A Review on Efficient Energy Consumption in Software-Defined Networking Using Routing Aware Protocols

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Abstracts: The concept of Software-Defined Networking (SDN) has been a fascinating and growing interest in the field of research. The programmable network component is allowed by the SDN's promising characteristics and partitions the control plane together with the forwarding plane. Energy Efficiency (EE) turned out to be a vital design requisite for modern networking mechanisms since the energy costs supply hugely to the entire costs in networks. Nevertheless, as it is necessary to handle the trade-off betwixt EE and Network Performance (NP), designing energy-effective solutions is non-trivial. Thus, by utilizing Energy-Aware Routing (EAR) approaches, this paper reviews the methodologies of Energy Consumption (EC) on SDN. The latest research related to the traffic-aware solution, compacting TCAM solution, end-host aware solutions, rule placement solutions, heuristic approach-centric solution, and EAR routing protocol was highlighted by this review article in terms of optimal EC on SDN. Finally, centered on the EC metrics, the current research methodologies' performance is assessed in the performance evaluation. By utilizing EAR routing, this type of research is helpful for future research in efficient EC in SDN.

Keywords: Software Defined Networking, routing aware protocols, efficient energy consumption, Ternary Content Addressable Memory.

1. INTRODUCTION

A novel networking epitome, which eases the usage of path-finding policies along with aids in accelerating network structure and its enlargement, is exploited by SDN [1]. In network design, operation, and management, they pave the way for novel opportunities when joined together [2]. The SDN hugely minimizes the communication overhead required to have a global view of network resources usage, which is a significant achievement. Moreover, the number of authorities is diminished by the SDN central control [3]. A centralized controller converts network management policies into packet forwarding rules together with employs them to network devices like switches along with routers in SDN. The forwarded rules are located in the local Ternary Content Addressable Memory (TCAM) that aids high-speed parallel lookup on wildcard paradigms, by every network device [4]. The expense and the EC will be higher when TCAM excels in packet processing. For instance, when weighed against Hash-centric match in Static-RAM, TCAM ternary match is 6 times more costly [5]. The system is decoupled into control and data planes by SDN. For recording the routing information for specific flows, a flow table is designed in either centralized or distributed manners in the control plane. The control plane can compute an optimal data path for either high-performance or green energy networking for various traffic patterns [5]. In Google, B4 is the architecture of data centers. It is designed on the basis of SDN [6]. Utilizing an abstracted symbolization of the network's low layers for higher-level systems along with applications is the other main feature of SDN [7]. For manipulating traffic flows in an extra sophisticated way, SDN empowers traffic engineering. The communication protocols should be suitable for the application and standardized to handle various sensors of different manufacturers for guaranteeing a proper working operation of the heterogeneous sensor networks [8]. Header, counter, and action are a few fields encompassed in the entry of flow tables that is hugely wielded. A lookup of the flow entries is conducted while a packet appears at a switch. While the header along with the counter of a network flow is changed for a few reasons like LB or rerouting, it is updated [9].

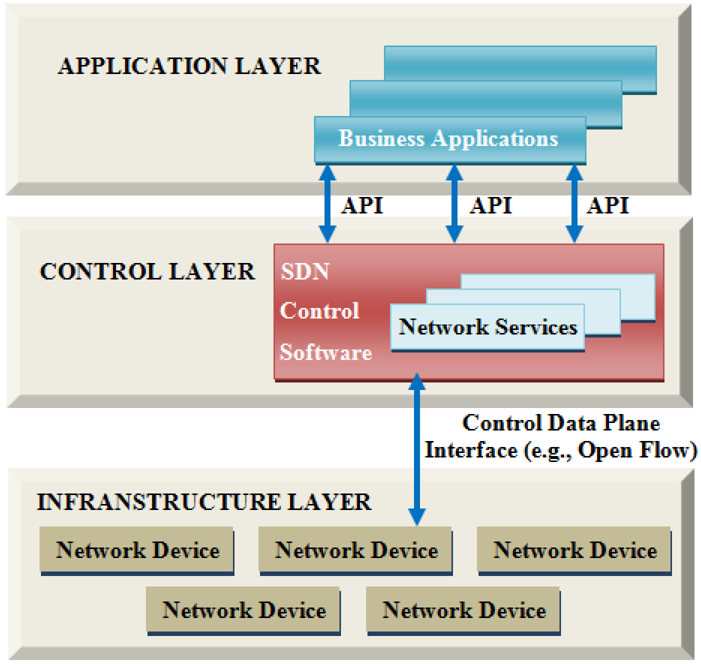


Figure 1. SDN architecture

The basic architecture of SDN that encompasses '3' layers is expounded in figure 1.

