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An Assessment of SDN-based Traffic Engineering for Data Center Networks Using the MOORA Method

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ABSTRACT

SDN-based Traffic Engineering for Data Center Networks employs Software-Defined Networking (SDN) principles to optimize network traffic within data centers. By dynamically managing network resources and routing paths, SDN-based Traffic Engineering enhances performance, scalability, and efficiency, catering to the complex demands of modern data center environments.

The significance of SDN-based Traffic Engineering lies in its ability to revolutionize data center networks. By leveraging Software-Defined Networking, it offers dynamic traffic control, efficient resource allocation, and scalability. This research holds the potential to enhance network performance, reduce congestion, and adapt to evolving data center requirements effectively.

The study's approach utilizes the MOORA technique (Multi-Objective Optimization on the Basis of Ratio Analysis) to improve SDN-based Traffic Engineering within Data Center Networks. This includes a systematic assessment of routing options using various criteria, leading to optimized traffic control and resource distribution. The MOORA method provides a systematic strategy for achieving effective and flexible network performance.

The evaluation of SDN-based Traffic Engineering for Data Center Networks involves analyzing the choices including OSPF, ECMP, Hedera, MicroTE, Mahout, and ANS. This analysis considers factors such as throughput, fault tolerance, network security, energy consumption, cost, and latency.

Hedera is ranked 1st, meaning it had the highest score and best overall performance against the criteria. OSPF routing ranked 2nd, followed by Mahout in 3rd and ANS in 4th. ECMP routing and MicroTE had the lowest rankings at 5th and 6th place respectively. This suggests Hedera performed best compared to the other options, while ECMP routing and MicroTE were assessed as the weakest alternatives according to the analysis. The rankings provide an ordered overview of how the different routing options stack up in terms of meeting the desired evaluation factors.

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Introduction

Due to the significant surge in the utilization of cloud computing services, there has been a substantial rise in data traffic within data center networks (DCNs). This dramatic increase in traffic has led to a sharp uptick in instances of congestion and the loss of data packets within DCNs. In order to effectively meet the escalating demands of cloud computing, it has become crucial for network administrators to have a clear understanding of how data packets are being transmitted between various switches [1]. The traffic matrix (TM) depicts the size and attributes of network flows connecting distinct source and target nodes. Therefore, precise estimation of TM within DCNs can assist operators in adeptly managing network traffic, whether for network allocation, planning virtual machine migrations, or ensuring security protocols. Nevertheless, prior TM estimation methods have primarily relied on direct measurements or deductions derived solely from link counts facilitated by the Simple Network Management Protocol (SNMP). Such approaches could encounter challenges like excessive resource consumption or insufficient accuracy [2,3]. Furthermore, acquiring the traffic matrix (TM) directly through measuring the size of individual flows is both costly and unfeasible, as it demands additional hardware instrumentation support. Equipping such instruments across extensive networks like data center networks (DCNs) is not achievable. Consequently, the task of promptly attaining precise TM estimates for real-world networks presents a considerable challenge [4].

SDN governs data center networks (DCNs) through two distinct approaches: inter-data center management, where SDN operates as a multi-layer controller linking various data centers, and intra-data center management, where SDN functions within a single data center. In the latter scenario, data center applications such as Hadoop involve servers serving as data nodes, facilitating the substantial transfer of data to other servers and services [5]. Typically, the data center experiences higher traffic volume compared to the traffic exchanged between users and the data center. Upon adding a file to the Hadoop system, sizeable files undergo segmentation into smaller segments, which are then transmitted to the relevant data nodes via the data center network. The efficiency of this process, including routing, is enhanced through the utilization of SDN, particularly for larger file transfers within the Hadoop framework [6]. The SDN controller manages the movement of data between data nodes. Moreover, the controller can be configured to identify major data streams and assign them higher priority to ensure the seamless operation of applications. Beyond optimizing data flow, it can enhance performance by analyzing diverse traffic patterns and redistributing the workload. Load balancing ensures an equitable distribution of traffic across multiple pathways, resulting in faster network processing times [7]. Furthermore, the operational sequence can be modified in real-time within data center networks (DCNs) to better handle workloads, employing SDN for increased efficiency. However, optimizing DCNs necessitates intelligent strategies that take various network performance factors into account. Addressing this challenge can be accomplished through the application of Artificial Intelligence (AI) methodologies [8].

