An Optimized Energy Aware Load Balancing Routing Protocol for Software Defined Network

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Research Article

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An Optimized Energy Aware Load Balancing Routing Protocol for Software Defined Network

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AbstractSoftware-Defined Network (SDN) has a possible pathway to overcoming resource management complexities. The Energy-aware (EA) routing protocol has been adopted and functioned in many network applications. However, the chief problem in this protocol is high energy consumption and collision. So, to improve the performance of routing protocol in SDN, the current work has designed a novel Buffalo-based Energy-Aware Duty Cycle Routing (BEADCR) protocol to diminish energy usage. Here, buffalo fitness monitors the high energy-consuming nodes and removes them. Moreover, the data rate of each node was observed, and the zero data rate nodes were considered as rest nodes. In addition, to avoid a collision, the data overhead of each node was monitored, and the migration function was performed to share the high load with the rest nodes by activating the presented BEADCR model. This improves performance by gaining high monitoring accuracy, less energy consumption, high packet-delivery ratio (PDR), high throughput ratio, and high energy efficiency. Further, the result obtained is compared with other existing models to determine the effectiveness of the proposed model.

KeywordsNetwork Lifetime · Energy Consumption · Software-Defined-Network · Data Rate · Data Overhead

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1 Introduction

The network facilities have rapidly grown in several digital applications to enrich their communication module [1]. Hence, different topologies were introduced to afford better communication in a unique way [2]; based on the topologies, the communication rate differed [3]. Hence, the motive bending in this Software-defined network (SDN) is rich in control functions [4]. It supports all kinds of incorporation of the threat detection models; this advancement has attracted researchers to the SDN [5]. Moreover, the SDN is a dynamic, adaptive, and cost-effective model architecture, making it an excellent fit for the higher bandwidth based on today's advancements [6]. This architecture decouples the forwarding functions and network control, allowing network control to be abstracted away from the underlying architecture for internet control [7].

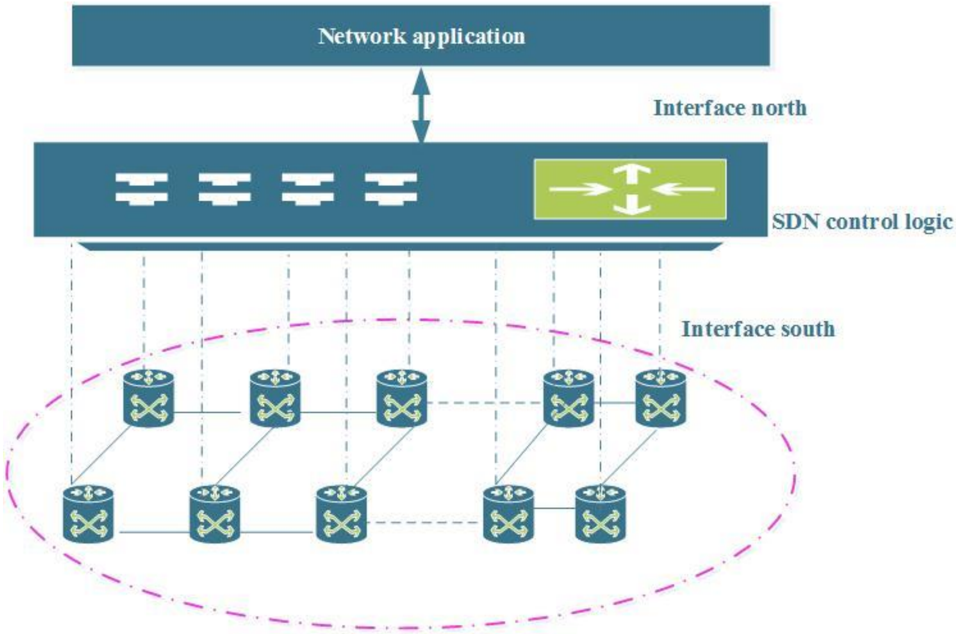


Fig. 1SDN architecture

In addition, the Open Flow SDN [8] protocol enables network managers to programmatically regulate flows of the controller function to describe the data transmission path between the source and destination [9]. Moreover, the open flow interference in the SDN [10] has generated considerable interest among the network developers and manufacturers [11]. By separating the data planes and the control functions [12], the forwarding devices become dump switches [13]. The control logic resides in the separate network operating system or centralized controller [14]. The nodes functions in the SDN framework based on their control logic [15]. Various control logic must be followed to minimize the energy consumption and improve the communication range [16]. The sleep-awake is one of the mechanisms to mitigate energy usage and improve the node density and data transferring rate [17]. Several models were implemented in the past, such as SDWSNs [19], two-phase routing SDN (TPR-SDN) [20], POLST [21], etc. But still, the problems were not addressed because of improper energy management between the connected nodes. So, the proposed model has planned to design the optimized routing paradigm with the monitoring strategy. Here, the presence of the optimized function is helped to optimize the energy by enabling rest and an active position.

The paper structure is described as follows: section 2 describes the recent works related to the EAR, section 3 explains the system model with the problem, section 4 describes the proposed method and its process, section 5 describes the result, performance, comparison, and discussion, and section 6 provides the paper conclusion.

2 Related Work

A few recent literatures related to Energy Aware Routing (EAR) are described as follows:

The reduction of control overhead and EAR methods was presented by Jurado-Lasso et al. [19] for prolonging the Software-Defined-based Multihop Wireless-based Sensor Networks (SDWSNs) lifetime. This method was an effort to optimize the consumption of energy of WSNs, which provide services to the Industrial-based Internet of Things (IIoT). Moreover, the developed algorithm balances the power of the network by choosing the paths with the highest level of remaining energy in multiple ways. The outcome of the presented approach shows that it increases the WSN lifetime by 6.5%, and the control overhead was mitigated by 12% approximately. However, the running time of the process is high.

Torkzadeh et al. [20] have presented a two-phase routing mechanism based on Software-Defined Network (SDN) to minimize energy utilization. To mitigate the energy consumption of the network, in the first stage, Ant Colony-based Optimization (ACO) based on a minimum graph was utilized, and in the second stage (MG-ACO), a weighed routing method is presented, which guarantees the Quality-of-Service (QoS) requirements. The result demonstrated that the proposed routing approach minimizes energy consumption, especially in congested traffic. Moreover, this method is applicable for only fewer traffic networks with small-sized flows.

A Power Optimization by Less State of Transition (POLST) method based on SDN was presented by Zhao et al. [21]. It mainly attains the two functions: (1) Real-time monitoring of network with low overhead and high accuracy (2) Optimization of power will-less state of transition. Moreover, a Power-Aware-based Routing with LST (PARLST) algorithm was proposed to minimize the consumption of power. The presented POLST method has attained 97.2% accuracy in measurement with less monitoring overhead. Furthermore, the flow consolidation is not improved, and design complexity is high.

Ruby et al. [22] have presented an SDN-enabled EAR in a multimodal Underwater sensor-based network (SDN-EAR-UWSN) for reducing optimization-based problems in hoc-like UWSN. In NP-hard nature provided the solutions for sensor nodes of both complete and half-duplex scenarios. The problems based on formulating routing in the full-duplex plan were solved by the rounding method, and the greedy method was utilized to solve problems in the half-duplex scenario. Moreover, the result demonstrated that the presented method had attained a longer lifetime and high energy efficiency. However, the security issues and computational time are high.

A heuristic algorithm named Maximum Bandwidth usage of Activated Links (MBAL) was presented by Lei et al. [23] for solving optimization problems. Also, the energy costs were minimized by improving the network devices turning and link utilization. Besides, a portioning method named Survivable-fixed telecommunication-based Network Design (SNDlib) was proposed to divide the networks. The proposed MBAL indicated that it improved the energy-saving rate by 0.34-19.69% by enhancing the active links utilization. Moreover, the design complexity is high and not applicable for inflow traffic.

