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PRESEP: Cluster Based Metaheuristic Algorithm for Energy-efficient Wireless Sensor Network Application in Internet of Things.

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Abstract

A metaheuristic approach based hybrid data routing algorithm is proposed in this paper for energy-efficient wireless sensor network (WSN) applications in Internet of Things (IoT). High speed generation of network demands of more IoT enabled services and platforms. Swarm optimization in route finding is integrated with energy-efficient heuristic method to obtain improved data routing algorithm for heterogeneous WSN. Particle swarm optimized Residual Energy based Stable Election Protocol (PRESEP) simulation yields multi objective solutions for use of residual node energy, prolonged network lifetime and stable cluster formation. Protocol minimizes the cluster head (CH) selection cycle as an outcome of reactive protocol benefits of easy global search of swarm optimization for sustainable data routing in energy-efficient cluster based heterogeneous WSN. Scaling of network is supported by the algorithm with varied heterogeneity factor. Support for heterogeneous WSN with various network sizes are evaluated and found it outperformed previous heterogeneous algorithm in terms of network lifetime, alive nodes, reduced energy consumption with minimum number of repeated CH selection process.

Keywords Metaheuristic algorithm; routing; energy-efficient; network lifetime; Internet of Things.

1 Introduction

Advancement in the microelectronics and wireless communication have tremendously progressed the WSN. WSN are autonomous, responsive, reconfigurable decentralized interconnection of sensor nodes (SN). Larger dimensions of WSN constitutes IoT infrastructures with complex machines involvement for many decision making tasks with cloud or standalone server computations. SN can be categorized in many ways based on its components capabilities. SN includes radio frequency transmitting and receiving device, storage, processing and analog to digital with digital to analog converter integrated in systematic way to perform tasks of communication, computing and forwarding messages [1]. SN are equipped with limited power source of battery and solar cells in recent days [2]. Due to maximum utilization of information fetch and communication link establishment, SN are always in scarcity of energy to stay active for long duration, which turns to be a major challenge for research to optimize the energy consumptions. WSNs are mostly deployed in remote and inaccessible environment to measure or record several events of occurrences. These events include atmospheric conditions, movements, air particles, pressure, heat, humidity, earthquake, fire, and many other specific happenings [3]. Due to vast types of SNs development, several applications of WSN are utilized. WSNs used in security systems, military fields, weather monitoring, biomedical, healthcare applications, agriculture and many more real time applications [4-6]. Data extracted from SNs are collected at base station (BS) or sink. IoT applications have BS further connected to internet access point through gateways to server system. In 5th generation communication these are frequently connected with cloud network for data availability at global level with shared computational procedures [7].

The enormous IoT application in 5G enabled high speed network demands more network lifetime in real time monitoring systems. Trend of smart applications in smart factories, smart cities, smart traffic, smart buildings, smart care for individual health and hospital networks, and other smart applications are evolving rapidly [8]. The hereditary constraints of WSN are due to its SNs limitations in network scaling and longevity are major challenges to be addressed for its application requirements. Improving routing efficiency shown prominence advantage in improving energy limitation than other techniques [9]. In this paper, data routing approach is presented with improvement in network lifetime and support for large heterogeneous SNs deployments. Hierarchical routing approach is used to form clusters of SNs with a leader to communicate with the BS as cluster head (CH). A metaheuristic CH selection technique is used along with novel heterogeneous routing protocol compatible with heterogeneity of the network in IoT environment.

Most of the energy in WSNs are consumed during transmission and reception of information's with neighbor nodes or BS [10]. In an active WSN, transmission of path establishment control messages, data recorded by SNs and other types of decision control signals are involved throughout the network lifetime. Essentially every application of WSN requires flow of data from multiple SN to a specific BS. So, data redundancy is very likely to occur and overload of data attribute based routing is on SN demands more resources of energy and storage [11]. Routing protocol in WSN are classified into two categories; cluster based routing protocol works in two stages; first, it forms a cluster based on radio coverage of the SNs and second, a CH is elected among cluster member nodes to send events to the BS [12].

The remaining paper discusses routing challenges faced by WSNs and requirement of efficient design in section 2. Heuristic cluster based routing protocols in WSNs is given in section 3. Section 4 presented heterogeneous network architecture considerations for analysis. Hybrid metaheuristic data routing approach for energy-efficient routing in heterogeneous network is proposed in section 5. Simulation and analysis based on the proposed algorithm is elaborated in section 6. We conclude our findings with future research area in section 7 of the paper.

2 Energy Efficiency in WSN and Related Design Issues

The indefinite applications of WSNs in current to upcoming generation of network i.e. 5G has made it very demanding to tackle the inheriting challenges. Challenges of limited resources in SNs as limited energy, processing, bandwidth and storage for storing routing attributes, calculations and radio transmission requirements. The common requirement of all the real time application is long network lifetime, durable connectivity and flexible coverage from small to large area. Routing protocols for WSNs must consider these with updated requirements. Generic routing challenges faced by WSN is presented by Pantazis et al [13]. Here, we summarize WSNs routing challenges in heterogeneous environment for high speed networks.

Challenge of nodes distribution: Distribution of SNs in WSN are highly application dependent and directly impact of routing process [14]. General categorization of nodes distribution is either in deterministic or random orders. When each SN are manually placed and routing is obtained from planned paths, nodes are placed in deterministic order. While, the nodes are scattered in random order to cover a specific area of network is termed as random distribution of nodes. Issue arises due to non-uniformity observed in the distribution for the routes in network access period. It is quite often that multi hop communication will be used for optimal link establishment between cluster and the BS. An optimal solution for efficient inter nodes transmission and under limited bandwidth is the mandatory requirements for any distribution.

Challenge of data transmission accuracy: The self-organized structure of WSNs requires every node to play multiple functions, such as sending data and forwarding packets received from one neighbor to the next node. A single energy exhausted node can create a void in the network path with immediate demand of rerouting causing major topological change for the existing organization. For an accurate delivery of data packets energy consumption of multifunctioning nodes has to be optimized in significant ways [15].

Challenge of nodes heterogeneity: In the new domain of WSNs application in IoT paradigm, SNs are more of heterogeneous in terms of communication, battery capacity, processing and storage. Its homogeneous counterpart is facing more issues in hierarchical routing, as cluster needs powerful node to become CH than nodes with low energy [16]. More heterogeneous features need optimized routing for fast decision making among the available SNs to play CH role or other lead roles in the network to prolong its lifetime.

Challenge of network expansion: Number of SNs deployed to measure or record events depends on application, which can vary from hundreds, millions or more. So, the routing protocol managing such varied density of SNs must be capable of finding route efficiently with scaling of its dimensions.

Challenge of data aggregation: Data redundancy is most common issue in WSNs as the nodes are responding to the queries without considering other nodes transmission states. Bottleneck of data in cluster based routing is another issue to be tackle by the routing mechanism. Various statistical models such as, average, minima, maxima are used to further enhance data accuracy at collection point in the network. Modern technique of beamforming is used for better incoming signal combination and noise reduction before sending data [17].

Challenge of Quality of Service (QoS): QoS of data depends on timely delivery of data to the BS. There is always a tradeoff between energy efficiency and QoS as network lifetime is more important in some application than speedy delivery of data and vice versa [18]. Thus, routing protocol will consider QoS while managing energy of the nodes.

