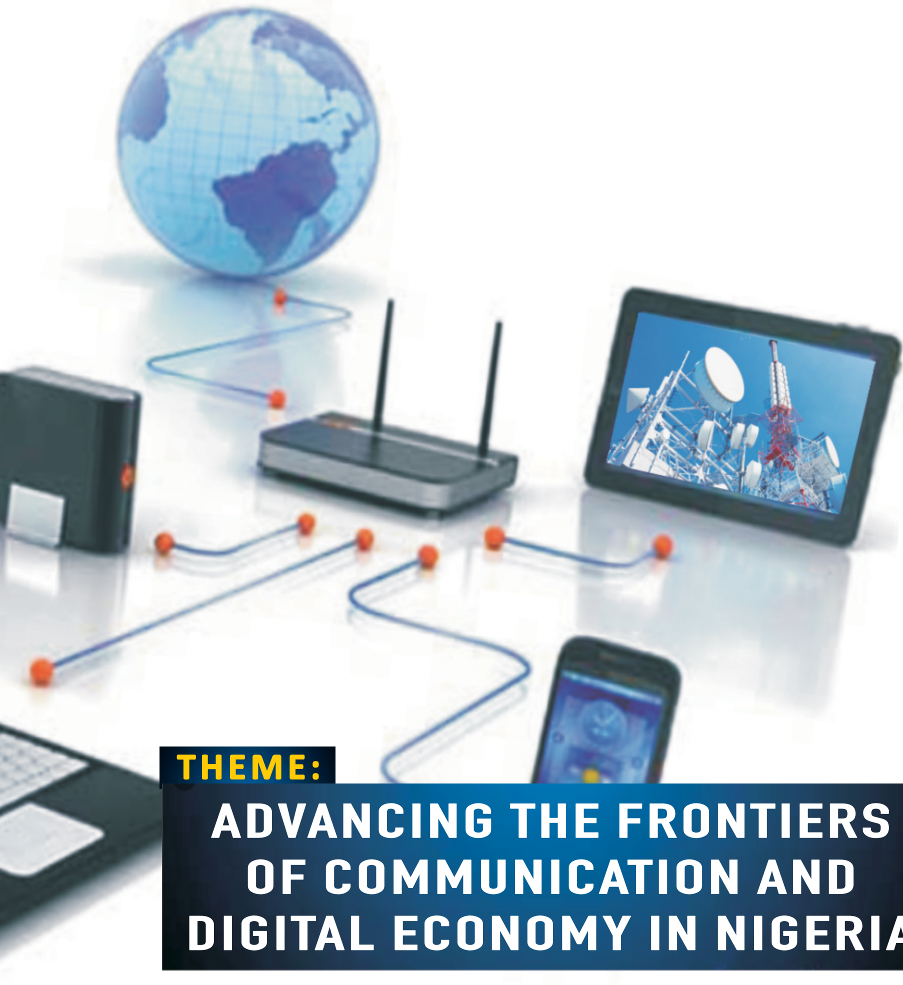
The Nigerian Society of Engineers

in collaboration with

THE FEDERAL MINISTRY OF COMMUNICATIONS AND DIGITAL ECONOMY

Presents

2022 NATIONAL ENGINEERING CONFERENCE, EXHIBITION AND ANNUAL GENERAL MEETING



THEME:

ADVANCING THE FRONTIERS OF COMMUNICATION AND DIGITAL ECONOMY IN NIGERIA

Programme of Activities

International Conference Centre, Abuja.

14th - 18th November, 2022

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OPENING CEREMONY PROGRAMME

Venue: International Conference Centre, Abuja
Date: Tuesday, 15th November 2022

8:00am - 6:00pm	- Registration
9:00am - 9:40am	- Arrival of Engineers and Guests
9:40am - 9:45am	- Arrival of NSE President, **Engr. Tasiu Gidari Sa'ad Wudil, FNSE** & Members of the Executive Committee
9:45am - 9:50am	- Arrival of the Special Guests of Honour
9:50am - 9:55am	- Arrival of the Chief Host, Honourable Minister of FCT, **Muhammad Musa Bello**
9:55am - 10:00am	- Arrival of the Distinguished Guest of Honour, **President Muhammadu Buhari, GCFR**
10:00am - 10:03am	- National Anthem
10:03am - 10:05am	- Opening Prayer
10:05am - 10:15am	- Recognitions
10:15am - 10:25am	- Welcome Address by Conference Planning Committee Chairman **Engr. Etido Inyang, FNSE**
10:25am - 10:30am	- NSE President's Opening Remarks
10:30am - 10:40am	- Keynote Address by **Prof. Isa Ali Pantami,** Hon. Minister of Communications and Digital Economy
10:40am - 11:20am	- Honorary Fellowship Conferment Ceremony **Mr. Kola Adesina MD, Sahara Energy Group**
11:20am - 11:30am	- Presentation of Special Awards
11:30am - 11:45am	- Interlude for Photographs
11:45am - 11:55am	- Goodwill Messages
11:55am - 12:00pm	- Address by the Distinguished Guest of Honour
12:00am - 12:05pm	- Vote of Thanks by the Executive Secretary, **Engr. Joshua Egube, FNSE**
12:05pm - 12:10pm	- National Anthem/ Closing prayer
12:10pm - 12:15pm	- Tour of Exhibition led by Distiguished Guest of Honour and Chief Host
12:20pm	- Refreshment and Lunch Break