Table 1 Literature summary

Authors	Techniques	Merits	Limitations
Jurado-Lasso et al. [19]	SDWSNs	It balances the network energy and consumes less energy	Running time of the process is high and high network overhead
Torkzadeh et al. [20]	MG-ACO	It reduces the energy usage in the congested traffic areas	Not applicable for less traffic networks
Zhao et al. [21]	POLST	It monitors the nodes accurately and mitigates network overhead	The design complexity is high and high packet loss
Ruby et al. [22]	SDN-EAR-UWSN	High energy efficiency, less power usage and high network time	The computational, and security issues are high
Lei et al. [23]	MBAL-SNDlib	Improved the energy saving rate and high performance	Design complexity is high and high running time

The overall literature summary is shown in table 1. The main drawbacks in recent research are energy consumption and high packet loss. To enhance this, a novel Buffalo-based Energy-Aware Duty Cycle Routing (BEADCR) protocol is developed in this research.

- The key contribution of the work is described as follows
- ü Initially, the SDN was designed with the desired number of nodes in the NS2 environment
- ü Hereafter, a novel BEADCR was intended, the fitness of buffalo was activated to find the energy status of all nodes
- ü Consequently, the present data transferring and receiving node has been seen by enabling the threshold value in the BEADCR model
- ü Hereafter, the high energy consumption nodes were removed, and the work-free node has moved to the rest position
- ü In addition, the migration function has been activated to avoid the collision by sharing the load with the neighboring hubs.
- ü Finally, the chief metrics were valued in energy efficiency, energy consumption, throughput ratio, network overhead, Network lifetime, and monitoring accuracy.

3 System Model and Problem Statement

The network became the basic need for today's life scenario for all digital applications [18]. In the data transferring from the source to the base station, the common issues in wireless communication are energy consumption, low network lifetime, and high packet drop. Hence, these kinds of problems occur because of high energy consumption. So optimizing the energy usage became the essential function in the wireless network to enrich the communication facilities. The SDN network has been adopted here, with more algorithm usage flexibility.

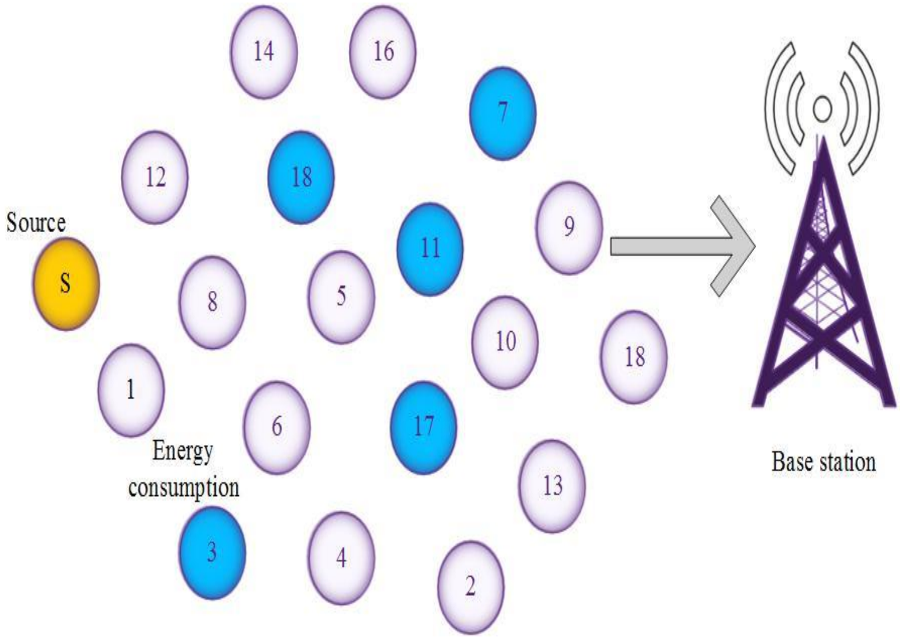


Fig. 2 System model with problem

However, the main drawback of this model is energy consumption and load balancing. The data overhead has caused a high packed drop, so balancing the load is the critical parameter that needs consideration. Moreover, the usual process of wireless communications and common difficulties is shown in fig. 2. This system architecture clearly defined that the SDN system has consumed higher energy due to the wake of the energy consumption node. So, this research aimed toward the SDN system by incorporating an energy awareness and load balancing system.

4 Proposed Methodolog

To enrich the SDN function, the present article aims to design a novel energy-aware optimized intelligent model known as the Buffalo-based Energy-Aware Duty Cycle Routing (BEADCR) protocol to transfer data and diminish energy usage SDN system efficiently. Here, the workless node has remained in the rest position; only the data transfer node is in the active state.

Initially, the required number of nodes is designed in the NS2 environment then BEADCR has is modeled with the parameters necessary to optimize the energy function. Also, the load balancing scheme has been activated by fixing the maximum load for one node in the buffalo fitness. After removing the energy consumption node, the SDN has been monitored continuously to predict the data overload; if a node contains more load than its threshold capacity, it migrates the loads to other free nodes. Finally, the parameters were calculated and compared with other existing models.

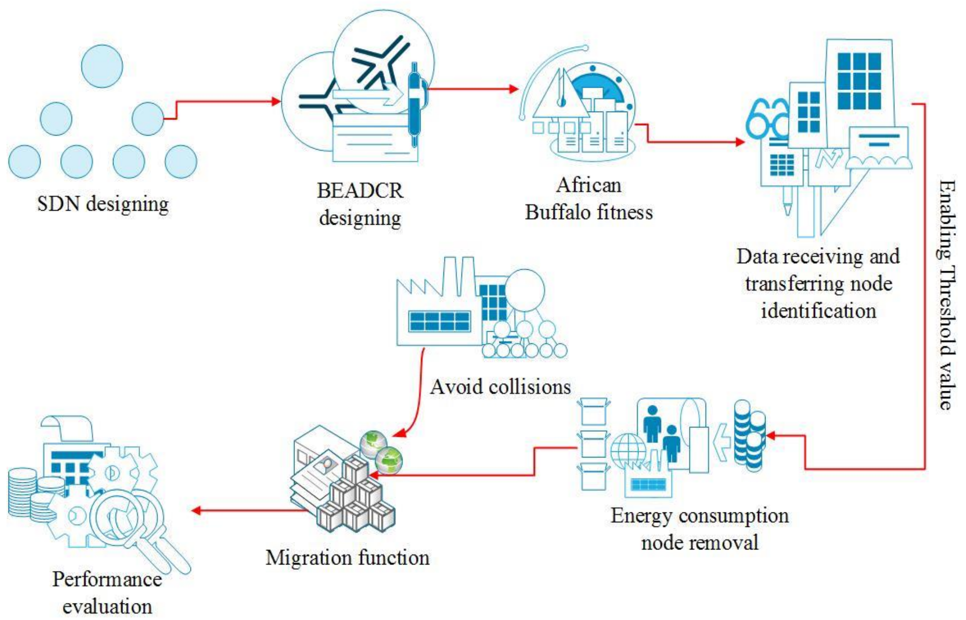


Fig. 3 Proposed method

4.1 Network design

The SDN is designed with nodes in this work to enrich wireless communication. This design is executed in the NS2 platform and the SDN module; the parameters were updated, which has resulted in moving nodes. Each node in SDN has some parameters like energy, data rate, and data overhead. The features are regularly monitored in the monitoring process to determine the high energy-consuming nodes.

