Babylonian Journal of Networking
Vol.2024, **pp**. 182–190
DOI: https://doi.org/10.58496/BJN/2024/018; ISSN: 3006-5372
https://mesopotamian.press/journals/index.php/BJN

Research Article

Optimizing Energy Efficiency in 6G Communication Networks Based on Data Transmission Rate Allocation

R. Mageswaran [1], Jose P [2], Nithisha J [3,*], T.Rengaraj [4], M.Neeladri [5], R.Senthil Rama [6]

[1]*Department of Electrical and Electronics Engineering, S.A. Engineering College, Anna University, Thiruverkadu, Tamil Nadu-600077, India.*
[2]*Department of Computer Science and Engineering, Vel Tech Rangaraja Dr.Sagunthala R&D Institute of Science and Technology, Avadi, Chennai – 600062 ,India.*
[3]*Department of Computer Science and Engineering , SRM Institute of Science and Technology, Ramapuram, Chennai, Tamil Nadu, India.*
[4]*Department of Electrical and Electronics Engineering, P. S. R Engineering College, Sevalpatti, Sivakasi-626140, Tamil Nadu, India.*
[5]*Department of Electronics & Communication Engineering, Aditya Engineering College, Surampalem, India.*
[6]*Department of Electrical and Electronics Engineering, DMI College of Engineering, Chennai, Tamil Nadu, India.*

ARTICLE INFO

Article History

Received 01 Jun 2024
Revised 30 Jul 2024
Accepted 15 Aug 2024
Published 15 Sep 2024

Keywords

6G communication network

Quality of service

network lifetime

energy efficiency

DTRA, and DMRP

ABSTRACT

To progress communication and sensing in recent years, the Sixth-Generation (6G) network was developed. To transform the technological landscape of model transmission networks we use the 6G network, and it also used to enhance the speed, decrease the latency and improve the connectivity of network. Yet, in the 6G infrastructure with these developments it has severe challenge, that is the 6G network does not negate the benefits of energy consumption associated with network. In 6G communication the sensing performance of the smart device only relay on the available power of the network, and in the 6G communication energy efficiency becomes crucial. To progress the energy efficiency of data transmission in 6G communication networks, we deployed a Data Transmission Rate Allocation (DTRA) method. Moreover, to progress the data transmission of efficient nodes we deploy a Residual Energy Cluster Head (RECH) method. In addition, to improve the reliability and speed in the 6G network we use Dynamic Multipath Routing Protocol (DMRP) method, and it also mitigate the channel defects. Atlast, in the 6G communication networks we certify QoS through optimizing the transmission rate of the user equipment through low energy consumption, and quality of channel by the use of DTRA method. Finally, in this paper we evaluate the metrices performance of the existing methods and proposed method, for instance: efficiency, energy consumption, network lifetime, and transmission speed. After evaluate the performance metrices the DTRA method enhance network lifetime and energy efficiency of 95.3% based on 6G communication networks.

1. INTRODUCTION

As mobile technology advances from 1G to 6G, the objectives of users and network operators are evolving. In the current communication environment, 6G mobile communication systems are expected to content various corporate objectives. Social processes are becoming more automated, data-driven, and system-focused in the present era. Heterogeneous networks have recently gained significant attention as a new framework for emerging networks due to their potential in social processes [1]. Modern communication networks need to achieve greater spatial spectrum reuse efficiency while improving users' quality of service (QoS). In particular, they support significant connectivity by providing a robust service experience in high-demand, high-population areas. These advanced networks outperform 6G communication networks regarding spatial spectrum efficiency and QoS metrics, ensuring users receive reliable, high-quality connectivity.