Other challenges are from network coverage, fault tolerance, connectivity, mobility of nodes faced by WSNs. Coverage of the network decided by the node deployment with respect to its radio range. In case of nodes fails to contribute due to lack of energy or other causes, network should be able to sustain communication is fault tolerance of the network [19]. SNs are expected to be connected during the lifetime of the network. The connectivity depends on the nodes distribution in the network. SNs mobility changes the topology of the network and rerouting is expected for data exchange. Routing protocol designing has to consider all or some of them depending on the application requirement for better energy efficiency in the network with prolong lifetime of the network [20-23].

In WSN based application designing most of the challenges discussed above are derivation of energy comsumption by individual or whole network components. The paper has proposed a hybrid method to tackle the energy comsumption of WSN to improve the challenge of longer duation of activity monitoring and rapid response by the nodes.

3 Heuristic Cluster Based Routing Protocols in WSN

Such protocols are initially proposed for wired network, which has been observed for improved performance in WSN. It improves the network lifetime; available node energy and better data fusion [24]. CH are those nodes which has relatively more energy than other SNs. Data aggregation, and other data operations are performed by CH and forwarded to the BS. Cluster members are collecting the events and respond to the CH query with the data. With such distribution of operations reduces energy consumption of the network significantly. Clustering algorithm are renowned for effective data transmission with minimum energy consumption. Thus, cluster based model help in prolonging the lifetime of network.

Most common protocol in this category begins with threshold sensitive energy-efficient sensor network [25]. A reactive protocol selects superior node as CH from the two level network distribution. Low energy Adaptive Clustering Hierarchy (LEACH) [26], randomized local CH rotation for uniform network energy distribution among SNs. Hybrid Energy-Efficient Distributed clustering [27], assures connectivity of nodes divided into clusters. The hybridization of residual energy (RE) with other nodes distance from neighbor etc. used for uniform CH selection in the WSN. A chain based data aggregation is introduced by power efficient gathering in sensor information systems (PEGASIS) with the help pf greedy algorithm in distributed manner [28]. Concentric clustering scheme, Energy balanced chain cluster routing and chain based hierarchical routing are similar to PEGASIS in terms of data transmission by them is chain based [29-31]. LEACH protocol is used massively to improve energy efficiency of WSN. Centralized cluster formation used for improved CH distribution in the network by LEACH-centralized [32]. Another variation of LEACH is a Two Level LEACH, which adds one more level of cluster over the LEACH formed cluster to reduce energy consumption in CH to BS data transmission [33]. Distributed A musical centralized cluster based metaheuristic protocol is presented by [34] as Harmony Search Algorithm (HSA). Minimum mean distances between cluster members and energy efficiency were considered for cluster set up and CH selection in HSA. Won and Stoleru proposed minimum energy cost tree based hierarchical routing protocol as Power Efficient Data gathering and Aggregation Protocol [35]. With new terminology network depth i.e. least number of hops from the source node to the parent node in tree structure used in Enhanced tree routing, which uses parent child links only [36]. Hierarchical Geographic Multicast Routing improvised the forwarding efficiency and encoding overhead of Geographical Multicast Routing and Hierarchical Rendezvous Point Multicast respectively [37].

Hybrid metaheuristic approach for routing in cluster based WSN uses delay, energy, distance and security cost metric for increasing energy efficiency, network lifetime and other network performance optimization. The mathematical model of bioinspired theory to obtain solution for optimization problems in WSN introduces metaheuristic methods. Genetic Algorithm (GA)-based Energy-Efficient Clustering and Routing is proposed by Obad and Ilyas [38]. Load balancing is used for SNs energy consumption. [39] uses GA for dynamic CH selection proposed Genetic Algorithm Based Energy-Efficient cluster. Particle Swarm Optimization (PSO) based routing algorithm developed by [40-42]. PSO utilizes the position and velocity of moving particles to get the globally best solution. Enhanced PSO based Clustering Energy Optimization used distance and RE for better performance of network lifetime [43]. Ant Bee Colony employed in multi hop communication to select CH from the fitness function of RE is proposed by [44]. Breeding Artificial Fish Swarm Algorithm utilizes end to end delay and energy with randomly split swarming behavior [45]. FireFly Cluster Head Selection Algorithm takes fitness function of energy, end to end delay and packet loss ratio for optimized CH selection [46]. Combined clustering and routing search method based Integrated Cuckoo and Harmony Search distributed the function of routing with harmony and clustering with cuckoo [47]. Spider Monkey Optimization provides sampling method for CH selection and optimizes coverage and energy of the SN in WSN [48].

Pure heterogeneous WSN (HWSN) in terms of different level of energy distribution is used by Stable Election Protocol (SEP) [49]. Whole WSN divided into two levels of energy with SNs having initial energy as level 1 and SNs with weighted energy of initial energy as level 2. Such two levels of heterogeneity increases stability period and throughput of the network.

Distributed Energy-Efficient Clustering (DEEC) optimizes WSN and better energy balancing achieved by [50]. A game theory inspired Threshold Game Theory Algorithm based DEEC considered weighted CH and member energy consumption for threshold [51]. Whale Optimization Algorithm optimally search the nodes with highest fitness value based on hunting behavior of humpback whales for CH election [52]. Rooster based classification used for CH selection proposed in Chicken Swarm Optimization algorithm [53].

4 Heterogeneous Network Architecture

The proposed protocol is deployed on HWSN keeping IoT application in demand for WSN. An example of the HWSN deployed for universal IoT application is shown in Fig. 1. The proposed protocol assumed the following for simulation in MATLAB environment.

1. Stationary SNs are distributed randomly in the network area.
2. SNs are initialized with different level of weighted energy for heterogeneity.
3. Correlated data observed for very closed nodes.
4. BS is stationary in most of the simulation time.
5. Radio model of the network utilizes the following energy distribution modelling.
6. Symmetrical communication channel is considered.
7. All SNs are assigned with 0.5 Joules of initial energy.
8. Periodic transmission of data taking place in the network.
9. BS send received data to cloud for IoT applications.

Threshold sensitive Stable Election Protocol is an improved version of SEP with features of reactive routing for three levels of heterogeneity. Heterogeneity defined by allotting three levels of energy to the SNs as:

1. Regular SNs (RSN)
2. Advanced SNs (ASN)
3. Super SNs (SSN)

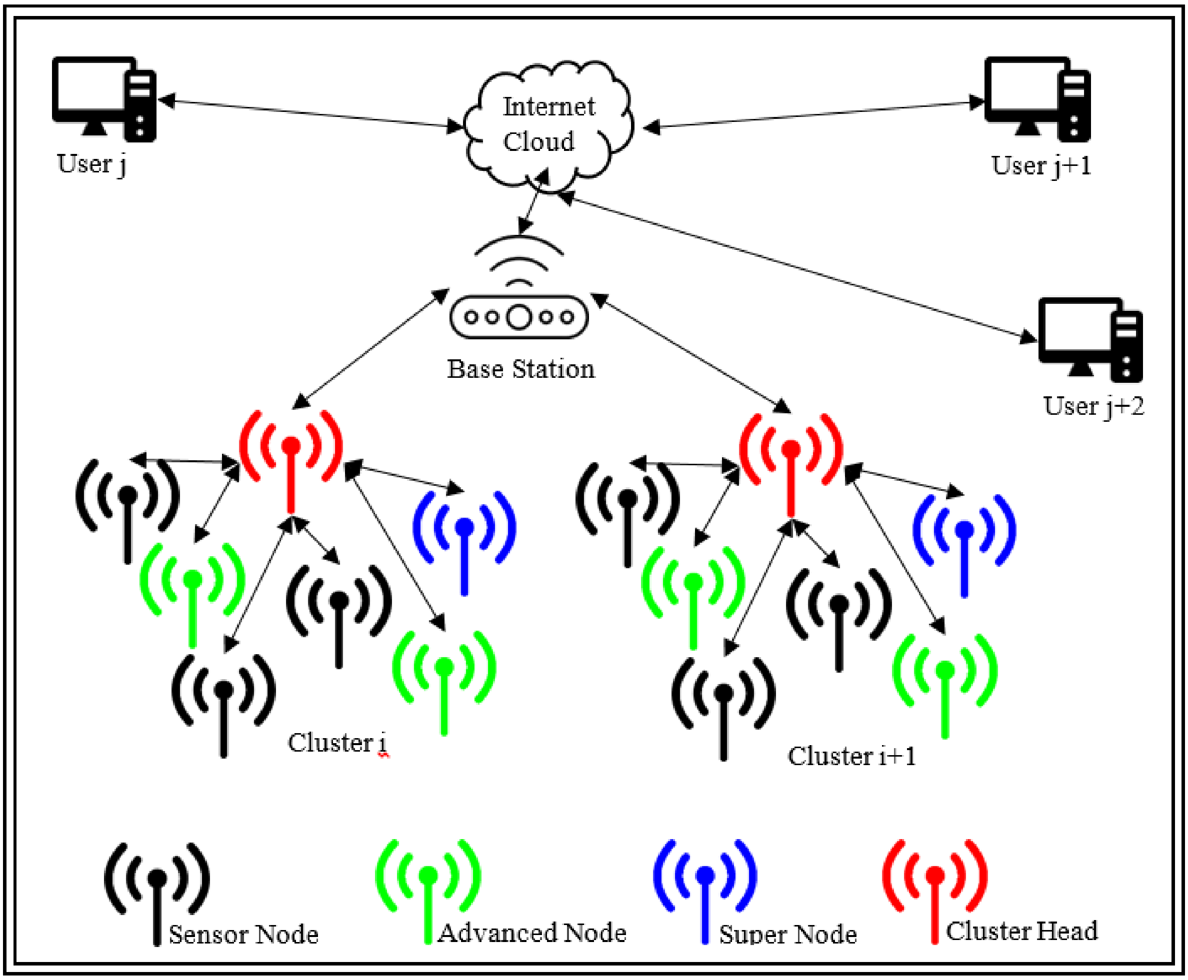


Fig. 1. HWSN Universal IoT Application

Consider, a HWSN with n SNs deployed in area m x m square meter. Energy levels among these SNs are denoted by E_{SSN}, E_{ASN} and E_{RSN} for SSN, ASN and RSN respectively. Their energies are related with the following expression in Eq. (1) as:

$$E_{SSN} > E_{ASN} > E_{RSN} \tag{1}$$

$$E_{SSN} = E_{RSN}\,(1+\beta) \tag{2}$$

$$E_{ASN} = E_{RSN}\,(1+\alpha) \tag{3}$$

$$\alpha = \frac{\beta}{2} \tag{4}$$

where,

E_{RSN}	-	initial energy of the node or regular sensor node
E_{ASN}	-	initial energy of the advanced sensor node
E_{SSN}	-	initial energy of the super sensor node
β	-	additional energy factor of super sensor node
α	-	additional energy factor of advanced sensor node

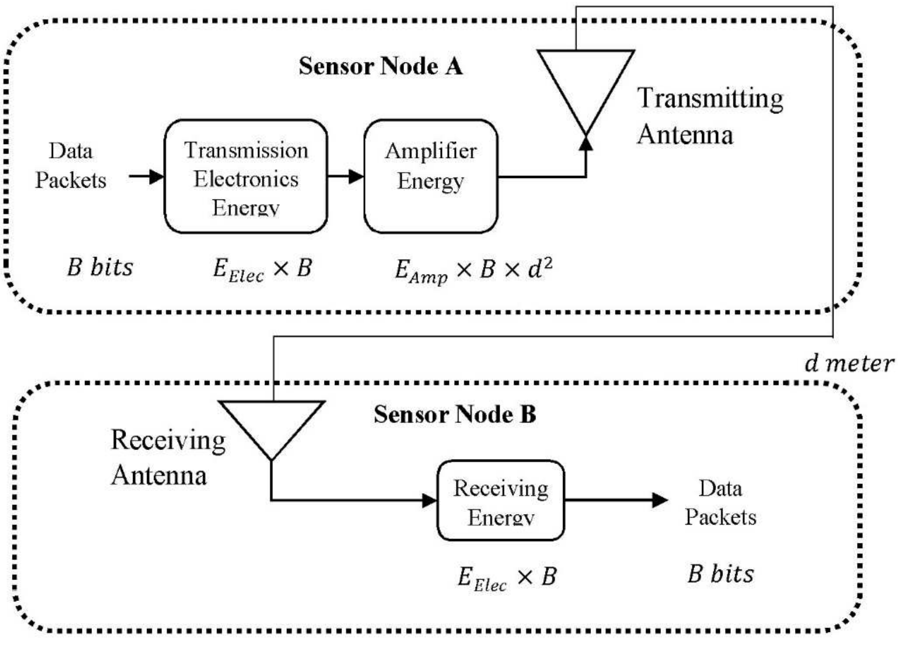


Fig. 2. SN Electronics Communication Model for Simulation

If *p* and *q* are the proportions of *n* SNs assigned as SSN and ASN respectively. Then, their total energy is computed in Eq. (8) from the following derivation as:

$$Total\ E_{RSN} = n\,E_{RSN}\,(1-p-q) \tag{5}$$

$$Total\ E_{ASN} = n\,q\,E_{RSN}\,(1+\beta) \tag{6}$$

$$Total\ E_{SSN} = n\,p\,E_{RSN}(1+\alpha) \tag{7}$$

$$E_{Total} = nE_{RSN}(1-p-q) + nqE_{RSN}(1+\beta)npE_{RSN}(1+\alpha)$$

$$= n\, E_{RSN}(1 + \alpha p\ +\ \beta q) \quad (8)$$

The energy required in transmitting 'B' bits of data from a SN to another SN with 'd' distance can be written as:

$$E_{Tx}(B, d) = E_{Tx\_elec}(B) +\ E_{Tx_{mp}}(B, d) \quad (9)$$

$$E_{Tx}(B, d) = \begin{cases} E_{elec} * B\ +\ E_{fs} * B * d^2, if\ d \leq d_0 \\ E_{elec} * B\ +\ E_{mp} * B * d^4, if\ d > d_0 \end{cases} \quad (10)$$

$$E_{Rx}(B) = E_{Rx\_elec}(B) = B * E_{elec} \quad (11)$$

where, E_{elec} is the energy required to send or receive a bit of data, it includes electronic processing of a bit of data. E_{fs} and E_{mp} are the energy required for short distance i.e. free space model and longer distance i.e. multi path model respectively. The value of d_0 is obtained by equating the two expressions of Eq. (10) at $d = d_0$, we get $d_0 = \sqrt{\frac{\mathrm{E}_{fs}}{\mathrm{E}_{mp}}}$. SN communication model used for simulation is shown in Fig. 2.

