassing extensions of cloud computing (CC) functionalities. The primary responsibility of fog networking involves establishing connections among all requisite elements within a node, thereby ensuring the preservation of Quality of Service (QoS) in the core network connectivity. Additionally, it serves the purpose of delivering services across these interconnected components. However, this task of coordination becomes intricate in the context of the widespread implementation of IoT. To address this complexity, emerging technologies such as Software Defined Networking (SDN) and Network Function Virtualization (NFV) should be strategically integrated to introduce flexibility and sustainability within such network environments. The combined deployment of SDN and NFV serves to streamline the achievement of augmented network scalability, concurrently reducing costs. This synergy holds substantial importance across various application scenarios, including virtual machine migrations, resource allocation, programmable interfaces, application-specific control, and traffic monitoring [11,12]. NFV and SDN constitute the principal technologies within the realms of 5G and the upcoming B5G/6G. The strategic deployment of computing services across the cloud layer, edge layer, and mobile edge layer, along with the seamless migration of these services between distinct layers, all fall under the purview of the SDN paradigm. These aspects hold significant importance for the practical execution of the cloud-edge orchestration architecture and remain subjects of active investigation. Moreover, the integration of this architecture's management into the Management and Orchestration (MANO) framework of the NFV architecture is pivotal for its effective real-world implementation. Furthermore, a noteworthy challenge pertains to how the management framework of the cloud-edge architecture can effectively handle edge servers that belong to diverse network providers. This particular issue remains an open question in ongoing research [13,14].

2. MATERIALS AND METHOD

This research delves deeply into the domain of Software-Defined Networking (SDN) and its application within the context of the Internet of Things (IoT) environment. The study investigates the effectiveness of SDN in augmenting dynamic network management and tackling the complexities arising from extensive connectivity of IoT devices. The examination critically analyzes four distinct SDN implementations: the Conventional IoT Network, SDN-enabled IoT networks employing Centralized Control, Distributed Control, Hierarchical Control, and Hybrid Control. The evaluation comprehensively considers key metrics such as Enhanced Scalability, Improved Traffic Engineering, Elevated Security, Complexity of Implementation, Challenges in Migration, and Dependence on Vendors.

Conventional IoT Network: This denotes the traditional, non-Software-Defined Networking (SDN) approach to overseeing an Internet of Things (IoT) network, where devices are interconnected without the dynamic regulation and optimization afforded by SDN.

SDN-Empowered IoT with Centralized Control: In this scenario, the IoT network operates based on SDN principles, with a single central controller making decisions for all devices. This tactic facilitates streamlined management but may encounter limitations in terms of scalability and resilience.

SDN-Empowered IoT with Distributed Control: In this instance, the IoT network employs SDN, yet control decisions are distributed across multiple controllers. This strategy has the potential to amplify scalability and reliability by reducing the burden on a single controller.

SDN-Empowered IoT with Hierarchical Control: Within this framework, network control is structured hierarchically, where different controllers oversee distinct segments or layers of the IoT network. This method aims to strike a balance between centralized and distributed control.

SDN-Empowered IoT with Hybrid Control: This approach amalgamates elements of centralized, distributed, and hierarchical control to shape a malleable and adaptive control structure for the IoT network.

Assessment Criteria: - Enhanced Scalability: How effectively does the SDN-empowered IoT strategy cope with the surge in IoT device numbers while upholding optimal performance and efficiency?

Optimized Traffic Engineering: To what extent does the SDN-empowered IoT network refine the routing and management of data traffic among IoT devices?

Heightened Security: How proficiently does the SDN-based approach elevate the safeguarding and defense of IoT devices and their associated data?

Complexity of Implementation: How intricate is the deployment and establishment of the SDN-empowered IoT network in terms of technical intricacy and resource requisites?

Migration Complexity: What level of difficulty is associated with transitioning from a conventional IoT network to an SDN-enhanced one? Are there hindrances or disturbances during the migration process?

Reliance on Vendors: To what extent does the operation of the SDN-empowered IoT network hinge on specific vendors or technologies? Can it flexibly adapt to diverse vendor solutions?

These benchmarks are utilized to evaluate and compare the assorted implementations of SDN in the context of IoT network management, weighing their merits and demerits across key aspects crucial for effective and efficient IoT functioning.

