







Research Article

Effects of Novel Material Field Effect Transistor for Heterogeneous Energy and Traffic-Aware Secure Applications

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The advent of the automated technological revolution has enabled the Internet of Things to rejuvenate, revolutionize, and redeem the services of sensors. The recent development of microsensor devices is distributed in a real-world terrestrial environment to sense various environmental changes. The energy consumption of the remotely deployed microsystems depends on its utilization efficiency. Improper utilization of sensor nodes' heterogeneity could lead to uneven energy consumption and load imbalance across the network, which will degrade the performance of the network. The proposed heterogeneous energy and traffic aware (HETA) considers the key parameters such as delay, throughput, traffic load, energy consumption, and life span. The residual energy and a minimum distance between the base station and cluster members are taken into consideration for the cluster head selection. The probability of hitting data traffic has been utilized to analyse energy and traffic towards the base station. The role of the sensor node has been realized and priority-based data forwarding are also proposed. As a result, the heterogeneous energy and traffic aware perform well in balancing traffic towards the base station, which is analysed in terms of maximum throughput and increase in a lifetime of heterogeneous energy networks more than 5000 rounds, and the algorithm outperforms 34.5% of nodes are alive with transmissible energy. The proposed research also endorses unequal clustering and minimum energy consumption. We have modeled our proposed research using various p-type junctionless nanowire FET without doping injunctions. The materials used in this analysis were silicon (Si), germanium (Ge), indium phosphide (InP), gallium arsenide (GaAs), and Al(x) Ga(1-x)As. The dimensions of the p-type cylindrical nanowire channel were 25 nm long and 10 nm in diameter.

1. Introduction

The pandemic monster, COVID-19, has become a huge challenge to present-day trauma-free automation technology. Now, the technology is moving in such a mode. So, beyond the specific application, the need for microsystems has been developed. Towards the smart living environment, wireless sensor network with multisourced Internet of things (IoT) has changed in many applications such as monitoring, surveillance, healthcare, automation, entertainment, and

industry. The only major challenge of the world for the last year has been the hazardous increase of COVID-19 positive test cases. The impending doom of the situation is the emergent need of the hour, and it has forced us to undergo basic health monitoring for the nonsymptom cases too. The technology in engineering always concerns with providing solutions to the medical field. Wireless sensor networks, artificial intelligence, robotics, and pervasive computing all as a whole have built an interdisciplinary concept to overcome day-to-day challenges in a smart way.

An environmental sensor such as RFID readers, video cameras, sound, pressure, temperature, humidity, and luminosity are some of the devices that provide information about the people to be monitored. The key problem for planning and managing the network for continuous monitoring will lead to maximum energy consumption. The types of multisources have been classified as link heterogeneity, energy heterogeneity, and computation heterogeneity which progresses the routing algorithm performance, network lifetime, network stability, reliability, etc., [1]. In the previous work, energy heterogeneity has been considered and topology has been designed to manage the energy by a centralized clustering scheme. Together with energy, network traffic is exponentially growing.

The development of micro-electro-mechanical system technology provides sophisticated applications that make the sensors relatively better and complex in technology advancement [2]. The cost of servicing and maintaining the IoT and handling with a larger number of sensors deployment play the major role [3], and replacing batteries in already deployed location is difficult based on the specific application.

This paper aims at balancing the traffic load towards the base station from the dual communication environment. With regards to direct communication and cluster-based communication, more traffic can be experienced in direct communication. The probability of traffic has been analysed concerning the data priority using finite-state mechanism, and from that, the sleep and awake schedule are provided for nonpriority and priority nodes. This would help in preventing the NP-hard problem and enhance the network lifetime with an increase in the number of heterogeneous energy nodes.

This paper is organized as follows. In Section 2, related works and required background are provided. Our proposed system model and algorithm are explained in Section 3. From the evaluation, the simulation results and analysis are discussed in Section 4. Finally, the article is concluded in Section 5.

2. Related Works

In [4], the author has concentrated on the scheduling of clustering through polling technique instead of traditional TDMA and CDMA, in cluster head election and routing algorithm have been developed under ABC and ant colony optimization. Fuzzy C means that clustering is taken for the artificial bee colony algorithm to find the optimal cluster head and to avoid the long-distance intracluster communication and the ant colony optimization has been applied for the best routing technique. The uneven clustering is balanced in [5]; the algorithm divides the network into different sizes such as near the base station clusters are smaller in size and the farther cluster is larger to balance the cost of the network and the increase of life too. Many energy-oriented algorithms are available using the Markov decision process formulated to balance the transmission energy. In [6], a centralized distributed algorithm is proposed to minimize the node's intracluster transmission

