Energy Efficient TABU Optimization Routing Protocol for WSN

Protocolo de enrutamiento de optimización TABU de bajo consumo de energía para WSN

Protocolo de Roteamento de Otimização TABU com Eficiência Energética para RSSF

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Received: May 17th, 2020
Accepted: July 30th, 2020
Available: September 2th, 2020

How to cite this article:
Varsha, Manju Bala, Manoj Kumar, Neeraj Kumar, "Energy Efficient TABU Optimization Routing Protocol for WSN," *Revista Ingeniería Solidaria*, vol. 16, no. 3, 2020.
doi: https://doi.org/10.16925/2357-6014.2020.03.07

Artículo de investigación. https://doi.org/10.16925/2357-6014.2020.03.07

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Abstract

Introduction: This article is the result of the research "Energy efficient routing protocols in wireless sensor network: Examine the impact of M-SEEC routing protocols on the lifetime of WSN with an energy efficient TABU optimization routing protocol"developed in the IKG, Punjab Technical University, India in 2019.

Problem: The task of finding and maintaining routes in WSNs is non-trivialsince energy restrictions and sudden changes in node status cause frequent and unpredictable changes.

Objective: The objective of this paper is to propose an energy efficient heterogeneous protocolwith the help of a hybrid meta-heuristic technique.

Methodology: In the hybrid meta-heuristic technique, the shortest route has been selected and the data forwarded to the sink in a minimal time span,savingenergy and making the network more stable. To evaluate the technique, a new hybrid technique has been created where the data transmission is implemented from the beginning under MATLAB 2013a.

Results: The proposed technique is better than the existing ones since the remaining energy in the network is increased by 62% compared to normal nodes in MSEEC, 65% compared to advanced nodes in MSEEC and 70% compared to super nodes in MSEEC. The network lifetime was also enhanced by 70.8% compared to MSEEC.

Conclusion: The proposed protocol was found to be superior based on the average residual energy.This paper proposes an efficient routing mechanism towards the energy efficient network.

Originality: Through this research, a novel version of MSEEC protocol is carried out using the TABU search mechanism to generate the functions of two neighbourhoods to detect the optimum path with the aim of maximizing the network lifetime in an area of 200×200m^2.

Limitations: The lack of other routing techniques falls under swarm intelligence.

Keywords:WSN, MSEEC routing protocol, TABU search, Throughput, and Energy efficiency.

Resumen

Introducción: Este artículo es el resultado de la investigación "Protocolos de enrutamiento energéticamente eficientes en la red de sensores inalámbricos: examine el impacto de los protocolos de enrutamiento M-SEEC en la vidaútil de WSN con un protocolo de enrutamiento de optimización TABU energéticamente eficiente" desarrolladoen el IKG, Punjab Technical University, India en 2019.

Problema: La tarea de encontrar y mantene rrutas en WSN no es trivial ya que las restricciones de energía y los cambios repentinosen el estado de los nodos causan cambios frecuentes e impredecibles.

Objetivo: El objetivo de este trabajo es proponer un protocoloheterogéneo de eficiencia energética con la ayuda de una técnica metaheurística híbrida.

Metodología: en la técnica metaheurística híbrida, se seleccionó la ruta más corta y los datos se enviaron al sumidero en un período de tiempo mínimo, ahorrando energía y haciendo que la red sea más estable. Para evaluar la técnica, se ha creado una nueva técnica híbrida donde la transmisión de datos se implementa desde el principio en MATLAB 2013a.

Resultados: La técnica propuesta es mejor que las existentes, ya que la energía restante en la red aumenta en un 62% encomparación con los nodos normales en MSEEC, el 65% encomparación con los nodos avanzados en MSEEC y el 70% encomparación con los nodos en MSEEC. La vidaútil de la red también se mejoróen un 70.8% encomparación con MSEEC.

Conclusión: se encontró que el protocolo propuesto era superior en función de la energía residual promedio. Este documento propone un mecanismo de enrutamiento eficiente hacia la red de energía eficiente.

Originalidad: a través de esta investigación, se lleva a cabo una nueva versión del protocolo MSEEC utilizando el mecanismo de búsqueda TABU para generar las funciones de dos vecindarios para detectar la rutaóptima con el objetivo de maximizar la vidaútil de la red en un área de 200 × 200m2.

Limitaciones: La falta de otras técnicas de enrutamiento cae bajo inteligencia de enjambre.

Palabras clave: WSN, protocolo de enrutamiento MSEEC, búsqueda TABU, rendimiento y eficiencia energética.

Resumo

Introdução: Este artigo é o resultado da pesquisa “Protocolos de roteamento de eficiência energética em sensores sem fio rede: Examine o impacto dos protocolos de roteamento M-SEEC no tempo de vida de RSSF com um TABU energeticamente eficiente protocolo de roteamento de otimização "desenvolvido no IKG, Punjab Technical University, Índia em 2019.

Problema: A tarefa de encontrar e manter rotas em RSSFs não é trivial desde as restrições de energia e súbita mudanças no status do nó causam mudanças frequentes e imprevisíveis.

Objetivo: o objetivo deste artigo é propor um protocolo heterogêneo de eficiência energética com a ajuda de uma técnica meta-heurística híbrida.

Metodologia: Na técnica meta-heurística híbrida, a rota mais curta foi selecionada e os dados encaminhados para a pia em um intervalo de tempo mínimo, economizando energia e tornando a rede mais estável. Para avaliar o técnica, uma nova técnica híbrida foi criada onde a transmissão de dados é implementada a partir do começando em MATLAB 2013a.

Resultados: A técnica proposta é melhor do que as existentes uma vez que a energia restante na rede é aumentou 62% em comparação com nós normais em MSEEC, 65% em comparação com nós avançados em MSEEC e 70% em comparação com supernós em MSEEC. A vida útil da rede também foi aprimorada em 70,8% em comparação com o MSEEC.

Conclusão: O protocolo proposto foi considerado superior com base na energia residual média. Este artigo propõe um mecanismo de encaminhamento eficiente para a rede com eficiência energética.

Originalidade: por meio desta pesquisa, uma nova versão do protocolo MSEEC é realizada usando a busca TABU mecanismo para gerar as funções de duas vizinhanças para detectar o caminho ótimo com o objetivo de maximizando a vida útil da rede em uma área de 200 × 200m2.

Limitações: A falta de outras técnicas de roteamento se enquadra na inteligência do enxame.

Palavras-chave: WSN, protocolo de roteamento MSEEC, pesquisa TABU, throughput e eficiência energética.

1. INTRODUCTION

Routingis a testing issue in the structure of WSNs, can greatly conserve energy and can also improve the network's life [1], while heterogeneity in WSNs can enhance the quality and time. Here, information sent from the transmitting node to the receiving nodeby lessening the over-head and increasing the throughput is the primary aim of routing. Developing a routing technique for WSNs is extremely critical. The realization of power saving to attain the green networking is the main objective of this paper.

Many energy efficient clustering techniques for WSNs were introduced in the past such as SEEC, MSEEC [2] and CBCCP [3] ones, but these studies have not scrutinized the proper arrangement of the nodes to make the protocol more energy efficient and stable [4,5].In the literature of MSEEC, there exists a lack of study to investigate the proper arrangements of different nodes viz. normal, super and advanced nodes and put forward an innovative routing scheme. In order to overcome this limitation, we address the case ofa network formation model which is deployed in the network. This launches the heterogeneity feature in the network and makes it more extensible. After that,a cluster formation procedure is introduced which depends upon the higher energy factor of the node and makes the network smooth on the way to WSN. On the contrary, a data transmission procedure is executed, which uses a novel approach towards clustering and routing via the TABU search mechanism for the optimization of energy parameters. The simulation results of this scheme aremore lithe and efficient compared to traditional WSNs [6-8].