4.2 Process of proposed BEADCR

The nodes in the SDN are designed with the help of buffalo fitness. Moreover, the developed BEADCR is the combination of African buffalo [24] and low duty-cycle [25] protocol. Initially, the required number of nodes is created in the SDN using the initialization of the buffalo function by Eqn. (1).

$$g(d) = (1,2,3,4,....,n) \tag{1}$$

Here, $g(d)$ represents the node initialization parameter. In the network simulator, nodes are arranged randomly by enabling the buffalo's random placement procedure. Hereafter, the proposed BEADCR is initiated to analyze the energy consumption node. Therefore, the energy consuming node analyzing process is done using Eqn. (2).

$$ve + 1 = ve + 1(C_t.k_l - Q) + 1(D_t.k_l - Q) \tag{2}$$

Where, ve represents the node energy, $ve + 1$ is the monitoring parameter, C_t denotes the energy consuming nodes, k_l is the energy node analyzing variable, Q represents the maximum energy threshold = 2000mJ, and D_t denotes the node lifetime. Moreover, after identifying the high energy consuming nodes, it was removed using Eqn. (3)

$$P_r = \sum_{n=1} \left(1 - C_t\right) \tag{3}$$

Where, P_r represent the energy consumption nodes removing parameter. After removing high energy-gaining nodes, the data rate of each node was monitored by Eqn. (4)

$$S_{dr} = G_w(1 - M)\left(1 - G_w(1 - M)\right) \tag{4}$$

Where, S_{dr} data rate analyzing module, G_w represents the less data rate nodes, and M is the minimum data rate threshold = 700Mbps. Here, the zero data rate nodes are considered as rest nodes. Moreover, after computing the nodes characteristics, the collision avoidance or data overhead module has been activated. Generally, while applying SDN in the wireless environment, the collision often occurs. In that time, the data overhead is analyzed using Eqn. (5).

$$H_{do} = \sum_{n=1} K_{do}\left\{\left(d_{(n)} - Y\right)\right\} \tag{5}$$

Where, H_{do} is the data overhead analyzing module, K_{do} data overhead monitoring parameter, Y denotes the maximum data overhead threshold = 560bytes, and $d_{(n)}$ denotes the data overhead nodes. Hereafter, the higher data nodes are divided and given to the rest nodes; the data are splitted by Eqn. (6).

$$D_{sp} = \frac{H_{do} + R_n}{0.5} \tag{6}$$

Where, R_n represents rest nodes, D_{sp} denotes data overhead splitting process and 0.5 is the maximum data overhead dividing range. After, these processes, the data are shared without any collisions. Moreover, if the destination node is in free status then it has forwarded the message from source to destination with less delay. The working process of BEADCR is detailed in algorithm.1.

Algorithm 1 BEADCR

Start
{
$int\ g(d) = 1,2,3,4,\ldots,n)$
// initializing nodes
Nodes energy monitoring ()
{
$if(ve > Q)$
{
High energy consuming node *// less lifetime*
}
Else
{
Normal node
// here, high energy consumption nodes are analyzing by buffalo fitness Eqn. (2)
Removal of high energy consumption node *// using Eqn. (3)*
}
Data rate monitoring ()
{

if $\left(S_{dr} < M\right)$

{

Less data rate node *// rest nodes*

}

Else (normal node)

// here, zero data rate nodes are analyzed by Eqn. (4)

}

Data overhead estimation ()

{

if $\left(H_{do} > Y\right)$

{

High data overhead node

}

// here, the higher data overhead nodes are analyzed using Eqn. (5)

splitting of higher data overhead and added to rest node by Eqn. (6)

}

}

}

Stop

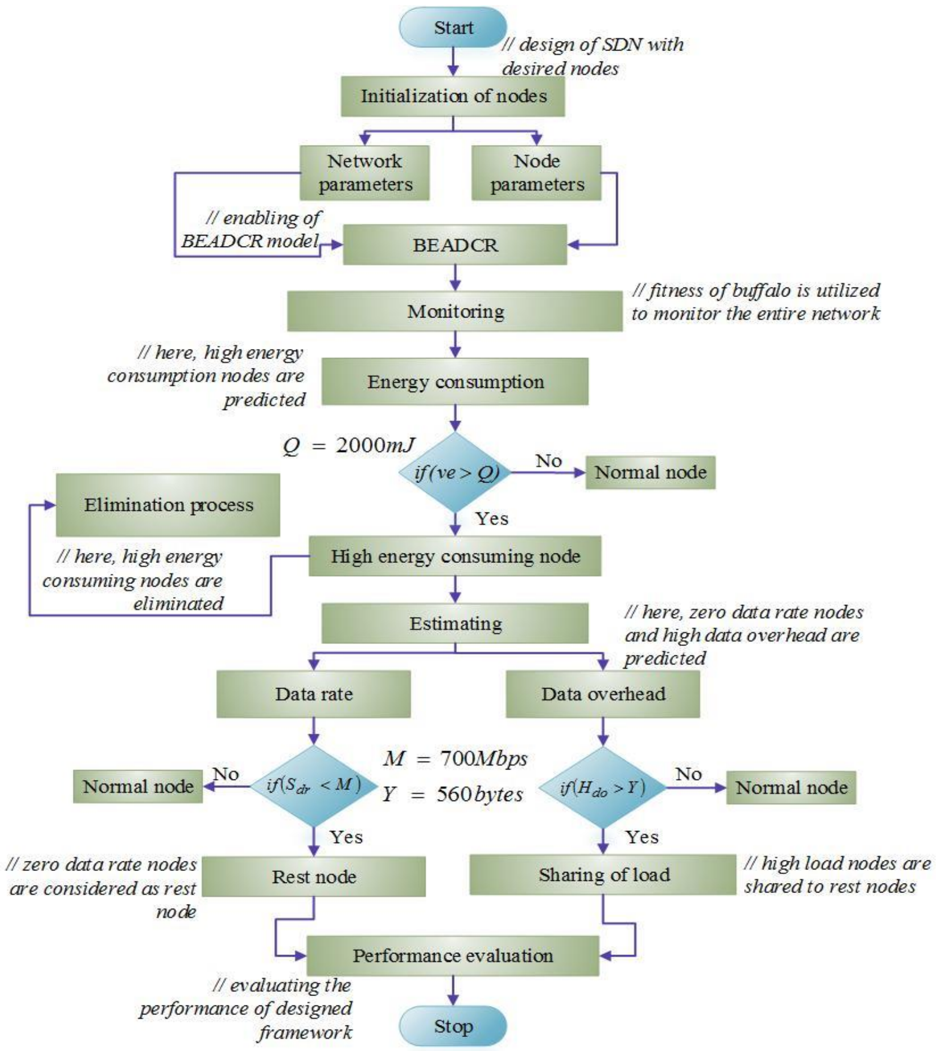


Fig. 4 Overall work process of proposed BEADCR

The overall work process of the proposed BEADCR framework is shown in fig.4. Here, the entire process was discussed in detail. The command language is written and executed in the NS2 environment based on this procedure. However, the parameters function is estimated to determine the presented model's robustness.

The figure shows the entire workflow process of the proposed framework; based on this, and the developed model was executed in the network simulator.

5 Result and Discussion

The planned SDN is implemented in the NS2 platform version.2.35 and running in the Ubuntu environment. The desired number of nodes is created in the network simulation, and the proposed BEADCR is executed; then, the entire process has been completed. Moreover, the parameters obtained for execution are tabulated in table 2.

Table 2 NS2 configuration

Specification	Configuration
Platform	Network simulator (NS2)
Operating system	Ubuntu
Total nodes	100
Running time	10ms
Energy consumption range	2000mJ
Data rate range	700Mbps
Data overhead range	560 bytes

5.1 Case study

This case study has been conducted to understand the designed novel BEADCR working module. SDN with 100 nodes was initially created in the NS2 platform, consisting of several normal nodes, high energy-consuming nodes, zero data rate nodes, and high data overhead nodes.

