Wireless Pers Commun
https://doi.org/10.1007/s11277-017-5019-0

An Analysis of Energy Efficiency Improvement Through Wireless Energy Transfer in Wireless Sensor Network

M. Dhurgadevi[1] · **P. Meenakshi Devi**[2]

Abstract In a wireless sensor network, wireless Energy transfer is a demanding technology for the energy difficulties in recent times. The foremost disadvantage of presentation is limited duration because WSN contains only restricted battery energy at a node. Therefore, we anticipated cluster-related wireless energy transfer in this document. The foremost intention of the method is to augment the duration of the sensor network through charging by the help of this wireless power transfer technology. So that, mobile charging vehicle (MCV) is established to move within the network and charge the sensor node battery wireless. The sensor nodes in the network are collected as a cluster for energy efficiency. Here, the cluster head is chosen for each one cluster in the network which is based on the rank metric value. Suppose, if one node in the network is reducing its energy, then the CH will send charge request and route ID to the MCV. Afterward, the MCV recognize the node by means of the exacting route and establish to charge the node. The reproduction consequences illustrate that the network lifetime of our anticipated method is enhanced than obtainable method.

Keywords Wireless Energy transfer · Wireless sensor network · Mobile charging vehicle (MCV) · Rank metric · Cluster head

1 Introduction

Generally, the wireless sensor network contains several battery sensors. Sensors misplace its energy on sensing, conveying and receiving. The battery charge will also misplace in redundant condition. In wireless sensor network, the demanding procedure is to augment

✉ M. Dhurgadevi
dhurgadevi1183@gmail.com

[1] KSR Institute for Engineering and Technology, Tiruchengode, Tamilnadu, India

[2] Department of Information Technology, KSR Institute for Engineering and Technology, Tiruchengode, Tamilnadu, India

Published online: 29 November 2017

the energy efficiency of the node in recent times. When the nodes are motorized by means of a battery, then it contains only restricted duration. If the battery stage of sensor nodes is restricted, then the energy-effectiveness enhancement is a foremost confront. In the process of sending, the sensors misplace their energy. Recently, the sensor performs a foremost function in all areas particularly in health care observation [1]. Previously, several researchers put their attempt to extend the duration of sensor network [2–4].

Normally, the energy-harvesting procedure [5–7] is used to remove energy from the surroundings, but the procedure is not accomplished because the appropriate function of the procedure is greatly reliant on the surroundings. In an energy harvesting sensor network, the sensors are motorized by means of reusable energy like solar energy, wind energy, thermal energy etc. [8]. The foremost intention of innovative monitoring eminence maximization difficulty is used to exploit the eminence. Moreover, the dynamic rate weight task and lessening procedures are used to diminish the simultaneous flow difficulty.

Here, the wireless charging technology is permitting a mobile charger for conveying energy to sensor nodes wirelessly [9–11] not including the battery. A vehicle is required to transmit a charger to move in the network for to execute the Wireless power transfer [WPT] technology. In [14], wireless charging vehicle (WCV) is transferring the cellular arrangement in the network and transferred the sensors wirelessly. On the other hand, the energy effectiveness and duration of the network is so pitiable in this technology. So, we recommend the cluster-related wireless energy transfer for to resolve these difficulties. Here, we offered rank related weight metric computation for cluster head choice. Wireless/Mobile charging vehicle is generally employed to charge the node in the network.

This document also contains: Some of the related works of wireless energy transfer technology is explained in Sect. 2. In Sect. 3, we depict our anticipated cluster-related wireless energy transfer. Consequences of our anticipated method are explained in Sect. 4. At last, this document is accomplished by Sect. 5.

2 Related Works

Madhja et al. [12] have examined the difficulty of competent wireless power transfer in wireless sensor networks. In their process, they offered particular mobile chargers for to charge the sensor nodes in the network. They have anticipated four innovative protocols. Here, two of them (CC, CCGK) are carried out as centralized, international network information management and charging. And, two of our protocols (DC, DCLK) are carrying out as disseminated, restricted network information coordination and charging.

Xu et al. [13] have explained a charging development, difficulty of discharging, several mobiles charging vehicles to charge sensors like the overall detachment of this observation occasion is diminished. Therefore, any one of the sensors will execute without energy among others. They have anticipated an estimation algorithm by the help of certain estimation proportion. They have invented a heuristic algorithm in the course of alteration to the estimation algorithm. They have diminished the service expenditure at 20% when contrast to the existing method.