Infrastructure Layer: It is termed a data plane, which is the bottom or first layer. The traffic/data forwarding network elements are included in it [10]. Router, switch, and access points are some of the network devices that are included in the SDN layer. Here, virtual switches like Nettle, Indigo, Open Switch, Open Flow, and physical switches co-occur [11].

Control layer: It is the second layer. For continually adapting the state to comply with policies dictated by the administrator, the controller performs management-control functions upon the resources within its scope. For every customer, the satisfaction of contractual commitments is included, however possibly with prioritized rules for exceptional cases. The controller behaves appropriately when there is a difference by enforcing the optimization policies [12]. For handling the connection betwixt switches, handling errors and exceptions along with for determining the Quality of Service (QoS) for various kinds of packets, the control plane is responsible [13]. With the applications being above the controller in the application plane, the designed controller's operations such as managing, configuring along with monitoring will be automated by utilizing customized programming characteristics. The communication betwixt the controller and the application is denoted as northbound Application Programming Interface (API) [14]. For deciding the sophisticated network resource utilization techniques along with for optimizing the underlying network fabric as per the improving service requisites, Software developers could wield the higher level of network abstraction provided through the control plane [15].

Application layer: It is the third layer. By utilizing the protocols namely Application-Layer Traffic Optimization (ALTO) along with eXtensible Session Protocol (XSP)/eXtensible Messaging and Presence Protocol (XMPP) the SDN applications continually extracts information regarding global network condition through south together with northbound; in addition, to write different functional applications like security monitoring [66] [67], traffic engineering, energy-efficient networking, Path Computation Element (PCE), etc, it manipulates the physical Network Elements (NEs) utilizing higher-level programming languages [16]. The seamless mobility along with migration, server load balancing, and dynamic access control together with network virtualization could be encompassed in SDN application [17].

Easy network management, intelligence and speed, virtual application networks, and multi-tenancy are the main benefits of SDN [18]. Recently, the networking researchers' attention is attracted by the improving EC of communication networks. Here, flexible programmability that is appropriate for the power-consumption optimization problem is permitted by SDN [19]. Thus, by wielding EA routing the prevailing research methodologies under the optimization of EC of the SDN are surveyed.

The leftover section of the paper is given as: the prevailing top-notch techniques are expounded in section 2; the performance of the prevailing research system is evaluated in section 3; the conclusion is given in section 4.

2. RELATED WORK

In the SDN architectures' various components, the Energy Optimization (EO) can be implemented or else SDN itself can be wielded by way of ES. In SDN, Energy Saving (ES) might be dealt with algorithmically or else via hardware-centric developments. Software-centric solutions are implemented in the controller. Compacting TCAM, end-host aware, rule placement, and traffic-aware-centric are the '4' divisions introduced for achieving EE. With the heuristic system-centric EC and various EAR protocol-centric EC, the '4' divisions are explained here.

2.1 Traffic Aware Solution

In [20], introduced an MER-SDN, which is a machine learning technique for traffic-aware energy-effective routing in SDN. The '3' major phases of a learning machine are feature extraction, training, and testing. By real-world network topology along with dynamic traffic traces as of SNDlib experiments were carried out on Mininet and POX controllers. The feature size reduction and accuracy obtained by the methodology were more than 65% and 70% in the energy-efficient heuristics algorithm's parameter prediction; in addition, when analogized to the brute force methodology the prediction refine heuristics intersect sthe predicted value to the optimal parameters values till 25X speedup. However, the systems' performance might be affected due to the higher feature dimensionality.