energy. The author concludes that using the decision policy, the power of transmission remains constant for the 40-time slots. Another work for centralized energy, proposed for the energy efficiency [7, 8], measured MDP for the transmission power selection, from which the state has been performed based on the fading channel and the reception error. Processing gain of the system is considered in modulation and coding schemes [9]. The simultaneous transmissions from different sensors are on different spreading codes. The interference of the base station concerns the priority frame selection-based CDMA [10]; from that, optimal selection of sensing groups has been given. In [11], the author has proposed the two priority schemes such as energy efficiency and data gathering. It mainly focuses on event-related data to be transmitted in the system. In [12], the matrix geometric method evaluates the performance of each traffic class by dynamic priority adjustment. Advanced zonal selection [13] is a heterogeneous routing protocol. In the middle zone, the nodes make direct communication with the sink node and they follow cluster-based communication at the boundary region. The cluster head selection is based on maximum residual energy and the minimum distance from the sink node. The unbalanced energy consumption due to the dynamic change of the topology is carried out using distance similarity index, and CH load is reduced using dual cluster head [14]. In [15], the author proposes an organized multipath and balanced load algorithm that ensures awareness of energy consumption. In [16], the author discusses the Markov decision process for adaptive intelligent dynamic water resource planning for urban areas to supply water on a sensitivity-driven method. The unequal clustering is addressed using a single path and mobile sink's multipath routing [17] and the HEESR is proposed. In [18–20], the swarm intelligence maximum coverage of the node has been discussed and compared with designed p-type junctionless nanowire FET without doping junctions. In [21–26], sensed heterogeneous data processing is carried out for different applications such as agriculture, weather information, and health monitoring for both live information and stored information. In [27–32], results have represented the feasibility that the sensor could be used to distinguish the different harnesses of the materials. To investigate the electrical transfer studies, various semiconductor materials such as silicon (Si), germanium (Ge), indium phosphide (InP), gallium arsenide (GaAs), and $\text{Al}(x)\text{Ga}(1-x)\text{As}$ are used. Additionally, surface charge and potential analysis are also studied.

3. Proposed Methodology

The HETA proposes a novel priority-based traffic-aware algorithm that the lifetime and stability of the network depends on the residual energy, the distance between the nodes, and the sleep and awake schedule is based on the coverage area-based node selection from the priority table to maintain the stability of the network even during the increase in the number of heterogeneous energy nodes.