Our contribution to this work can be summarised in the following order:

1. Network formation for the deployment of nodes is mentioned here. This structure has a network scalability feature and extends up to the 500m×500m level. For energy efficient communication, direct communication between the Normal Node (NN) and Super Node (SN) and alsobetweenSNand AdvancedNode (AN) is provided.
2. Consideration to the optimization problem in the proposed scheme with respect to load balancing and energy consumption for the implementation of an effective and scalable network. Thus, TABU-MSEEC is proposed under the influence of cluster formation and data transmission to solve the optimization dilemma. This approach is related to the implementation of the green network.
3. With extensive simulations using a random placement of sensor nodes, the suggested technique outperforms the traditional WSN schemes and are observed to be progressively supported for different applications of WSN.

1.1 The proposed scheme is as follows:

In this convention, NNs, ANs and SNsare utilized depending on their underlying initial energy. ANs have α times and SNs have β times more energy than the NNs. The members of the cluster will send information to advanced and super node's cluster heads. After receiving the frames from the cluster member, the aggregation operation is performed to reduce the excessinformation.From that point onward, the information will be sent to the sink.The novelapproach to this paper is with regards to cluster formations for sensor nodes and data transmission procedures to reduce power consumption and to improve the lifetime of the system. The procedure comprises two stages: during the first stage, the cluster formation is made on the basis of the average residual powerin the node. The average residual energy ofthe Cluster Head (CH) node is more prominent than the residualpower in the node in the system and in the second stage a 2-opt method is generated using the TABU search mechanism, which is a noteworthy criterion for routing. In this work, MSEEC protocol using the TABU search mechanism has been recommended which is a strategy with a more elevated heuristic quality for taking care of optimization issues. It can discover the ideal and close ideal answer for issues. Lots of studied have proposed routing techniquesfor saving nodal energy and improving the routing in WSNs. In this work,we address the matter of routing in WSNs utilizing the TABU search with the aim of maximizing the system lifetime. Initially, a new MSEEC protocol using the TABU search for routing in WSNs with the aim of maximizingsystem lifetime in networks of the order of 200m × 200m is proposed.

The rest of the manuscript is in the following order: Section 2 examines the related work. Methodology has been described in Section 3.Section 4 shows thenetwork and procedures utilized.Section 5 depicts the results and discussion. Finally, Section 6 concludes the paper with future directions.

2. RELATED WORK

The available studies have discussed the applications and limitations of the networks. It has also given basic ideas of the functioning of the routing mechanisms and optimum low energy framework of the sensor nodes.

Vijayalakshmi et al. [9] have discussed the identification of optimum paths for routing that enhancethe life-time and decrease the power that is consumedby the network. Results showthat the efficiency of the TABU-PSO is increased by improving the formation of cluster heads, the ratio of active nodes and decreasing therate of mean packet loss, but in the paper the parameters are limited depending on the formation of network chosen. Kaur et al. [10]have proposed a hybrid data aggregating technique known as ACO/PSO,which improves the aggregation of data between the clusters. It is a tree-based algorithm where the selection of CHs iscompletely dependent upon the remaining nodes' energy. The proposed protocol has improved the life of theWSN over the other techniques but the author has failed to improve the area scalability as the size of network is so small.

Shankar et al.[11]haveexhibited ahybrid approach of a HAS & PSO algorithm for providing better energy efficient cluster heads. These algorithmshaveshown anincrease in residual energy by 83.89% and throughput by 29%when compared tothe PSO algorithm. However, other meta-heuristic optimization techniques make better improvement over the network. Amuthan et al.[12] have reviewed the meta-heuristic techniques which are applied on combinatorial problems. This technique relieves local search methods from the local optima problem and finds the solution from a single point which is fitted in all the aspects of computer science including VANET, software development effort estimation etc, but has not been implemented with TABU. V.Raghavendranet al.[13] have portrayed the system routing research is Swarm Intelligence (SI) which links to the complex behaviour which emerges from exceptionally straightforward individual conduct and communication that is seen naturally, particularly with social flies, for example, honey bees, ants and so forth. Every individual has little knowledge and pursues the essential guidelines utilizing nearby data adjusted from nature. Ants directing is an essential instrument from SI and gives a proficient arrangement. Fifi et al.[14] exhibited the two energy-effective grouping convention, which utilized the ideal number of energetic nodes that accomplishes the base energy utilization for the system. The M-SEEC is a heterogeneous convention and drags out the soundness time frame, expands the energy effectiveness or more normal throughput.

Tandon, Ravi et al. [15]have devoted their efforts to progressively bunched heterogeneous sensor systems. They uncovered that the presented heterogeneity aware conventions could not disperse the utilization of energy consistently. The paper has proposed Cluster Re-election Protocol (CRP),that is aware of heterogeneity and upgrades the system dependability time over prevailing conventions.Shilpaet al.[16] proposed an energy balanced cluster head selecting strategy based on QoSfor WSN, which provides the weight selection method of CH known as Cluster-Chain Weight Metric approach (CCWM) for improving theeffectiveness of the entire network. With this approach the conservation of energy of sensors and load balancing takes place. Our objective in this paper is to select appropriate cluster headsby enhancing the quality of routing in HWSNs by lessening the general energy utilization, expanding the security time of the system and extending the system lifetime. The summary of work performed by various researchers in the past is given below:

Table 1. Brief study of related work

Author/Year	Title	Technique Discussed	Contribution
Vijayalakshmi [2018]	A multi objective TABU particle swarm optimization for effective cluster head selection in WSN	Identification of optimum paths for routing that enhance the life-time and decreases the power that is consumed by the network	Enhances the network lifetime
Kaur [2018]	Hybrid meta-heuristic optimization-based energy-efficient protocol for wireless sensor networks.	Tree based algorithm where the selection of CH is basedon the remaining node's energy.	Improve the data aggregation technique.
Shankar [2016]	Hybrid HSA and PSO algorithm for energy efficient cluster head selection in wireless sensor networks.	Energy efficient cluster head.	Enhancement in throughput and overall network lifetime.
Amuthan [2016]	Survey on TABU search meta-heuristic optimization	Relieved local search method from local optima problem and found solution.	Improvement in VANET, software design effortestimation.
V.Raghavendran [2013]	Intelligent routing techniques for mobile ad hoc networks using swarm intelligence.	Routing research with Swarm Intelligence techniques.	Honey bees and ants
Fifi [2014]	Multi-level stable and energy-efficient clustering protocol in heterogeneous WSN.	MSEEC protocol	Expands the energy effectiveness
Tandon [2013]	Cluster head Re-election Protocol for heterogeneous wireless sensor networks	Selection of Cluster Head (CH)	Cluster Re-election.
Shilpa [2014]	An energy balanced QoS based cluster head selection strategy for WSN	Weight selection method applied.	Enhancement in network's lifetime by appropriate CH.

Source: own work

3. METHODOLOGY

In this system, the base station is static in nature and three unique kinds of nodes are utilisedwhich are NNs, ANs and SNs as explained previously. The base station's (BS) position is at the centre. A region of A2 =M2 ×M2 square meters over which nodes are consistently circulated aside from at the separation ≤R1. At first, SNs are situated at a place of separation R2 from the BS, and the ANs are situated at a place of separation R1 from the BS. The territory (M1 ×M1) of the system is separated into a few equivalent clusters as the equivalent of the two-level heterogeneity network model, - the rest of the region (M2 ×M2) – (M1 ×M1) is likewise partitioned into a few equivalent groups as indicated by the quantity of SNs. Every sensor network goes about as a cluster head and is in charge of its group. NNs are conveyed haphazardly in every group. The total clusters and their heads do not get altered during the life of the system. The clusters transmit the information stored in the sensors to the CHs. Once a CH gets information outlines from the clusters, the collected information is evaluated to eliminate any excess information. At that point, CHs transmit the collected information to the BS. Although a static environment is good, such type of environment is failed in heterogeneous conditions because all sensor nodes are fixed;hence it is an energy efficient protocol but it suffers from the heterogeneity of a routing protocol. If the Super Node (SN) which acts as a Cluster Head (CH) dies or fails, the whole network will collapse.If a Super Node dies, then a Normal Node will directlycommunicate with an Advanced Node(AN) and energy consumption will be high which will reduce the network lifetime of a network;the whole network is Static and it also causes flooding at the sink or base station.