In [20], recommended link utility-centric heuristic algorithms like Next Shortest Path (NSP) along with Next Maximum Utility (NMU) that was not just general inapplicability also balance the trade-off betwixt ES and performance. Regarding the link utility information, an Internet Protocol (IP) formulation was used for traffic together with the EAR fault. The algorithms are analyzed by real traces of lower, medium, higher traffic volumes along with network topologies. On account of path length, the suggested techniques surpass the prevailing solutions along with obtained up to 37% ESs. The values are selected randomly; hence, the EC might be increased.

In [21], developed a traffic-aware QoS routing scheme in the Software-Defined (SD) Internet of Things (SDIoT). When taking into account the QoS requisites of every packet, the greedy methodology was wielded centered on Yen's K-shortest paths for computing the optimal forwarding path. Similarly, the SDN controller employed sufficient flow rules at the forwarding appliances. The simulation outcomes showed that when weighed against the taken rules in the study, the end-to-end delay together with the flows' percentage, which violated QoS restrictions, were drastically diminished. When analogized to the prevailing SPD, LARAC along with MRC methodologies the system obtained 13%, 14% along with 15% for AttMpls topology along with 38%, 37% together with 39% for Goodnet topology specifically with 2000 flows. The flows given in the network were either delay- or loss-sensitive or together. But, it was expected that various heterogeneous appliances were involved in the large-scale network.

In [22], recommended an effectual routing algorithm for minimizing the cost centered on power consumption found by several active OpenFlow switches in an SDN whilst satisfying Throughput (Tp) requirements of every flow as per constraints on link capacities. For various network topologies in enormous scenarios, the algorithm's performance was examined centered on the number of active switches. However, the number of parameters was lesser; thus, it was not effectual.

In [23], introduced an EE optimization framework on the basis of traffic prediction in SDN, targeting to minimize network EC whilst guaranteeing communication quality. Initially, for getting the network traffic's temporal features along with offering a data base for the employment of ES strategies, a real-time traffic prediction mechanism was designed centered on a gated recurrent unit neural network of deep learning. Next, for balancing flow demand and

EC along with for obtaining Load Balancing (LB) together with ES, a heuristic algorithm was wielded for EE optimization. At the end, via Ryu controller, Mininet, and TensorFlow, a simulation was conducted. Experimental outcomes revealed that regarding the overall EC, the algorithm attained about 47.71% reduction with good network LB. However, the system was not reliable.

Table 1. Surveys the existing traffic-aware based energy efficiency SDN methods

Reference	Method	Purpose	Result	Limitation
[24]	A Mixed-Integer Programming (MIP).	For optimizing the network devices' power consumption through Energy-Aware (EA) traffic engineering.	For the fully wielded leaf and spine topology, the traffic steering was ensuring those ES even for higher workloads achieving 50%.	Hence, the MIP algorithm was intricate.
[25]	A novel routing strategy, combined taking into account QoS needs and energy awareness.	For minimizing the power consumption without Performance Degradation (PD).	Simulation outcomes verify the performance improvement on critical network parameters.	Diminishing the number of active network elements was not reliable.
[26]	A fast heuristic algorithm is termed Hybrid EA Traffic Engineering (HEATE).	For EC.	In EE, the algorithm obtained a major development.	If the weight link's weight value was higher then, it gives the packet drop thus it might affect the system performance.
[27]	Optimal topology composition along with traffic LB.	For decreasing the Data Center Network's (DCN) power consumption.	When compared with a static routing scheme the technique was minimized to about 41% for DCN and about 60% on average for Maximum Link Utilization (MLU).	The outcome was only confirmed with the specified data.
[28]	'4' diverse Strategic Greedy Heuristics that could be effectually implemented in large-scale networks.	For minimizing EC in terms of the present traffic load.	The outcomes showed that in the night time, it saved up to 45% of the EC.	For a higher fluctuating or slowly changing traffic, the safety margin for the maximal link bandwidth wants to modify correspondingly.

The examination of the prevailing traffic-aware solution of the SDN EE is illustrated in table 1. Here, the methodology, purpose, result, and disadvantages are depicted. However, there were enormous disadvantages. Table 2 displays the different existing research methods in the compact of TCAM in SDN EE.