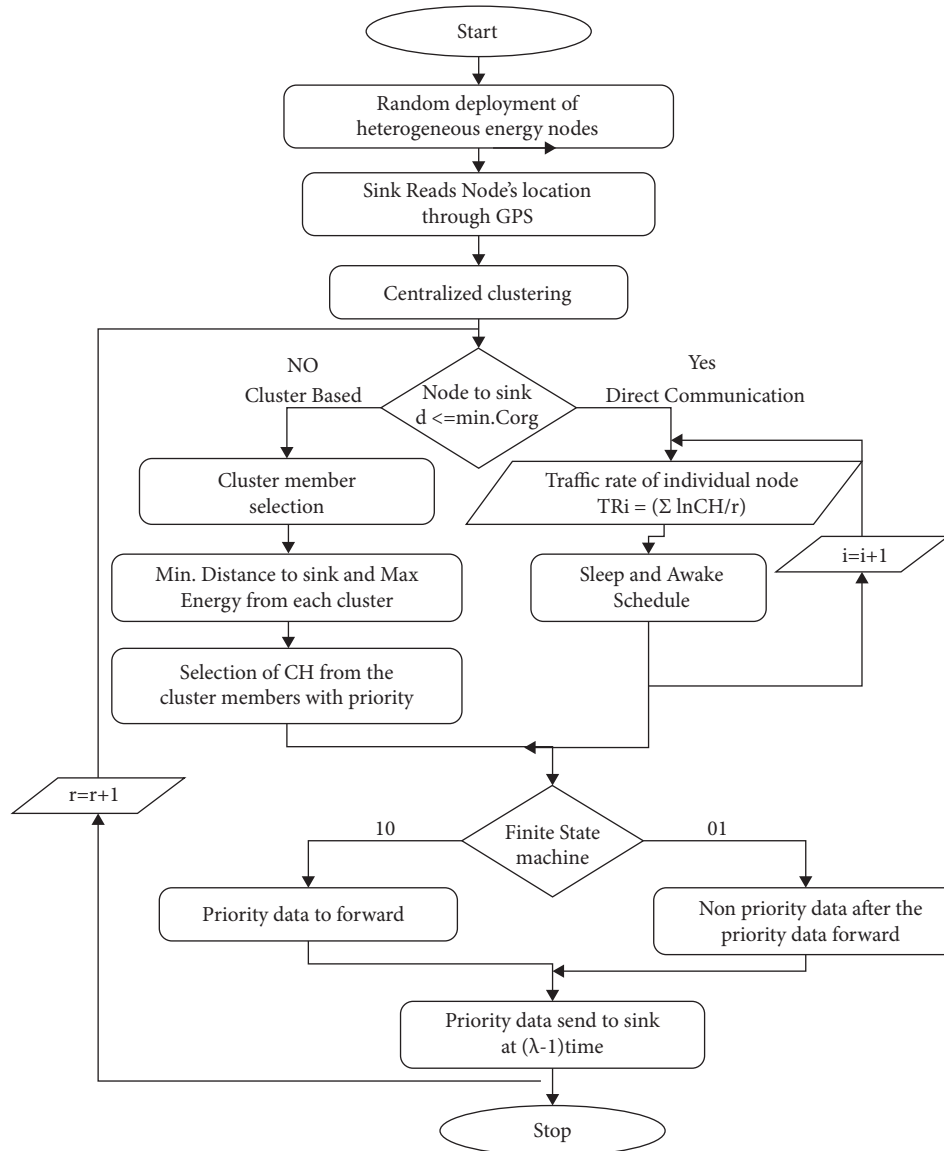


FIGURE 1: Flow diagram of HETA algorithm.

3.1. HETA Method. The proposed research is the priority-based balancing of the load over the network. The energy consumption of each node depends on the total number of packets and distance towards the receiving node. Here, the sink node performs the centralized clustering algorithm as explained in the previous work. The cluster head selection has been carried out in two important parameter considerations. Firstly, in each zone, the nodes which have maximum energy are selected as CH, and while increasing the number of transmission rounds, it should not become less than minimum energy (ETX + EDA). Secondly, the node has a minimum intracluster distance and less threshold distance to the sink to which the cluster member can be added.

The increase in scalable leads to a decrease in throughput. Due to the simultaneous transmission by the different sensors, whose transmission is on different spreading codes, interference could occur at the base station. Hence, the priority-based data processing is carried out

using Moore's finite state machine. Since the state of the node always depends on the present situation and also this data information is controlled by the state, this method has been followed. The prioritized code division multiple access is used for the data transmission between the zone1 active nodes and the CHs from the other zones. Active sensors are classified into different priorities that are controlled by the base station. In Figure 1, HETA is explained via flow diagram to differentiate the low-priority nodes from high-priority nodes, and we preassign the priority level at the system setup. From Figure 2(b), the CH has a high priority, and other active nodes (CM) from zone1 have low priority of the nodes' state diagram. The gate contact work function is achieved by applying gate terminal input potential. The SiO₂ gate has 4.1 eV work function and relative permittivity value of 4.2. On both ends of the wire, perfect ohmic contacts were established. Figure 2(a) shows the structure and electrical connection of the junctionless nanowire FET. Because of

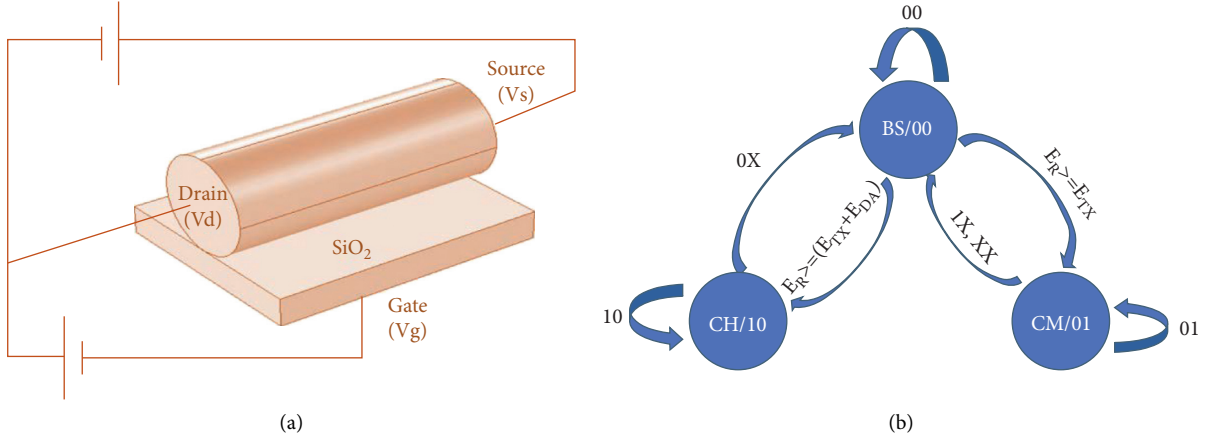


FIGURE 2: (a) Structure and electrical connections of junctionless nanowire FET. (b) Finite state mechanism.