The expansion of Data Centers' capabilities necessitates a deliberate approach to energy consumption, prompting the need for a novel and adaptable network architecture. This architecture should facilitate the seamless integration of new elements into the network, such as traffic coordination, innovative routing techniques, and energy consumption tracking. In the pursuit of energy-efficient network solutions, various strategies can be considered, and exploring potential enhancements to the network topology is particularly intriguing as a means of addressing this challenge [9]. Software-Defined Networking (SDN) emerged as a fundamental approach to realize this enhancement. SDN introduces a (virtually) centralized control hub within the network, elevating its programmability, and enabling remote administration across infrastructures through a unified open protocol. This framework enables collaborative interactions between network and business applications, facilitated by analytics, and empowers the adaptation of network policies in response to evolving user experiences and application effectiveness [10,11]. The network's configuration and arrangement remain constant, while applications and systems progress to a more advanced state. SDN introduces a tangible separation between the data and control planes within packet-forwarding devices (switches). With the assistance of a logically centralized controller (control plane), individual network flows are independently overseen by imposing tailored flow directives onto the switches responsible for routing (data plane) [12]. The regulations consist of data flow details merged with a command section outlining the required actions for the flow, alongside trackers monitoring these flow statistics. OpenFlow stands as a principal embodiment of the SDN concept. SDN offers the benefit of a centralized network view, facilitating the incorporation of diverse traffic management techniques, and central control, presenting an appealing design alternative for Data Center networks [13].

1. MATERIALS AND METHODS

The assessment of SDN-based Traffic Engineering for Data Center Networks entails the examination of alternatives, namely OSPF, ECMP, Hedera, MicroTE, Mahout, and ANS. This scrutiny encompasses variables like throughput, fault tolerance, network security, energy usage, expenses, and latency, all while incorporating the MOORA method.

OSPF, known as Open Shortest Path First, is a networking protocol applied in expansive networks like data centers. It computes the shortest path for data packets, ensuring streamlined data transfer. ECMP, or Equal-Cost Multi-Path, is a method that uniformly disperses network traffic over multiple paths with comparable costs, contributing to network optimization and congestion mitigation. Hedera, in this context, refers to a distinct technology or technique within SDN-centered Traffic Engineering. Its specific role depends on the broader framework's context. MicroTE, or Micro Traffic Engineering, optimizes network routes to refine traffic flow and minimize delays, concentrating on refining minor-scale data patterns alongside wider traffic control methods. Mahout might allude to the Apache Mahout project, a machine learning library beneficial for functions like recommending, clustering, and categorizing data in network scenarios. ANS, the Alibaba Network Stack, is an Alibaba-developed tool tailoring network operations in their data centers to augment packet processing efficiency and diminish latency, with the aim of boosting overall performance.

Throughput: Throughput pertains to the volume of data that can be conveyed across a network or specific connection within a designated timeframe. In SDN-centered Traffic Engineering, enhancing throughput involves ensuring efficient data conveyance and mitigating congestion to attain heightened data transfer rates.

Fault Tolerance: Fault Tolerance encompasses a network's capacity to sustain functionality amidst faults or failures, such as hardware glitches or connectivity disruptions. Within SDN-oriented Traffic Engineering, fault tolerance guarantees swift adaptation and rerouting of traffic to preserve operations during failure instances.

Network Security: Network Security encompasses strategies taken to safeguard data, devices, and communication within a network from unauthorized entry, attacks, and breaches. In the context of SDN-focused Traffic Engineering, the integration of security mechanisms safeguards data center networks against potential threats and vulnerabilities.

Energy Usage: Energy Usage signifies the quantum of power consumed by network components and devices. In SDN-driven Traffic Engineering, optimizing energy consumption involves structuring and managing the network to reduce power usage while upholding performance and dependability.

Cost: Expenses denote the expenditures tied to establishing, up keeping, and running network infrastructure. SDN-based Traffic Engineering seeks to optimize resource allocation and traffic control, thereby curtailing operational expenditures while aligning with performance prerequisites.

Latency: Latency signifies the time lag or duration taken for data to traverse from source to destination in a network. In the realm of SDN-driven Traffic Engineering, curtailing latency assumes paramount importance for achieving instantaneous and responsive interaction between network elements, particularly in applications like online gaming, video streaming, and real-time data analysis.