2.2 Compacting TCAM solution for SDN

Table 2. Analysis of the existing solutions by the compacting TCAM of SDN

Reference	Method	Purpose	Result	Limitation
[29]	Tag-centric Rule Placement Scheme (TRPS).	For enhancing the NP.	When compared to the prevailing hybrid routing solutions the hybrid routing algorithm maximized network Tp by about 43%.	Time complexity was not superior.
[30]	Compact TCAM methodology with the shorter tags.	To reduce the flow entry size of TCM and shorter tags, compact TCAM is wielded for the purpose of identifying the flows.	For the provided number of flows, the experiments with real-world along with synthetic traffic depict an average reduction of TCAM power by 80% in SDN switching appliances.	To decrease the knowledge located in the flow table along with to complement other compression methodologies the method was utilized.
[31]	Heuristic routing algorithm with bandwidth assurance.	For increasing the entire network Tp, a bandwidth-gratifying path betwixt a couple of communication nodes was built and the chance of dismissing traffic demands was decreased.	Regarding the average rejection rate together with average network Tp under various network sizes, the techniques surpass other routing algorithms.	The convergence problem of the entire heuristic algorithm might influence the performance of the entire system.

[32]	Binary linear programming formulation.	Taking into account traffic demand along with rule space constraints, the number of network elements to be switched off is increased.	In carrier-grade networks, the methodology attained energy-efficient routing.	The transmission was delayed since no limits were set for the maximum length of paths.

2.3 Rule Placement

In [33], intended on utilizing SDN for EAR. EAR permitted putting un-wielded links into sleep mode for saving energy because traffic load had little influence on the power consumption of routers. SDN gathered traffic matrix; then, when being minimum in EC computed routing solutions satisfying QoS. Regarding ability limitations on links along with rule space constraints on routers, an optimization technique was used for reducing EC for a backbone network. A clear formulation was introduced by Integer Linear Program (ILP). Also, an effective greedy heuristic technique was developed. It illustrated that it was possible to save about equal power consumption as the classical EAR methodology with the smart rule space allocation centered on simulations. However, it might be complex because it was tackled with ILP and heuristic.

In [34], [35] recommended an SD-DCN related data centre EO with united contemplation of VM Placement (VMP) together with forwarding rule placement. SDN's inherent TCAM ability limitation feature was regarded particularly. The optimization issue was formulated as ILP. Also, a lower-complexity 2-phase heuristic approach was wielded. Nevertheless, the higher efficacy of the algorithm was examined by the Extensive simulation outcomes.

In [36], researched how to reduce the EC in SD-DCNs by electively activating the switches along with cautiously scheduled the Multi-Path Routing (MPR) as per the data center traffic demands. Particularly, the SNN's inherent feature (TCAM size constraint) was considered, and developed the issue into an ILP problem. For resolving the computational complexity, a heuristic minimum switch activation MPR was wielded. The algorithm's higher EE has been proven due to the fact it discovered a near-optimal solution whilst having a need for lesser scheduling time via extensive simulations. However, it might take a long time or induce the packet to drop, if the selected path was a longer length.

In [37], suggested a Multi-Objective (MO) Genetic Algorithm (GA) for EE and Rules Reduction (MOGA-E2R), which conjointly secured the EC issue along with TCAM size disadvantages in SDN networks. Simulations on an actual network illustrated that power-saving achieves 20% at non-peak TM together with atmost TCAM usage at 5%; the system surpassed other current methodologies. However, the performance of the entire system might be affected since the searching ability of the GA was not better.

In [38], examined an Intelligent Rule Management Scheme (IRMS) that investigated the one-big-switch method along with deployed a hybrid rule management technique. Initially, every rule was transformed into path-centric rules. While the paths for flows were chosen at the network's edge switches, the path-centric rules were pre-installed. Path-centric rules were updated entirely along with a lazy update policy was deployed for sustaining the forwarding paths' consistency. By an intelligent partition algorithm, node-centric rules were optimally divided into disjoint chunks and arranged hierarchically in the flow table. The methodology was analyzed by comprehensive experiments. The flow entities and the update time were minimized by IRMS on an average of 59.9% and 56% respectively. Nevertheless, the flow setup request was also diminished by more than one order of magnitude.