TABLE 1: Simulation parameter consideration.

Parameter	Value
Network size	100 m × 100 m
Number of sensor nodes	100–300
Normal node initial energy	0.5–1.5 J
Eelec	50 nJ per bit
Efs	10 pJ per bit
Emp	0.0013 pJ per bit
Packet length (l)	4000 bits

p-type nanowire FET, the gate signal, which has the negative bias and drain, also has negative bias with respect to the source.

By using the Markov model, the FSM has been realized. The probability of getting priority information is $P(x)$, and the probability of getting nonpriority information is $P(y) = 1 - P(x)$. The data aggregation from different sensing devices based on the TDMA schedule is given by the CH.

The transition probability matrix of the state diagram given in expression expresses the present state i to the next state j transition matrix as

$$P = \begin{pmatrix} P_{11} & \cdots & P_{1l} \\ \vdots & \ddots & \vdots \\ P_{lj} & \cdots & P_{ij} \end{pmatrix}. \quad (1)$$

The probability of data forwarding from state i to state j extends to t -step transitions, given in equation (2); the transmission at t times is expressed in equation (3):

$$P_{ij} = P(X_{t+1} = j | X_t = i), \quad (2)$$

$$P(X_t = j | X_0 = i) = P(X_{n+t} = j | X_n = i) = (Pt)_{ij}. \quad (3)$$

For any n , here, we can consider the CH as the subset of the state space S . The hitting probability of the CH from its cluster members considered the data transmission from the steady-state phase. Equation (4) is the hitting probability:

$$hiCH = (X_t A: t \geq 0 | X_0 = i). \quad (4)$$

In the nonclustering environment, the increase in the number of sensing nodes creates an increase in the data rate. Hence, the traffic towards the BS increases, so the traffic aware of sleep and awake is needed for the network stability. The traffic rate of each node (TR_i) per round is given as

$$TR_i = \frac{\sum_1^{r-1} l_{nCH}}{r}, \quad (5)$$

where l is the data packet of each node noncluster head (nCH) in zone1 and r represents the number of rounds. From that, the HETA algorithm helps in a minimum number of CH allocations based on the increased residual energy and minimum distance to the base station. Since the data forwarding in the direct communication-sensing nodes follow the event driven, the average traffic rate of the network is given as

$$TR_{NW} = \frac{\sum_1^{r-1} l_{nCH} + K_{CH}}{r}. \quad (6)$$

A larger traffic rate of the node increases the average traffic rate of the network. Therefore, an alternate sleep-and-awake schedule is given by the BS concerning the node's position. Each node in the zone1, based on the Euclidian distance neighboring nodes' table, has been updated. In each cycle, one from each segment will endure for data transmission using

$$E_{Z1} = \sum_{i=1}^{nAN} E_{TX} \cdot l. \quad (7)$$

The sum of the transmitting energy of the active nodes (AN) in zone1(Z1) is the total energy of the direct communication of the nodes with priority scheduling. Hence, by using equation (8), the total energy consumption of the network per round is given:

$$ETot = E_{Z1} + \sum_{i=1}^{nCH} (E_{TX} + E_{DA}) \cdot l + \sum_{i=1}^{nCM} E_{TX} \cdot l. \quad (8)$$