5 PRESEP : Particle Swarm Optimized RE Based SEP

Metaheuristic approach based routing in WSN had reduced memory and computational advantages in route discovery. PSO is one of the fastest optimizing technique for multi objective solution motivated author to apply with the proposed algorithm for data routing in HWSN. Swarm behavior of bird's flock inspired the mathematical model for PSO. The i^{th} particle occupies a position X_i with velocity V_i in Dth dimensional space. The global solution is searched in the nth optimal parameters space. Each particle is iterated with an objective function $f\ (x_1, x_2, \cdots, x_n)$ for $f\ : R^n \rightarrow R$. Once, the global best solution achieved by PSO, the position of the particle *i* with its lowest fitness value stored as personal best position, $pbest_i$. global best position of the whole swarm is denoted as $gbest_i$. Particle updates its position and velocity from the following rules:

$$V_i(iter + 1) = w. V_i(iter) + a_1. r_1. \left(pbest_i - P_i(iter)\right) + a_2. r_2\left(gbest_i - P_i(iter)\right) \quad (12)$$

$$P_i(iter + 1) =\ P_i(iter) +\ V_i(iter) \quad (13)$$

where, $iter$ is the current iteration and the next iteration is $iter + 1$, w is the inertial weight, a_1 and a_2 are acceleration factors known as cognitive and social component respectively. r_1 and r_2 are random numbers within range [0,1].

The threshold probability used for CH election from SEP is given as:

$$T(S) = \begin{cases} \frac{P}{1 - P \times r \times mod(1/P)} & , if\ S\ \in F \\ 0 & , if\ S\ \notin F \end{cases} \quad (14)$$

where F is the set of nodes not yet selected as CH in the current round, S is the node, r is the current round, P is the probability of the node to be selected as CH.

The respective threshold for the three categories of nodes can be obtained from the following threshold probability relationships.

$$T(S_{RSN}) = \begin{cases} \frac{P_{RSN}}{1-P_{RSN}\times r\times mod(1/P_{RSN})} & ,if\ S\ \in F_{RSN} \\ 0 & ,if\ S\ \notin F_{RSN} \end{cases} \tag{15}$$

$$T(S_{ASN}) = \begin{cases} \frac{P_{ASN}}{1-P_{ASN}\times r\times mod(1/P_{ASN})} & ,if\ S\ \in F_{ASN} \\ 0 & ,if\ S\ \notin F_{ASN} \end{cases} \tag{16}$$

$$T(S_{SSN}) = \begin{cases} \frac{P_{SSN}}{1-P_{SSN}\times r\times mod(1/P_{SSN})} & ,if\ S\ \in F_{SSN} \\ 0 & ,if\ S\ \notin F_{SSN} \end{cases} \tag{17}$$

where, $T(S_{RSN})$, $T(S_{ASN})$, and $T(S_{SSN})$ are the threshold probability for regular, advanced and super nodes respectively.

In the proposed algorithm, remaining energy of node is given importance for the selection of CH in the current round. Threshold probability is modified to include energy left with the node to assure the node with higher energy will be selected as new CH in that round. The threshold formula is replaced with the new threshold calculation as given below:

$$T(S) = \begin{cases} \frac{P}{1-P\times r\times mod(1/P)} \times re(i) & ,if\ S\ \in F \\ 0 & ,if\ S\ \notin F \end{cases} \tag{18}$$

and

$$re(i) = \frac{E(i)}{E_{av}\times E_{const}} \tag{19}$$

where,

$re(i)$	remaining energy in node
$E(i)$	energy left with node in the current round
E_{av}	average energy of the current node
E_{const}	energy constant.

The node with maximum value of $re(i)$ will have higher probability of becoming CH in the round. The function is calculated as:

$$Maximum\ re(i) = \sum_{i=1}^{n} E_{CHi} \tag{20}$$

where, $E_{CHi} = E - \{E_{xi\rightarrow ch} \times b + E_{ch\rightarrow xi} \times h + D_{BS-CH} \times p + E_{active+idle} \times time\}$ (21)

The hybrid PSO will combine these in a single objective function as:

$$Minimum\ Fitness = \left(\rho \times D_{CH-BS} + \sigma \times {D_{SN-CH}}^{2}\right) + \frac{\Omega}{re} \tag{21}$$

where, D_{CH-BS} is the distance between CH and BS, D_{SN-CH} is the distance between SN and CH, ρ, σ and Ω are the weighted factors for the function of distance of CH to BS, SN to CH and RE respectively.

CH has many operations to perform in the HWSN. Energy level of CH utilized for cluster maintenance and forwarding aggregated data to the BS as well as some data processing task before sending it to BS. Thus an optimal CH selection can prolong the network lifetime massively. Proposed algorithm nominates super nodes as CH which is replaced with maximum RE left with the node in next round of operation for next CH using swarm optimization. It adds more nodes available for CH with higher energy left as the number of SNs participation reduced by global search solution. Also, SNs are not processed frequently for the selection of CH as in the previous version of heterogeneous routing protocols. Reducing number of CH selection calls, overall energy consumption of the network is reduced enormously. With the reactive approach of SEP increases the sleep time of SN which in turn increases RE with them. Average time of cluster lifetime increased with PSO optimization of data positioning and faster delivery of data from optimized route. Support for heterogeneity boosted the HWSN for high speed network application of HWSN in future network of 5G and beyond IoT applications. Pseudocode for the proposed algorithm is presented in Table 1.

Table 1. PRESEP Algorithm

Parameters: *Swarm size **n**, iteration up to **r** rounds, inertia weight **w**, learning factor **c1***

Input:

(1) *Matrix BS*

(2) *RE vector re = re(1), re(2), ..., re(n-1)*

(3) *Distance vector Di = Di(1), Di(2), ..., Di(n-1)*

Output: gbest.P // *optimized data routing*

Step 1: **initialize** Init

Step 2: **for** i=1 to N_p **do** // *Swarm Population initialization*

    Route[i].P = P_{init} // *random distribution of nodes*

    Route[i].V = 0 // *initial velocity*

    pBest[i] = Route[i]

    Route[i] = MaximumFitness // *fitness value calculation*

End

Step 3: gBest = {Route[j] | fitness(pBest[j]) = min(fitness(pBest[i])) //

Step 4: **while** (!(terminate))

  for i=1 to N_p **do**

      Update Route[i]

      Store New Position: Init = Init ∪ new Route[i]. P If

      Calculate Route[i]. MaximumFitness

      Update pBest:

  End

16.		**Update** gBest: gBest = pBest[best]
17.		**End**
18.	Step 5:	**output** gBest.P

6 Simulation and Analysis

Network parameters used for simulation of the proposed algorithm is given in Table 2. HWSN is shown in Fig. 3, with less round of operation i.e. 2000 rounds for heterogeneous nodes distribution. The RSN, ASN, SSN, CH and BS are marked as ‘o’, red ‘◊’, blue ‘☆’, ‘□’ and ‘△’ respectively. Total of 100 SN are deployed in all the network area for less impact of radio on coverage with moderate density. Color of ‘□’ representing the corresponding types of nodes elected as CH in that round of operation. PRESEP tested for IoT network scaling support, improved network lifetime and heterogeneity in terms of network size, number of SNs alive, number of SNs dead and throughput are shown in Fig. 4, 5 and 6 respectively. Number of rounds selected as 7000 for uniform network size of 100x100 square meters.

Fig. 4 (a), (b) and (c) are providing prolonged network stable period. The stable period is defined as the period from beginning of the network activities to the first dead node. PRESEP provides more alive nodes for longer duration of network lifetime. The overall RE improved the node management in data routing process.

Fig. 5 (a), (b) and (c) are providing prolonged network lifetime period. The network lifetime period is defined as the time period from the start of network processing to the last dead node reporting time. PRESEP consumed less energy from the nodes due to optimized CH election involving global search by PSO. The overload of computation by CH is reduced in maintaining the data routing in WSN.