2.4 End Host Aware Solution

In [39], intended on the discrete data rate of the link for minimizing EC in the network. The underutilized links even functioned at a higher data rate that raised EC in wired networks. The links should be functioned according to the utilization factor for diminishing the network's EC. For checking the NP, an output buffer queue with '2' levels of threshold values was utilized. Without majorly affecting the Tp, the system results in a huge amount of ES.

In [40], introduced a developed Virtual Machine (VM) placement device termed EE and QoS aware VMP (EQVMP) for surpassing the issue of unbalanced traffic load in switching on together with off VMs to save energy.

Hop reduction, ES, and LB were the ‘3’ key methodologies jointed by EQVMP. Hop reduction could reorganize VMs to reduce the traffic load amongst them. For selecting the suitable servers, ES methods were presented. VMP was updated regularly by load balancing. The EC was minimized and QoS was maintained. The introduced methodology improved system Tp by 25% along with had an enhanced evaluation score when analogized to other prevailing placement policies.

In [41], suggested an optimal resource allotment along with a consolidation VMP scheme for multi-tier applications in modern large cloud Data Centers (DCs). Via SDN control features, it focused to optimize the DCs' energy together with communication costs that influenced the entire cloud performance. An adaptive GA was wielded for resolving the examined MO optimization problem. The techniques’ efficiency was verified by synthetic and real workload traces via extensive simulations. The EC and the cloud QoS were jointly optimized.

Table 3. End host aware solutions of the existing research methodologies

Reference	Method	Purpose	Result	Limitation
[42]	Novel algorithms with united host-network power scaling.	For lessening the EC.	When analogized to the benchmark algorithm, which merely reduced migration evade of ensuring the low power consumption, experimental outcomes depict that the algorithm minimized power consumption by 11% whilst completing betwixt 18 to 25% more VM migrations.	Features were not sufficient.
[43]	The algorithm wielded one or more centralized controllers.	For enhancing the NP and optimizing EC.	The methodology expounded that for ES, 87.5% of ports along with 33.33% of links were turned off.	The mathematical model consumes more duration.
[44]	Lion optimization algorithm.	It was facilitated to maintain future network functions and intelligent applications together with packet optimization.	Compared to the current research works the approach provides enhanced outcomes.	Poor performance was caused by the premature convergence in the Lion optimization algorithm. A strategy that doesn’t reduce the search space was required and returned to the actual search space after a prolonged period.
[45]	VM migration’s Integration mechanism centered on a mixed-single parent genetic algorithm.	To control EC.	The VM and the integration problems were resolved by the algorithm and it was enhanced when compared to the present methodologies.	Still, the complexity time of the algorithm was higher.
[46]	A unified solution joining ‘2’ strategies that were flow migration and VM migration.	For reducing the energy and increasing the Tp.	On average with just 2.2% energy overhead, the methodology increased the Tp by 42.5%.	It didn’t tackle flow control that might affect the system’s performance.

Various solutions under the end host awareness of the SDN EE system are expounded in table 3.

2.5 Heuristic Approach Based Energy Consumption

In [47], introduced a Priority-centric Energy-effective, Delay and Temperature Aware Routing Algorithm (PEDTARA) by a hybrid optimization of MO Genetic Chaotic Spider Monkey Optimization (MGCSMO). Primarily, the patient Data Transmission (DT) in the WBAN was divided into normal, on-demand together with emergency DTs for the prioritized routing procedure. For normal data, high priority critical data, and on-demand data the PEDTARA performed optimal shortest path routing, energy-effective emergency routing, and faster, but precedence verified routing respectively. Hence, congestion-controlled, energy-effective together with delay and temperature-aware routing were guaranteed at any provided health monitoring period. Experimentations were executed above higher-performance simulation circumstances. With regard to temperature, congestion, energy, delay, and Network Lifetime (NL), this system performed effectual routing enhanced compared to traditional methodologies. However, environmental factors and mobility problems were introduced.

In [48], suggested optimizing EE of QoS-centric Routing in SDN. (A): formally determined the Routing

Optimization (RO) crisis in SDN under multiple QoS limitations, (B): developed a RO that enhanced the traditional Shuffled Frog Leaping Algorithm (SFLA) was the ‘2’ key phase. To implement the current RO algorithm in an SDN surrounding, a two-phase procedure was introduced. When weighed against the state-of-the-art solutions it gave the outcomes by Mininet simulation framework that confirmed the benefits of the current QoS RO algorithm. However, the premature convergence problem in SFLA might affect the system’s performance.