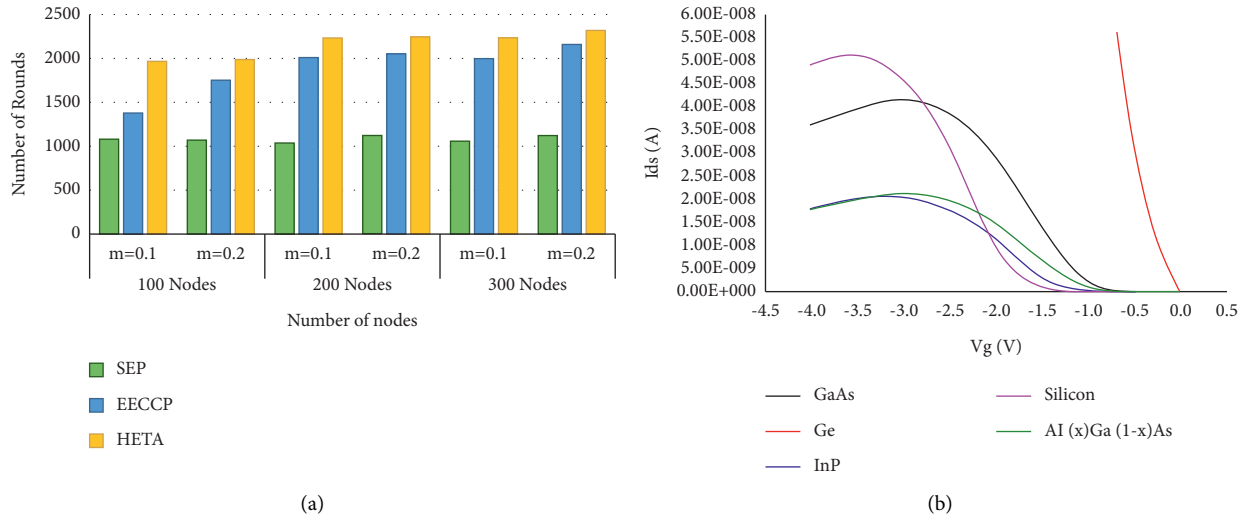


FIGURE 3: (a) Stability of the network with an increase in the number of nodes. (b) Characteristics of drain current with negative gate voltage.

TABLE 2: Stability of the network in various heterogeneous energy.

Stability	100 nodes		200 nodes		300 nodes	
	$m = 0.1$	$m = 0.2$	$m = 0.1$	$m = 0.2$	$m = 0.1$	$m = 0.2$
SEP	1083	1074	1045	1130	1069	1128
EECCP	1389	1759	2014	2057	2008	2164
HETA	1973	1999	2235	2252	2236	2325

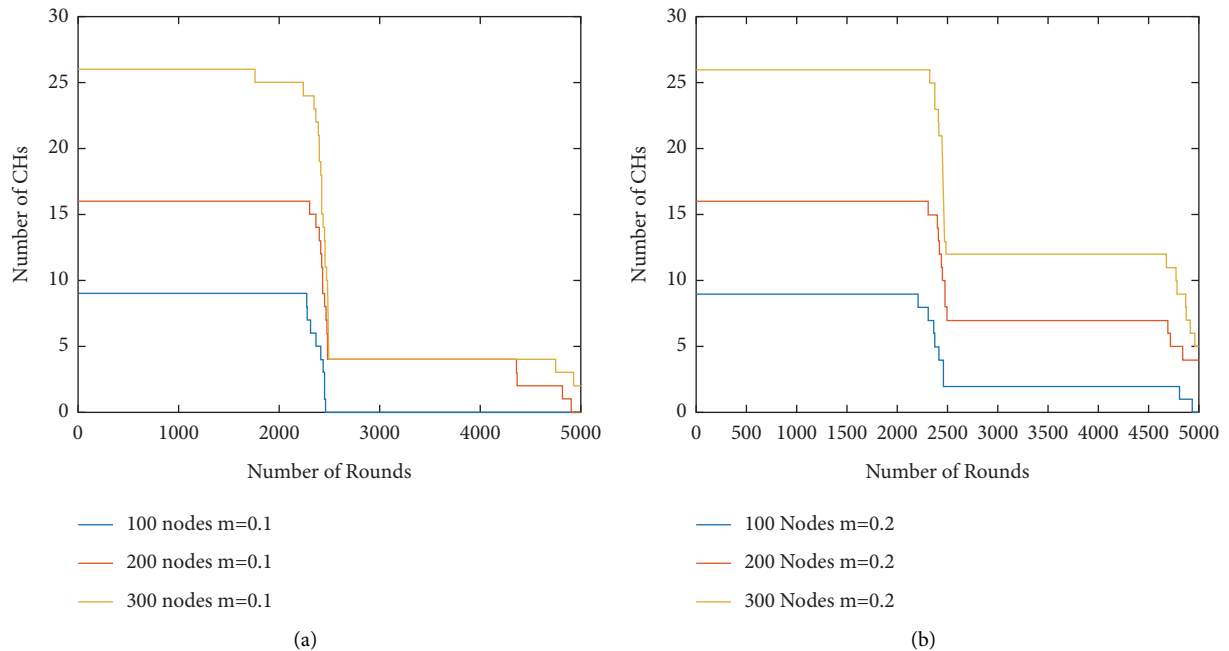


FIGURE 4: The static CH allocation in different nodes. (a) 10% of heterogeneous energy; (b) 20% of heterogeneous energy.

4. Results and Discussion

The proposed HETA algorithm evaluation is based on the simulation in MATLAB, with a $100m \times 100m$ square region. The nodes are deployed randomly with heterogeneous

energy within the monitoring area. Table 1 lists the simulation initial parameters consideration.