Heterogeneity support of the algorithm performed in Fig. 6, with heterogeneity factor ρ as 10, 20 and 40 percentages in Fig. 6. (a), (b) and (c) respectively of total SNs, which varies corresponding values of β for SSN. It also provides enormous data handling capacity of the network with the proposed algorithm.

Table 2. Specific Values of Network Parameters for Simulation

Parameters	Values
Distance constant, d_0	87m
Free space propagation factor, ε_{fs}	10 pJ bit^{-1} m^{-2}
Multi path fading factor, ε_{mp}	0.0013 pJ bit^{-1} m^{-4}
Energy consumption per bit, E_{elec}	50 nJ bit^{-1}
Energy for data aggregation, E_{DA}	5 nJ bit^{-1}
Length of the message, B	4000 bit

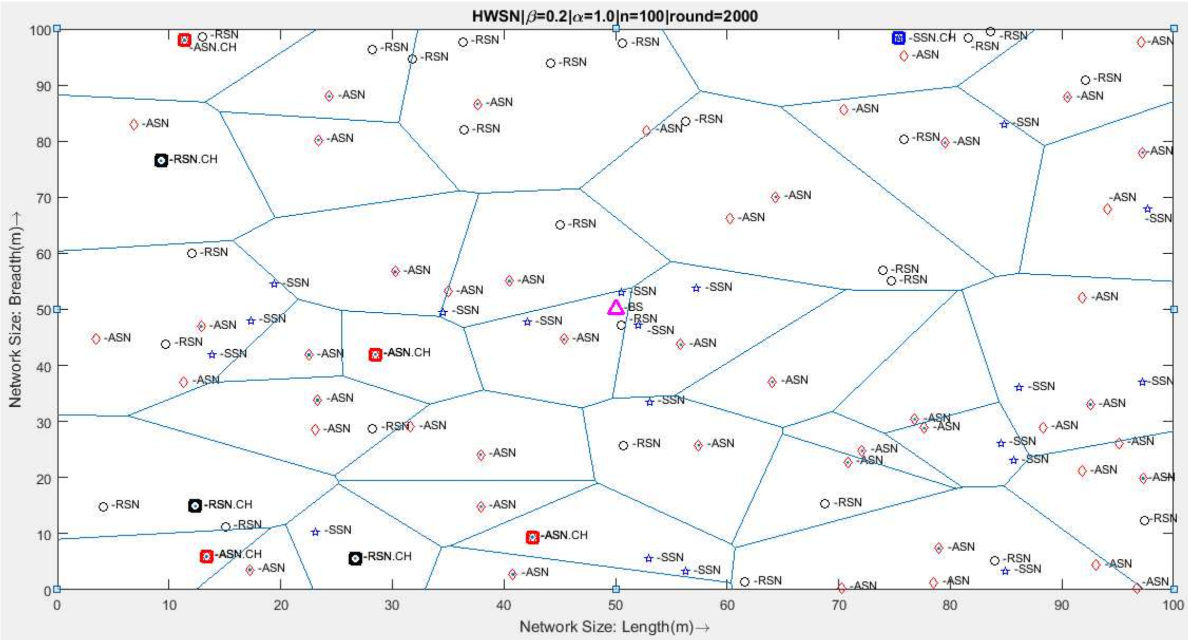
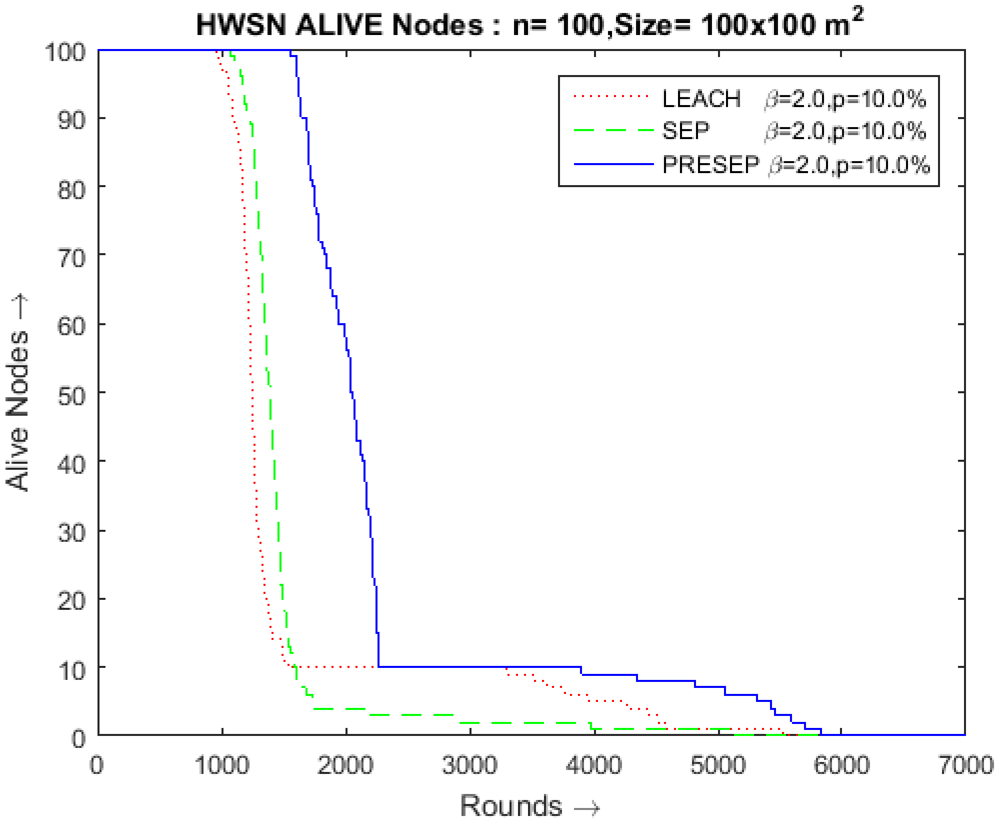
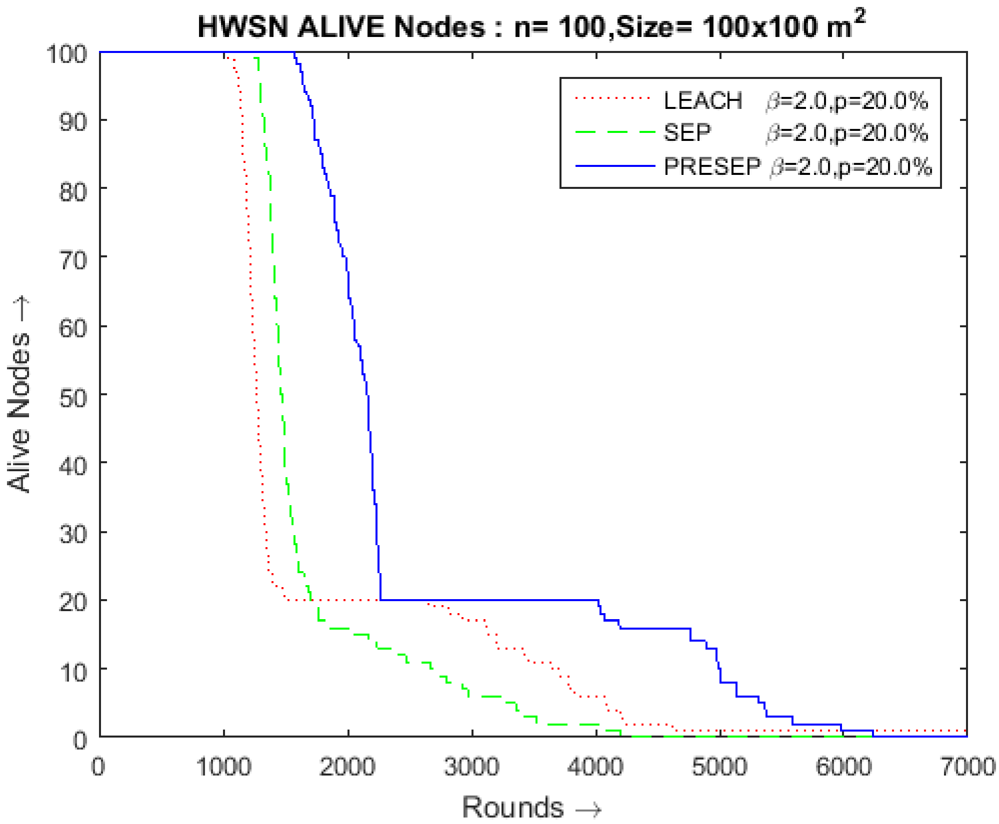