In [49], intended an optimal combined route selection and flow allocation methodology centered on which, it implemented network virtualization technology along with wielded virtual network architecture. It developed the entire EC of user flows together with created an optimization issue that reduced the EC, exposed to DT and flows’ service limitations collectively taking into account various user flows’ transmission performance along with stressing the EC’s significance at transmission links and switches. It is transformed into a minimal-cost commodity flow crisis along with resolved the fault by an N-algorithm since the developed optimization error is an NP-complete crisis that could not be handily resolved. But, the efficacy was illustrated by the numerical outcomes.

In [50], recommended a fresh clustering, by a Whale Optimization Algorithm (WOA) centered on the SDN paradigm. The sensor resource restrictions along with the node densitys’ random diversification were considered in the geographical area. As per the node density in each Virtual Zones (VZ), it starts by categorizing the SDN controller into VZs for balancing the number of cluster heads (CHs). Next, for defining the optimal set of CHs, the WOA, which considers communication cost, residual energy together with node density was utilized. The protocol had increased NL and ended up in effective energy dissipation. Moreover, when weighed against traditional protocols and an optimization-centric routing protocol, it had improved the number of packets transmitted to the sink by almost 55% and 20% respectively.

In [51], introduced a hierarchical cluster-centric routing system by Lion Optimization (LO). By the LO algorithm, the sensor nodes were clustered along with the routers were determined to send data. Regarding average latency, packet delivery rate, EC, and NL, the NP was evaluated. Compared to the prevailing methodologies this system showed enhanced outcomes. At the end, with the SDN-centric routing optimization, the Quality of Services (QoS) was improved. However, the system’s performance might be affected as the exploration searching ability was not good.

In [52], intended on scheduling algorithm-centered SDN architecture. Initially, the SDN architecture was presented. Next, an SDN-centric adaptive Multi-Path (MP) LB was employed. Lastly, for analogizing the algorithm’s performance and the traditional equal-cost MPR, it was simulated on the Mininet simulation platform utilizing Ryu as the controller. In the network data traffic allotment scheduling, the algorithm had increased Tp, high bandwidth usage along with short transmission time, resulting in an effective reduction of network congestion together with guaranteeing the network’s reliability. In the network data traffic allocation scheduling, the study confirmed the efficacy of the technique. For the SDN architecture-centric allocation scheduling's additional application, provided a few theoretical bases.

Table 4. Survey on the heuristic approach based energy consumption on SDN

Reference	Method	Purpose	Result	Limitation
[53]	A minimal graph-centric Ant Colony Optimization (ACO) methodology was wielded.	For minimizing the network EC.	When compared to the state-of-art techniques 20% of EC performance was maximized with the aid of the ACO.	Since the investigation was conducted by a lesser number of traffic patterns, thus it was not reliable.
[54]	MO Particle Swarm (PS) Optimization (MOPSO) algorithm.	For optimizing the link weight for path cost together with LB.	Regarding network resources usage, LB, and maximum link usage, the algorithm-centric system achieved enhanced performance.	The packet dropping might take place because it didn’t consider an optimal path.

[55]	MOPSO	For dynamic traffic demands, it distributed optimal paths. Idol switches and links were made into sleeping mode.	About 30 % of energy is saved by the MOPSO. With acceptable computation time kept Maximum Link Utilization (MLU) under 50 %.	The PS had a local optimum problem, which might affect the system's performance.
[56]	PS Optimization–centered and Power-Effective Routing (PSOPR) heuristic was utilized.	To power-efficient routing.	The optimality gap (fault) minimized with the increase in the number of particles is illustrated by the performance assessments.	The routing was not optimized by the algorithm.

The prevailing research techniques centered on the heuristic approach in SDN for EC are depicted in table 4. The disadvantages of those methodologies are evaluated. However, the algorithm-centric techniques have convergence and local optimum problems.