The MOORA method:

MOORA embodies a multi-faceted strategy for decision-making, providing substantial capability to comprehensively evaluate choices in the presence of extensive diversity and numerous influential factors. The MOORA technique was introduced by Brauers and Zavadskas (2006) as a component of a set of methods for multi-objective optimization strategically designed to effectively tackle intricate decision-making dilemmas. The principal aim of this approach is to pinpoint the optimal selection from a set of alternatives, considering a spectrum of criteria that frequently clash with one another. In other words, this methodology concurrently assesses both beneficial and adverse facets [14,15]. MOORA has been recognized for its various merits in comparison to specific prevailing decision-making methods. These advantages encompass decreased mathematical computations, abbreviated computational timeframes, improved simplicity, and increased stability when juxtaposed with particular Multi-Criteria Decision-Making (MCDM) techniques such as AHP, TOPSIS, ELECTRE, VIKOR, and PROMETHEE [16].

MOORA engages in the simultaneous enhancement of two or more conflicting attributes (objectives), all while adhering to specific constraints. In a decision-making context, the quantification of these objectives is conducted for each potential decision, laying the foundation for option evaluation and consequently facilitating the determination of the most advantageous (appropriate) selection [17]. Therefore, the utilization of multi-objective optimization techniques seems suitable for organizing or selecting one or multiple options from a range of feasible alternatives, depending on various attributes that frequently conflict. Previous observations have highlighted that the MOORA method is notably straightforward, reliable, and robust, requiring minimal mathematical calculations and computational resources [18].

Multi-objective optimization entails the simultaneous improvement of two or more conflicting benchmarks (goals) within defined constraints. Examples that illustrate scenarios of multi-objective optimization encompass optimizing product profitability while minimizing expenses, enhancing vehicle performance while decreasing fuel usage, and striking a balance between reducing weight and enhancing strength in a specific engineering component [19,20]. In real-world manufacturing scenarios, the involvement of various decision-makers with diverse interests and principles introduces intricacies into the decision-making process. In a decision-making context, the objectives (criteria) must be measurable, and their outcomes can be quantified for each potential option. Within this interplay of conflicting criteria (objectives), specific criteria are advantageous (preferring higher values), while others are non-advantageous (preferring lower criterion values). The multi-objective optimization by ratio analysis (MOORA) technique encompasses both favorable and unfavorable objectives (criteria) to rank or choose one or more alternatives from a given set of possibilities [21,22].

Step 1: Define the Problem and Criteria: Identify the decision problem and list all the relevant criteria (objectives) that need to be considered. These criteria should reflect the different aspects you want to evaluate for each alternative.

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Step 2: Normalize the Data: Standardize the data for each criterion to achieve uniformity in scale. This step is essential to prevent any single criterion from overpowering the decision-making procedure due to its larger measurement range.

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \tag{3}$$

$$where\ i \epsilon [1, m]\ and\ j \in [1, n]$$

Step 3: Determine the Weights (W)- Allocate proportions to each criterion to signify its comparative significance. The assigned proportions should total 1. Various approaches can be employed for weight assignment, including expert assessment, the analytical hierarchy process (AHP), or pairwise evaluation.

$$w_j = [w_1 \cdots w_n], \text{ where } \sum_{j=1}^{n}(w_1 \cdots w_n) = 1 \tag{2}$$

Step 4: Create the Weighted Normalized Matrix- Multiply the normalized matrix by the weights for each criterion to create the weighted normalized matrix.

$$W_{n_{ij}} = w_j n_{ij} \tag{4}$$

Step 5: Compute the Evaluation Score (yi) - Determine the performance rating for each option by considering the normalized values and weights. The performance score (yi) for alternatives is calculated as follows :

$$y_i = \sum_{j=1}^{g} N_{ij} - \sum_{j=g+1}^{n} N_{ij} \tag{5}$$

where g is the number of benefit criteria and (n-g) is number of cost-criteria.

Step 6: Once the performance scores for each choice have been calculated, the subsequent stage involves organizing them based on these scores. The alternative that attains the highest performance score is assigned the leading rank (usually denoted as 1), and this pattern is maintained throughout. Conversely, the alternative with the least performance score is attributed the lowest rank (typically placed at the bottom). Display a roster of the alternatives along with their corresponding ranks to visually illustrate their positioning determined by their performance scores. The option holding the rank 1 is deemed the favored or optimal selection according to the evaluation criteria.