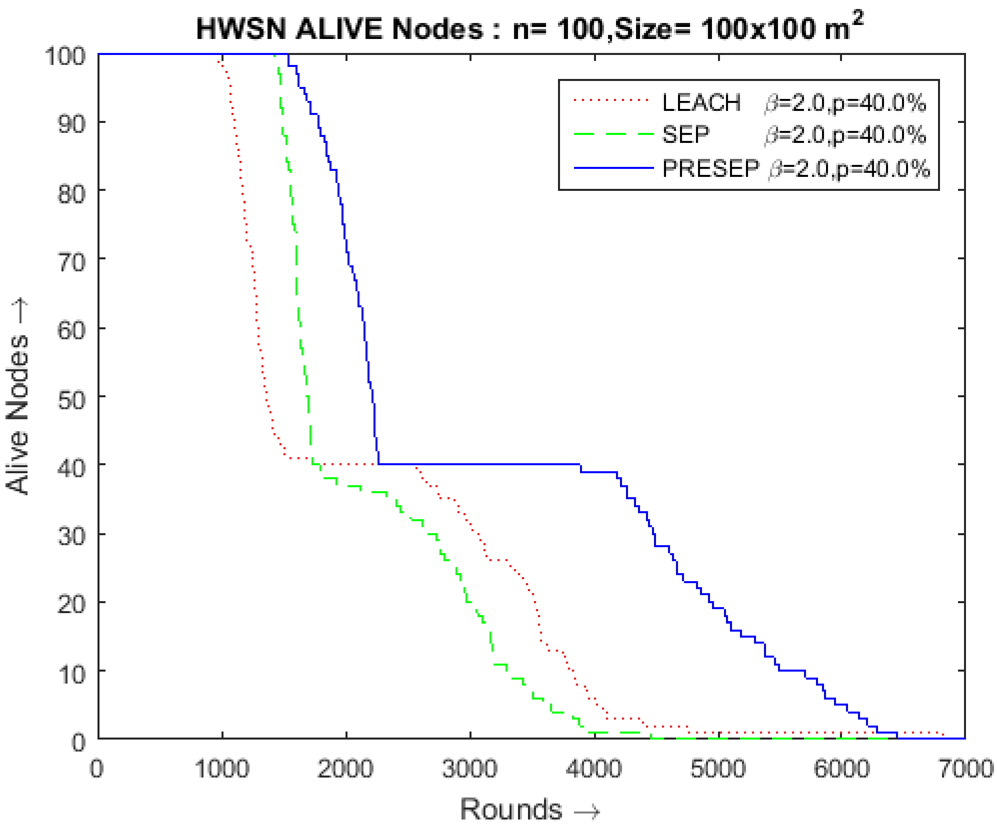
Fig. 3. Heterogeneous WSN



(a)