SPOUSES' PROGRAMME

THEME: THE ROLE OF WOMEN IN SUSTAINABLE HOUSE HOLD WASTE MANAGEMENT

Order of Event

Day One:	**Monday 14th November, 2022**
6:00am – 8:00am	Arrival / Registration at Nigeria Society of Engineers HQ, Abuja.
11:00am – 1:00am	City Tour
1:30pm – 3:00pm	Spouses' Picnic at Millennium Park
6:00pm	Presidential Cocktail at the NSE, Headquarters, Abuja
Day Two:	**Tuesday 15thNovember, 2022**
6:00am – 8:00am	Registration at Nigeria Society of Engineers HQ, Abuja.
9:00pm – 12:00noon	Opening Ceremony at the International Conference Center, Abuja.
12:00noon – 1:00pm	Spouses converge at NSE Headquarters (Dancing and Networking)
1:00 - 1:15pm	Welcome Address by the Chairperson of Abuja Branch Engre's Oluchi Nwamaka Okoh
1:15pm – 1:45pm	Reception and Lunch at the NSE Headquarters, Abuja
1:45pm – 2:15pm	1st motivational talk. (Letting go negative thoughts to be a strong woman by Aisha Adaviruku
2:15pm—2:45pm	National executive and all Branch chairpersons meeting
3:00pm – 3:40pm	Goodwill Messages
3:40pm – 4:00pm	Music/ Visit to Spouses' Exhibition Stand
7:00pm –	Welfare / Student Night
Day Three:	**Wednesday 16thNovember, 2022**
8:00am – 8:30am	Arrival of Spouses to venue at (NSE Headquarters, Abuja)
9:30am – 9:45am	Welcome Address by President of NSE Spouses' Forum HAJIA UMMAH GARBA WUDIL.
9:45am – 10:45am	Lecture on **THE ROLE OF WOMEN IN SUSTAINABLE HOUSEHOLD WASTE MANAGEMENT** by Engr. Maimuna Abdulsalam Yakubu (FNSE)
10:45am – 10:15am	motivational talk (Building Resilience through self-confidence for aspiring women leadership by Olayode Abdulrazaq (philosopher king)
10:20am- 11:40am	2nd lecture on PROPER WASTE DISPOSAL by Engr. Linda Bitrus Elesa (MNSE, FNIEE, FNIWE)
11:40am – 1:00pm	Branches Presentation
1:00pm – 1:30pm	Lunch
1:30pm – 2:15pm	Awards Presentation
2:15pm – 3:00 pm	Goodwill Messages from Past Presidents
3:00pm – 3:45pm	Dance! Dance!! Dance!!!
3:45pm – 4:00pm	Closing Prayer
7:00pm	Cultural Night at International Conference Center, Abuja
Day Four:	**Thursday 17th November, 2022**
6:30am – 7:00am	Arrival of Spouses to venue at (NSE Headquarters, Abuja)
7:00am – 9:00am	Walk for spouses
9:00am- 9:15am	Refreshment
9:15am – 9:45am	Health talk: How to use food as medicine to prevent/manage chronic diseases by Engre's Olushola Ijirotimi
9:45am – 10: 15 am	Motivational talk. The gift of Imperfection, Embracing our uniqueness by Mrs. Frances Ndu
10:15am- 10:30am	Vote of thanks by Mrs. Juliana Atume (VP.NC)
11am	Shopping Time
7:00pm	Dinner at the International Conference Centre, Abuja.