Weighted Sum Method: An effective decision-making framework known as MCDM (Multi-Criteria Decision Making) is employed to evaluate and rank various options in the presence of multiple, often conflicting, selection criteria. MCDM methodologies provide a structured and systematic approach to addressing challenges, facilitating a clear and organized way for decision-makers to assess the problem and tailor it to align with their specific requirements [15]. In scenarios involving Multi-Criteria Decision Making (MCDM), the determination of the sequence of options is greatly contingent on the scrutiny of data, encompassing the significance and nature of attributes within both the application and choice matrices. The actual importance assigned to this data substantially influences the results yielded by MCDM methodologies. Within MCDM scenarios, the input data often exhibits fluctuations and inconsistencies. Consequently, the outcomes produced by MCDM algorithms lack reliability due to the unpredictability inherent in the input data [16,17]. Given its widespread recognition and uncomplicated nature, the "WSM" stands out as a prominent and uncomplicated approach within the realm of Multi-Criteria Decision Making (MCDM). It is occasionally recommended for use due to its inherent ease of application. The selection of the WSM for this task stems from its versatility, particularly in catering to a diverse user base, including those without technical expertise. In instances where the goal is to generate organized concepts for issue identification or systematically identify potential ideas, the surveyed approach is most frequently observed across the examined Sustainable Urban Mobility Plans (SUMPs). This popularity is largely attributed to its simplicity in conveying to community participants. However, it is imperative to underscore that the solidity and reliability of this approach hinge on the transparent elucidation of the weights employed, grounded in rational criteria [18,19]. The weighted sum approach (WSA) is a technique designed to pinpoint the most advantageous alternative among a set of available choices. This method revolves around the computation of the collective utility value of the alternatives, with consideration given to the normalized weights assigned to the criteria. The process can be succinctly broken down into two fundamental stages: normalization and the calculation of the overall total, as outlined by Taşabat et al. in 2015. Characterized by limited inherent constraints, this approach stands out as the simplest and most practical method applicable in daily scenarios. In cases where measurement units vary, the qualification values are standardized. Subsequently, after amalgamating the scores based on the weight of each criterion, the overall score for each potential option is established [20,21,22].

3. ANALYSIS AND DISCUSSION

TABLE 1. SDN-Enabled IoT Networks

Alternative	C1	C2	C3	C4	C5	C6
A1	3	4	2	2	3	1
A2	7	8	5	5	6	8
A3	8	6	7	2	1	3
A4	9	7	8	6	7	6
A5	6	9	6	7	8	4

Table 1 presents a comprehensive comparative assessment of various implementations of Software-Defined Networking (SDN) within Internet of Things (IoT) networks, evaluating their performance against six key criteria. These criteria encompass Improved Scalability (C1), Better Traffic Engineering (C2), Enhanced Security (C3), Implementation Complexity (C4), Migration Difficulty (C5), and Vendor Dependency (C6). The first implementation, Conventional IoT Network (A1), achieves moderate scores in Improved Scalability and Better Traffic Engineering, yet lags in terms of Enhanced Security. Notably, it showcases low Implementation Complexity, moderate Migration Difficulty, and minimal Vendor Dependency. In contrast, the SDN-enabled IoT with Centralized Control (A2) excels in Improved Scalability, Better Traffic Engineering, and Enhanced Security. Nevertheless, this approach entails higher levels of Implementation Complexity, Migration Difficulty, and significant Vendor Dependency. SDN-enabled IoT with Distributed Control (A3) strikes a balance with commendable performance in Improved Scalability and Enhanced Security. It also demonstrates low Implementation Complexity, minimal Migration Difficulty, and a reasonable level of Vendor Dependency. The SDN-enabled IoT with Hierarchical Control (A4) emerges as a standout, outperforming others in Improved Scalability, Better Traffic Engineering, and Enhanced Security. While it presents moderate levels of Implementation Complexity, Migration Difficulty, and Vendor Dependency, its holistic performance remains noteworthy. Lastly, SDN-enabled IoT with Hybrid Control (A5) achieves high scores in Better Traffic Engineering and Migration Difficulty. It also ranks well in Improved Scalability and Enhanced Security, although it does involve higher Implementation Complexity and Vendor Dependency.