The random deployment of the heterogeneous energy nodes in the monitoring area and the sink node is placed at the center of the network. Nearer nodes of the base station

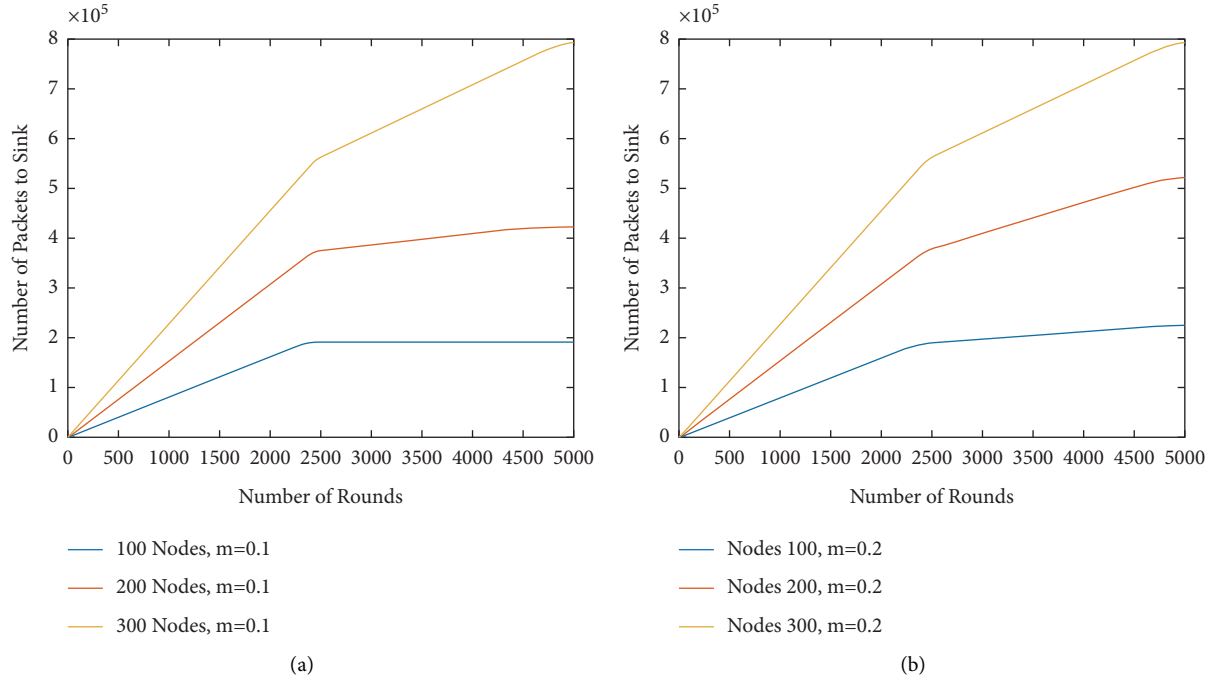


FIGURE 5: Throughput of the network in different scales. (a) 10% of heterogeneous energy; (b) 20% of heterogeneous energy.

TABLE 3: Traffic near to the base station.

S.No	Node ID	Residual energy	Distance (m)	Duty cycle of EECCP	Duty cycle of HETA
1	9	1.4998	10.1	1	1
2	6	1.4998	20.2	1	1
3	1	1.4998	23.5	1	1
4	47	0.4998	9.3	1	2
5	85	0.4998	12.7	1	2
6	87	0.4998	14.4	1	2
7	30	0.4998	21.9	1	2
8	88	0.4998	25.1	1	2
9	5	1.4998	11	1	3
10	51	0.4998	17.5	1	3
11	81	0.4998	26	1	3
12	48	0.4998	27.9	1	3

TABLE 4: Residual energy (in Joules) after 5000 transmission rounds.

HWSN	Initial energy	EECCP	HETA
100 nodes with 10%	64.97	53.38	54.38
100 nodes with 20%	79.97	67.36	67.44
200 nodes with 10%	129.94	117.22	117.98
200 nodes with 20%	159.94	146.28	147.47
300 nodes with 10%	194.92	181.89	182.51
300 nodes with 20%	239.92	226.09	227.49

will carry over the direct communication and farther nodes will undergo cluster-based communication. Figure 3(a) illustrates the stability of the network by understanding the first node dead (FND) with the maximum number of successful rounds with all nodes in the network are active. Our algorithm outperforms well in the various energy level

of nodes up to 300. The time taken by any of the nodes in a network to reach its dead condition defines the stability of the network. Table 2 demonstrates the performance of the proposed algorithms with respect to stability. While considering 10% heterogeneous energy nodes initially starting with 100, 200, and 300 nodes, whereas the FND after 1972