Xie et al. [14] have offered a multi-node wireless energy transfer technology. It is verified by whether it is a scalable technology to tackle energy problem in a WSN or not. They have measured wireless charging vehicle (WCV) for to incriminate the sensors in the network. They have anticipated a cellular arrangement which divides the two-dimensional plane as adjacent hexagonal cells which are derived from the charging-series of the WCV.

They have depended on a recognized optimization arrangement through mutually optimizing flow routing, traveling course and charging time.

Shi et al. [15] have offered a dynamic routing algorithm for renewable wireless sensor networks among wireless power transfer. Their anticipated process encompasses the roaming course of WCV and charging program like the proportion of the WCV's holiday time in the sequence time. Moreover, they have established the perception of (N + 1) segment explanation with a competent dynamic routing process. Their most favorable wandering course is established by the direct Hamiltonian sequence.

Lin et al. [16] have anticipated a game hypothetical mutual charging format for wireless rechargeable sensor networks which is also recognized as GTCharge. They have transformed the charging progression as a collaborative game which obtained by wireless charging vehicles (WCVs). They have examined the quality of payment level, charging precedence and earnings. In this method, WCV has accomplished the greatest earnings.

3 Cluster-Based Wireless Energy Transfer in WSN

3.1 Overview

Here, we have offered wireless energy transfer with wireless charging vehicle or mobile charging vehicle for to develop the energy effectiveness and network duration. The sensor nodes in the network are collected as a cluster for energy efficiency. The cluster head will be elected for each one cluster in the network which is derived from the rank metric value. Rank metric value is premeditated by means of a amount of adjacent nodes, outstanding energy and the detachment among the node and its adjacent nodes in a cluster. In the node, the highest rank metric value is preferred as a CH. The CH is used to combine the entire information from the non-CH element in a cluster. Afterward, the basis node sends the data package to the target through choosing the least hop count as a subsequent hop node. Suppose, if the cluster head is reducing its energy, then it will be accused by means of mobile charging vehicle (MCV) which is previously charged at a service location. Suppose, if the non-CH element in the route is reducing its energy, then it will send charge request to the related CH. Afterward, the CH sends route ID and accusation demand to the MCV. In this process, the exacting non-CH component will be charged.

3.2 System Model

Here, Fig. 1 illustrates the system representation of our anticipated method. This process contains a combination of cluster and cluster head which is preferred by means of rank metric. In a cluster, every node is modernized by its adjacent table which contains outstanding energy and hop-count of adjacent nodes. The CH is used to combine the entire information from the non-CH component. Suppose, if the node is reducing its energy, then it will be accused by means of mobile charging vehicle (MCV) which is previously accused at a service location.

3.3 Cluster Formation

In group related process, the cluster head (CH) is the fundamental uncertainties for energy capable communication in remote sight and sound sensor system. In this document, we