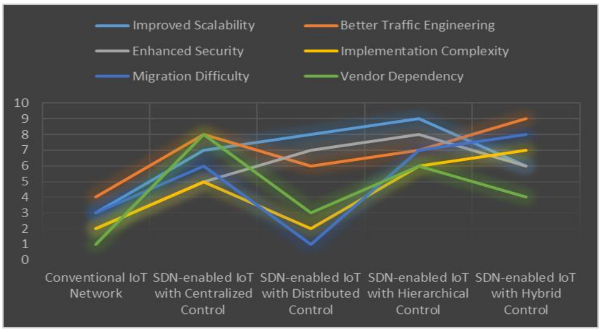


FIGURE 1. SDN-Enabled IoT Networks

Figure 1 provides a comprehensive comparison of Software-Defined Networking (SDN) implementations in Internet of Things (IoT) networks across six evaluation criteria: Improved Scalability (C1), Better Traffic Engineering (C2), Enhanced Security (C3), Implementation Complexity (C4), Migration Difficulty (C5), and Vendor Dependency (C6). The Conventional IoT Network (A1) performs moderately in Scalability and Traffic Engineering, with weaker Security. It showcases low Implementation Complexity, moderate Migration Difficulty, and minimal Vendor Dependency. In contrast, SDN-enabled IoT with Centralized Control (A2) excels in Scalability, Traffic Engineering, and Security but entails higher Complexity, Migration Difficulty, and Vendor Dependency. SDN-enabled IoT with Distributed Control (A3) demonstrates balanced performance with good Scalability and Security, low Complexity, minimal Migration Difficulty, and reasonable Vendor Dependency. SDN-enabled IoT with Hierarchical Control (A4) outperforms others in Scalability, Traffic Engineering, and Security, with moderate Complexity, Migration Difficulty, and Vendor Dependency. SDN-enabled IoT with

Hybrid Control (A5) scores well in Traffic Engineering and Migration Difficulty, maintaining Scalability and Security, but presents higher Complexity and Vendor Dependency.

TABLE 2. Normalized Matrix

0.3333	0.4444	0.25	1	0.333333	1
0.7778	0.8889	0.625	0.4	0.166667	0.125
0.8889	0.6667	0.875	1	1	0.3333
1	0.7778	1	0.3333	0.142857	0.1667
0.6667	1	0.75	0.2857	0.125	0.25

Table 2 presents a normalized matrix using the weighted sum method, capturing the performance of various alternatives across six criteria: Improved Scalability, Better Traffic Engineering, Enhanced Security, Implementation Complexity, Migration Difficulty, and Vendor Dependency. Conventional IoT Network scores moderately in most categories, while SDN-enabled IoT with Centralized Control excels in Scalability, Traffic Engineering, and Security. SDN-enabled IoT with Distributed Control demonstrates strong performance, Hierarchical Control showcases high Security, and Hybrid Control excels in Traffic Engineering and Migration Difficulty.

TABLE 3. Weight

0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
0.1667	0.1667	0.1667	0.1667	0.1667	0.1667
0.1667	0.1667	0.1667	0.1667	0.1667	0.1667

Table 3 illustrates the uniform distribution of weights employed to assess alternatives across six criteria: Enhanced Scalability, Improved Traffic Engineering, Strengthened Security, Implementation Complexity, Migration Difficulty, and Vendor Dependency. This balanced approach ensures equal significance to each criterion, establishing a well-rounded framework for evaluation.

TABLE 4. Weighted Normalized Matrix

0.055567	0.07409	0.041675	0.1667	0.0556	0.1667
0.129656	0.14818	0.104188	0.0667	0.0278	0.0208
0.148178	0.11113	0.145863	0.1667	0.1667	0.0556
0.1667	0.12966	0.1667	0.0556	0.0238	0.0278
0.111133	0.1667	0.125025	0.0476	0.0208	0.0417

Table 4 presents the Weighted Normalized Matrix, created using the weighted sum approach, evaluating various options based on six factors: Improved Scalability, Improved Traffic Engineering, Strengthened Security, Complexity of Implementation, Migration Difficulty, and Dependency on Vendors. The Conventional IoT Network achieves consistent scores, while SDN-enabled IoT with Centralized Control outperforms in Scalability, Traffic Engineering, and Security. SDN-enabled IoT with Distributed Control highlights its Security aspect, and Hybrid Control excels in Traffic Engineering.