2.6 Energy-Aware Routing Protocol Based Routing Strategy in SDN

In [57], introduced a segment routing approach jointed with MPTransmission Control Protocol (MPTCP) traffic that ends up in an effectual routing approach. For obtaining Tp maximization via preserving link residual capacity together with proper usage of links, a segment routing-centric EAR approach for an SD data center was intended. Moreover, in terms of maximum segment label depth, the system showed a reduction in the segment label stack's length. With the EAR approach in distributed surroundings, evaluation was carried out by analogizing the performance of other prevailing methodologies in a single-controller environment. The network was saved from a single point of failure by the distributed controller setup. Thus, it aided to save controller overhead along with offered developed NP via Tp.

In [58], [59]recommended a Smooth EAR (SENAtoR) for guaranteeing EAR in a circumstance of progressive migration as of legacy to SDN hardware. SENAtoR offered enormous characteristics to securely guarantee ES services like smooth node disabling, tunneling for fast rerouting along with detection of traffic spikes and link failures; while normally, turning off-network appliances was a fragile task since it led to packet losses. Through extensive simulations and experimentation, it examined the solution. In a network, SENAtoR was continuously employed by the SDN paradigm. When weighed against legacy protocols it permitted in reduction of EC of ISP networks by 5 to 35% relying on the penetration of SDN hardware whilst minimizing the Packet Loss Rate (PLR).

In [60], introduced an SD wireless sensor framework, whilst the network was categorized into various clusters otherwise zones along with every zone were controlled by an SDN controller that was aware of the topology in that zone. In SD-EAR, the route requests' transmission was entirely eradicated. The optimum route selection was energy effective. The asleep grant mechanism was wielded, which permitted nodes to head for sleep devoid of hampering live communication sessions. Hence, the EC was hugely decreased along with the number of alive nodes and NP was maximized.

In [61], recommended an EA dynamic routing methodology for resolving the link load-balancing issue whilst decreasing power consumption by the MO Artificial Bee Colony (MOABC) along with genetic operators. When compared to the primary genetic-ant colony, basic-ant colony, and round-robin methodologies this system had shown maximized PLR, round trip time together with jitter metrics. Besides, the EC was less.

In [62], presented a fresh routing decision technique that utilized a fuzzy-centric Dijkstra's Algorithm (DA). During DT, which was the main factor of the approach and was obtained via the adoption of the SDN model, the architecture changed the prevailing path. For a more realistic performance appraisal, every component and algorithm was modelled along with simulated by the Riverbed Modeler software. Regarding EC ratio, the SDN-permitted structure with fuzzy-centric DA surpassed the one by the regular DA and the ZigBee-centric counterpart. Whilst extending the NL, the architecture offered an effective cluster routing.

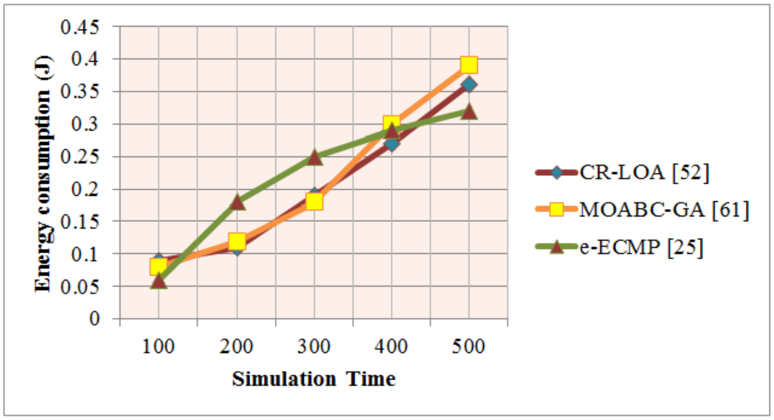
Table 5. Analysis of existing energy-aware routing protocol of the SDN