*Corresponding author. Email: nithisha.j@gmail.com

Proper network management is critical to efficiently supporting highly heterogeneous applications with stringent QoS requirements. The 6G mobile heterogeneous network (HetNet) addresses the challenges of highly dense environments by facilitating seamless connectivity between various network elements. The ecosystem creates a robust infrastructure that reduces energy consumption and improves operational costs. Managing these issues is crucial for achieving stable, high-performance networks in the 6G communication system [2]. For making on advances on wireless communication technology by their predecessors the cellular data networks represent the 6G networks. To enhance the capacity of data transmission, and reduce the delay the 5G and 6G networks use the higher frequency bands. The unprecedented communication latency of just 1 ms, and enhance 5G capabilities for thousand times is the main objective of 6G technology [3].
The traditional cell-based networks present significant challenges due to inherent ruggedness and fluctuations it increases cell-to-cell interference in the current wireless infrastructure. The drawback is lead to an inconsistent QoS across network, and it is troubles for mobile network operators. To improve the user experience and operation efficiency there is need highly adaptable and efficient network [4]. So, we use modern wireless network, in this infrastructure it encounters reliability challenges and it produce consistent QoS across diverse user nodes. But the modern wireless network face the limitations of conventional cellular designs, so it produce the some drawback such as network efficiency and user experience.
This paper contributes to the energy efficiency of data transmission in 6G communication networks using the proposed DTRA method. In addition, a RECH selection algorithm improves data transmission between network nodes. The DMRP technique can also mitigate channel defects and enhance network reliability and speed. Finally, the proposed method is used to improve the transmission speed of the terminal according to the channel quality in 6G communication and to ensure the QoS by reducing energy consumption.

2. LITERATURE SURVEY

The author [5] proposed developing and implementing sustainable practices in 6 G wireless communication systems to provide industry practitioners and policymakers with sustainable solutions and valuable insights. However, the impact and energy consumption of 6G communication systems is a more significant environmental problem. Therefore, to solve the problems related to 6G communication, it evaluates communication systems based on SIMs connected to the transmitter and receiver via holographic multiple input multiple outputs (HMIMO). In addition [6], HMIMO provides fundamental insights for theoretically analyzing channel capacity. Routing optimization in wireless mesh networks analyzes quantum computing speed based on Quantum Approximate Optimization Algorithms (QAOA). However, traditional computer processing power is still required to analyze these characteristics [7].
The analysis of active Heterogeneous Cellular Networks (HCNs) will assess the feasibility of implementing node selection schemes for information sharing in 6G and other networks [8]. However, the current node cannot improve the sampling process through the selection scheme. The study explores new services and technologies for developing 6G data communication options [9]. The author proposed the Fuzzy-Based Spectrum Allocation (FBSA) technique to distribute resources for 6G communication across devices effectively and equitably [10]. Next, a Multi-Objective Particle Swarm Optimization (MOPSO) algorithm for collective resource optimization is suggested to assess the power and spectrum optimization of small and macro cell base stations [11]. Sharing resources efficiently among various users is challenging in 6G mobile networks. In microcell networks, a handover method for cell edge users is developed in the study [12]. To modify the interference intensity a handover methodology on the basis of Reference Signal Received Quality (RSRQ) was presented.
In Wireless Sensor Networks (WSN) for conventional 5G/6G communication the author [13] deployed Collaborative Energy-Efficient Routing Protocol (CEEPR) method. To replace the concave fractional programming optimization in a Mixed Integer Nonlinear Programming (MINLP) the author [14] suggested an outer approximation approach. To meet the rigorous connectivity requirements and improve capabilities of various 6G applications the author [15] dep0oyed a DMR method.

3. PROPOSED METHODOLOGY

For improve the energy effectively of data transmission among 6G communication networks the DTRA method was deployed on this section. Optimize the data transmission among network nodes and confirms efficient use of energy resources the RECH method was used. To improve the speed and reliability of data transmission and mitigate channels in all along network through the DMRP algorithm. To optimize the user equipment communication rates via real-time channel quality estimation the DTRA method was used. By following we compute the key execution metrices for instance, throughput, energy efficiency, network lifetime, and transfer speed through benchmarking. For the 6G communication framework the GTRA provides the optimal solution.