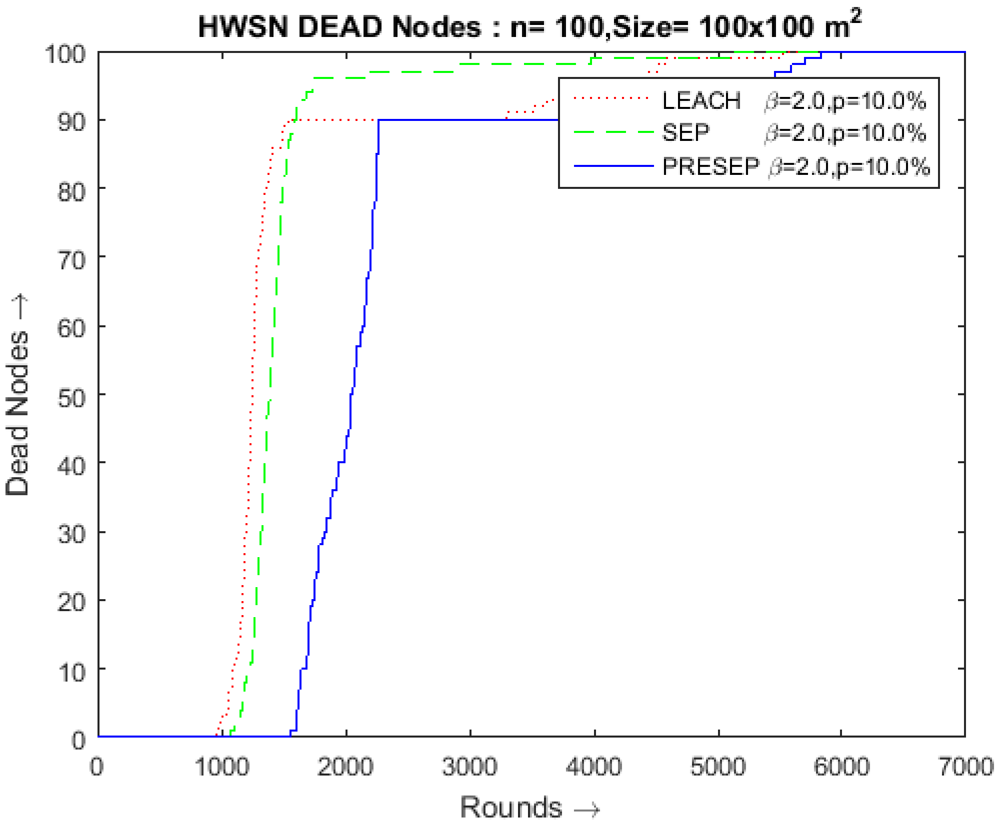


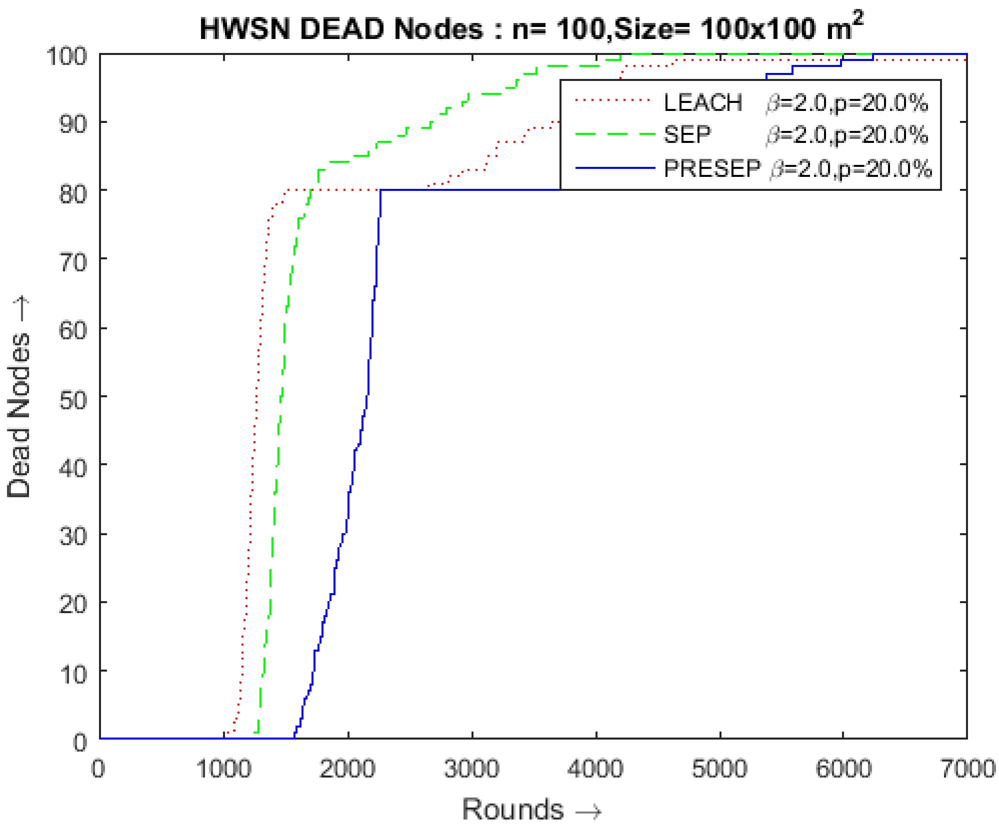
(b)

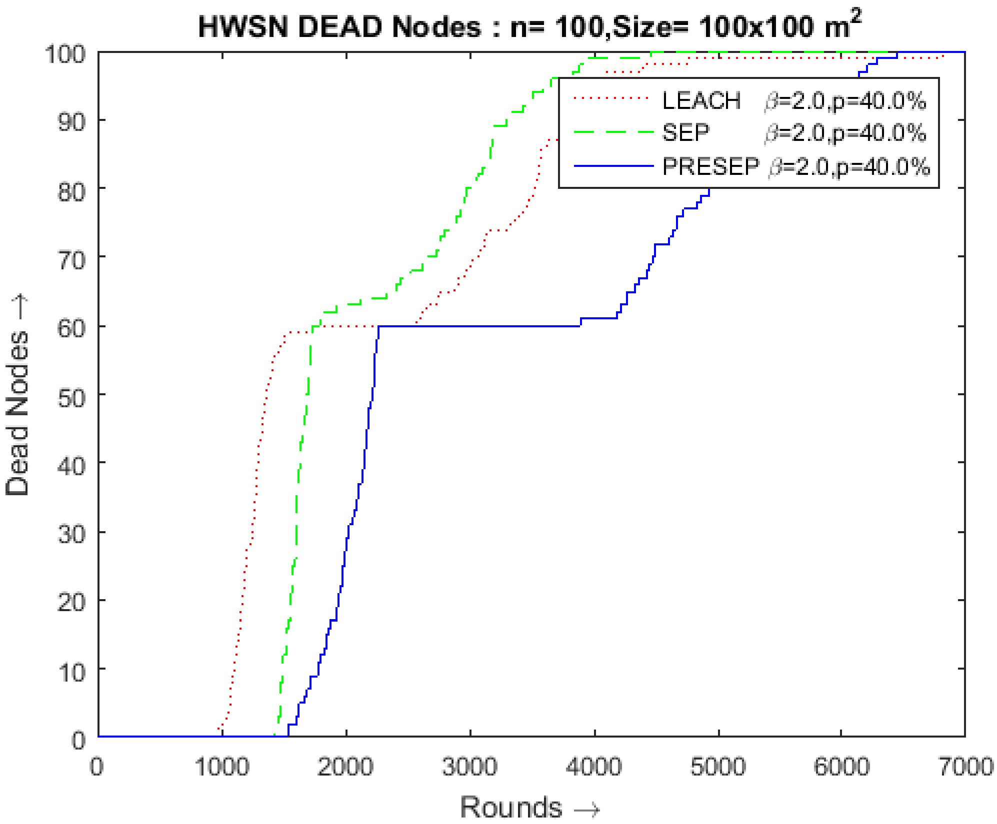


(c)

Fig. 4. Nodes Alive with heterogeneity of (a) 10 percent (b) 20 percent and (c) 40 percent

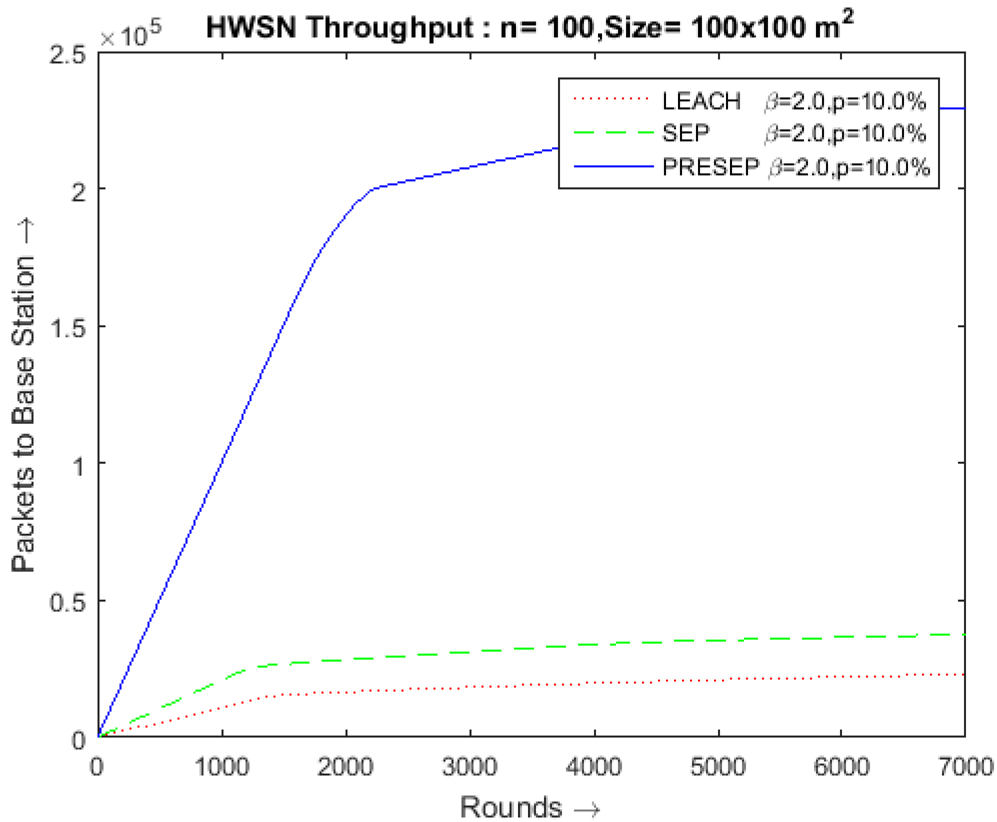

HWSN DEAD Nodes : n= 100,Size= 100x100 m2
LEACH β=2.0,p=10.0%
SEP β=2.0,p=10.0%
PRESEP β=2.0,p=10.0%
Dead Nodes →
Rounds →
0
10
20
30
40
50
60
70
80
90
100
0
1000
2000
3000
4000
5000
6000
7000
(a)