TABLE 5. Preference Score and Rank

Alternative	**Preference Score**	**Rank**
Conventional IoT Network	0.56030	3
SDN-enabled IoT with Centralized Control	0.49732	5
SDN-enabled IoT with Distributed Control	0.79414	1
SDN-enabled IoT with Hierarchical Control	0.57022	2
SDN-enabled IoT with Hybrid Control	0.51300	4

Table 5 presents the outcome of the Weighted Sum Method evaluation, displaying Preference Scores and Rankings for each alternative based on the evaluated criteria. The Conventional IoT Network secures a moderate 3rd position with a Preference Score of 0.56030, while the SDN-enabled IoT with Centralized Control holds the 5th rank at 0.49732, despite excelling in specific domains. The SDN-enabled IoT with Distributed Control achieves the top rank with a notable Preference Score of 0.79414 due to comprehensive performance, followed by the SDN-enabled IoT with Hierarchical Control securing the 2nd spot (Preference Score: 0.57022), and the SDN-enabled

IoT with Hybrid Control taking the 4th position (Preference Score: 0.51300), particularly excelling in Traffic Engineering.

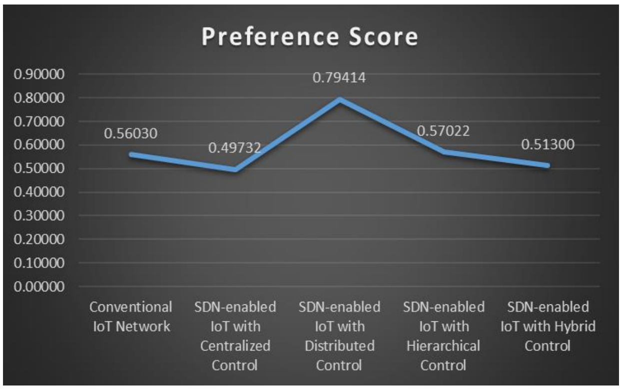


FIGURE 2. Preference Score

Figure 2's Preference Scores offer a quantified measure of each alternative's comprehensive performance across the evaluated criteria. A higher score reflects greater performance favorability. The Conventional IoT Network records 0.56030, indicating balanced yet unspectacular performance. The SDN-enabled IoT with Centralized Control attains 0.49732, excelling in specific domains but falling short overall. The SDN-enabled IoT with Distributed Control secures the lead at 0.79414, signifying preferred, well-rounded performance. The SDN-enabled IoT with Hierarchical Control achieves 0.57022, showcasing comprehensive and balanced performance. The SDN-enabled IoT with Hybrid Control obtains 0.51300, excelling in Traffic Engineering but moderately across other aspects.

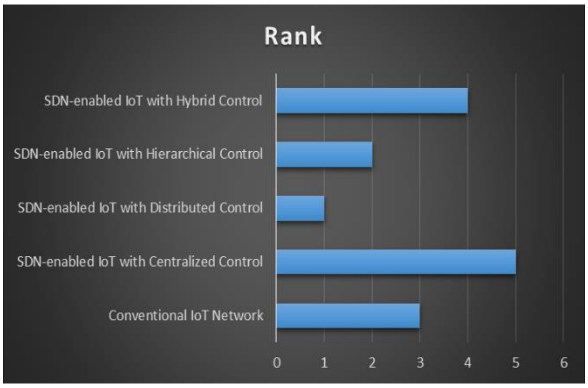


FIGURE 3. Rank

The rankings depicted in Figure 3 reflect the performance of alternatives as determined by their Preference Scores. The Conventional IoT Network attains a moderate 3rd rank, while the SDN-enabled IoT with Centralized Control, despite excelling in specific domains, holds the 5th rank. The SDN-enabled IoT with Distributed Control secures the 1st rank, highlighting its comprehensive performance. Ranking 2nd is the SDN-enabled IoT with Hierarchical Control, and 4th is the SDN-enabled IoT with Hybrid Control, excelling primarily in Traffic Engineering.