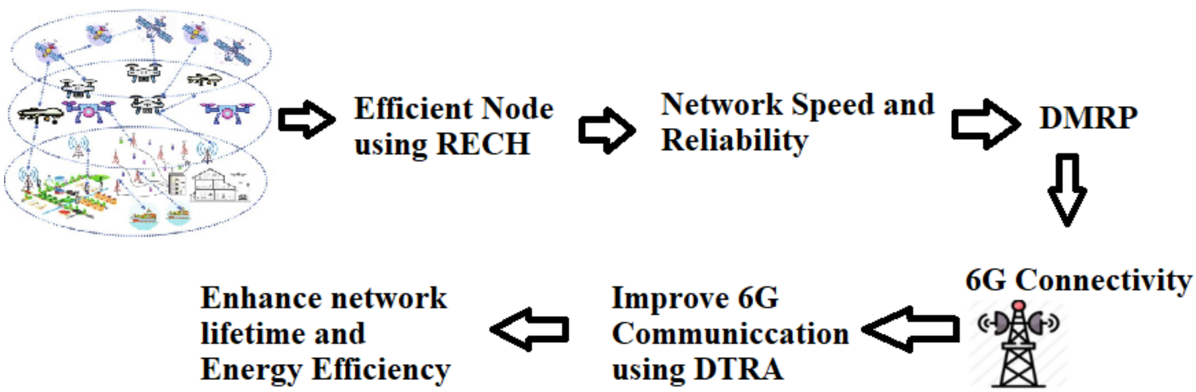

Fig .1. The Architecture Diagram Based on Proposed DTRA Method

The architectural diagram of the DTRA method was illustrate in Fig 1. In this diagram the DTRA method is used to optimize the energy efficiency for the data transmission based on 6G communication networks. It is able to enhance the real-time transmission rate of user equipment. Furthermore, the proposed method gives an ideal outcome for the 6G communication network field.

3.1 Residual Energy Cluster Head (RECH)

To optimize the data transmission for the efficient node based on 6G communication network this section picks out RECH method. This is used to update each and every node energy estimation via data bytes based on sending and receiving. By using RECH the remaining energy of data transmit to the first destination and it is used to examine optimal cluster. Than other sensor nodes the cluster head consumes more energy while transmitting, receiving and processing data. Then, to re-establish the cluster head in each and every round the RECH method is used, and the proposed method employing the residual energy of the network nodes. These provide effective nodes to improve data transmission in 6G communication networks.

The sensor nodes in the network use Equation 3 to select a cluster head by generating a random number. The cluster head ratio determines the probability of a sensor node being selected in round 0, and then the node's value in the current round of the 6G network is calculated. Let's assume C_H −cluster head, ζC_H −ratio, Ru_c −set of nodes round, W_y −threshold value, n-random umber.

$$W_y(d_j) = \begin{cases} \frac{\zeta C_H}{1-\zeta C_H\left(Ru_c * mod\left(1/_{\zeta C_H}\right)\right)}, & d \in W \\ 0 & Otherwise \end{cases} \quad (1)$$

Equation 2 illustrates the distances between the initial and base stations for selecting CH based on residual energy. Let's assume L_O −optimum constant value, N-distance, N_A −average distance node and base station, N_j −distance between the nodes

$$W_y(d_j) = \frac{\zeta C_H}{1-\zeta C_H\left(Ru_c * mod\left(1/_{\zeta C_H}\right)\right)} \times \left(L_O \times \frac{N_A}{N_j}\right) \quad if W \in Y \quad (2)$$

Equations 3 and 4 represent the distance between the nodes and the base stations for each cluster member. Let's assume N_{ws-BS} −distance between node and base station, N_{ws-CH} −distance between efficient node and cluster head.

$$N_{ws-BS} = \sqrt{\left(U_j - U_{bs}\right)^2 - \left(V_j - V_{bs}\right)^2} \quad (3)$$

$$N_{ws-CH}(n) = \sqrt{\left(U_j - U_{bs}\right)^2 - \left(V_j - V_{bs}\right)^2} \quad (4)$$

The cluster members estimate the distance between nodes and BSs and between CHs. By following these equations, we illustrate that RECH method can effectively optimizes the data transmission for the 6G communication network nodes.