2. ANALYSIS AND DISCUSSION

TABLE 1. SDN-based Traffic Engineering for Data Center Networks

Alternative	**Throughput (Gbps)**	**Fault Tolerance**	**Network Security**	**Energy Consumption (kWh)**	**Cost (in 1000 $)**	**Latency (ms)**
OSPF routing	150	9	8.5	450	120	2.5
ECMP routing	130	8	8.2	500	110	3.1
Hedera	180	9.5	8.9	400	130	2.8
MicroTE	120	7.5	8	520	105	3.5
Mahout	160	8.5	8.6	470	115	2.6
ANS	140	8.8	8.3	490	112	3.2

The first table presents a variety of options for SDN-based traffic engineering in data center networks, evaluating their characteristics. The options, encompassing OSPF, ECMP, Hedera, MicroTE, Mahout, and ANS, are assessed based on criteria like throughput, fault tolerance, network security, energy usage, expenses, and latency. OSPF showcases a throughput of 150 Gbps and a robust fault tolerance score of 9. Conversely, MicroTE showcases lower throughput (120 Gbps), and fault tolerance (7.5) yet delivers diminished latency (3.5 ms). Hedera distinguishes itself with remarkable throughput (180 Gbps), high fault tolerance (9.5), and moderate energy consumption (400 kWh). Each alternative involves a trade-off among distinct performance metrics, allowing decision-makers to opt based on their network's specific prerequisites and priorities.

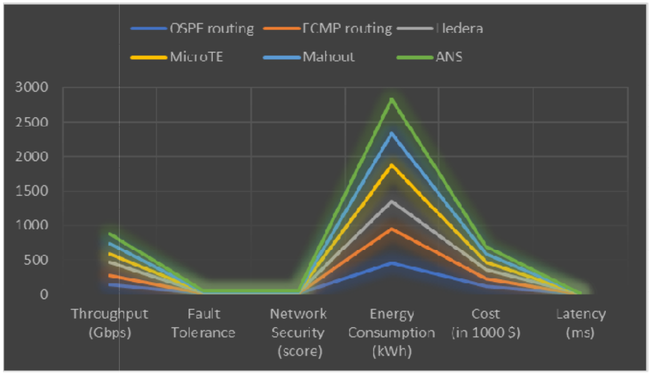

FIGURE 1. SDN-based traffic engineering in data center networks

Figure 1 illustrates choices for SDN-driven traffic management in data center networks, juxtaposing six options based on throughput, fault tolerance, network security, energy use, expenses, and latency. OSPF routing presents moderate throughput and elevated fault tolerance and security, albeit at the expense of energy efficiency. ECMP routing delivers marginally reduced throughput, whereas Hedera merges elevated throughput with exceptional fault tolerance and security. MicroTE trades throughput for diminished latency and costs. Mahout harmonizes substantial throughput, fault tolerance, and security. ANS presents intermediate values for all criteria.

Table 2. Normalized matrix

0.41380294	0.42847914	0.412044032	0.388176318	0.4237506	0.3435635
0.35862922	0.38087034	0.397501301	0.431307021	0.388438	0.4260187
0.49656353	0.45228353	0.431434339	0.345045616	0.4590631	0.3847911
0.33104236	0.35706595	0.387806148	0.448559301	0.3707818	0.4809889
0.44138981	0.40467474	0.416891609	0.405428599	0.4060943	0.357306
0.38621608	0.41895738	0.402348878	0.42268088	0.3955005	0.4397613

Presented in Table 2 is a normalized matrix created through the MOORA approach, aimed at appraising alternatives concerning throughput, fault tolerance, network security, energy usage, cost, and latency. Each option, namely OSPF routing, ECMP routing, Hedera, MicroTE, Mahout, and ANS, is allocated normalized figures that mirror their relative achievements in each aspect. Notably, Hedera excels with the greatest normalized figures in throughput and fault tolerance, underscoring its exceptional proficiency in these domains. In contrast, MicroTE spotlights reduced energy consumption and latency as its strengths.

Table 3. Weights

0.125	0.125	0.125	0.125	0.125	0.125
0.125	0.125	0.125	0.125	0.125	0.125
0.125	0.125	0.125	0.125	0.125	0.125
0.125	0.125	0.125	0.125	0.125	0.125
0.125	0.125	0.125	0.125	0.125	0.125
0.125	0.125	0.125	0.125	0.125	0.125

Table 3 delineates the allocated proportions for various benchmarks within the evaluation of options. Each choice, including OSPF routing, ECMP routing, Hedera, MicroTE, Mahout, and ANS, is assigned an even weight (0.125) to categories such as throughput, fault tolerance, network security, energy consumption, cost, and latency. This uniform apportionment signifies an equitable assessment of these factors during decision-making, guaranteeing an equivalent impact from each facet on the overall appraisal of alternatives. This approach underscores a neutral perspective in the evaluation of their effectiveness.