3.1 Network Model

An energy-efficient communication environment has been formalised as illustrated in Figure 1. The network consists of the three unique kinds of nodeswhich areNNs, SNs and ANs. One Base Station (BS) is used which is static in nature and positioned centrally in the network. The position of SNs and ANs is fixed for the whole lifetime of the system but the position of NNs is changed after every round. The number of ANsis 8% of the overall nodes. Similarly, the SNs are 8% of total nodes in the system. M_{AN}characterises the part of all nodes that have α times (α =4) more energy than the NNs,known asadvancednodes, and M_{SN} is the bit of all nodes having β times (β =3) more energy than the NNsand these are known as SN. The rest of the nodes haveinitial energy as E_0.

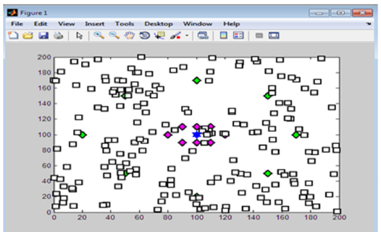


Figure 1. (a)Scenario of static nodes

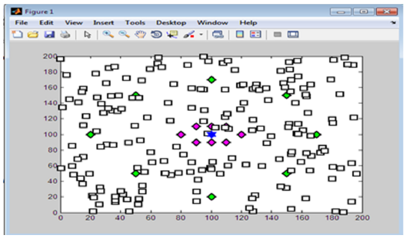
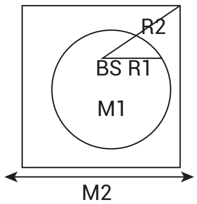


Figure 1. (b) Scenario of moving nodes



Source: own work

Figure 1(a) represents the networking model of the Enhanced MSEEC protocol, in which the base station is stationary and normal nodes are also static. In Figure 1(b) the nodes are changed after each round and SNs are located at a distance R2 contingent with the base station and the ANs are located at a distance of R1 contingent with the base station.

3.1.1 Energy required for the Network

The nodes must be identified for evaluating the entire energy of heterogeneous systems with three levels.M_{AN} of ANs has an initial energy of (1+α) E_0. Similarly, M_{SN} of SN's has an initial energy of (1+β) E_0 and n1 of NN hasapreliminary energy of E_0. So the entirepreliminary energy required is

$$E_{total} = n.\ E_0 + MAN.\ (1+\alpha)\ .\ E_0 + Msn\ .(1+\beta\ ).\ E_0(1) \qquad (1)$$

In this manner, the three-level M-SEEC has ($\alpha\ .M_{AN} + \beta.\ M_{SN}$) times more energy.

3.1.2 Total quantity of rounds in the network

It is necessary to compute the total quantity of rounds in the lifetime of the network for all three kinds of node for evaluating the required energy of that system.In the following equation, E_{total} describes the entire energy in the WSN and E_{total} denotes the consumed energy in the WSNfor every individual round. Hence, $Rounds_{AN}$, $Rounds_{SN}$ and $Rounds_{NN}$ can be evaluated by following equation

$$Rounds_{AN} = \left(\frac{E_{total}}{E_{round}}\right)_{AN} \qquad (2), \text{ and}$$

$$Rounds_{SN} = \left(\frac{E_{total}}{E_{round}}\right)_{SN} \qquad (3), \text{ and}$$

$$Rounds_{NN} = \left(\frac{E_{total}}{E_{round}}\right)_{NN} \qquad (4)$$

4. NETWORK AND PROCEDURES UTILIZED

To achieve the desired objectives, a different kind of network and several algorithms are required. A brief explanation about network implemention and procedures utilized in this work have been mentioned below:

4.1 Improvised Energy Efficient TABU Optimization Routing Protocol

In the first case, an improvised TABU optimization routing protocol that has high energy efficiency has been proposedfor WSN in the presence of node heterogeneity with the routing done by TABU search in the stable environment. In this,the threek-inds of nodes areon the basis of their energy value in the initial stage. The position of ANs and SNs are fixed but the position of NNs is not fixed.$M_{SN,}$ which represents the super node, is the ratio of the nodes having α times higher energy than NNs to the total nodes. The rest of the nodeshave energy E_0. P=p1+p2 where p1 is the overall number ofNNslinked to ANs and p2 is the overallNNslinked to SNs.The overall energy of the triple layered networks is represented by:

$$E_{total} = p.\, E_0 + M_{AN}.\, (1+ \alpha)\, .\, E_0 + Msn\, .(1+\beta\,).\, E_0 \quad (5)$$

Therefore, the three-level M-SEEC has ($\alpha\, .M_{AN} + \beta.\, M_{SN}$) times more energy.

Lemma 1: *In a Z * Z network with normal nodes, advanced nodes and super nodes, the best results are obtained when the energy value given is in the ratio of 1:3:4, meaning*

$$AN= 3*NN\ (Normal\ Node) \quad (6)$$

$$SN= 4*NN\ (Normal\ Node) \quad (7)$$

Proof: *The results are provenby simulating the different energy of nodes in the ratio of 1:3:4.This means that the ANs have an energy thricethat of NNs and SNs havean energy four times more than that of NNs. Simulations are performed on 200 nodes on a 200×200 network respectively considering two parameters which are"First Node Dead"(FND) and "Last Node Dead"(LND).*

Lemma 2: *A node is something belonging to a cluster that is either a member of head.*

Proof: *As theTABU-MSEEC protocol is well spread across and hence has a good chance to select the CH. The node may be designated as a CH only when the average remaining-energy of a CH is higherthan the remaining nodes in the WSN. Initially the*

e-ISSN 2357-6014 / Vol. 16, no. 3 / 2020 / Bogotá D.C., Colombia
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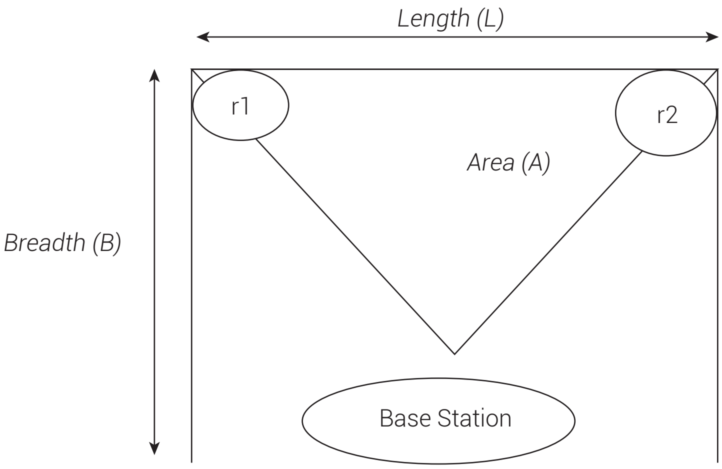
SN will act as a CH,but for any hardware or network failure, the node having more remaining energywill act as a CH and the other nodes will be the members.

Lemma 3: *Data aggregating and clustering techniques are the top approaches for conserving energy in networks.*

Proof: *It is assumed that the transferinitiated from the upper-left corner to its opposite corner without any clustering technique and this means transferring directly.*

Energy gain may be considered as the difference between the power consumed by transferring directly and power consumed by clustering technique.



So,

$$Energy_{gain}=E_{direct\_trans}-E_{clustering} \quad (8)$$

The nodes are spread in the network in a random manner and every group has a cluster head.