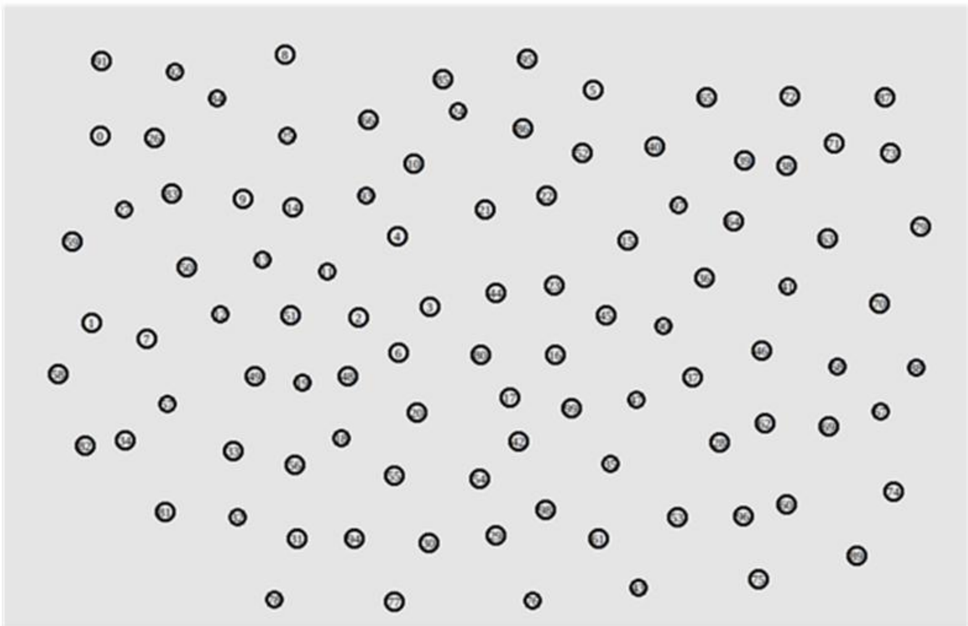


Fig. 5 Network design

Fig. 5 shows the initial stage of network design with nodes. After node designing, the high energy-consuming nodes are monitored by the proposed BEADCR framework. Here the fitness of buffalo was incorporated with less duty-cycle routing protocol with some significant features like energy consumption analysis and estimation of node's energy.

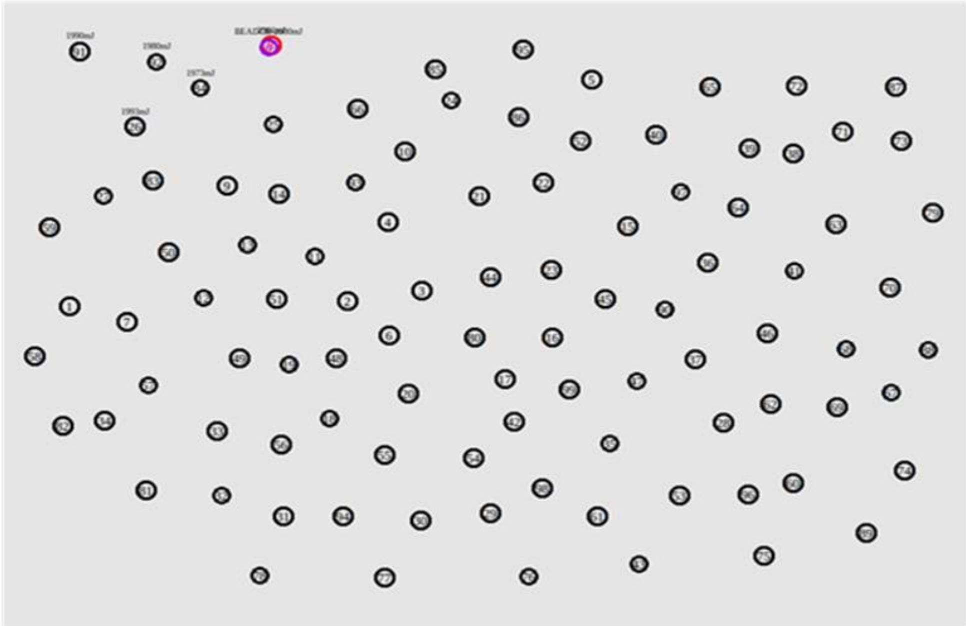
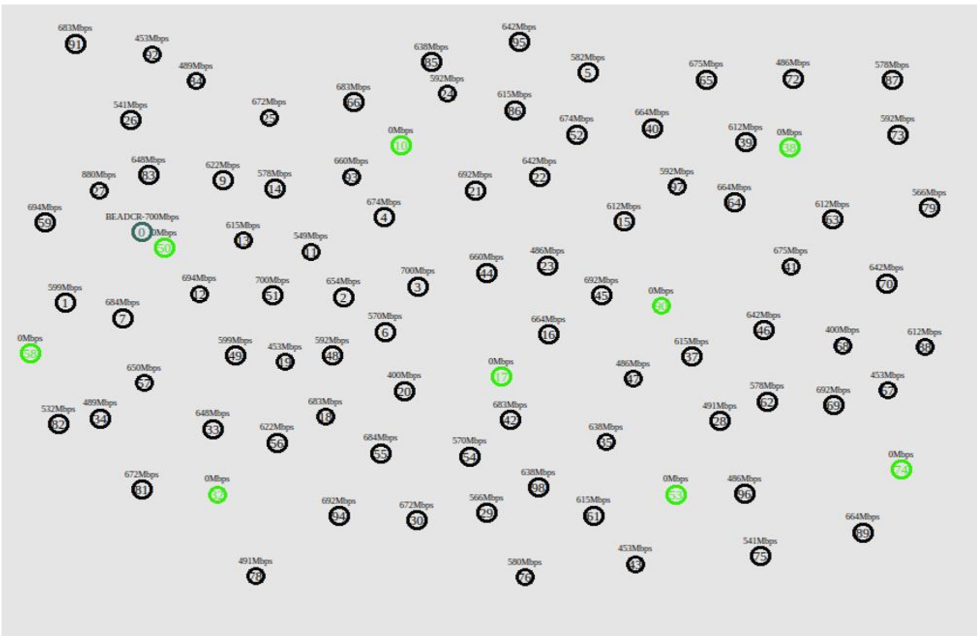


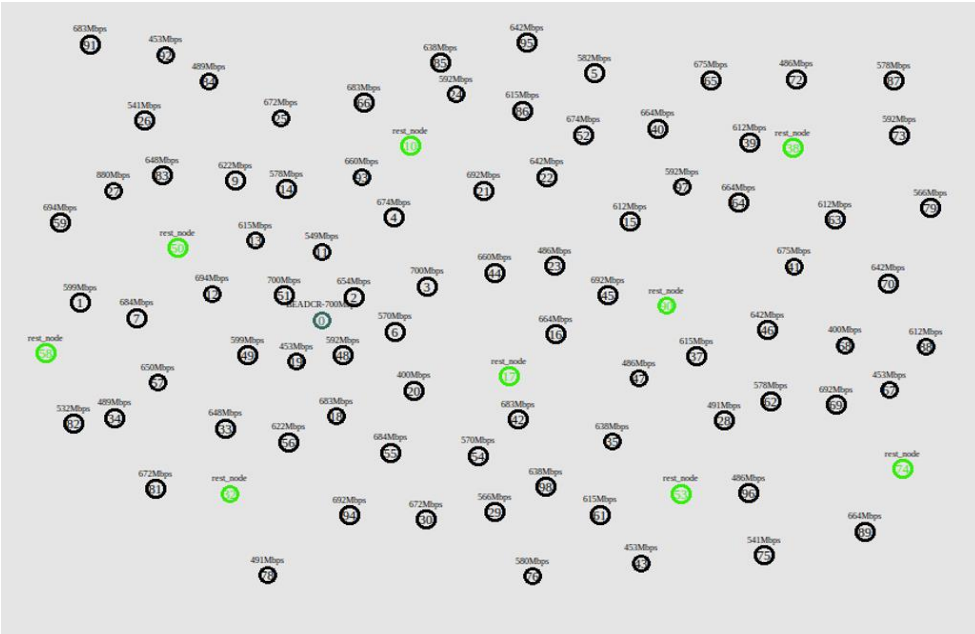
Fig. 6 Monitoring and removal of a high energy-consuming node

BEADCR model, and it was represented in fig.6. The red color is the high energy-consuming node, and the magenta color represents the proposed model. In addition, the designed network has eight high energy-consuming nodes, which were removed. Hereafter, the data rate monitoring process is enabled, in which zero data rate nodes are monitored.