SCHEDULE OF TECHNICAL SESSIONS

WEDNESDAY 16TH NOVEMBER, 2022

2:30pm – 4:30pm

THIRD CONCURRENT SESSION

Venue: Executive Hall, International Conference Centre, Abuja

TECHNICAL SESSION H

THEME FOCUS: **POLICY AND STRATEGY TO DEPLOY NNBP FOR THE ADVANCEMENT AND SUSTENANCE OF DIGITAL ECONOMY IN A DISTRESSED ECONOMY**

Chairman: **Engr. Dr. E. J. S. Uujamhan, FNSE**
Past President, Nigerian Society of Engineers

Speakers/Paper:

Paper H1: Energy Efficiency in Software Defined Networking (SDN)-Based Iot Networks: A Review
Bello E. Abdulwahab, Suleiman Zubair, Achonu Adejo, Salihu Bala, Attah Benjamin

Paper H2: Design and Analysis of a Grid -Tied Photovoltaic System for Enhanced Power Supply in Owerri Municipal Using Bluesol
Okwe Gerald. I., Okafor I. F., Offiah S.U. and Okebaram P. N.

Paper H3: Unlocking Programming Skills in Nigerian Youths Through Software Development in Local Languages Arthur
Ibukunoluwa Arokhamoni, Joel Ogunyemi and Isa Hassan Usman

Paper H4: Digitalizing Agricultural Field Operations for Recovery of a Distressed Economy: Potentials And Prospects
J. C. Adama, D. U. Udo, T. S. Tehinse and C. A. Ezeaku

Paper H5: Implementation Of Telecommunication Corridor On Infrastructure Roll Out (Rail, Road, Powerlines And Inland Waterways) To Fast Track Broadband Penetration And Nation-Wide Surveillance
Lasisi Salami LAWAL, Sa'ad Gidari-Wudil TASIU , Francis Ayomide ADEDEJI

Rapporteurs:

Engr. Prof. O. A. U. Uche, FNSE
Engr. Prof. James Akanmu, FNSE
Engr. Joshua Aboyeji Adeoye, FNSE
Engr. Dr. Ukamaka Josephine Eze, MNSE

The Nigerian Society of Engineers

announces the

2023 NATIONAL ENGINEERING CONFERENCE EXHIBITION AND ANNUAL GENERAL MEETING

"ABUJA 2023"

THEME:

"RE - ENGINEERING THE MANUFACTURING SECTOR FOR COMPETITIVENESS AND ENHANCED GROWTH"

DATE:

20th - 24th November, 2023

VENUE:

International Conference Centre, Abuja

Mark Your Diary Now!

ENERGY EFFICIENCY IN SDN-BASED IOT NETWORKS: A REVIEW

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ABSTRACT

The Internet of Things (IoT) is a new paradigm that intends to connect all intelligent physical things to the internet so that they can work together to offer intelligent services to users. Some of the IoT applications include smart retail, smart cities, smart metering, smart grids, smart wearables, etc. Since IoT devices are growing explosively in number and are characterised by resource constraints and heterogeneity, managing IoT systems has become a problem. Software Defined Networking (SDN) is a new paradigm deployed in IoT networks as a management solution for achieving agile, flexible, and sustainable IoT systems. Energy is a major concern in SDN-based IoT networks since IoT devices are resource-constrained. This review examined the state-of-the-art contributions on energy efficiency in SDN-based IoT networks, the gap, and proposes future research directions.

Keywords: Internet of Things, IoT networks, Software defined networking, Energy efficiency, Resource constraints, Heterogeneity

1.0 INTRODUCTION

Internet of Things (IoT) is a paradigm where the physical objects of our daily life (e.g., sensors, actuators, home appliances, and so forth are connected to the Internet and can communicate in an intelligent fashion [1], [2]. IoT aims at making our daily life more agreeable, more connected, and more productive. Due to its unique capabilities and characteristics, IoT has been successful in influencing different aspects of human life. Today, billions of devices cooperate with each other and provide different services to play a remarkable role in making human life smarter and improving the way people interact with the environment and their surrounding objects. Statistical research estimates that there will be around 75.44 billion connected devices worldwide in 2025 [3]. The communication horizon between all physical items is expanded by modern technology innovation and communication network evolution [4]. It is therefore difficult to control, monitor, and safeguard IoT devices across numerous networks due to the large growth in IoT devices, which is a major problem for research facilities and businesses.

The recent technological advances in low-power devices contributed to fostering the development of IoT applications ranging from smart healthcare, smart agriculture, smart transportation, smart grid factory of the future, and so forth. Nowadays, IoT environments are characterised by the presence of many heterogeneous and resource-constrained devices often massively deployed in an area of interest to enable an IoT application. Massive scale, along with other characteristics such as rapid growth, heterogeneity, noisiness, and diversity make IoT data different from normal big data gathered by other networks [5]. The extreme diversity of IoT devices has made managing, securing, processing, storing, and analyzing such big data more difficult and complex tasks to achieve. Current state-of-the-art architecture for IoT devices is not capable of supporting features like mobility, higher scalability, and heavy traffic all at the same time along with the above-mentioned functionalities.