TABLE 4. Weighted normalized decision matrix

0.051725	0.05356	0.051506	0.048522	0.052969	0.042945
0.044829	0.047609	0.049688	0.053913	0.048555	0.053252
0.06207	0.056535	0.053929	0.043131	0.057383	0.048099
0.04138	0.044633	0.048476	0.05607	0.046348	0.060124
0.055174	0.050584	0.052111	0.050679	0.050762	0.044663
0.048277	0.05237	0.050294	0.052835	0.049438	0.05497

Provided in Table 4 is a decision matrix generated through the MOORA method, incorporating weighted and normalized data. This matrix evaluates various options like OSPF routing, ECMP routing, Hedera, MicroTE, Mahout, and ANS, considering diverse factors such as throughput, fault tolerance, network security, energy usage, cost, and latency. The values represent each alternative's performance in a standardized manner. Notably, Hedera excels in normalized scores for throughput, fault tolerance, and network security, while MicroTE places emphasis on reduced energy consumption and latency.

Table 5. Assessment value

Alternative	**Assessment value**
OSPF routing	0.012354
ECMP routing	-0.0136
Hedera	0.023923
MicroTE	-0.02805
Mahout	0.011766
ANS	-0.0063

The evaluation values derived from the MOORA methodology in Table 5 offer an encompassing viewpoint regarding the performance of each available alternative. Within the selection, Hedera stands out with a promising assessment score of 0.023923, indicating its robust performance across the established criteria. Similarly, Mahout attains a positive score of 0.011766, signifying its competitive position relative to the others. Conversely, ECMP routing, MicroTE, and ANS exhibit negative assessment values of -0.0136, -0.02805, and -0.0063, respectively, underscoring their relatively inferior performance within the evaluated parameters.

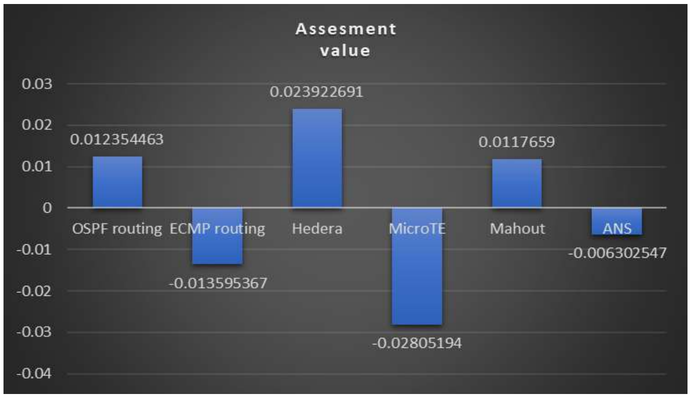

Figure 2. Assessment value

Figure 2 shows the evaluation scores calculated using the MOORA method for the different options. The scores represent an overall assessment of how well each option meets the criteria. Positive scores, like those for Hedera and Mahout, mean these options perform well against the criteria. Negative scores, like those for ECMP routing, MicroTE, and ANS, suggest these options may perform worse based on the factors considered.

Table 6. Rank

Alternative	Rank
OSPF routing	2
ECMP routing	5
Hedera	1
MicroTE	6
Mahout	3
ANS	4

Table 6 displays the prioritization of six distinct routing alternatives based on their evaluation scores. Hedera secured the top position, indicating the highest score and most favorable overall performance according to the criteria. OSPF routing obtained the second position, followed by Mahout in third and ANS in fourth place. ECMP routing and MicroTE were ranked at the bottom, landing in fifth and sixth positions respectively. This implies that Hedera outperformed the other choices, whereas ECMP routing and MicroTE were identified as the least effective options based on the analysis. These rankings offer an organized overview of how the various routing selections compare in terms of fulfilling the desired assessment factors.