HWSN DEAD Nodes : n= 100,Size= 100x100 m2
LEACH β=2.0,p=20.0%
SEP β=2.0,p=20.0%
PRESEP β=2.0,p=20.0%
Dead Nodes →
Rounds →
0
10
20
30
40
50
60
70
80
90
100
0
1000
2000
3000
4000
5000
6000
7000
(b)

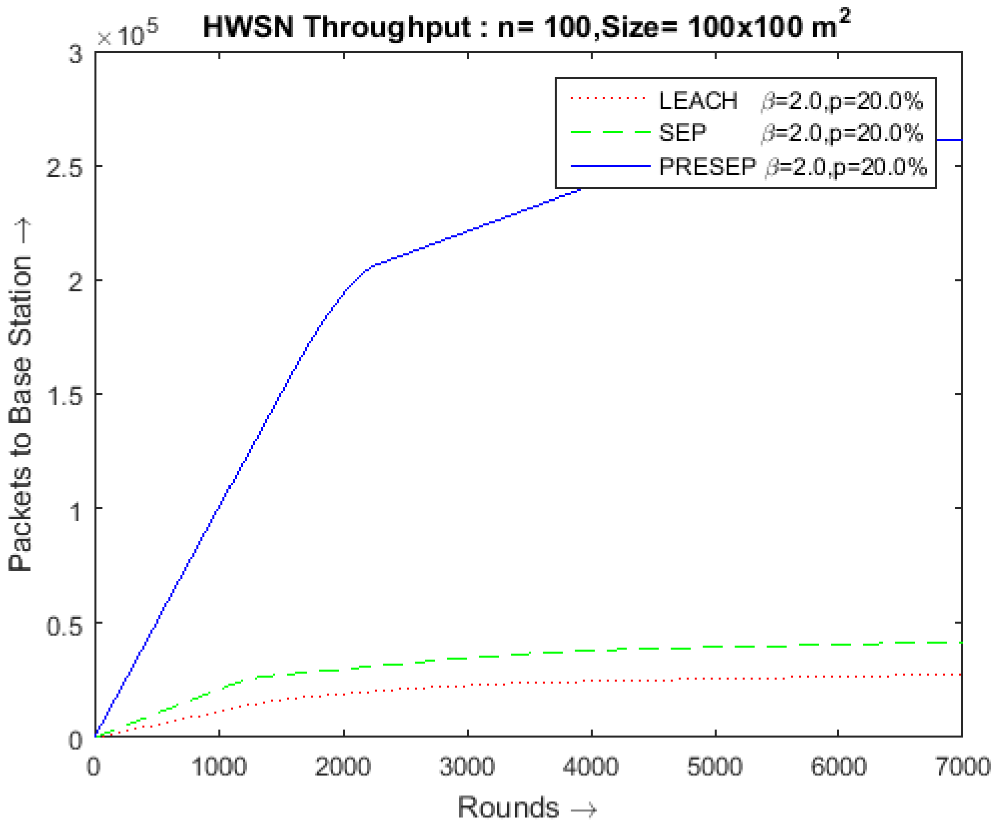


(c)

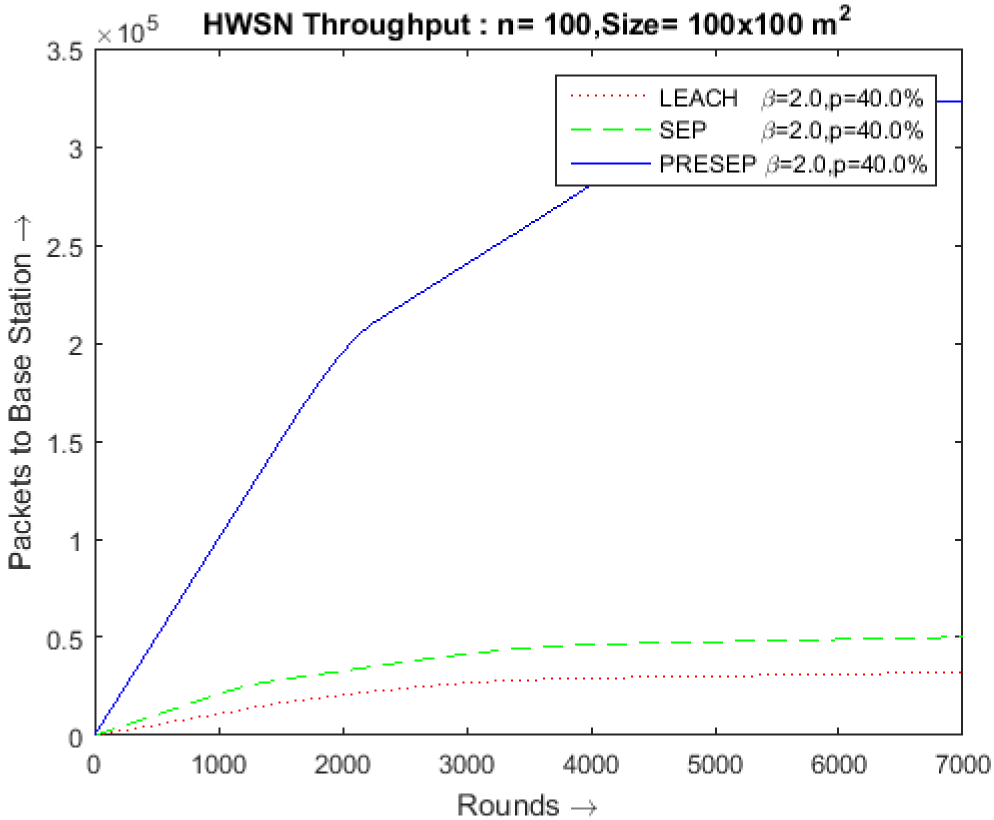
Fig. 5. Dead Nodes with heterogeneity of (a) 10 percent (b) 20 percent and (c) 40 percent



(a)



(b)



(c)

Fig. 6. Throughput of the network with heterogeneity of (a) 10 percent (b) 20 percent and (c) 40 percent

7 Conclusion

Evaluation of the proposed PRESEP for large HWSN shows significant increase in network lifetime and support for scaling up the network made it favorable for IoT applications. It outperforms the heterogeneous algorithm in terms of less repetition of CH selection iterations and prolonged CH lifetime. For conventional network area of 100 square meter with 100 SNs, 50 percent improvement in network period for first dead node in comparison with previous algorithms from 1000 rounds to more than 1500 rounds of operation. Nodes are found alive after 5000 rounds in 7000 rounds operation from the proposed algorithm compared to previous routing algorithm. Heterogeneity check for the protocol evaluated with 10, 20 and 40 fractions of total strength assigned with different uniform energy distribution. More than 15 percentage of the advanced nodes remain available with their residual energies. Heterogeneity improved network performance with a significant amount of 40 percent in prolonged lifetime, network stability and energy efficiency. Hence, PRESEP is well suited for high speed 5G environment IoT application with balanced energy-efficient data routing of heterogeneous SNs. The future research will be towards real scenario implementation and improving QoS with respect to mobile nodes distribution.

Declarations

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate

Not applicable.

Consent for publication

The authors affirm that research article with figures provided are informed consent for publication.

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Availability of data and materials

All data and materials are available to the author.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

Both authors performed the primary literature review, data collection, experiments, and approved the final manuscript. Mridul Chawla supervised the research and Sarvesh Kumar Sharma drafted the final manuscript.

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