4. CONCLUSION

The integration of Software-Defined Networking (SDN) within the context of Internet of Things (IoT) networks holds great promise for enabling dynamic network management and addressing the challenges posed by the massive proliferation of IoT devices. This study comprehensively evaluated various implementations of SDN-enabled IoT networks, considering their performance across key evaluation criteria: Improved Scalability, Better Traffic Engineering, Enhanced Security, Implementation Complexity, Migration Difficulty, and Vendor Dependency. The analysis revealed intriguing insights into the effectiveness of different SDN-enabled IoT network architectures. The Conventional IoT Network, representing a traditional approach, demonstrated moderate performance across the criteria, positioned at the 3rd rank. Although it exhibited a balanced performance, its lack of exceptional performance in any particular criterion underscored its limitations in meeting the demands of modern IoT ecosystems. Surprisingly, the SDN-enabled IoT with Centralized Control, while excelling in Scalability, Traffic Engineering, and Security, garnered the 5th rank, emphasizing the importance of a holistic approach that considers all evaluation aspects. On the other hand, the SDN-enabled IoT with Distributed Control emerged as the preferred choice, claiming the 1st rank with its high Preference Score. This architecture showcased remarkable performance across various criteria, reflecting its ability to efficiently manage IoT devices and dynamic network requirements. The SDN-enabled IoT with Hierarchical Control secured the 2nd rank, highlighting its well-rounded performance and suitability for balancing centralized and distributed control. Meanwhile, the SDN-enabled IoT with Hybrid Control, excelling primarily in Traffic Engineering, secured the 4th rank, underscoring its potential for optimizing data traffic flow. In essence, this study underscores the significance of evaluating SDN-enabled IoT networks using a comprehensive and balanced approach, considering multiple criteria. While each alternative exhibited strengths and weaknesses, the SDN-enabled IoT with Distributed Control emerged as the most preferable due to its ability to efficiently handle IoT device connectivity, adapt to dynamic network demands, and enhance overall network performance. The findings emphasize the importance of not only excelling in individual aspects but also achieving a harmonious balance across various criteria to achieve effective and efficient IoT network management. As the IoT landscape continues to evolve, such insights are crucial for guiding the development of future-proof network architectures that can effectively accommodate the ever-growing demands of IoT devices and applications.

REFERENCES

[1]. Bera, Samaresh, Sudip Misra, and Athanasios V. Vasilakos. "Software-defined networking for internet of things: A survey." *IEEE Internet of Things Journal* 4, no. 6 (2017): 1994-2008.

[2]. H. Farhady, H. Lee, and A. Nakao, “Software-defined networking: A survey,” Comput. Netw., vol. 81, pp. 79–95, Apr. 2015

[3]. Kreutz, Diego, Fernando MV Ramos, Paulo Esteves Verissimo, Christian Esteve Rothenberg, Siamak Azodolmolky, and Steve Uhlig. "Software-defined networking: A comprehensive survey." *Proceedings of the IEEE* 103, no. 1 (2014): 14-76.

[4]. McKeown, Nick, Tom Anderson, Hari Balakrishnan, Guru Parulkar, Larry Peterson, Jennifer Rexford, Scott Shenker, and Jonathan Turner. "OpenFlow: enabling innovation in campus networks." *ACM SIGCOMM computer communication review* 38, no. 2 (2008): 69-74.

[5]. Hu, Long, Meikang Qiu, Jeungeun Song, M. Shamim Hossain, and Ahmed Ghoneim. "Software defined healthcare networks." *IEEE Wireless Communications* 22, no. 6 (2015): 67-75.

[6]. Mavromatis, Alex, Aloizio Pereira Da Silva, Koteswararao Kondepu, Dimitrios Gkounis, Reza Nejabati, and Dimitra Simeonidou. "A software defined device provisioning framework facilitating scalability in Internet of Things." In *2018 IEEE 5G World Forum (5GWF)*, pp. 446-451. IEEE, 2018.

[7]. Marcos-Garcia, Maria Dolores, and Maria Victoria Ramos-Gonzalez. "The safe administration of medication within the electromagnetic scenarios of the Internet of Things (IoT): looking towards the future." (2021).