Software Defined Network (SDN) and IoT are two emerging technologies. The IoT aims to connect objects over the Internet and the SDN provides orchestration for network management by decoupling the control plane and the data plane [6]**.** Recent research endeavours are blending SDN architectures with IoT technologies forming a new approach called Software-Defined Internet of Things (SD-IoT). Therefore, SD-IoT is proposed for efficient IoT data collection, transmission, and processing. SD-IoT paradigm brings new prospects to IoT architecture, control, management, and operation with programmability features allowing efficient and adaptable network protocol operation to the specific requirement of IoT applications [7]. The centralised control for real-time flow management and the overall network view for greater reliability offered by SDN are needed to

SD-IoT is a disruptive technology in many aspects of our society that has attracted a lot of attention these recent years from both researchers and industries. The energy consumption of ICT equipment and services is increasing due to the quick growth and spread of ICT [9]. However, little attention has been given to analyzing the trade-off between computing energy for large data processing (such as data aggregation and reconstruction) and communication energy for information forwarding to achieve overall energy efficiency. Therefore, minimizing the energy consumption in SDN-based IoT networks is crucial because ICT can control the rising energy demand by improving energy-use efficiency. We are therefore driven to investigate research on energy efficiency from many perspectives of SDN-based IoT applications. As a result, we offer an evaluation of energy efficiency in SDN-based IoT networks, identified the gray areas, and proposed future research directions.

This review aimed to focus on the most recent research studies, discoveries, and future research directions on energy efficiency in SDN-based IoT networks. This study categorically brought together different research studies and contributions on energy efficiency in SDN-based resource-constrained IoT networks, which answers the following questions:

1. IoT devices and network lifespan optimization
2. knowledge scope widening
3. Helping researchers discover future research directions in the research area.
4. Different reviews were carried out on SDN, SDWSN, and SDN-based IoT networks, but there have not been many reviews specifically on energy efficiency in SDN-based IoT networks to the best of our knowledge except this study, "A Survey on SDN based Energy-Efficiency Approaches in IoT" by ChaibAinou et al. [10]. Therefore, our review considered state-of-the-art research contributions needed for future research directions on energy efficiency in different SDN-based IoT networks, which is different from the approach used in [10].

The remaining part of the paper is structured as follows: Section 2 showcases some related review studies. Section 3 strictly reviews and criticizes different works on energy efficiency in SDN-based IoT networks, considering different types of IoT components such as M2M, IIoT, IoE, IoA, SIoT, WoT, etc. Section 4 contains limitations, open research issues, and future research directions, while Section 5 contains the conclusion of the study.

1.2 METHODOLOGY OF THE REVIEW

Another advantage of this review is that all the works of literature investigated were limited to the last five years to date, while those beyond five years were filtered and dropped. Figure 1 below shows the flowchart of the review methodology.