Fig.7 (a) represents the data monitoring process; the light green color in the figure is zero data rate nodes, and the dark green color is the BEADCR node. After identifying the zero data rate nodes, it was changed to a rest node, shown in fig.7 (b). Here, the rest nodes are identified as 9. Hereafter, the data overhead monitoring process is performed; the migration function is activated.



(a)



(b)

Fig. 7 Monitoring and changing process (a) Data rate monitoring (b) Rest node .

This process is done for nine collision nodes, the green color represents the high data overhead nodes. The high information overhead nodes are split and shared to rest position nodes. The migration function is shown in fig.8.

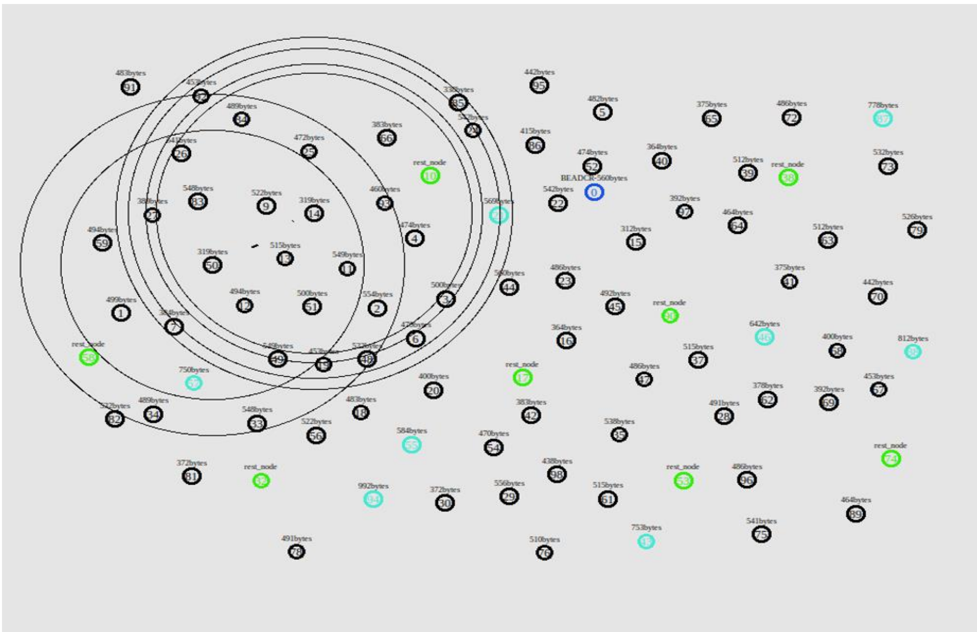


Fig. 8 Migration function

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completing the migration function, the proposed BEADCR node was dark blue, and all the other nodes were black. The result of the shared data overhead is shown in fig.9.

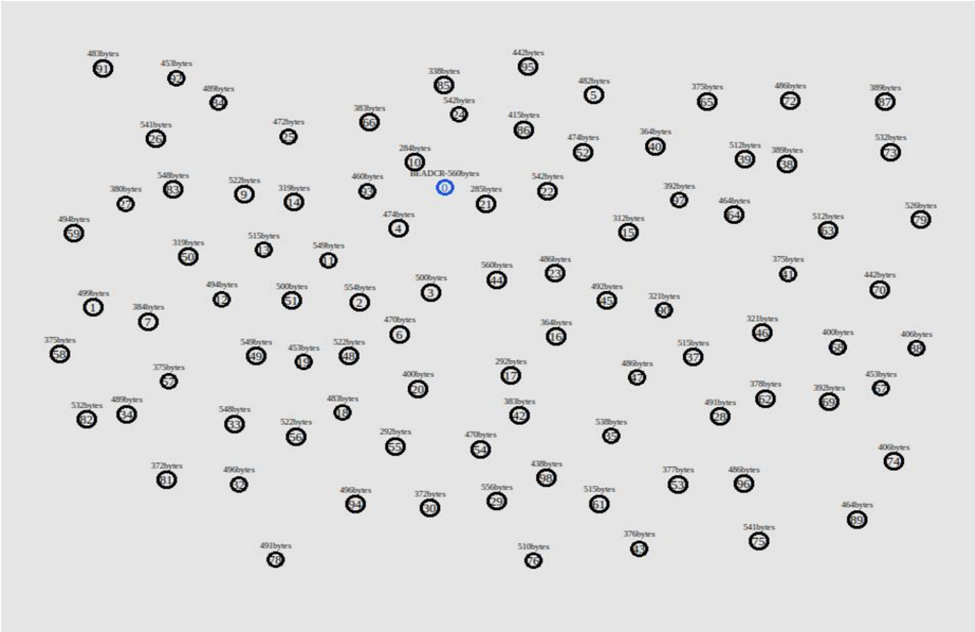


Fig. 9 Outcome of shared data overhead nodes

To compute the improvement score of the developed BEADCR, the performance assessment is done. The metrics like monitoring accuracy, network lifetime, packet delivery ratio, network overhead, throughput ratio, energy efficiency, and consumption are evaluated for the developed framework.

5.2.1 Monitoring accuracy, Network lifetime and overhead

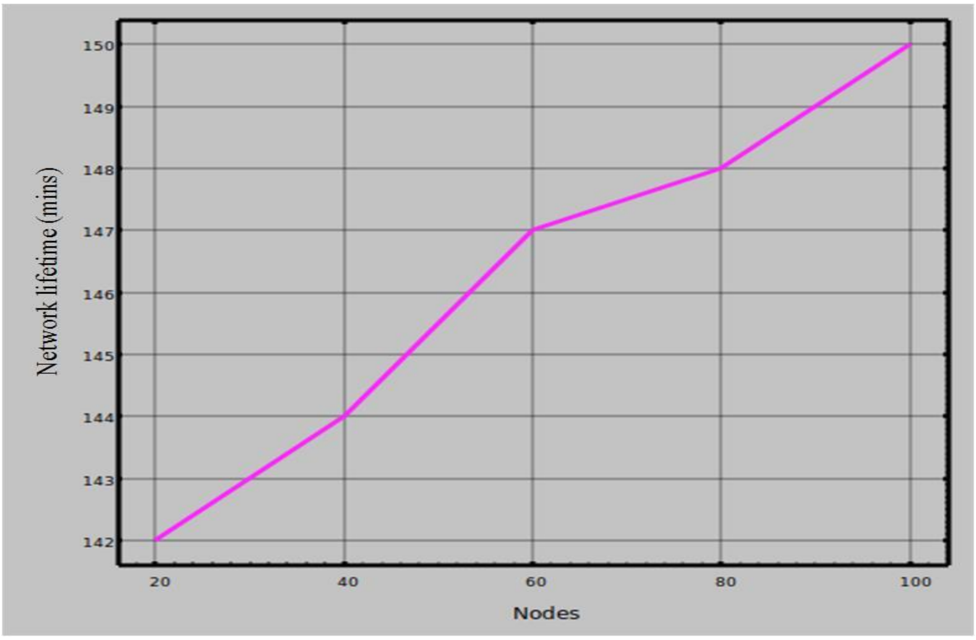
To quantify the monitoring mechanism measurement performance, monitoring accuracy is computed. The accuracy is varied for varying nodes; the proposed method has attained the monitoring accuracy of 98.22% for the 20th node, 98.59% for the 40th node, 98.74% for the 60th node, and 98.9% for the 80th node, and 99.1% for the 100th node. Moreover, the obtained monitoring accuracy, network lifetime, and overhead are shown in table 3.