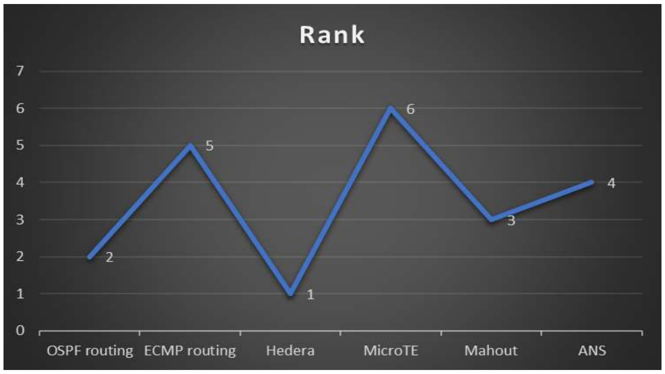

Figure 3. Rank

The rankings of six different routing alternatives are shown in Figure 3. Hedera is ranked first, meaning it had the highest score and best overall performance against the criteria. This suggests that Hedera performed best compared to the other options. OSPF routing ranked second, followed by Mahout in third and ANS in fourth. ECMP routing and MicroTE had the lowest rankings at fifth and sixth place respectively. These two routing options were assessed as the weakest alternatives according to the analysis. The rankings provide an ordered overview of how the different routing options stack up in terms of meeting the desired evaluation factors. This information can be used to select the best routing option for a particular application or environment.

Conclusion

The implementation of Traffic Engineering based on Software-Defined Networking introduces a groundbreaking approach to boost the efficiency and efficiency of data center networks. By leveraging principles of Software-Defined Networking, this strategy enables flexible traffic management, efficient allocation of resources, and agile adaptation to evolving network needs. The assessment of SDN-based Traffic Engineering, using techniques like the MOORA method, has yielded insightful viewpoints on prioritizing and enhancing routing choices. This empowers network planners and administrators to make informed choices, leading to improved network performance and strategic network administration. By rigorously implementing the MOORA technique, a meticulous examination of six routing alternatives – OSPF, ECMP, Hedera, MicroTE, Mahout, and ANS – was systematically conducted against a diverse array of criteria. This comprehensive assessment encompassed factors such as throughput, fault tolerance, network security, energy consumption, costs, and latency. The resultant rankings have established a holistic hierarchy, illuminating the relative merits and limitations of each alternative. Hedera emerged as the foremost choice, underscoring its supremacy in fulfilling the desired objectives across the assessment criteria. This underscores the significance of advanced technologies or methodologies like Hedera in augmenting SDN-based Traffic Engineering within data center networks. In contrast, ECMP routing and MicroTE secured the lowest rankings, pinpointing avenues for potential refinement and optimization. The implications derived from this evaluation extend beyond mere ranking, delving into strategic considerations that guide decision-makers within the realm of data center network management. The prioritization of options, as guided by the MOORA method, equips stakeholders with a nuanced understanding of the potential trade-offs associated with different facets of network performance and administration. In the dynamic landscape of data center networks, marked by scalability, reliability, and real-time responsiveness, the conclusions drawn from this assessment offer valuable guidance for crafting and implementing SDN-based Traffic Engineering approaches. As digital ecosystems continue to grow in complexity and scale, the incorporation of innovative techniques like MOORA ensures the flexibility and resilience of network architectures, positioning them to effectively tackle the challenges of an increasingly data-centric world in the years ahead.