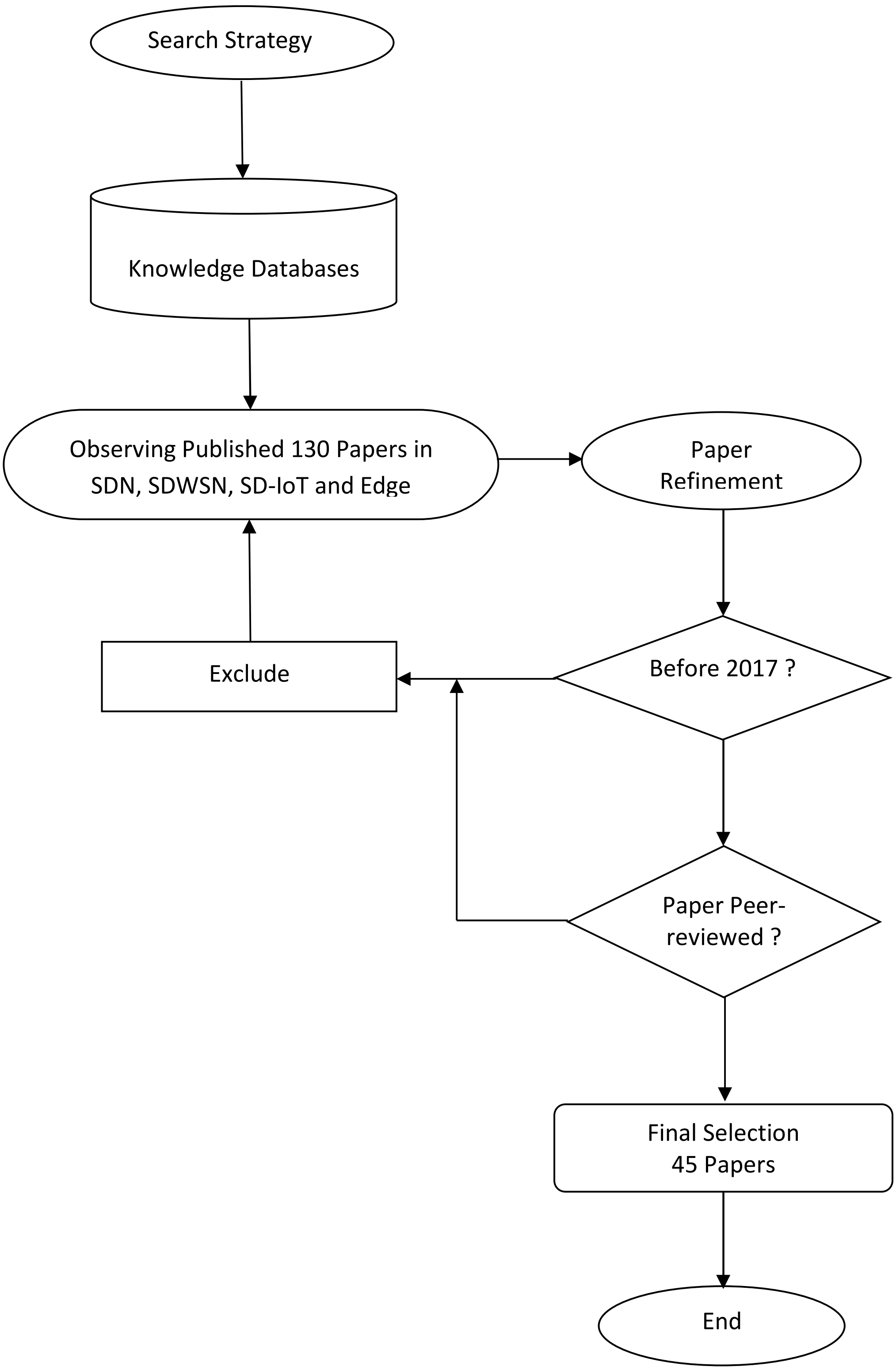

Figure 1: Paper refinement and selection flowchart

2.0 RELATED WORKS

In this section, we did a thorough literature review on reviews and other related works on energy efficiency in SDN-based IoT networks.

SDN is a novel paradigm we needed to explore, which led us to gather the following findings in this subsection. Kaur et al. [11] reviewed load balancing in SDN. They found out that SDN load balancing has become smarter, efficient, minimises the statistic collection overhead, and maintains better QoS data rates. Keshari et al.[12] did a systematic review of different controllers' performance based on certain QoS parameters such as reliability, scalability, consistency, and load balancing in SDN. The state of the art for SDN-enabled Wireless Mobile Backhaul (WMBH) architectures was reviewed by Do et al.[13] together with WMBH networking. The investigation of the SDN paradigm's use in WMBH networking, together with an analysis of its difficulties and potential solutions, was the review's main contribution from the authors. Singh and Behal[14] reviewed Distributed Denial of Service (DDoS) attacks detection and mitigation in SDN. The authors gave an overview of SDN layered architecture, its strengths to combat the problem of DDoS attacks as well as its vulnerabilities, and the possibility of new DDoS attacks instead of conventional DDoS attacks as research advances.

In this subsection, we extended our review to Software Defined Wireless Sensor Networks (SDWSN). Egidius et al. [15] reviewed existing works on the design and implementation of programmable SDN-enabled sensor nodes that enable rapid communication and responses between the data plane and control plane in SDWSN. Sharma et al. [16] reviewed the most recent and impactful works on performance improvement in heterogeneous Wireless Sensor Networks (WSN) through efficient routing algorithms. The paper provided wide coverage and discussed a variety of routing algorithms for different heterogeneous scenarios along with the key challenges and future research directions in WSNs. Letswamotse et al. [17] reviewed Quality of Service (QoS) provision in WSN specifically for mission-critical applications. The author's goal was to promote WSN applications and their implementations by streamlining QoS provision for restricted technology. To enhance network performance, they suggested SDWSN solutions for effective resource management and supported assured QoS.