[8]. Tayyaba, Sahrish Khan, Munam Ali Shah, Omair Ahmad Khan, and Abdul Wahab Ahmed. "Software defined network (sdn) based internet of things (iot) a road ahead." In *Proceedings of the international conference on future networks and distributed systems*, pp. 1-8. 2017.

[9]. Benzekki, Kamal, Abdeslam El Fergougui, and Abdelbaki Elbelrhiti Elalaoui. "Software□defined networking (SDN): a survey." *Security and communication networks* 9, no. 18 (2016): 5803-5833.

[10]. Haque, Israat Tanzeena, and Nael Abu-Ghazaleh. "Wireless software defined networking: A survey and taxonomy." *IEEE Communications Surveys & Tutorials* 18, no. 4 (2016): 2713-2737.

[11]. Osanaiye, Opeyemi, Shuo Chen, Zheng Yan, Rongxing Lu, Kim-Kwang Raymond Choo, and Mqhele Dlodlo. "From cloud to fog computing: A review and a conceptual live VM migration framework." *IEEE Access* 5 (2017): 8284-8300.

[12]. Anawar, Muhammad Rizwan, Shangguang Wang, Muhammad Azam Zia, Ahmer Khan Jadoon, Umair Akram, and Salman Raza. "Fog computing: An overview of big IoT data analytics." *Wireless Communications and Mobile Computing* 2018 (2018).

[13]. Wu, Yulei. "Cloud-edge orchestration for the Internet of Things: Architecture and AI-powered data processing." *IEEE Internet of Things Journal* 8, no. 16 (2020): 12792-12805.

[14]. Kourtis, Michail-Alexandros, Michael J. McGrath, Georgios Gardikis, Georgios Xilouris, Vincenzo Riccobene, Panagiotis Papadimitriou, Eleni Trouva et al. "T-nova: An open-source mano stack for nfv infrastructures." *IEEE Transactions on Network and Service Management* 14, no. 3 (2017): 586-602.

[15]. Kumar, Gaurav, and N. Parimala. "A sensitivity analysis on weight sum method MCDM approach for product recommendation." In *Distributed Computing and Internet Technology: 15th International Conference, ICDCIT 2019, Bhubaneswar, India, January 10–13, 2019, Proceedings 15*, pp. 185-193. Springer International Publishing, 2019.

[16]. D. Stanujkic, G. Popovic, D. Karabasevic, I. Meidute-Kavaliauskiene and A. Ulutaş, "An Integrated Simple Weighted Sum Product Method—WISP." in *IEEE Transactions on Engineering Management* 70, no. 5 (2023): 1933-1944.

[17]. Stanujkić, Dragiša, Darjan Karabašević, Gabrijela Popović, Edmundas Kazimieras Zavadskas, Muzafer Saračević, Predrag S. Stanimirović, Alptekin Ulutaş, Vasilios N. Katsikis, and Ieva Meidute-Kavaliauskiene. "Comparative analysis of the simple WISP and some prominent MCDM methods: A Python approach." *Axioms* 10, no. 4 (2021): 347.

[18]. Garcia-Ayllon, Salvador, Eloy Hontoria, and Nolberto Munier. "The contribution of MCDM to SUMP: The case of Spanish cities during 2006–2021." *International Journal of Environmental Research and Public Health* 19, no. 1 (2021): 294.

[19]. Baydaş, Mahmut, and Orhan Emre Elma. "An objectıve criteria proposal for the comparison of MCDM and weighting methods in financial performance measurement: An application in Borsa Istanbul." *Decision Making: Applications in Management and Engineering* 4, no. 2 (2021): 257-279.

[20]. Kumar, Gaurav, and N. Parimala. "A weighted sum method MCDM approach for recommending product using sentiment analysis." *International Journal of Business Information Systems* 35, no. 2 (2020): 185-203.

[21]. Petrović, Goran, Jelena Mihajlović, Žarko Ćojbašić, Miloš Madić, and Dragan Marinković. "Comparison of three fuzzy MCDM methods for solving the supplier selection problem." *Facta Universitatis, Series: Mechanical Engineering* 17, no. 3 (2019): 455-469.

[22]. Sorooshian, Shahryar, and Yasaman Parsia. "Modified weighted sum method for decisions with altered sources of information." *Mathematics and Statistics* 7, no. 3 (2019): 57-60.