Table 3 Obtained accuracy, network lifetime and network overhead

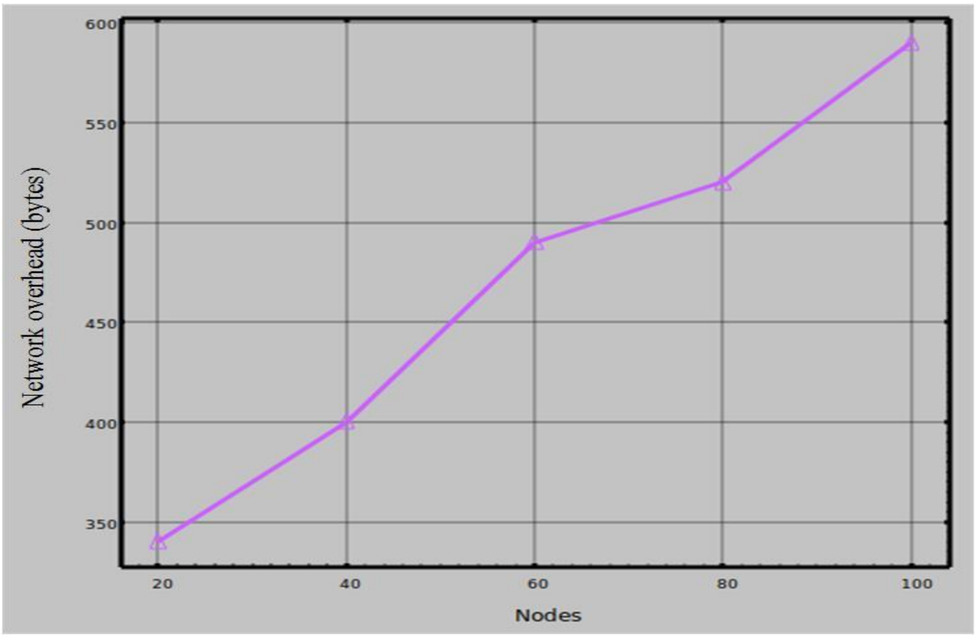
Node	Monitoring accuracy (%)	Network lifetime (mins)	Network overhead (bytes)
20	98.22	142	340
40	98.59	144	400
60	98.74	147	490
80	98.9	148	520
100	99.1	150	590

The network's network lifetime is described as when the SDN can perform the needed functionality. It may be described in various ways based on the network applications; moreover, it is the time when all the designed nodes in the SDN die. The obtained network lifetime at different data counts is shown in fig. 10. (a).

Overhead is a significant term for in-network designing, performance, and implementation issues. Network overhead is called header data, which is needed to transport and route data over the SDN. The network overhead is validated in the form of bytes. Moreover, the obtained network overhead is shown in fig.10. (b). The network overhead was varied based on the nodes with an increase or decrease in bytes. It is described as the total number of packets accumulated over the running time.



(a)



(b)

Fig. 10 Obtained outcomes (a) Network lifetime (b) Network overhead

5.2.2

The data transfer score depends on the throughput ratio; the method that gained the finest throughput rate then has an excellent data transmission rate. Moreover, it is an important metric to measure the quality and network connection performance. The throughput is calculated using Eqn. (7).

$$Throughput = \frac{total \;\; packet \;\; received}{time \;\; taken} \tag{7}$$

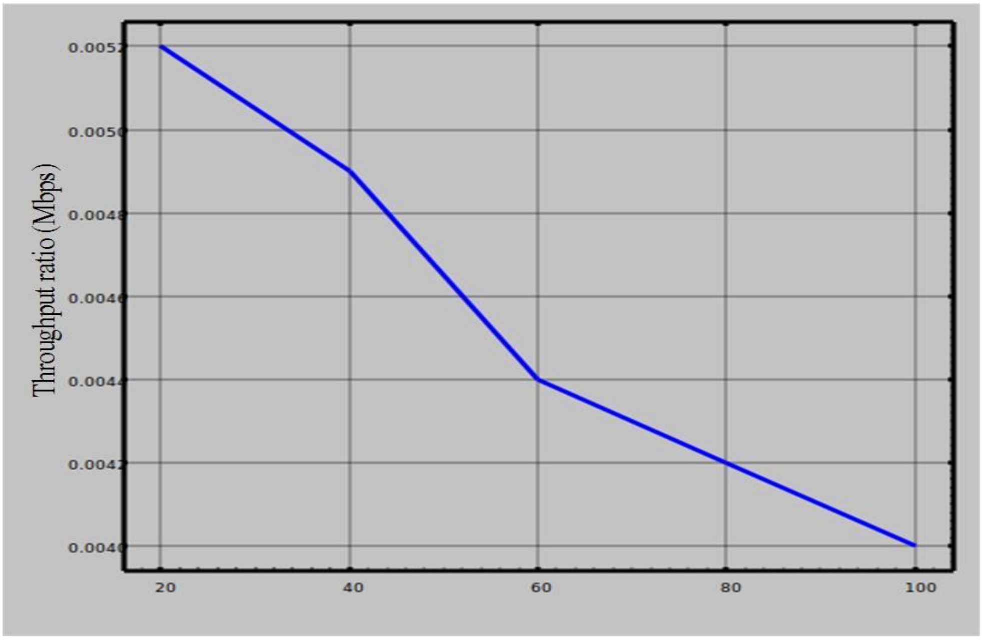
The lower throughput led to a high packet drop ratio during data transmission. The throughput is validated in bits/sec; the throughput ratio is also varied as per the number of nodes. Moreover, the obtained throughput and PDR are shown in table 4.

Table 4 Obtained throughput ratio and PDR

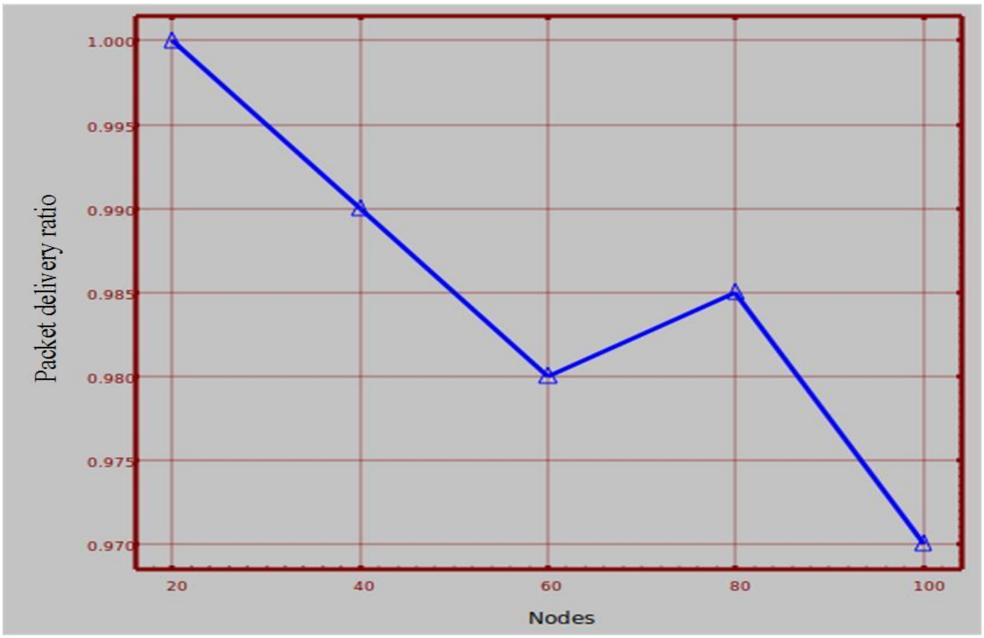
Node	Throughput ratio (bps)	PDR
20	5200	1.0
40	4900	0.99
60	4400	0.98
80	4200	0.985
100	4000	0.97

PDR is defined as the ratio of several packets received to the number of packages sent, and Eqn computes it. (8). Moreover, the PDR may differ based on the nodes; the obtained packet delivery ratio for the presented BEADCR method is shown in fig.11 (b).

$$PDR = \frac{no.\ of\ \ data\ \ packets\ \ received}{no.\ of\ \ \ packets\ \ sent} \tag{8}$$



(a)