This subsection contains the most recent review on IoT networks. First, Manocha and Kumar[18]reviewed so many works on security and energy efficiency in SDN-based IoT networks with an emphasis on security. The authors proposed a new IoT security model with SDN and blockchain called "Improving Spider Monkey Optimization Algorithm SDN Routing for IoT Security." In [1], Aboubakar et al. reviewed different perspectives on IoT network management, such as requirements and management solutions, and identified challenges for the efficient that exploit the synergies between SDN and EC in IoT networks, as well as issues, challenges, and solutions. Prabakaran et al.[20] did a holistic review of SDN-based next generation smart networks, where the authors pointed out the challenges to be improved upon. Filipe et al. [21] reviewed the evolution of conventional IoT architecture to SDN-based IoT architecture for better resolution of big data issues. They highlighted some open issues for future research directions toward resolving big data issues. Imran et al. [22] reviewed IoT leveraging SDN solutions to address security challenges, cost of hardware, centralisation, and resource management in the IoT environment. In the same study, the authors also reviewed IoT leveraging machine learning based SDN solutions for IoT applications. They exposed the limitations and promising research directions for research institutes and research groups. ChaibAinou et al. [10] in a study titled "A Survey on SDN-based Energy Efficiency Approaches in IoT," reviewed different approaches to energy-efficiency-based SDN in IoT considering the edge, the core backbone, and the data center layers separately. The authors examined, analysed, and compared recent works in each subsection of IoT architecture, according to the functional and relevant parameters of every IoT layer.

3.0 ENERGY EFFICIENCY IN SDN-BASED IOT NETWORKS

From the knowledge database, we have found this set of research works very relevant for review, and criticism.

3.1 Energy-efficient and SDN-enabled routing algorithm for wireless body area network

Cicioğlu and Çalhan[23] examined energy efficiency in Software Defined Wireless Body Area Network (SD-WBAN) architecture using the Fuzzy-based Dijkstra technique for path selection policies. In this study, the authors proposed an Energy-efficient and SDN-enabled routing algorithm (ESR-W) for the SD-WBAN. The proposed solution adopted the 802.15.6 standard with low energy consumption and unlimited data rate among other important features compared with the 802.15.4 standard which increases network performance more in the WBAN architecture. It was observed that ESR-W considered new metrics such as SNR, hop count, and battery level, which provided a lesser additional route discovery and more stable network connectivity whereas other literature considered transmission power, link distance, or remaining energy as metrics to determine the optimal path.

The experimental results showed that ESR-W outperformed the existing SDNRouting and AODV routing algorithms by using the real-time metrics to select paths with higher energy levels for optimal path decisions which aid a reducing overhead on coordinator nodes and lesser energy consumption.

3.2 Energy-Efficient Relay Selection-based Dynamic Routing Algorithm for IoT-Oriented Software-Defined WSNs

In this article, “Energy-Efficient Relay Selection based Dynamic Routing Algorithm for IoT-Oriented Software-Defined WSNs” published by Ding Z. et al.[24], a dynamic routing algorithm based on energy-efficient relay selection (RS) called DRA-EERS was proposed to adapt to the higher dynamics in time-varying IoT-oriented software-defined wireless sensor networks (SDWSNs). The authors investigated and modeled the time-varying features of SDWSNs from which the state-transition probability (STP) of the node was determined using the Markov chain. They first analysed the residual energy dynamics of the nodes based on a traffic model and proposed a dynamic link weight by jointly considering the link reward concerning the link energy efficiency (EE) and the node STP.

The result showed that DRA-EERS improved the energy efficiency as compared with Dijkstra’s shortest path algorithm while setting the adjustable coefficient ρ1 correctly was useful for the tradeoff between the energy efficiency and the throughput. Furthermore, the network size determined the complexity of DRA-EERS and its little impact did not compromise the effectiveness of the algorithm.

Therefore, it was a good idea that the authors used the MATLAB simulator to evaluate the performance of the suggested routing algorithm and verified the obtained results using the NS3 network simulator. The flaw in their approach was that they failed to include any of the state-transition probability matrices produced using a Markov chain in the course of their work.

3.3 SD–NFV as an Energy Efficient Approach for M2M Networks using Cloud–Based 6LoWPAN Testbed

Al-Kaseem and Al-Raweshidy[25] came up with Software Defined–Network Function Virtualization (SD–NFV) architecture as an energy-efficient approach for M2M networks in the cloud computing platform using 6LoWPAN testbed.