Which means, $Energy_{gain > 0}$

If

$$No\ of\ nodes > 2\sqrt{2}\ (\text{Length} * \text{Breadth})\ A_{Length}\times A_{Breadth} \quad (9)$$

$$\text{AsLength} * \text{Breadth} >> A_{Length}\times A_{Breadth}$$

The optional length of the path from the node in uppermost cell to the bottom-most cell is $\sqrt{L^2+B^2}$ by using Euclidian distance.

In case of clustering, the path deviates by the $2\sqrt{A_{Length}^2 + B_{Breadth}^2}$ from the optimum path $2A_{Breadth}$. So optimum path for breadth is

$$Sub_{Optional}= \sqrt{A_{Length}^2 + 4\,A_{Breadth}^2} \times \sqrt{L^2 + B^2}\,\square 2A_{Breadth} \tag{10}$$

The meanpower consumed by the nodes in every cluster is represented by

$$Nodes_{average}=(\textit{no of nodes} \times A_{Length} \times A_{Breadth})\ 2LB \tag{11}$$

E_d is the power consumedby the entire nodes in the cell for transmittingthe information along the path $\sqrt{L^2 + B^2}$

So,

$$E_d=(\textit{no of nodes} \times A_{Length} \times A_{Breadth})\ \square 2LB \times \sqrt{L^2 + B^2} \tag{12}$$

E_c is the power consumed by the entire nodes in the cluster for transmitting thedata to the respective CHs and from CH to the destination.

Total no of CH is $N_{totalCH}$

$$E_c = N_{totalCH}\,(((\textit{no of nodes} \times A_{Length} \times A_{Breadth})\ \square\ 2LB)-1) \times A_{Breadth} + 2B \tag{13}$$

$$E_c \doteqdot ((N_{totalCH} \times \textit{no of nodes} \times A_{Length} \times A_{Breadth}^2)\ \square\ 2LB) + 2B$$

By substituting the values:

$$Energy_{gain}=E_{direct\_trans} - E_{clustering}$$

$$=(\textit{no of nodes} \times A_{Length} \times A_{Breadth})\square\ 2LB \times \sqrt{L^2 + B^2} - ((N_{totalCH} \times \textit{no of nodes} \times A_{Length} \times A_{Breadth}^2)\ \square\ 2LB) - 2B > 0 \tag{14}$$

As$Energy_{gain > 0}$

Therefore,

e-ISSN 2357-6014 / Vol. 16, no. 3 / 2020 / Bogotá D.C., Colombia
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$=(no\ of\ nodes \times A_{Length} \times A_{Breadth}\ )\square\ 2LB \times \sqrt{L^2+B^2}$ - $((N_{totalCH} \times no\ of\ nodes \times A_{Length} \times A^2_{Breadth})\ \square\ 2LB) > 0$

By taking no of nodes × A_{length} × $A_{Breadth}$) 2LB as common

$$= no\ of\ nodes \times A_{Length} \times A_{Breadth})\ \square\ 2LB\ ((\sqrt{L^2+B^2} - (N_{totalCH} \times A_{Breadth}))) > 2B \tag{15}$$

$$=n > 2B(2LB/A_{Length} \times A_{Breadth}(\sqrt{L^2+B^2} - A_{Breadth}) \tag{16}$$

$$=n > 4LB^2\square(A_{Length} \times A_{Breadth}(\sqrt{L^2+B^2} - A_{Breadth}))$$

$$Since\ Length > A_{Breadth}\ therefore,\ \sqrt{L^2+B^2} > A_{Breadth}$$

4.1.1 Level of heterogeneity

The level of heterogeneity is represented by the given formula that is

$$R_{i-1} = \frac{\sqrt{2}}{0.765} R_{i-2} \tag{17}$$

Where i denotes the heterogeneity level.

4.1.2 Optimumcount of ANs

The amount of power that is consumed at the time of single transferis expressed by following condition

$$E_{AN} = n_A.\ L.\ E_{elec} + n_A.L.\ E_{DA} + L.\ E_{elec} + L.\ e_{fs}.R1^2 \tag{18}$$

Where E_{DA} represents the data aggregation cost and R1 represents the distance between advanced node and base station. The energy utilized by normal nodes is expressed by the following equation

$$E_{NN} = L.\ E_{elec} + L.\ e_{fs}.d^2_{tO\ AN} \tag{19}$$

Where $d^2_{tO\ AN}$ represents the distance between the normal node and advanced nodes.

The total power that is consumed at the time of a single transfer is expressed by the following condition

$$E_{Round} = m_{AN}\left(\frac{n1}{m_{AN}}.L.E_{elec} + \frac{n1}{m_{AN}}.L.E_{DA} + L.E_{elec} + L.E_{fs}.R1^2 + \frac{n1}{m_{AN}}.L.E_{elec} + \frac{n1}{m_{AN}}.L.E_{fs}.d^2_{to\ AN}\right)$$

After differentiatingE_{Round} corresponding to M_{AN} and comparing with zero, the optimumcount of advanced nodes is found to be

$$m_{AN\ opt} = 0.7668\sqrt{n1} \tag{20}$$

4.1.3 Required energy for AN

For computing the energy of ANs, the total life of a WSNis first calculated,which is the total of all rounds from beginning to end.

$$Rounds_{AN} = \left(\frac{E_{total}}{E_{round}}\right)_{AN}$$

and

$$Rounds_{NN} = \left(\frac{E_{total}}{E_{round}}\right)_{NN} \tag{21}$$

The value of an advanced node should be greater than that of normal nodes in each cluster

$$\alpha \geq \left[\frac{n_A.\text{Eelec} + \text{n}_A E_{DA} + E_{elec} + E_{fs}.R1^2}{E_{elec} + E_{fs}.\ d_{to\ AN}^2}\right] - 1 \quad (22)$$

4.1.4 Optimal Number of SNs

The amount of power that is consumed at the time taken for a single transfer is expressed by the following condition

$$\text{E}_{\text{SN}} = \text{n}_{\text{S}}.\ \text{L.}\ \text{E}_{\text{elec}} + \text{n}_{\text{S}}.\ \text{L.}\ \text{E}_{\text{DA}} + \text{L.}\ \text{E}_{\text{elec}} + \text{L.}\ \text{e}_{\text{fs}}.\ R2^2$$

Where E_{DA}represents the data aggregation cost and R1 represents the distance between advanced nodes and the base station. The energy utilized by normal nodes is expressed by the following equation

$$\text{E}_{\text{NN}} = \text{L.}\ \text{E}_{\text{elec}} + \text{L.}\ \text{e}_{\text{fs}}.d_{tO\ CH}^2$$

Where $d_{tO\ CH}^2$ represents the distance between the normal node and its super and advanced nodes.

The total power that is consumed at the time taken for a single transfer is expressed by the following condition

$$\text{E}_{\text{Round}} = \text{M}_{\text{AN}}(E_{AN} + n_A.E_{NN} + m_{SN}\ .(E_{SN} + n_S.E_{NN})$$

After differentiating$E_{Round}$with respect to M_{SN} and equating with zero , the optimum count of super nodes found to be

$$\text{M}_{\text{SN opt}} = 0.7668\ \sqrt{n2} \quad (23)$$

4.1.5 Required energy for SN

For computing the energy of advanced nodes, firstly calculate the total lifetime of a network which is the total of all rounds from beginning to end.

$$\text{Rounds}_{SN} = \left(\frac{E_{total}}{E_{round}}\right)_{SN} \tag{24}$$

and

$$\text{Rounds}_{NN} = \left(\frac{E_{total}}{E_{round}}\right)_{NN} \tag{25}$$

The value of advanced nodes should be greater than that of normal nodes in each cluster

$$\beta \geq \left[\frac{n_{SN}.\text{Eelec} + \text{n}_{SN}E_{DA} + E_{elec} + E_{fs}.R2^{2}}{E_{elec} + E_{fs}.\ d_{to\ SN}^{2}}\right] - 1 \tag{26}$$

4.2. ALGORITHMS UTILIZED

These are several algorithms/procedures developed and utilized to reach our objectives.These algorithms are given below:

4.2.1 Network Formation Procedure

The TABU-MSEEC model considers a structure made out of a predefined quantity of nodes placed discretionarily in a testing area. The entire group of nodes have a starting energy that is proportional to E0. In the proposed estimation, 3 stages are invoked. The first stage is a network formation procedure where the roles of different nodes are selected. The accompanying stage is the cluster formation procedure and this is where the clusters are formed. The last one is the data transmission procedure, where the routing is done via the process of theTABU algorithm.