Reference	Method	Purpose	Result	Limitation
[63]	EA multi-hop routing protocol called EASDN	To improve EC.	The experimental outcomes depict that when analogized to the prevailing energy effectual routing protocol for SDWSN along with a traditional source routing technique, the system achieves promising outcomes regarding NL, average EC, the packet delivery ratio, and average delay.	Only with the small scale ratio, the methodology was only tested.
[64]	The ratio for ES in RESDN (Software Defined Network).	Centered on link utility intervals, the technique quantified the EE.	In ES, power saving, and link saving, the RESDN obtained a better ratio of 30%, 14.7 watts per switch, and 38% respectively; in addition, in average path length, reduced 2 hops along with maximized traffic proportionality by 5%.	The methodologies efficacy was directly affected by the utility interval parameters.
[65]	Ambience Awake location-based routing protocol.	To manage mobility and gateway functions.	When compared to the prevailing routing solutions this system running on top of the decentralized SDN controller proved to be 19.59% highly effectual.	It was intricate.
[68]	Time Efficient EAR (TEAR).	Time-effectual EAR in SDN-enabled networks.	The outcomes proved that the number of wielded links was promisingly decreased by the TEAR and also surpass the other methodologies in computation time.	It was not reliable.
[69]	EA SDWSN routing aims to lengthen the NL till the initial node falls owing to energy depletion.	For balancing the EC across the WSN together with minimizing the packets count flowing thereon.	When analogized to the standard shortest-path algorithm, the methodology lengthens the WSN's NL by 6.5% on average. While sustaining a higher packet delivery ratio, the control overhead was decreased appropriately by 12%.	Still, there is an issue in EC because the protocol hadn't resolved the issue entirely.

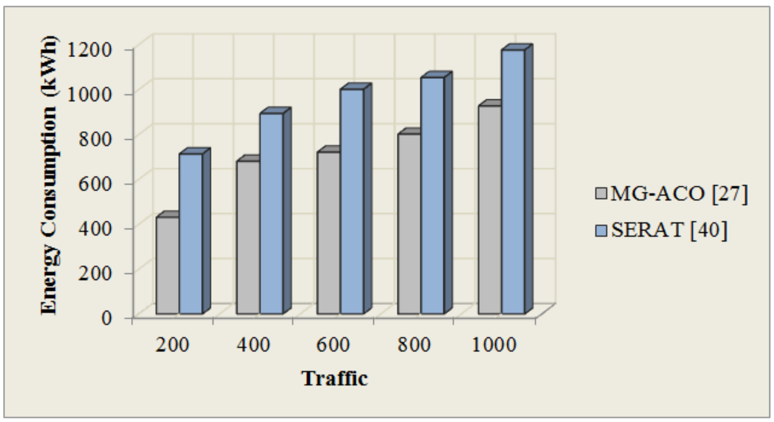
The state-of-art approach and its outcomes along with limitations of the EAR protocol-centric EC in SDN are expounded in table 5.

3. PERFORMANCE ANALYSIS

Here, in terms of simulation time with the EC, the performance of the prevailing research techniques like Cluster-based Routing by Lion Optimization Algorithm (CR-LOA) [51], MO Artificial Bee Colony – Genetic Optimization (MOABC-GO) [61], and e-Equal Cost MP (e-ECMP) [23] is evaluated. Next, regarding EC and traffic, the minimal Graph-centric Ant Colony Optimization (MG-ACO) [25] algorithm, and SERAT [39] are analyzed.



(a)



(b)

Figure 2. Energy consumption analysis

The EC evaluation of the prevailing research methodologies is depicted in figure 2. Regarding time, the EC is evaluated in Figure 2 (a), where CR-LOA obtains enhanced EC analogized to prevailing techniques. Regarding traffic, the EC is evaluated in Figure 2 (b), where SERAT obtains enhanced EC. Hence, it expounds that the optimization methodology provides enhanced performance.

4. CONCLUSION

In the deployment and operation of current data networks, EC is a key concern for which SDN turns out to be a propitious substitute. These methodologies might cause PD while QoS requirements are rejected, even though enormous works have been proposed to enhance EE. To optimize the EC of the SDN, various researchers have designed a lot of systems. With respect to optimal EC on SDN, this research highlights the recent research on the traffic-aware solution, compacting TCAM solution, end-host aware solutions, rule placement solutions, heuristic approach-based solution, and EAR protocol. Regarding EC, the performance of the prevailing research techniques is analogized. By the variation of ‘2’ scales (i.e. traffic and time), the EC is evaluated. The optimization algorithm-centric EC along with the system has developed techniques in both the comparison; thus, it attained enhanced performance. Hence, this review article recommends the advanced method-centric EC that provides optimal outcomes. For carrying out further research on the EC of SDN, this review is beneficial.

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