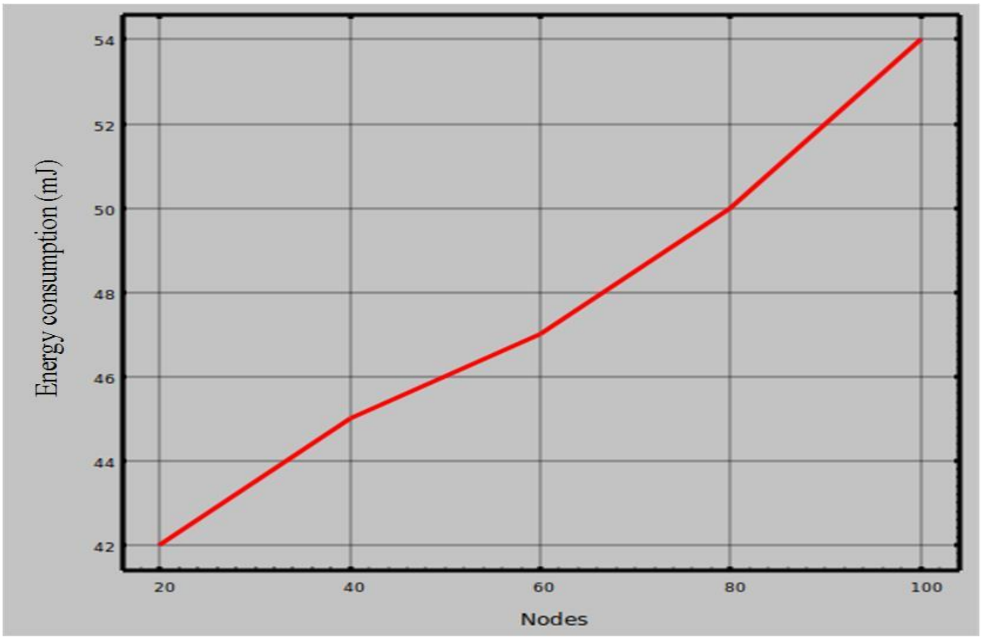
(b)

Fig. 11 Obtained outcomes (a) Throughput ratio (b) PDR

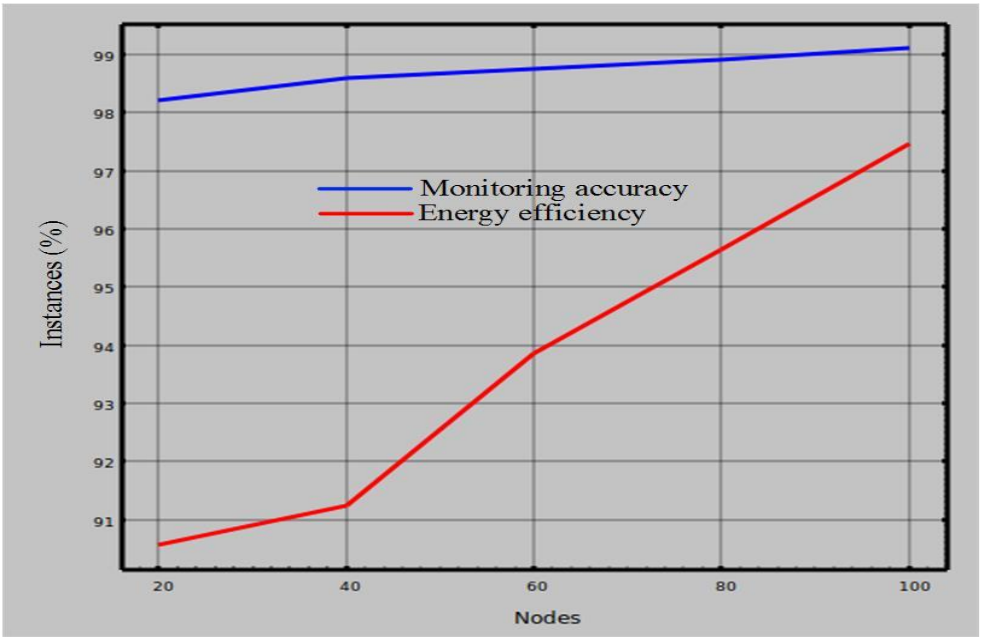
Energy efficiency is defined as the energy used to generate the same amount of outcome from the designed network. SDN requires a sufficient amount of energy to gather data, which intended the SDN needs to keep the node's balanced point. In addition, the obtained energy efficiency and consumption are illustrated in table 5.

Table 5 Obtained Energy efficiency and consumption

Node	Energy efficiency (%)	Energy consumption (mJ)
20	90.57	42
40	91.24	45
60	93.82	47
80	95.65	50
100	97.46	54



(a)



(b)

Fig. 12 Obtained performance (a) Energy consumption (b) Energy efficiency and monitoring accuracy mitigating the data coverage area provides less energy consumption and enhances the node's lifetime. The proposed BEADCR method has consumed less energy using the routing method. However, the nodes are designed with sufficient power to transmit the data and measure the data transmission energy consumption. Moreover, the obtained energy consumption, efficiency, and monitoring accuracy are shown in fig. 12 (a) and (b), respectively.

5.3 Comparison assessment

To determine the improved rate of the presented BEADCR model, some of the recent models are compared with the current approach. The other models like SDWSNs [19], SDN-EAR-UWSN [22], fuzzy logic routing system for flying ad hoc-based networks (FLRS-FANET) [26], SDN/network function-based virtualization (SDN/NFV) [27], and energy-optimized traffic control dependent on temperature aware-based routing algorithm by enhanced multi-objective-based Spider Monkey algorithm (EOCC-TARA-EMSMO) [28] are compared with presented BEADCR model.

Table 6 Comparison assessment

Sl.no	Techniques	PDR	Network lifetime (min)	Network overhead (bytes)	Energy consumption (J)
1	SDWSNs [19]	0.967	140	600.83	-
2	SDN-EAR-UWSN[22]	0.8	100	-	-
3	FLRS-FANET [26]	0.905	-	480.6	45.5
4	SDN/NFV [27]	0.95	10	-	0.0805
5	EOCC-TARA-EMSMO [28]	0.96	7.8	-	6.2
6	Proposed (BEADCR)	0.985	146.2	468	0.0476

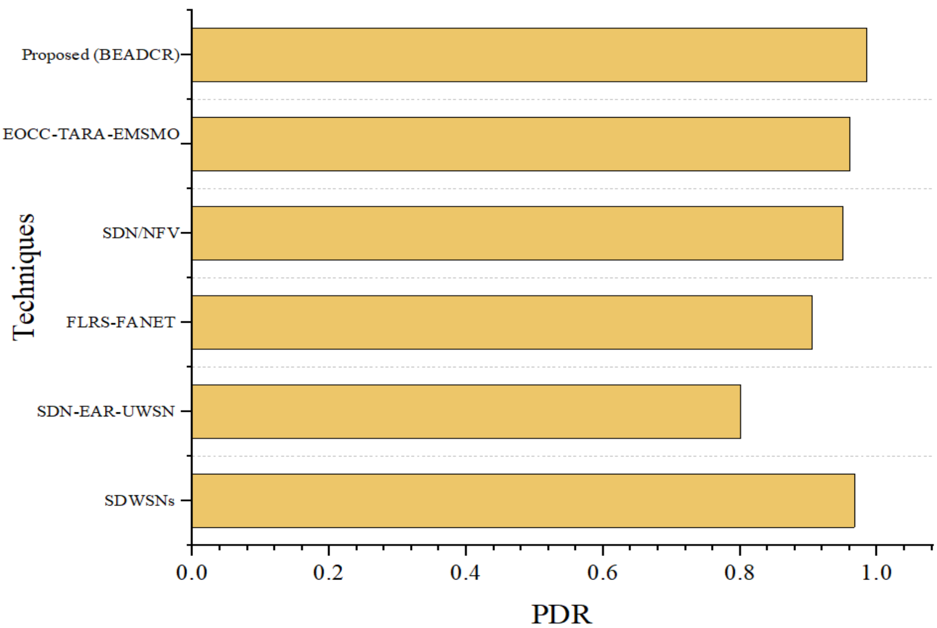


Fig. 13PDR comparison

The overall comparison assessment is shown in table.6. The comparison assessment indicates that the presented BEADCR model has high PDR, network lifetime, less energy consumption, and network overhead. The comparison of PDR is shown in fig.13.