The authors implemented the proposed approach using an open-source hardware platform, an Arduino microcontroller board based on the ATmega328 chip. The Arduino board was chosen due to its low energy consumption, small size, cost-effectiveness, and programmability feature. The XBee module was deployed as a radio communication for MAC and PHY layers of the IEEE 802.15.4 standard. The proposed architecture used M2M sensor nodes with subsystems such as sensing, communication, computation, and power subsystems. The authors developed a customised SDN controller with C++ language and deployed it in the 6LoWPAN gateway. The Network Function Virtualisation (NFV) was used to migrate the network layer and adaptation layer from the node's protocol stack to the gateway protocol stack and merged them with the SDN controller. The virtualisation function called Sensor Function Virtualisation (SFV) transformed multiple node tasks into software packages inside the 6LoWPAN gateway. Accordingly, the 6LoWPAN gateway handled the 6LoWPAN coordinator for network initialisation, the two layers (network and adaptation layers) from the 6LoWPAN protocol stack, and the customised SDN controller. The developed 6LoWPAN testbed was integrated with a cloud computing platform to provide global access to the M2M sensor network.

The proposed approach was tested using a temperature and humidity sensor as a sensing unit for the M2M node transmitting the sensed data to the M2M gateway. The result showed that the implemented architecture achieved a 60% reduction in the node discovery time in the gateway compared to the traditional 6LoWPAN node discovery time and also achieved an improved network lifetime by 65% in comparison to the existing 6LoWPAN node joined by the traditional 6LoWPAN gateway or edge router. However, in this study, the authors restricted their work to a short running time by using an Arduino board that can only work for a day compared to other microcontrollers that can last months or years.

3.4 SDN-enabled Energy-Efficient Routing Optimization Framework for Industrial Internet of Things

In this study," SDN-enabled Energy-Efficient Routing Optimization Framework for Industrial Internet of Things," Naeem et al.[26] proposed a QoS-enabled efficient parallel routing optimization scheme, called SEQOS, for Industrial Internet of Things (IIoT) based smart health-care system using the SDN network paradigm that considers the diverse QoS requirements for medical applications.

The SEQOS is a fast parallel online routing optimization framework that dynamically optimised multi-constrained QoS parameters in IIoT by using the massive processing power of the graphics processing unit (GPU) to speed up the computational speed of the proposed heuristic. The proposed scheme takes care of heterogeneous requirements such as delay-sensitive, jitter-sensitive, loss-sensitive, or a combination of any QoS traffic types for smart healthcare flows. The proposed scheme used the Mininet network emulator, and POX controller on Nvidia GPUs implemented on the PyCUDA (API for python) to determine the shortest path in parallel on GPU.

The experimental results showed that the proposed work outperforms prior work in the aspect of different QoS parameters, computational speed, and rule-capacity constraints. The SEQOS scheme was found to satisfy the service level agreement (SLA) requirement, efficiently utilised the bandwidth and energy resources of the network as well as 8 times faster compared to current schemes, which is essential for the future generation of smart healthcare systems. The authors, therefore, hope to consider machine learning techniques such as deep reinforcement learning techniques for satisfying the QoS of the network in their future work.

3.5 Energy-efficient clustering and routing algorithm for large-scale SDN-based IoT monitoring

In another study titled, "Energy-efficient clustering and routing algorithm for large-scale SDN-based IoT monitoring," a two-level control mechanism called Software Defined Multi-Hop Clustering RPL (SD-MHC-RPL) was proposed for an energy-efficient large-scale SDN-based IoT monitoring by Ouhab et al.[27].

The first level comprised of a small-scale IoT management solution called multi-hop clustering-based Routing Protocol for Low-Power and Lossy Networks (MHC-RPL). The proposed MHC-RPL was only applied to cluster heads but not to the remaining nodes in the area, as it occurs in the original RPL protocol. The MHC-RPL locally controlled the organised nodes in clusters and then chose the most powerful node as Cluster Head (CH). The hierarchically organised CHs handled data aggregation, data collection from the nodes in their respective clusters, and sent them to the next hop which resulted in a multi-hop topology. The MHC-RPL protocol organised the topology using Directed Acyclic Graph (DAG), with only one root node and a tree of all remaining nodes. The second level used SDN with a Q-routing algorithm for smart management of the global network. Mininet simulator with ONOS 2.1 was used alongside OpenFlow protocol for communication while Cooja simulated the RPL instances. The RPL nodes were connected to the SDN controller, using the contiguous SDN-Wise environment.

The results showed that the average energy consumption reduction of SD-MHC-RPL with regards to CDABC varied from approximately 12.4% (7000 nodes) up to 47.1% (12000 nodes) while with regards to SD-6lowpan it reduced from roughly 12% (7000 nodes) up to 27.7% (12000 nodes). Therefore, the proposed approach handled scalability and reduced energy consumption in the IoT network greatly.