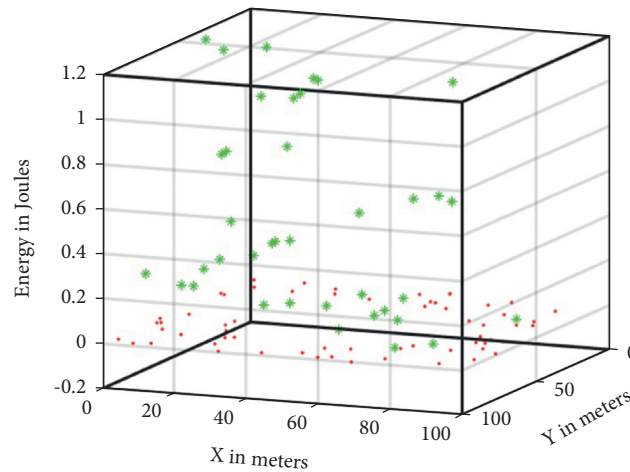


FIGURE 6: The residual energy of the network after 5000 rounds in 20% of heterogeneous energy of 100 nodes.

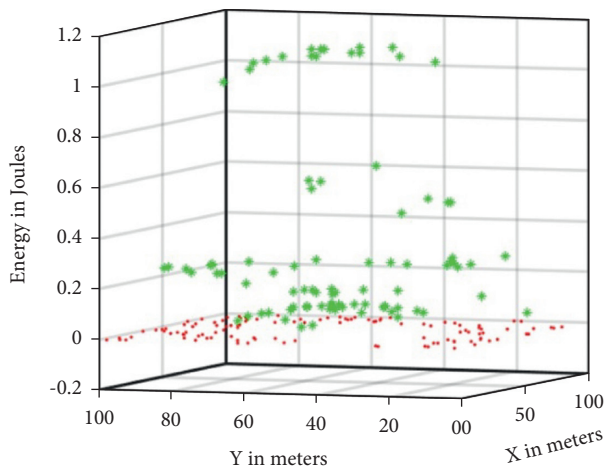


FIGURE 7: The residual energy of the network after 5000 rounds in 20% of heterogeneous energy of 200 nodes.

rounds, 2234 rounds, and 2235 rounds, respectively. Similarly, nodes with 20% of heterogeneous energy from 100, 200, and 300 increase in nodes the stability of the network lifetime achieved from the FND after the 1998 rounds, 2251 rounds, and 3223 rounds, respectively. While comparing the stability with SEP 22% better stability and with EECCP, 7% of better stability has been obtained.

4.1. Effect of Gate Voltage on Drain Current for Heterogeneous Energy. The drain currents were measured by changing the negative gate voltage from zero to 4.0 volts. Variations of drain current with biasing the negative gate voltage from 0 to -4 V is shown in Figure 1. The measured values are taken from the center point of the nanowire. The plot indicates that the values of drain current of indirect band gap materials are higher than the direct bandgap materials and alloy. From Figure 3(b), Ge and Si have higher values of drain current compared with other materials. The $\text{Al}(x)\text{Ga}(1-x)$ As semiconductor alloy has lower drain current changes. The electron mobility behavior attributes the lower current in InP and higher variations in Ge.

From Figures 4(a) and 4(b), the maximum energy consumption part of the network is the number of CH allocation with 10% and 20% of heterogeneous energy nodes, respectively. An increase in CH leads to an increase in energy consumption. From that, the HETA algorithm helps in a minimum number of CH allocations based on the increased residual energy and minimum distance to the base station. The algorithm was performed on centralized clustering technique, with static topology consideration. Hence, the lifetime of the network is increased to more than 5000 rounds.

Figures 5(a) and 5(b) illustrate the throughput of the network in 10% and 20% heterogeneous energy, respectively. HWSN with a different increase in node deployment is also carried out. In both scenarios, the successful packet delivery has been balanced even in the increase in the number of nodes for direct communication. Priority-based sleep and awake schedule provided the excellent load balancing of the network for more than 5000 rounds.

In Table 3, the traffic near the BS of the HETA protocol has been compared with the EECCP protocol [19]. From that, EECCP creates more traffic expressed in the form of all Zone1 nodes and cluster heads hit the BS. However, in HETA algorithm, based on the flow control technique, three segments were formed and the controlled data forwarding has been achieved on a priority basis. The run-time scenario also has been carried out to understand the cluster head allocation with respect to the distance and residual energy.

In Table 4, the energy utilization of HETA has been compared with EECP, 300 nodes of energy efficiency obtained 0.6%, and for 200 nodes, it is 0.7%, and for 100 nodes, it is 1.5% increase. The priority model of high and low has been considered. The classification of the priority of hierarchical approach need to considered.

Figure 6 illustrates the remaining energy of the network having 100 nodes with 20% of heterogeneous energy. On various energy levels, the higher energy level node of either advanced or intermediate nodes are elected as CH and also the cluster members are managed within the threshold distance, so the energy consumption of the normal nodes is well balanced.