The average PDR obtained by the presented BEADCR model was 0.985, which was high compared to other existing models. Moreover, SDWSNs have obtained a PDR of 0.967, and SDN-EAR-UWSN has acquired a PDR of 0.8. In addition, the FLRS-FANET, SDN/NFV, and EOC-TARA-EMSMO have obtained the PDR as 0.905, 0.95, and 0.96, respectively. Consequently, the network lifetime comparison is shown in fig.14.

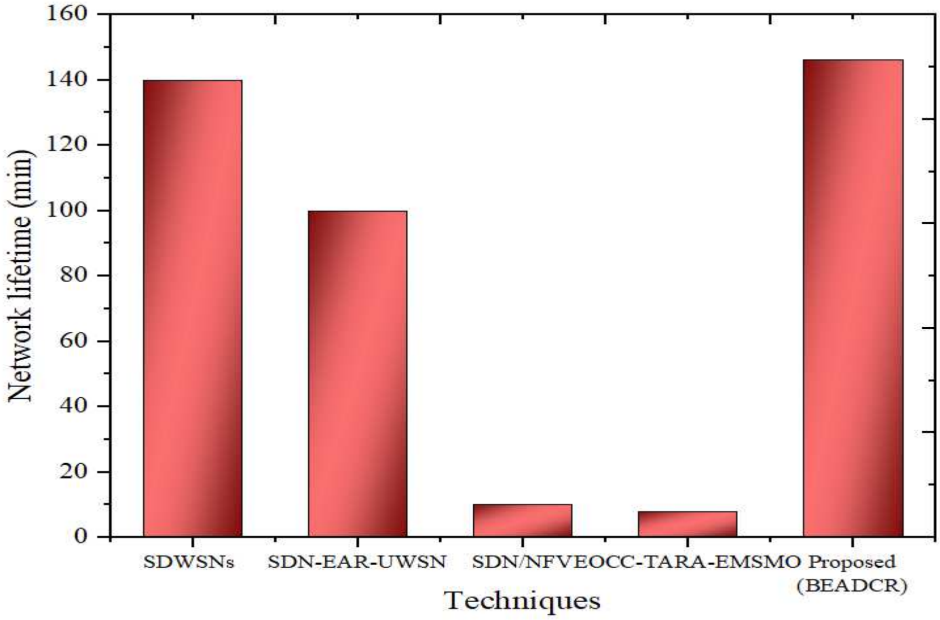


Fig. 14 Network lifetime comparison

The average network lifetime obtained by the presented BEADCR model was 146.2min, which was high compared to other existing models. In addition, the intermediate network overhead obtained by the proposed BEADCR model was 4678bytes, which is less than other models. Moreover, SDWSNs have obtained the network lifetime and overhead as 140min and 600.83bytes, respectively, and SDN-EAR-UWSN has acquired the network lifetime of 100min. Further, the FLRS-FANET has earned the overhead as 480.6bytes, SDN/NFV, and EOCC-TARA-EMSMO have obtained a network lifetime of 10min and 7.8min, respectively.

The average energy consumed by the presented BEADCR model was 0.0476J, which was less than other existing models. Further, the FLRS-FANET has consumed 45.5J energy, SDN/NFV, and EOCC-TARA-EMSMO have consumed the energy of 0.0805J and 6.2J, respectively. Moreover, the energy consumption comparison is shown in fig. 15.

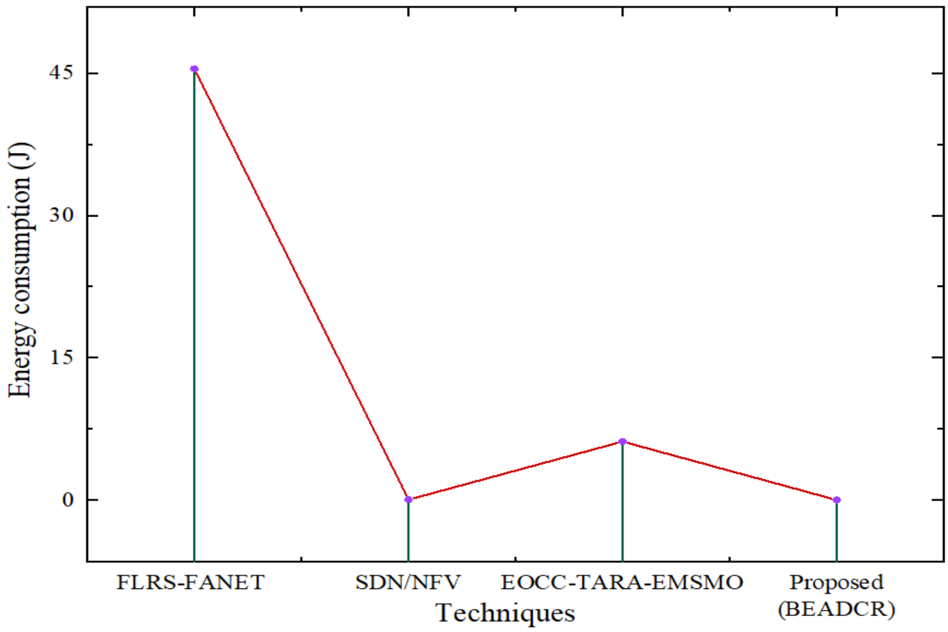


Fig.15 Energy consumption comparison

5.4 Discussion

The presented framework has achieved the finest results; it has proved the given BEADCR models effectiveness in the routing protocol. In this research, different metrics were calculated to evaluate the proposed system's effectiveness. Finally, the average of each metric was also measured and compared with other existing models. The overall performance of the proposed BEADCR is shown in table 7.

Table 7 Overall performance of BEADCR

Performance of BEADCR	
Parameters	Obtained score
PDR	0.985
Network lifetime	146.2min
Energy consumption	47.6mJ
Network overhead	468bytes
Monitoring accuracy	98.71%
Throughput ratio	4540bps
Energy efficiency	93.75%

Hence, the designed framework is suitable for energy-aware load balancing routing protocol with high energy efficiency and monitoring accuracy. Moreover, the network lifetime, PDR, and throughput ratio are higher than in other models. Therefore, it is an effective technique for routing protocols.

6 Conclusion

The primary concern of this present research work is to overcome the issues in the software-defined networks (SDN). So, a novel BEADCR model is designed for the NS2platform. Initially, the required number of nodes is created with the required parameters. The proposed BEADCR has been started function to monitor the present nodes in the network environment. Once the initial phase of monitoring was completed, the buffalo fitness was used to identify the high energy consumption nodes, and it was removed. The data rate was determined hereafter, and the zero data rate nodes were considered rest nodes. Moreover, data overhead was monitored, and to avoid the collision; the migration function was initiated in the BEADCR procedure. In which the high load is shared with the rest nodes. The metrics are calculated regarding energy consumption, PDR, throughput ratio, network overhead, etc.; in each metric calculation, the presented BEADCR model has gained better outcomes than other models. Moreover, it has achieved a 4540bps throughput ratio, 98.71% monitoring accuracy, 93.75% energy efficiency, 47.6mJ energy consumption, and 0.985 PDR. In addition, the presented model was compared with other existing techniques to determine the effectiveness of the proposed model. The result demonstrated that the presented method had obtained better outcomes.

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None

Compliance with Ethical Standards

1. Disclosure of Potential Conflict of Interest:

The authors declare that they have no potential conflict of interest.

2. Statement of Human and Animal Rights.

   i. Ethical Approval

All applicable institutional and/or national guidelines for the care and use of animals were followed.

   ii. Informed Consent

For this type of study formal consent is not required.

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