3.2 Dynamic Multipath Routing Protocol (DMRP)

In this phase to decrease channel faults and then progress the reliability and speed of 6G networks we use DMRP method. In the 6G network to minimize the energy consumption and maximize the network lifetime the DMRP is used. The deployed method utilizes the multiple path to progress the data transfer among source and destination. Which relay on pre-defined paths the DMRP chose and keep inform on the best path based on network conditions for instance congestion, latency and link quality. The routing decisions are adaptive and it able to adjust in traffic volume within the network. By dividing traffic along several channels, the DMR can efficiently balance the load and enhancing overall network performance. In order to satisfy the demanding low-latency specifications of 6G networks the DMRP is swiftly adjust the optimal paths. To briefly describe the DMRP performance we execute some equations in below.
In the equation 5 we compute the path cost,

$$E_q = N_{ws-CH}\left(u_1.G_q + u_2.K_q^{-1} + u_3.H_q\right) \quad (5)$$

here, E_q is known for the cost of path, the u is meant for weighting factors, G_q is meant for latency accompanying through path, the K_q is meant for bandwith available at path, and the H_q is meant for energy consumption on path. There are several metrics that can be used to obtain the answer to equation 1, including latency, bandwidth, and energy consumption. Through the following equation 1we estimate the quality of link through equation 6,

$$L_{x,y} = \frac{R\ Z_{x,y}}{S_{loss}}.Z_{xy} \quad (6)$$

here, L is known for the quality of link, x, y are the nodes, R is known for signal-to-noise ratio, S_{loss} is known for the packet loss probability at link, and Z_{xy} is the data rate of the link. The following in equation 7 we compute the routing decision metric,

$$D_q = \alpha.E_q + \beta.\left(\frac{1}{L_{x,y}}\right) \quad (7)$$

here, D_q is mention for decision metric for path, and the α, β is known for weighting coefficients. Path cost and link quality may influence the total routing choice metric used to choose a path. A popular strategy is to reduce the path cost and inverse link quality weighted sum. In equation 8 we compute the flow optimization based on multipath routing,

$$\min max\left(f\left(i_q\right)\right) \quad (8)$$

here, the i_q is known for the amount of flow on path, and the $f\left(i_q\right)$ is known for the capacity of path and flow of the function. In order to maximise performance, dynamic multipath routing frequently distributes traffic among several paths. Minimising the greatest congestion $f\left(i_q\right)$ on any path can be the objective if i_q is the flow quantity on path. After identify the flow quantity of path in below equation 9 we compute the energy-efficient routing,

$$H_q = \sum_{(x,y)\in q} h_{x,y}.i_q \quad (9)$$

here, $h_{x,y}$ is known for the energy consumption per unit among nodes. The equation 10 is used to minimize the total energy consumption across all paths.

$$C_q = \sum_{(x,y)\in q} g_{xy} \quad (10)$$

in this equation 10 the g_{xy} is known for delay, the C_q is illustrate for the path of latency. It is used to path selecting through the lowest g. The speed and reliability are computed in equation 11 via LB.

$$LB = \sqrt{\frac{1}{n}\sum_{q=1}^{n}\left(i_q - \bar{\imath}\right)^2} \quad (11)$$

in equation 11 the LB is minimized and it attain the balanced traffic distribution. By following these equations, it achieves best performance in various characteristics for instance latency, energy efficiency and reliability in 6G networks.

3.3 Energy-Efficient Data Transmission Rate Allocation (DTRA)

In this phase we ensuring QoS by increasing transmission speed and diminishing the energy consumption of network node through DTRA method, and it is also used for progress the data transmission effectively in 6G communication networks. In this method the each and every user able to employ the deployed method to adjust the transmitted data on the basis of quality of channel, and it is used to estimate channel coefficients. In the 6G communication network we can assess the data transmission rate of the consumption of whole power based on user terminal. If the transmission speed falls below by the use of this method the user able to modify the equipment transmission energy. DTRA is updating the current channel state to maintain QoS and enhancing the data transmission.