Network Formation Procedure

Step 1: Initialize all nodes i.e. NN, AN, SN withAN= 3×NN,SN=4×NN.
Step 2: The AN is situated at a location that is R1 units away from the BS.

$$\theta_j = \varnothing + (j-1) \times 360/m_{AN}$$

$$\text{Where, } j = (1,2,3,\ldots\ldots.m_{AN})$$

$$\text{and } \varnothing = 180/m_{AN}$$

Step 3: The SN is located at a position of distance R2 with respect to the remaining area(M2×M2)-(M1×M1).
Step 4: The normal nodes are randomly deployed.

Algorithm for Network Formation Procedure

Begin
Initialise i, i € N, where, N={NN, AN and SN}
Set value as,
AN= 3*NN
SN=4*NN
Source= NN (process will start from normal nodes)
Set position of AN atdistance R1 with respect to base station.
$\theta_j = \text{Ø}+(j-1) \times 360/m_{AN}$
Where, $j = (1,2,3,.......m_{AN})$
and $\text{Ø}=180/m_{AN}$
Set position of SN at distance R2 with respect to remaining area.
(M2×M2)-(M1×M1)
The NNsare deployed in a random manner in the network.
End

4.2.2 Cluster Formation Procedure

Once the network model is fixed, the next aim is to identify the cluster head from the entire network. A CH should be selected on the basis of their highest energy parameter. Since all the sensor nodes have extremely restricted energy, the CH must gather all the node data and after that, forward it to the sink;the rest of the energy of the node ought to be viewed while picking the CH. Thechoosing process of the CH is as follows:

Cluster Formation Procedure

Step 1: As per the directions of the nodes in every locale, the focal point of locale's gravity is determined. This point (X_f, Y_f) ought to be correspond with the slightest square and least separation of nodes in the network, and the following formula is used.

$$(X_f, Y_f) = \min \sum_{i=1}^{N} [(x - x_i)^2 + (y - y_i)^2]$$

Where$(X_f, Y_f)$is the direction of every node;

Step 2: The distance between the nodes and its focal point of gravity is obtained by equation

$$d=\sqrt{x_c - x_i)^2 + (y_c - y_i)^2}$$

Step 3:Compute the normal remaining power in the nodes of every group. Supposing$E_i$is the preliminary energy of the node, thenthe power that is consumed by the node E(t) at time tis given by

$E(t)= (Number_{s\_packet} * \alpha) + (Number_{r\_packet} * \beta)$

Where, $Number_{s\_packet}$ = total packetstransmitted,

$Number_{r\_packet}$= total packets received

(α,β) € range [0,1]

Now, E_{rem} at time t is calculated by utilisingexpression

$E_{rem} = E_i - E(t)$

Step 4: If the remaining energy of the nodes is more prominent than every node in the mean residual energy, then that node is chosen as the head. If not, then the next node is compared. A sensor node whose energy is more prominent than the mean remaining energy is identified as the CH.

Algorithm for Cluster Formation

Begin

Initialise i, i € N, where, N={NN, AN and SN}

Set value as,

SP (Selection Parameter) = Average remaining energy of NNs / Residual energy of SNs

If SP < 1

Then SN will act as a CH

ElseSP > 1

Then next super node will act as a CH on the basis of its residual energy.

The residual energy of the super node >average remaining energy of normal nodes

Endif

End

4.2.3 Data Transmission Procedure

In the TABU-MSEEC protocol, the TABU technique is employed in order to make the network more energy-saving. A cluster in the network is chosen on the basis of its energy parameter and these clusters gather details from their members and send it to the sink [17,18]. For the transmission phase, the TABU technique is used, which makes the network more methodical and reliable. In order to perceive the optimal solution,the initial solution is produced by the TABU search achievably and simultaneously.The inceptive solution becomes the best solution and the current solution is placed in the TABU list which is the memory list and is usedinorder to avert the cycling. The first selected element in the list is replaced by a novel oneif the existing list is already filled. The result of the TABU search,which is the current solution, is updated in the TABU list. Each time, the set of neighbours of the existing solution is obtained by performing neighbourhood techniquesand the neighbour with the maximum value is marked as the newer solution in the list;this is then accepted for the selection of the candidate solution, otherwise the solution having the subsequentmaximum number becomes the candidate.The rate of newer solution is related with the existing solution,otherwise, iterations are increased and the newly obtained solution is incorporated into the list and is then allocated as the newsolution for the next selection[19, 20].

Data TransmissionProcedure

By random generation, we choose the initial feasible solution, and we choose it to be the current solution.The TABU search algorithm is then applied in order toincrease the existing solution. Itis represented as a pack of n routes which are R1,R2,R3,….. Rn, and the challenge here istoobtain the shortest,boosting the network lifetime and significantly reducing in energy consumption. Thesubsequent steps are as follows:-

Step1: A solution is represented by a sequence of randomly generated solutions and is searched in accordance with the constraints. Theobjective function is then calculated by utilizing the initial solution as the current solution.

Step 2: In order to producethe neighbourhood solutions, the 2 opt method is utilized which is performed by swapping the position of two randomly selected solutions. By doing so,"n*(n-1)/2" sequences are generated. The framework is initiated with a randomly generatedpreliminary solution and travels from one neighbour to anotherwhile continuously altering the value of the objective functions. E.g., let the initial sequence be (1,2,……a,…b……n).After exchanging the positions of the two solutions, the newly obtained sequence will be(1,2,……b,…a,….n), which will become the new solution for every iteration in the list.

Step 3: In accordance with the aspiration criteria, the neighbourhood solution is found and the current solution is then amended in the TABU list. If the solution is good when compared to the existing optimum solution, then it is updatedin the list and the solution is monitoredto verify if itis a TABU. If it is, then choose the next ideal solution and if it is not, then the existing oneis updated as the present solution and updated in the list.

The process of steps from 1 to 3 is repeated with a specific iterated step and the last-value of shortest route among the entire network is given as the output.

Algorithm for Data Transmission

Begin

Select a preliminary solution i in solution space.

Fix i* = i

K (Number of iteration) = 0

FixK=K+1 and create a subset V * of solution in N(i, K)

Where N= neighbouring solution (// Here, any of the TABU conditions are violated or minimum one aspiration condition hold)

Select the best j in V* and seti* = I (// if new value is better than the previous one)

Update TABU and aspiration criteria

If the condition is satisfied, then it is stopped

Else

Goto the next iteration

Endif

End

---

5. RESULTS AND DISCUSSION

In order to analyse the results of TABU-MSEEC,a MATLAB 2013a simulator is used for the implementation. In the network scenario, 200 nodes are placed of which eightANs and eightSNs are fixed and rest of the NNs are located in a random manner inside the area of 200×200 m^2.The position of the BS is fixed at (100,100). Nodes are assumed to be dead when their energy parameters value is zero. For the evaluation, the radio energy model that was proposed byHeinzelman[21] is utilised. Results of MSEEC arerelated with TABU-MSEEC protocol.They are assessed on the basis of these parameterswhich are mentioned below in Table 4.