Remarkably, the solution looks very reliable since it changes the cluster head before it runs out of energy because the cluster head selection is dynamic and a new one is chosen when the nodes' performance varies.

3.6 Energy Optimized Congestion Control-Based Temperature Aware Routing Algorithm for Software Defined Wireless Body Area Networks

Ahmed et al. [28] examined SDN for Wireless Body Area Network (WBAN) architecture needed for healthcare and military applications with efficient control and management of Inter-WBAN transmission through the congestion and temperature-aware energy-efficient routing algorithm. The authors proposed an energy-efficient, temperature and congestion-aware routing algorithm called EOCC-TARA.

It was observed that energy efficiency, temperature as well as congestion control-related factors were primarily considered in the routing model. The proposed solution initially selected the forwarding nodes based on energy and temperature as priority objectives and excluded the node with high temperature for route formation. The cost model was derived using link reliability, path loss, queue length, and residual energy to select the optimal routing paths using EMSMO[29]. In the model, it was observed that each WBAN user had sensor nodes and a hub which allowed Intra-WBAN communication for sending data to the hub and the coordinator nodes. Through Inter-WBAN communication, WBAN users also communicated with one another.

The suggested EOCC-TARA routing algorithm worked better than the conventional routing models for the SDN-based WBAN, according to simulated results. The suggested approach demonstrated enhanced energy efficiency, reduced congestion, high throughput, and balanced temperature in the network and the patient's body.

Notably, the study did not consider the mobility problems and unfavorable environmental conditions that could come with the real application of SDN-based WBANs.

3.7 An Energy-efficient SDN Controller Architecture for IoT Networks with Blockchain-based Security

A secure and energy-efficient blockchain-enabled architecture of SDN controllers for IoT networks was examined by Yazdinejad A., et al.[30]. In this study, the authors proposed a customised and IoT-friendly blockchain architecture using a cluster structure with a new routing protocol, which can effectively eliminate the traditional blockchain's overheads. In the proposed architecture, each cluster was named SDN domain with an SDN controller as the coordinator (cluster head) and responsible for the activation of IoT devices within it. The SDN controllers were connected to one blockchain, such that IoT devices can effectively communicate. The architecture used public and private blockchains for Peer to Peer (P2P) communication [31], [32], [33] between IoT devices and SDN controllers. It was observed that the architecture removed Proof-of-Work (POW) and used an efficient authentication method with the distributed trust, making the blockchain suitable for distributed P2P network where, without a trusted intermediary, untrusted individual IoT devices securely interacted in a verifiable manner with each other in each SDN domain. It was observed that IoT devices used a non-changeable private distribution ledger in each domain that was centrally managed by the SDN controller. The architecture permitted IoT devices to store their data in the cloud when necessary.

The experimental results indicated that the routing protocol based on the cluster structure has lower energy consumption, lower delay, and higher throughput than EESCFD, SMSN, AODV, AOMDV, and DSDV routing protocols. The authors in their work used a cluster structure to optimize energy consumption and enhance security simultaneously. Therefore, the proposed architecture undoubtedly outperformed the classic blockchain.

The flaw in this work is that the authors failed to name their proposed architecture and routing protocol accordingly for the sake of knowledge and future referencing.

4.0 LIMITATION AND OPEN ISSUES

Scalability in low power IoT networks is a concern that researchers will always consider for the best and most realistic outcomes in their work due to the rising nature of huge IoT devices and data collections. Due to the inadequate storage and computational resources built into network devices, implementing machine learning techniques to manage the enormous amounts of big data, which can enhance intelligence and aid in optimising energy efficiency in networks, has become a significant problem. Only SDN-based solutions are not practical now, given the emerging IoT trends. The adaptability of the machine learning based SDN controller should be further investigated by the research community to enable real-time management of huge amounts of data and reap further benefits. The proposed energy efficient IoT architecture, algorithms, and protocols cannot be easily tested due to a lack of suitable IoT simulation tools and platforms, which is a significant impediment for the development of a future smart network. Therefore, the research community and manufacturers should offer tools and enhanced testbeds to facilitate more research and the provisioning of newer and more optimized IoT solutions. We think that future research directions have been indicated based on the limitations above.

5.0 CONCLUSION

In conclusion, a review of energy efficiency in SDN-based IoT networks of some selected applications has been undertaken. This review has shown some state-of-the-art approaches used by researchers to address energy issues of resources-constrained SD-IoT applications putting in mind the large set of devices and huge volume of data they exhibit. Most of the cited literatures were directed at understanding some innovative parameters, the gap, and open issues for future research

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