Algorithm: DTRA
Input Progress the speed and reliability ← LB
Output: Improves data transfer in the 6G network← j
Start
Evaluate the number of user equipment and base stations
For each $j = 1, D_{UE}, D_{BS} = 8$
    Select a base stationBS_i
End for each
Calculate the total amount of interference from all users ← J_j
Compute white Gaussian noise← d_j
Calculates total energy consumption of user equipment← P_{ji}
Calculate the user's transmission power← j
    For each $0 \leq g_j^{tr} \leq g^{max}$
Evaluate the probability density function $V_{ji} \in V$
Calculate the device's total power consumption← G_j^{con}
Compute the optimal channel coefficients

$$\hat{q}_j^{opt} = \underset{\hat{q}_j}{\arg\max}\, b\left(v_{ji}|\hat{q}_j\right) \quad (12)$$

Evaluate $T_r\left(\sum_{q_j}\right)$ and $R_j(q_j)$
Evaluate wireless user equipment transmission and rate
If $\left(\sum_{j=1}^{l} T_r\left(\sum_{q_j}\right) \leq \varepsilon\right)$ or $\left(R_j(q_j) < R_{min}\right)$
Observe the user's payoff ← j
End if
Update ← q

$$j = j + 1 \quad (13)$$

Estimate the transmit power of all users
Return ← j
End

Let's assume j_j −interfering all user, d_j −gaussian noise, data transmission energy, j − Improve the transmission of user data, g^{max} −Maximum power, g_j^{tr} −covariance matrix of the transmitted power, $\hat{g}_j^{opt}$ −optimal compact user, $v_{ji} \in v$ −pprobability density function, q-compact. The DTRA algorithm increases the transmission speed to ensure QoS and effectively improve the data transmission in the 6G communication network.

4. RESULT AND DISCUSSION

This section validates the proposed DTRA algorithm through simulations conducted with the NS2 tool, focusing on optimizing energy efficiency during data transmission. Furthermore, the previous methods for instance FBSA, CEEPR, and QAOA were compared to the clustering-based approach. This method optimizes transmission power based on the channel expansion level, enhancing transmission speed and improving the QoS performance of data transmission in 6G communication networks. Furthermore, the proposed DTRA method can enhance network performance in 6G communications by utilizing metrics such as throughput, energy efficiency, network lifetime, and transmission speed.

TABLE I. SIMULATION PARAMETER

Parameter	Value
Simulator	NS-2
Number of network node	501
Transmission range	32m
Packet Size	513bytes
Cluster head	18
Bandwidth	16
Initial energy	0.34mJ
Simulation time	550sec
Number of iterations	102
Location	700m × 700m

Table 1 displays the parameters utilized in the simulation and compares them with the proposed performance analysis. The parameter values can also estimate various other factors, including the number of network nodes, transmission range, and packet size.