Table 2. Simulation Parameter

Parameter	Value
Size of Network	200×200
Position of Base station	100×100
Number of Nodes	200
Probability(p)	10%
Preliminary Energy	0.5
Energy of the transmitter	0.05 pJ/bit
Energy of the receiver	0.05 pJ/bit
Free space	10nj/bit/m^2
Multi-path	0.0013pJ/bit/m^4

Source: own work

On applying the TABU search mechanism, the following results are obtained. For the simulation,the MATLAB 2013a tool is used for easy computing of results.All results were compared with the basic multi-level protocol which has high energy efficiency and stability. The performance metrics used in the results show that the proposed TABU based MSEEC protocol is stable for a longer time,has higher energy efficiency and higher throughput when compared to basic multi-level clustering protocols. For simulation, we analyse the results based on two conditions i.e. with static nodes and moving normal nodes with each round.

Evaluation of MSEEC and TABU-MSEEC in terms of alive nodes

It is the amount of individual types of nodes and also the aggregate amount of nodes which has not used their entire energy.This measurement demonstrates the entire lifespan of the system. All the more essentially, it providesa portion of the covered area of the system after some time. The FND refers to the initial deadnode in the rounds. This parameter gives details as to how stable the protocolis. The TABU-MSEEC has more stability than that of a MSEEC Protocol. The FND is delayed by 1450, 1950 and 3500 rounds in NN, AN and SN respectively.Also the LND is delayed by 100, 4200 and 5000 rounds in NN, AN and SN respectively.

e-ISSN 2357-6014 / Vol. 16, no. 3 / 2020 / Bogotá D.C., Colombia
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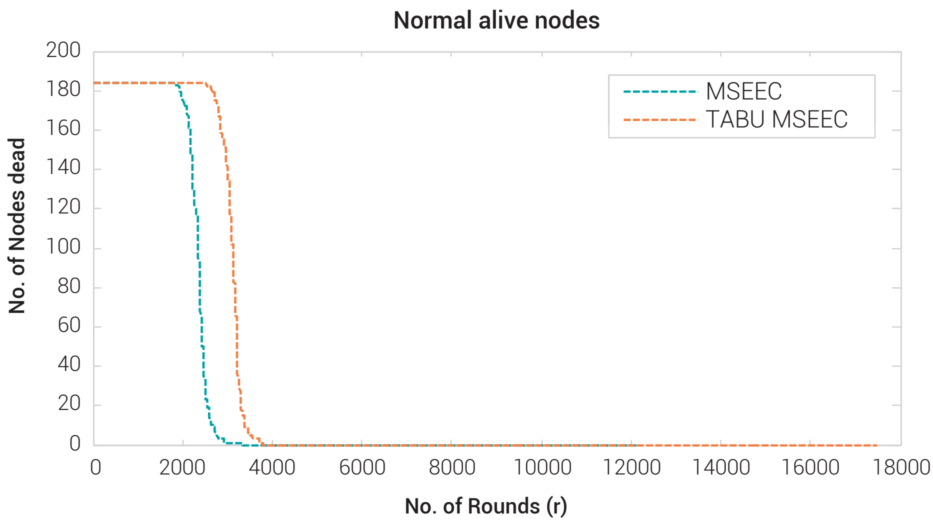

Figure 2. Normal alive node vs. rounds for 200 nodes in 200×200 network
Source: own work

200 nodes are simulated in a 200×200 network for MSEEC and the proposed TABU-MSEEC protocol as seen in Figure 2. From the obtained results, theFND and LND are calculated. From the figure, it is observed that the value of FNDforMSEEC is 2050 and the value of LND for MSEEC is 3900. On the other hand,the value in the case of TABU-MSEEC is 3500 for FND and 4000 for LND.

Table 3. FND and LND of normal nodes

Nodes	Protocol	FND	LND
NN(Normal Node)	MSEEC	2050	3900
	TABU- MSEEC	3500	4000

200 super alive nodes are simulatedin a 200×200 for MSEEC and TABU-MSEEC protocol as seen in Figure 3. From the obtained results, the FND and LND are calculated. From the figure, it is observed that the value of FND for MSEEC is 6050 and the value of LND in the case of MSEEC is 7800;on the other hand, the value in the case of TABU-MSEEC is 8000 for FND and 12000 for LND.

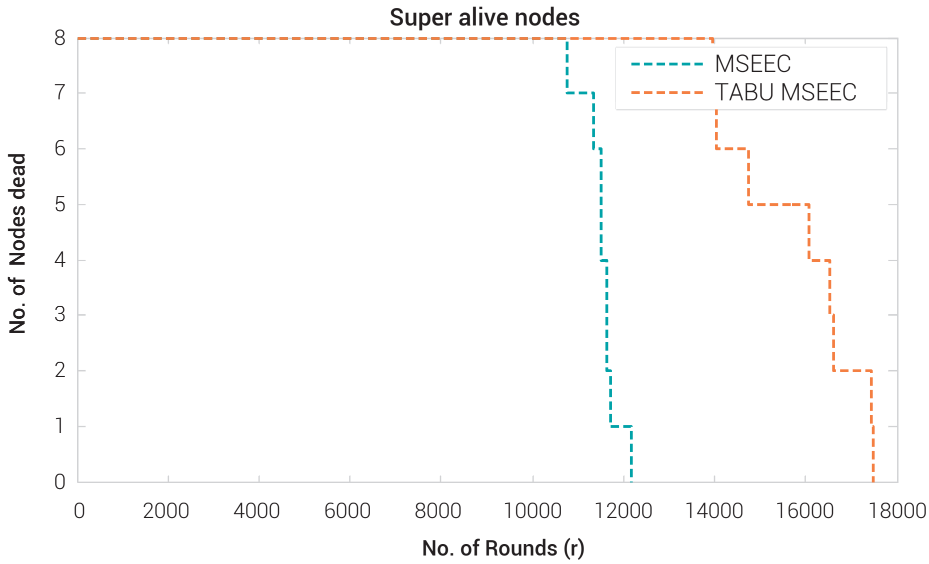

Figure 3. Super alive node vs. rounds for 200 nodes in 200×200 network

Source: own work

Table 4. FND and LND of advanced nodes

Nodes	Protocol	FND	LND
AN(Advanced Node)	MSEEC	6050	7800
	TABU- MSEEC	8000	12000

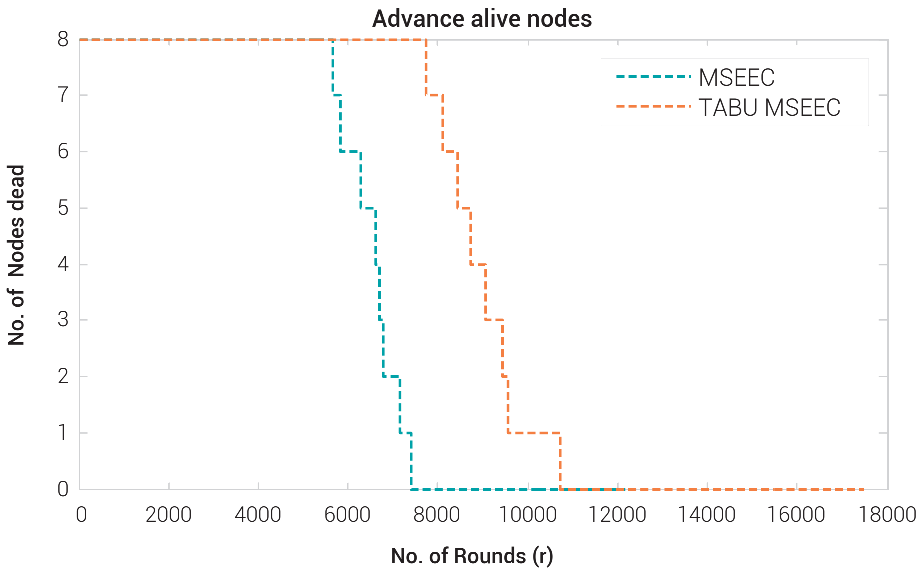

Figure 4. Advanced alive node vs. rounds for 200 nodes in 200×200 network

Source: own work

Similarly, 200 advanced alive nodes are simulated in a 200×200 network for MSEEC and the proposed TABU-MSEEC protocol as seen in Figure 4. From the obtainedresults,FND and LND are calculated. From the figure, it is observed that the value of FND for MSEEC is 11000 and the value of LND in the case of MSEEC is 12500; on the other hand, the value in case of TABU-MSEEC is 14500 for FND and 17500 for LND.