References

1. Liu, Guiyan, Songtao Guo, Bin Xiao, and Yuanyuan Yang. "SDN-based traffic matrix estimation in data center networks through large size flow identification." *IEEE Transactions on Cloud Computing* 10, no. 1 (2019): 675-690.
2. Fu, Qiongxiao, Enchang Sun, Kang Meng, Meng Li, and Yanhua Zhang. "Deep Q-learning for routing schemes in SDN-based data center networks." *IEEE Access* 8 (2020): 103491-103499.
3. Babayigit, Bilal, and Banu Ulu. "Deep learning for load balancing of SDN□based data center networks." *International Journal of Communication Systems* 34, no. 7 (2021): e4760.
4. Zaher, Maiass, Aymen Hasan Alawadi, and SándorMolnár. "Sieve: A flow scheduling framework in SDN based data center networks." *Computer Communications* 171 (2021): 99-111.
5. Conterato, Marcelo da Silva, Tiago Coelho Ferreto, Fábio Rossi, Wagner dos Santos Marques, and Paulo Silas Severo de Souza. "Reducing energy consumption in SDN-based data center networks through flow consolidation strategies." In *Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing*, pp. 1384-1391. 2019.
6. Yi, Bo, Xingwei Wang, Min Huang, and Yong Zhao. "Novel resource allocation mechanism for SDN-based data centernetworks." *Journal of Network and Computer Applications* 155 (2020): 102554.
7. Majidi, Akbar, Xiaofeng Gao, Shunjia Zhu, NazilaJahanbakhsh, and Guihai Chen. "Adaptive routing reconfigurations to minimize flow cost in sdn-based data center networks." In *Proceedings of the 48th International Conference on Parallel Processing*, pp. 1-10. 2019.
8. Wang, Yao□Chun, Ying□Dar Lin, and Guey□Yun Chang. "SDN□based dynamic multipath forwarding for inter–data center networking." *International Journal of Communication Systems* 32, no. 1 (2019): e3843.
9. Pranata, Alif Akbar, Tae Soo Jun, and Dong Seong Kim. "Overhead reduction scheme for SDN-based data center networks." *Computer Standards & Interfaces* 63 (2019): 1-15.
10. Queiroz, Wander, Miriam AM Capretz, and Mario Dantas. "An approach for SDN traffic monitoring based on big data techniques." *Journal of Network and Computer Applications* 131 (2019): 28-39.
11. Alotaibi, Modhawi, and Amiya Nayak. "Linking handover delay to load balancing in SDN-based heterogeneous networks." *Computer Communications* 173 (2021): 170-182.
12. Thazin, Nwe, Khine Moe Nwe, and Yutaka Ishibashi. "Resource allocation scheme for SDN-based cloud data center network." PhD diss., MERAL Portal, 2019.

13. Tang, Qian, Huan Zhang, Jun Dong, and Lianming Zhang. "Elephant flow detection mechanism in SDN-based data center networks." *Scientific Programming* 2020 (2020): 1-8.
14. Daulay, Nelly Khairani, Bunga Intan, and Muhammad Irvai. "Comparison of the WASPAS and MOORA Methods in Providing Single Tuition Scholarships." *The IJICS (International Journal of Informatics and Computer Science)* 5, no. 1 (2021): 84-94.
15. Siregar, Victor MarudutMulia, Mega RomaulyTampubolon, Eka PratiwiSeptaniaParapat, Eve Ida Malau, and Debora Silvia Hutagalung. "Decision support system for selection technique using MOORA method." In *IOP Conference Series: Materials Science and Engineering*, vol. 1088, no. 1, p. 012022. IOP Publishing, 2021.
16. Shahzadi, Gulfam, AnamLuqman, and Mohammed M. Ali Al-Shamiri. "The extended MOORA method based on Fermatean fuzzy information." *Mathematical problems in engineering* 2022 (2022): 1-15.
17. Sinaga, NovendraAdisaputra, HeruSugara, Ewin Johan Sembiring, Melva EpyMardianaManurung, HarsudiantoSilaen, PipinSumantrie, and Victor MarudutMuliaSiregar. "Decision support system with MOORA method in selection of the best teachers." In *AIP Conference Proceedings*, vol. 2453, no. 1. AIP Publishing, 2022.
18. Fadli, Sofiansyah, and Khairul Imtihan. "Implementation of MOORA method in evaluating work performance of honorary teachers." *Sinkron: jurnal dan penelitianteknikinformatika* 4, no. 1 (2019): 128-135.
19. Lubis, Ahmadi Irmansyah, PoltakSihombing, and Erna BudhiartiNababan. "Comparison SAW and MOORA Methods with Attribute Weighting Using Rank Order Centroid in Decision Making." In *2020 3rd International Conference on Mechanical, Electronics, Computer, and Industrial Technology (MECnIT)*, pp. 127-131. IEEE, 2020.
20. Arslankaya, Seher, and Miraç Tuba Çelik. "Green supplier selection in steel door industry using fuzzy AHP and fuzzy Moora methods." *Emerging Materials Research* 10, no. 4 (2021): 357-369.
21. Sutarno, S., M. Mesran, S. Supriyanto, Y. Yuliana, and A. Dewi. "Implementation of Multi-Objective Optimazation on the Base of Ratio Analysis (MOORA) in Improving Support for Decision on Sales Location Determination." In Journal of Physics: Conference Series, vol. 1424, no. 1, p. 012019. IOP Publishing, 2019.
22. Emovon, Ikuobase, Oghenenyerovwho Stephen Okpako, and Edith Edjokpa. "Application of fuzzy MOORA method in the design and fabrication of an automated hammering machine." *World Journal of Engineering* 18, no. 1 (2021): 37-49.