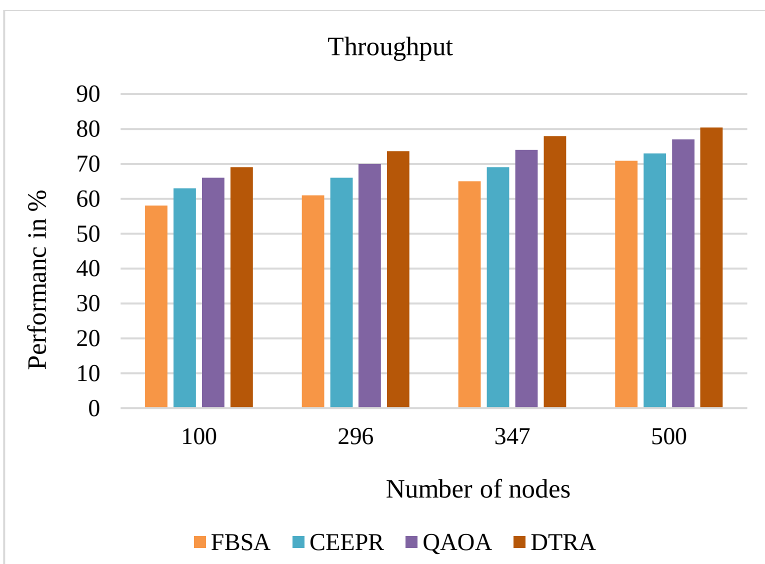

Fig .2. Analysis of Throughput

Fig 2 demonstrates that energy efficiency in a 6G communication network can be optimized through throughput analysis. Additionally, it highlights the proposed and previously established methods to enhance energy efficiency during data transmission. As a result, improvements of 80.4% were noted compared to the proposed DTRA technique in the throughput analysis. Furthermore, when comparing previous approaches such as FBSA, CEEPR, and QAOA with the proposed method, performance evaluations showed improvements of 70.9%, 73%, and 77%, respectively, further enhancing data transmission in the 6G communication network.

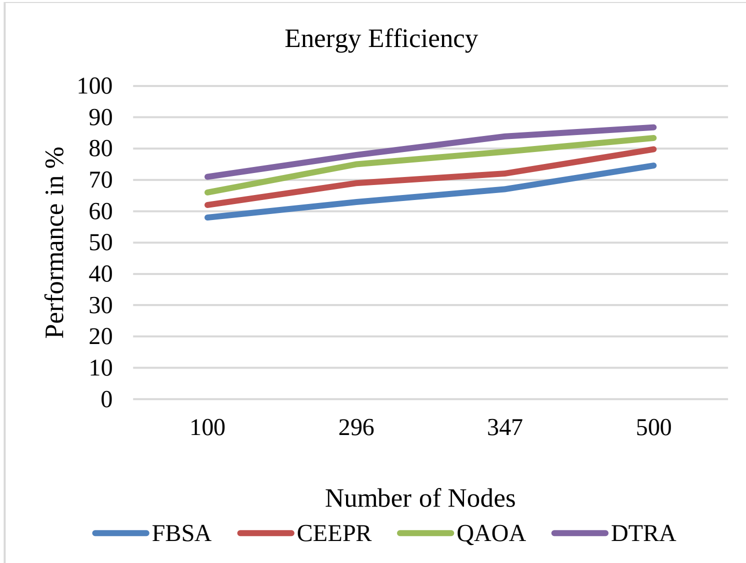

Fig .3. Analysis of Energy Efficiency

As shown in Fig 3, data transmission can be optimized in 6G communication networks based on energy efficiency analysis. Additionally, presents the proposed method and previous methods to improve the power efficiency of data transmission. Therefore, an 86.8% improvement in energy efficiency analysis was measured compared to the proposed DTRA technique. Furthermore, comparing the previous FBSA, CEEPR, and QAOA methods with the method proposed in this article, the energy efficiency estimation reaches 74.6%, 79.8%, and 83.4%, respectively, which can improve data transmission of 6G communication networks.

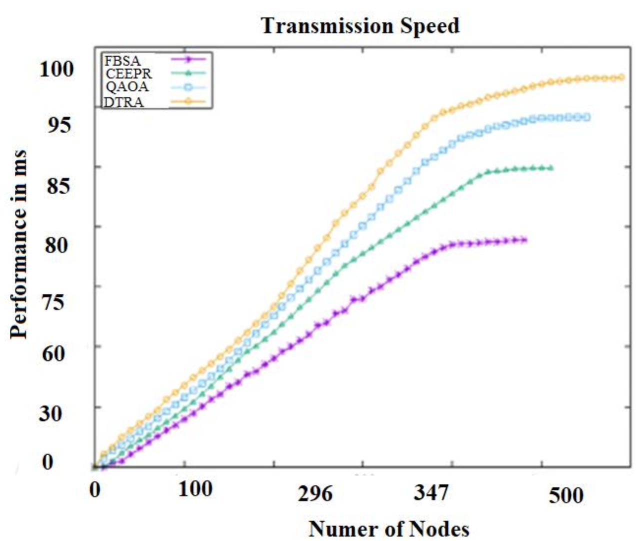

Fig .4. Analysis of Transmission Speed

In Fig 4, it is demonstrated that 6G communication networks have the potential to enhance data transmission through energy efficiency analysis. Furthermore, comparing the proposed method with the previous technique to enhance the data transmission speed can improve energy efficiency. The study shows a 90.01% enhancement in transfer rate compared to the proposed DTRA technique. Additionally, the method proposed in this paper demonstrates a transmission rate estimation of 76.9%, 83.8%, and 85.3% when compared to previous FBSA, CEEPR, and QAOA methods, respectively.