Table 5. Stability comparison for different protocol

Nodes	Protocol	FND	LND
NN(Normal Node)	MSEEC	2050	3900
	TABU- MSEEC	3500	4000
AN(Advanced Node)	MSEEC	6050	7800
	TABU- MSEEC	8000	12000
SN(Super Node)	MSEEC	11000	12500
	TABU-MSEEC	14500	17500

Source: own work

Hence, it may be concluded from the comparison in Table 1that the optimum results are obtained when the energy value of nodes is increasing. This also indicates that TABU-MSEEC has more valuable results than the MSEEC protocol.

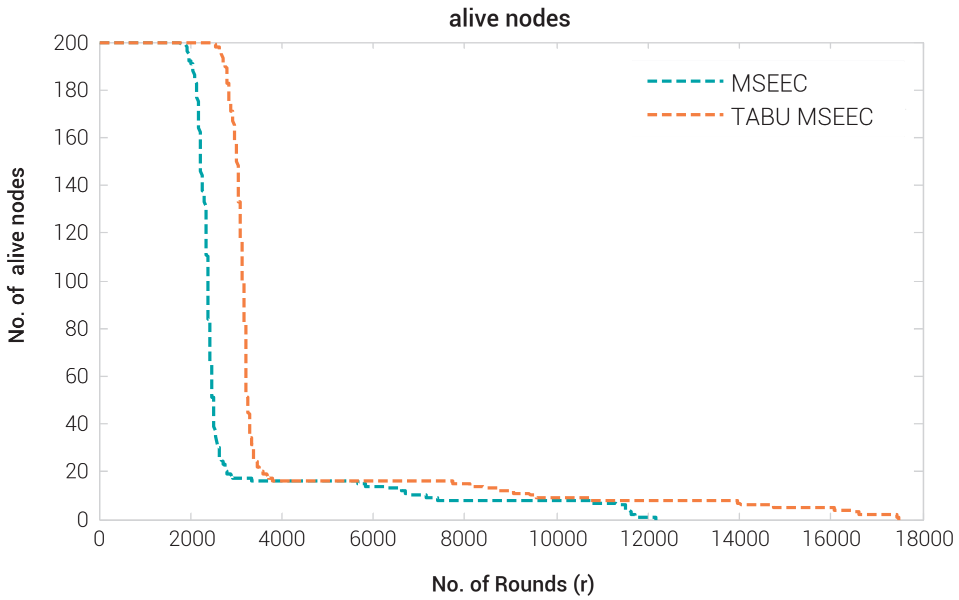

Figure 5. Total alive node vs. rounds for 200 nodes in 200×200 network
Source: own work

Figure 5depicts the total nodes which are alive for all rounds. It is seen that the FND of MSEEC begins at around 2050 rounds, whereas LND begins at around 12050. Similarly, for TABU-MSEEC, FND begins at around 3050 rounds, whereas LND begins at around 17000: because the TABU takes time to find the best solution initially.

Evaluation of MSEEC and TABU-M-SEEC in terms of dead nodes

The performance of MSEEC and TABU-MSEEC protocol is also determined on another parameter; dead nodes. Here, the dead node parameter is calculated among NNs, ANs, SNsand the total nodes in the network.

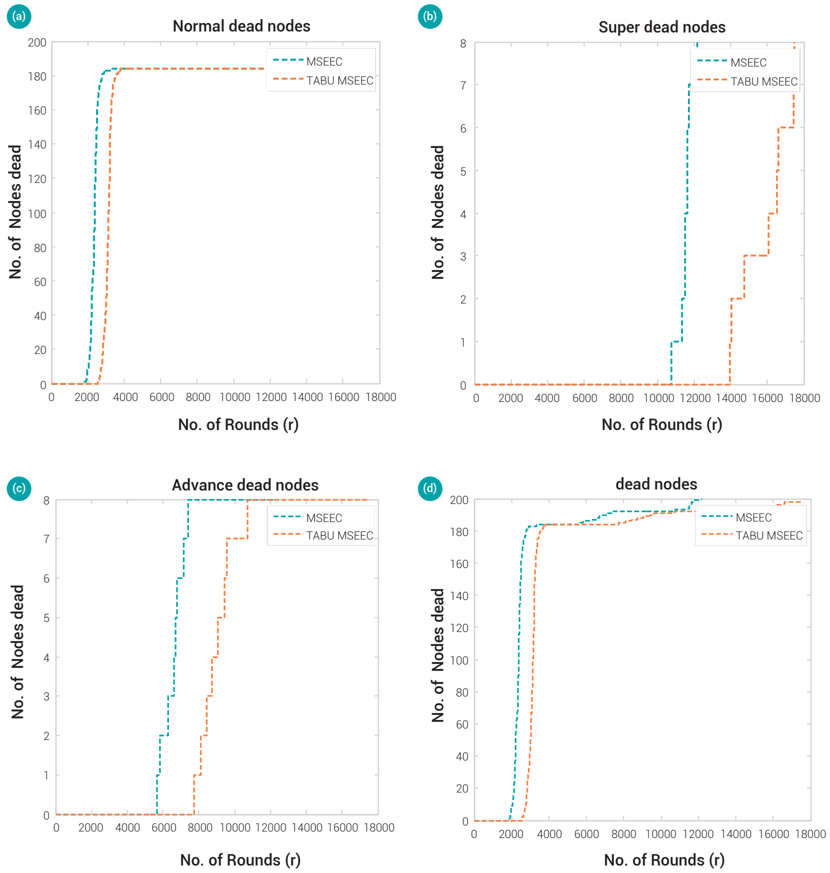

Figure 6. Number of dead nodes
Source: own work

(a) Normal dead node vs. rounds for 200 nodes in 200×200 network
(b) Super dead node vs. rounds for 200 nodes in 200×200 network
(c) Advanced dead node vs. rounds for 200 nodes in 200×200 network
(d) Total dead nodes vs. rounds for 200 nodes in 200×200 network

Figure 6represents the behaviour of dead nodes in a detailed manner for MSEEC and TABU-MSEEC routing protocols. It is seen that TABU-MSEEC works better than MSEEC. In MSEEC, the death of the first node begins after 2000 rounds, whereas for TABU-MSEEC it begins after 2200 rounds for normal nodes. In the case of super nodes,the death of the first node begins after 10050 rounds in MSEEC, whereas for TABU-MSEEC it begins after 14000 rounds. For advanced nodes, the death of the first node begins after 5900 rounds, whereas for TABU-MSEEC it begins after 6500. This is because the advanced nodes and super nodes lose their lifeslower than the normal nodes.

Evaluation of MSEEC and TABU-MSEEC in terms of throughput

Throughput is the amount of data packets which are obtained at the sink. It is considered as the totaldata which is transferred through the network, the total data sent from ANs or SNs to the BS. It can also be considered as the total data sent from the NNs to the ANs and SNs.When the proposed protocol is compared with existing protocol, it can be seen that the proposed protocol shows improved throughput.