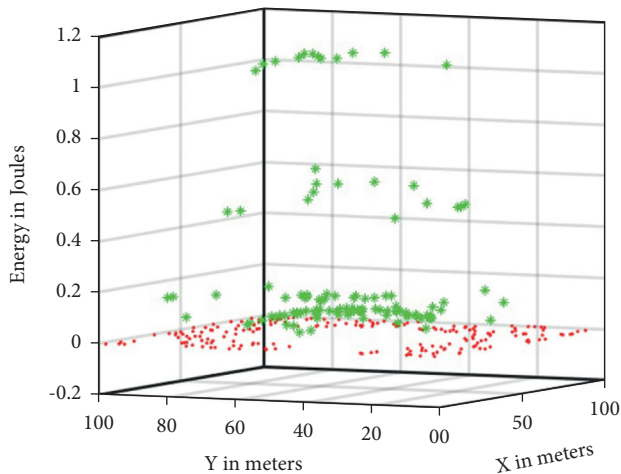


FIGURE 8: The residual energy of the network after 5000 rounds in 20% of the heterogeneous energy of 300 nodes.

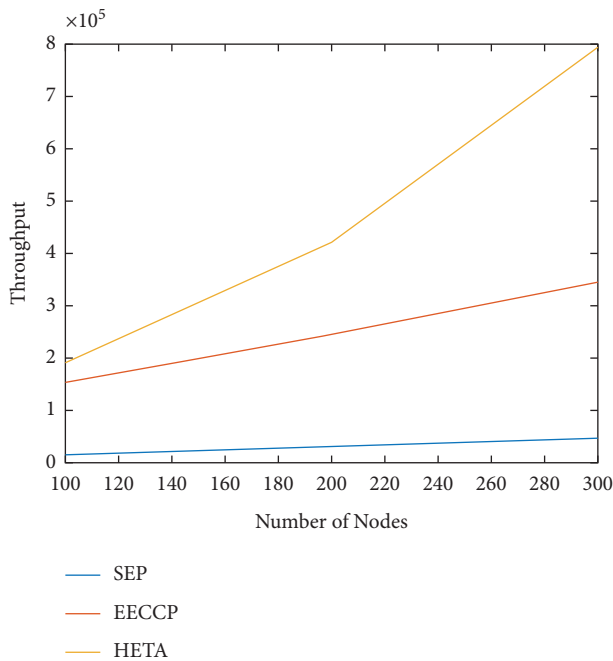


FIGURE 9: Throughput.

Near to the BS, load balancing is achieved based on the traffic-aware sleep-and-awake schedule and the energy consumption that has been reduced; hence, 25% of nodes are still alive after 5000 rounds.

Figure 7 illustrates the remaining energy of the network having 200 nodes with 20% of heterogeneous energy. In 80% of normal nodes, applying the HETA algorithm helps cluster head selection from higher energy nodes such as advanced or intermediate nodes; also, the cluster members are managed within the threshold distance, so the energy consumption of the normal nodes is well balanced. Near the BS, load balancing is achieved based on the traffic-aware sleep-and-awake schedule; the energy consumption has been reduced; 38.5% of nodes are still alive after 5000 rounds even with an increase in the number of nodes.

Similarly, Figure 8 illustrates the remaining energy of the network that has 300 nodes with 20% of heterogeneous energy. In 80% of normal nodes, applying the HETA algorithm moderately helps in increase of the number of nodes, and load balancing achieved comparatively more than 5% from 200 nodes and more than 15% from 100 nodes scenarios. Figure 9 illustrates the throughput, comparing HETA algorithm, performs 92% better than SEP and 40% better than EECCP. In more than 300 nodes, the algorithm results are stable due to the increase in traffic near the base station.

5. Conclusion

The proposed heterogeneous energy and traffic-aware algorithm serves as a better solution for scalable and priority-based packet forwarding. From the quality-of-service analysis, the proposed algorithm outperforms well in network stability. The network stability parameter of FND is compared with SEP, and it provides better stability up to 1097 rounds and 65% more energy efficient in heterogeneous network. Further incorporating the priority-based traffic-aware packet forwarding technique, the designed HETA outperforms the existing in terms of throughput by 40%, ultimately increasing the performance of the network. The proposed method includes an improvement of cluster head selection to reduce the data congestion with minimized energy consumption. To conclude, the designed algorithm gives a better performance for a heterogeneous network, leaving a track of additional delay which will be dealt in the future work. The indirect bandgap materials have higher response over the direct band gap material. InP has the highest surface potential values. This high change of surface potential in nanowire FETs can be used in nanostructured sensor applications.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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