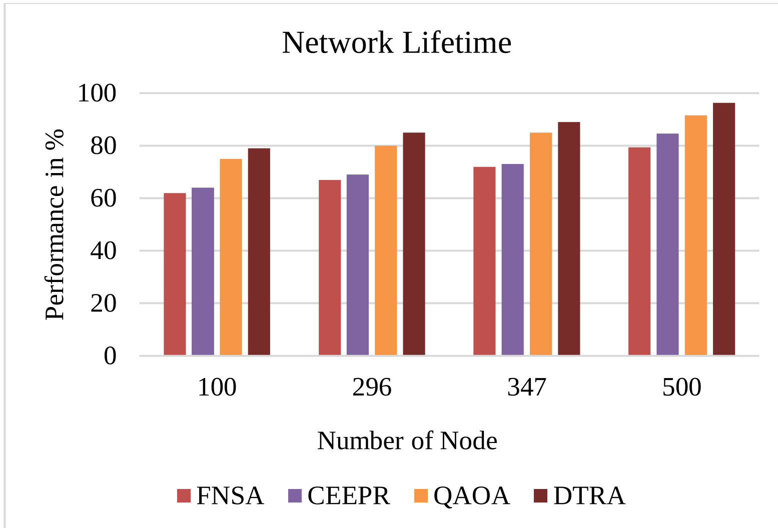

Fig .4. Analysis of Network Lifetime

The analyses of network lifetime were illustrated in Fig. 5. It is aimed at enhancing data transmission speed for the proposed method through compared with existing methods such as FBSA, CEEPR, and QAOA. By following the FBSA provides 79.4%, the CEEPR provides 84.6%, and QAOA provides 91.6% and the DTRA provides 96.3%. When the lifetime increases in 6G communication networks the data transmission able to enhance.

5. CONCLUSION

The DTRA method which progress the energy efficiency of data transmission through communication networks were illustrate in this conclusion part. By using RECH the remaining energy of data transmit to the first destination and it is used to examine optimal cluster. Than other sensor nodes the cluster head consumes more energy while transmitting, receiving and processing data. In the 6G network to minimize the energy consumption and maximize the network lifetime the DMRP is used. The deployed method utilizes the multiple path to progress the data transfer among source and destination. By dividing traffic along several channels, the deployed method can efficiently balance the load and enhancing overall network performance. In the 6G communication network we can assess the data transmission rate of the consumption of whole power based on user terminal. If the transmission speed falls below by the use of this method the user able to modify the equipment transmission energy. DTRA is updating the current channel state to maintain QoS and enhancing the data transmission. Furthermore, the previous methods for instance FBSA, CEEPR, and QAOA were compared to the DTRA to analyse the transfer rate. The DTRA method enhance network lifetime and energy efficiency of 95.3% based on 6G communication networks.

Conflicts of Interest

The paper explicitly states that there are no conflicts of interest to disclose.

Funding

The acknowledgments section of the paper does not mention any financial support from institutions or sponsors.

Acknowledgment

The author acknowledges the support and resources provided by the institution in facilitating the execution of this study.

References

[1] H. F. Alhashimi et al., "A Survey on Resource Management for 6G Heterogeneous Networks: Current Research, Future Trends, and Challenges," Electronics, vol. 12, p. 647, 2023, doi: 10.3390/electronics12030647.

[2] M. A. Hossain, A. R. Hossain, and N. Ansari, "AI in 6G: Energy-Efficient Distributed Machine Learning for Multilayer Heterogeneous Networks," IEEE Network, vol. 36, no. 6, pp. 84-91, Nov./Dec. 2022, doi: 10.1109/MNET.104.2100422.