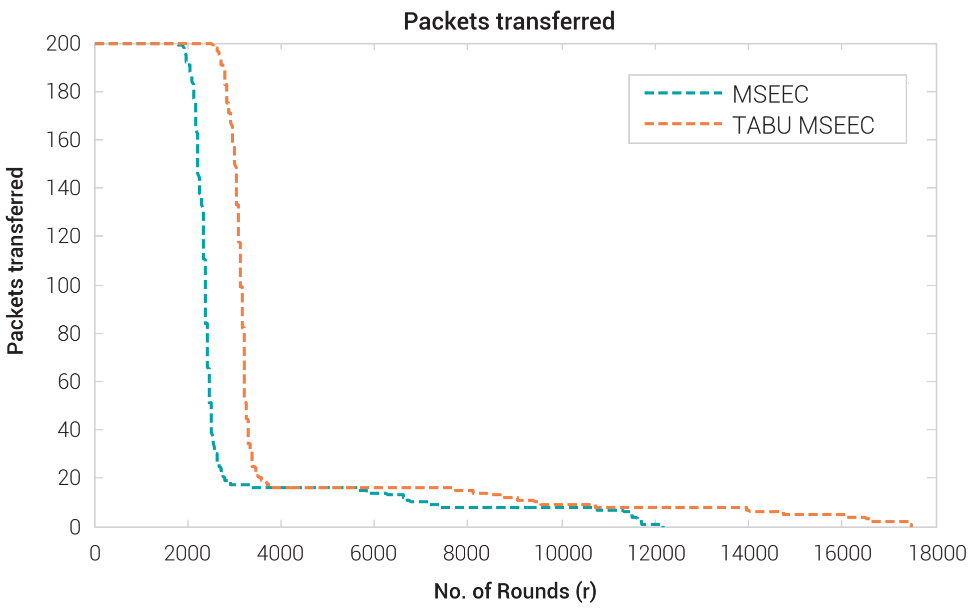

Figure 7. Packets transferred vs. rounds for 200 nodes in 200×200 network
Source: own work

Figure 7represents the throughput in the WSN, which means the total packets received at the BS. The network's lifespan is goodwhen the death rate of the nodes is less and vice-versa. When the alive nodes are high, it will send more data to theBS. It has been shown that TABU-MSEEC proved to be better than MSEEC. In MSEEC,the packets which aresent to the BS is at 12050 rounds while for TABU-MSEEC it is after 17000 rounds.

Evaluation of MSEEC and TABU- MSEEC in terms of remaining average energy

It is the amount of energy left with sensor nodes. It is computed in the beginning of each round during execution of the algorithm. This parameter helps to determine the stability period, consumption of energy and lifetime of WSNs. The residual energy is a major parameter to be considered for WSNs, that is calculated using

$$\text{RemEng(re)} = \sum_{N=1}^{n} E_{rr}(\text{Nd}) \tag{27}$$

Where E_{rr} (Nd) is the energy of Nd^{th} node for n^{th} round.

Here,it is seen from the results that the average energy consumed is around 2200 rounds in MSEEC, whereasforTABU-MSEEC, it occurs even after 3500 rounds in the case of NNs.In the case of ANs, the average energy consumed is after 7500 rounds in MSEEC,while it occurs in the case of TABU-MSEEC even after 11500 rounds. In the case of super nodes the average energy consumed is after 12000 rounds in MSEEC,while it occurs in the case of TABU-MSEEC even after 17000 rounds.Here, the observations reveal that the performance of TABUsearch is very high when compared to the MSEEC protocol because TABU search chooses the most effective solution.

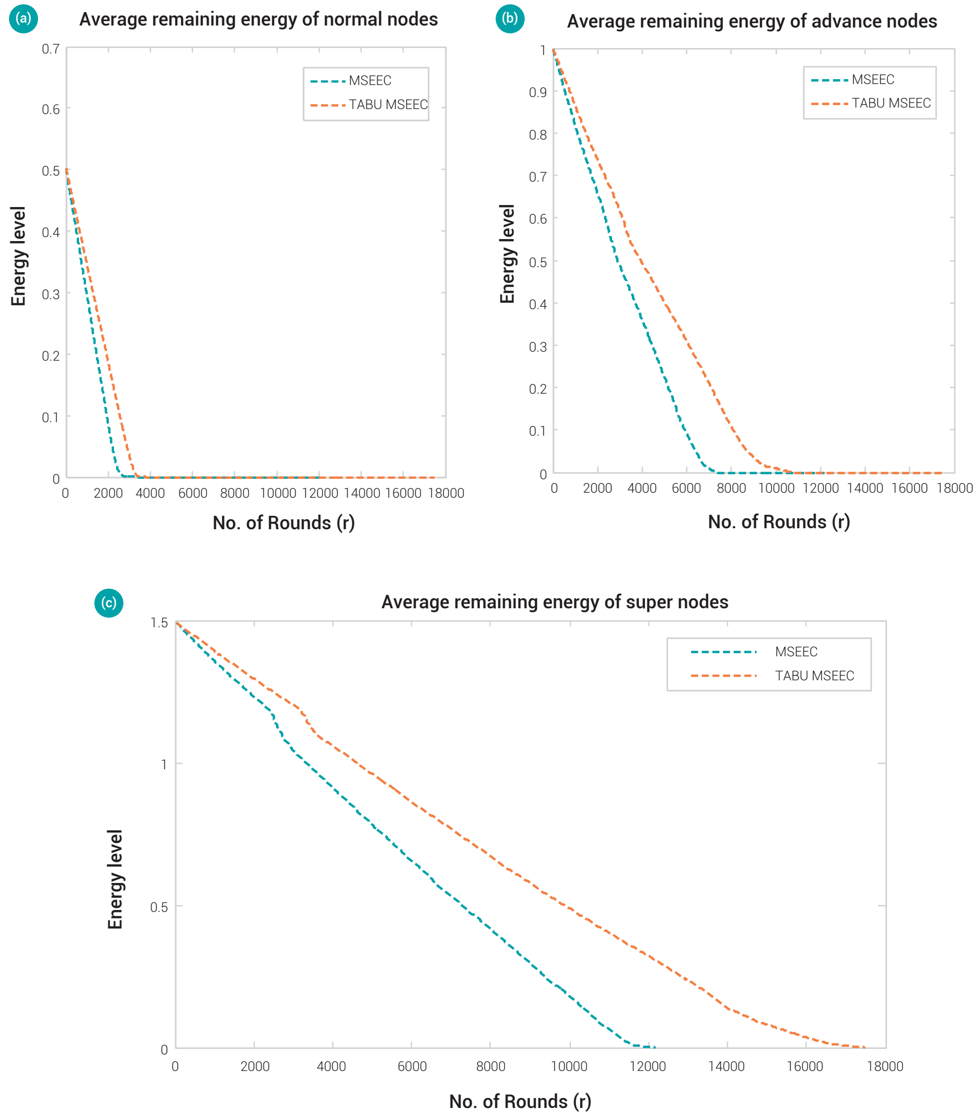

Figure 8. Average remaining energyvs. rounds for 200 nodes in a 200×200 network

Source: own work

(a) Normal Nodes
(b) Advanced Nodes
(c) Super Nodes

6. CONCLUSION AND FUTURE DIRECTIONS

The TABU-MSEEC protocol presents an improvement over the MSEEC protocol. The method adopted for transmission is governed by the candidate solution of the TABU. If the proposed solution has greater effectivenessthanthe existing optimum solution, then it is updated into the TABU list and the solution is judged to be a TABU.If it is TABU, then the 2ndbest solution is selectedfor the steps and if it is not TABU, then the solution is updated as the existing solution and the TABU list is updated. This approach may lead to a greater stability period and makes the network more efficient. The proposed techniqueis better than the existing one since the remaining energy in the network is increased by 62% compared to normal nodes in MSEEC, 65% compared to advanced nodes in MSEEC and 70% compared to super nodes in MSEEC. The network lifetime is also enhanced by 70.8% when compared to MSEEC. The simulated results shows the improvements of TABU-MSEEC over MSEEC. The FND is delayed by 1450, 1950 and 3500 rounds in NN, ANand SN respectively. Also, the LND is delayed by 100, 4200 and 5000 rounds in NN, AN and SN respectively. As a future work, the gathered data can be utilized to decide the impact of the path loss in applications that rely upon RSSI and the path loss exponent, for example, RSS-based confinement and energy analysis and also work on clustering and routing with other bio-inspired algorithms like cuckoo search, flower pollination, spider monkey optimization, Glow-worm and Meerkat Clan Algorithm.

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