[3] I. S. Bayram and R. Jovanovic, "Energy-efficient architectures for 6G networks," in The Role of 6G and Beyond on the Road to Net-Zero Carbon, pp. 113-136, Nov. 2023, doi: 10.1049/PBTE108E_ch6.

[4] A. L. Imoize, H. I. Obakhena, F. I. Anyasi, and S. N. Sur, "A Review of Energy Efficiency and Power Control Schemes in Ultra-Dense Cell-Free Massive MIMO Systems for Sustainable 6G Wireless Communication," Sustainability, vol. 14, p. 11100, 2022, doi: 10.3390/su141711100.

[5] R. Kumar, S. K. Gupta, H.-C. Wang, C. S. Kumari, and S. S. V. P. Korlam, "From Efficiency to Sustainability: Exploring the Potential of 6G for a Greener Future," Sustainability, vol. 15, p. 16387, 2023, doi: 10.3390/su152316387.

[6] J. An et al., "Stacked Intelligent Metasurfaces for Efficient Holographic MIMO Communications in 6G," IEEE Journal on Selected Areas in Communications, vol. 41, no. 8, pp. 2380-2396, Aug. 2023, doi: 10.1109/JSAC.2023.3288261.

[7] H. Urgelles, P. Picazo-Martinez, D. Garcia-Roger, and J. F. Monserrat, "Multi-Objective Routing Optimization for 6G Communication Networks Using a Quantum Approximate Optimization Algorithm," Sensors, vol. 22, p. 7570, 2022, doi: 10.3390/s22197570.

[8] V. S. Pandi, S. Mohanalakshmi, A. Devasena, J. Jegan, V. Parimala, and A. Anandh, "Dynamic Node Selection Approach for 6G Heterogeneous Cellular Networks (HCN) to Enhance QoS and Low Latency," J. Electrical Systems, vol. 20, no. 3, pp. 2336-2353, 2024.

[9] S. Kumar, "6G Mobile Communication Networks: Key Services and Enabling Technologies," Journal of ICT Standardization, vol. 10, no. 1, pp. 1-10, 2022, doi: 10.13052/jicts2245-800X.1011.

[10] S. B. Prakalya, V. S. Pandi, S. Sujatha, R. Thangam, D. Karunkuzhali, and G. Keerthiga, "A Novel Fuzzy-based Spectrum Allocation (FBSA) Technique for Enhanced Quality of Service (QoS) in 6G Heterogeneous Networks," International Journal of Advanced Computer Science & Applications, vol. 15, no. 6, p. 888, 2024, doi: 10.14569/ijacsa.2024.0150690.

[11] G. C. Das, A. Kumar, S. Saha, and A. Bhowmick, "6G Ultra-Dense O-RAN Heterogeneous Network and Its Performance Analysis," First Published-2024, Imprint CRC Press, pp. 14, eBook ISBN: 9781003407836.

[12] M. E. Benson, K. C. Okafor, L. S. Ezema, N. Chukwuchekwa, B. Adebisi, and O. C. Anthony, "Heterogeneous cyber-physical network coexistence through interference contribution rate and uplink power control algorithm (ICR-UPCA) in 6G edge cells," Internet of Things, vol. 25, p. 101031, 2024, doi: 10.1016/j.iot.2023.101031.

[13] H. L. Gururaj et al., "Collaborative Energy-Efficient Routing Protocol for Sustainable Communication in 5G/6G Wireless Sensor Networks," IEEE Open Journal of the Communications Society, vol. 4, pp. 2050-2061, 2023, doi: 10.1109/OJCOMS.2023.3312155.

[14] U. Ghafoor and T. Ashraf, "Maximizing throughput and energy efficiency in 6G based on phone user clustering enabled UAV assisted downlink hybrid multiple access HetNet," Telecommunication Systems, vol. 85, no. 4, 2024, doi: 10.1007/s11235-024-01101-0.

[15] C. Annadurai, I. Nelson, K. N. Devi, and G. T. Raja, "Dynamic multipath routing for energy-efficient and reliable communication in 6G networks with MIMO," Internet Technology Letters, e559, 2024, doi: 10.1002/itl2.559.