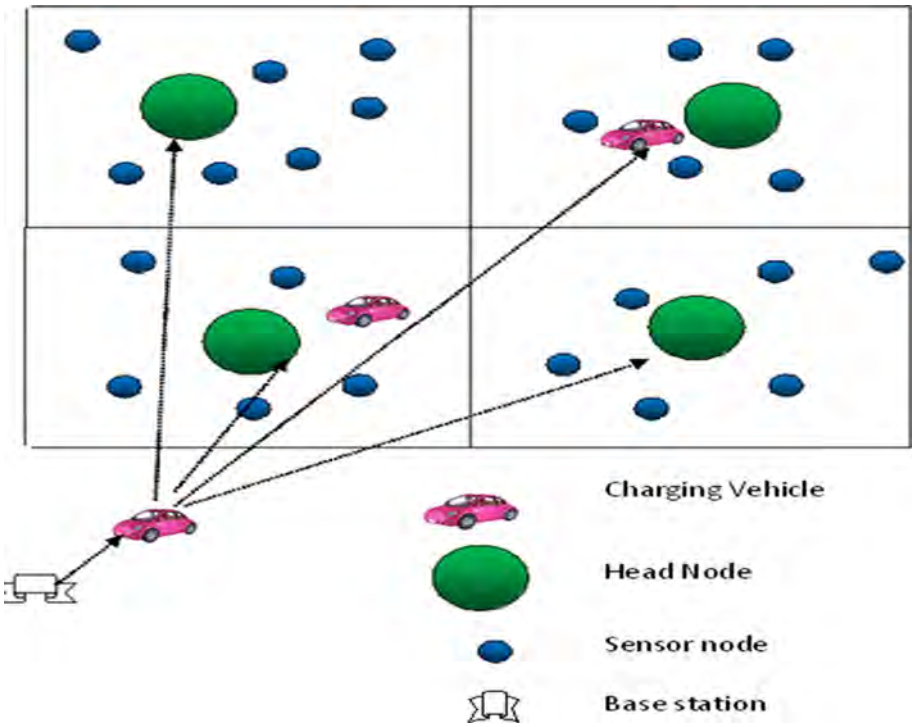

Fig. 1 System model

have established rank related cluster head determination procedure. Before picking a basic cluster head in a group, the conveying of HELLO message is used to combine video or audio data from each hub. In a cluster, each hub contains two tables such as a Neighbor table (NT) and Information Table (IT). The Information Table contains the type of each hub. Initially, the hub sends REQ message from basis to the adjacent hub. In this occasion, the basis hub obtains REP message from the adjacent hub and it improves the position of the adjacent hub in Neighbor Table. Normally, the association is removed from the path.

According to the previous conversation, a Rank Metrics process is combining every structure limitations by means of definite computing fundamentals which are selected through structure requirements. The flexibility of weight component is an aid to implement this computation to dissimilar systems. The cluster head selection progression is the collection of hubs which containing a superior evaluation of Rank metrics. The communication variety of hub is selected by CH, which means no two CHs are adjacent. There may be a situation if two CHs are produced the identical established assessment of the Rank metric. In this situation, a perfect array is used to select a hub with short misfortune value in the middle of hubs (Tables 1, 2).

Table 1 Information table of node

Node id	Residual energy	Distance between node and neighbor node	No of hub

Table 2 Neighbor table of nodes

Neighbor node ids	Residual energy	Distance between node and neighbor node	No of hub

According to the previous conversation, a Rank related Weight Metric method is premeditated to unite the system limitation among definite weighing.

Adjacent nodes are resolute by the transmission range (R_{tx}) of the nodes. Here, the values are standardized by utilizing the neighbor table (NT) of the node.

$$N_s = \sum_{s' \in s' \neq s} \{d(s, s') < R_{tx}\} \tag{1}$$

here s and s' are indicating the basis node and adjacent nodes in an identical way. N_s is explain about the overall quantity of adjacent nodes of the basis s. The detachment among basis and adjacent nodes i.e. $d(s, s')$ are premeditated through Euclidean detachment formula which is specified as

$$T_s = \sum_{s' \in N_s} \{d(s, s')\} \tag{2}$$

here the Eq. (2) is used to find out the overall failure in a routing path. The standard energy of each node is specified as,

$$E_{avg_s} = \frac{1}{N_s} \sum_{s \in N_s} E_{res_s} \tag{3}$$

here E_{res_s} is the outstanding energy of the entire adjacent nodes. In Eqs. (1), (2) and (3), Rank metric value of each one node is specified as,

$$Rank_s = \alpha \cdot N_s + \beta \cdot E_{avg_s} + \gamma \cdot \left(\frac{1}{T_s}\right) \tag{4}$$

here α, β *and* γ is representing the weighting feature for the corresponding group elements. The node among highest Rank metric is selected as the foremost cluster head (CH) (Figs. 2, 3, 4).

3.4 Wireless Energy Transfer

After that, the preferred CH sends the HELLO message to every non-CH element in the cluster. Figure 5 is illustrated in the arrangement of HELLO message which is sent by means of CH. This message also contains the cluster ID, CH–ID, outstanding energy detachment among node and an adjacent node, and a number of hops. Afterward, every non-CH member is modernizing their information in the message. Here, the CH is established to congregate the entire data package from the non-CH element and promote it to the target or base location. For routing, the node among least hop count is preferred as a next hop node from the adjacent table. A source node is conveying its data package to the CH and the CH conveys the composed data package to the target in the course of the next CHs in the network. The Route-ID of the cluster is gathered in the CH for every communication (Fig. 6).

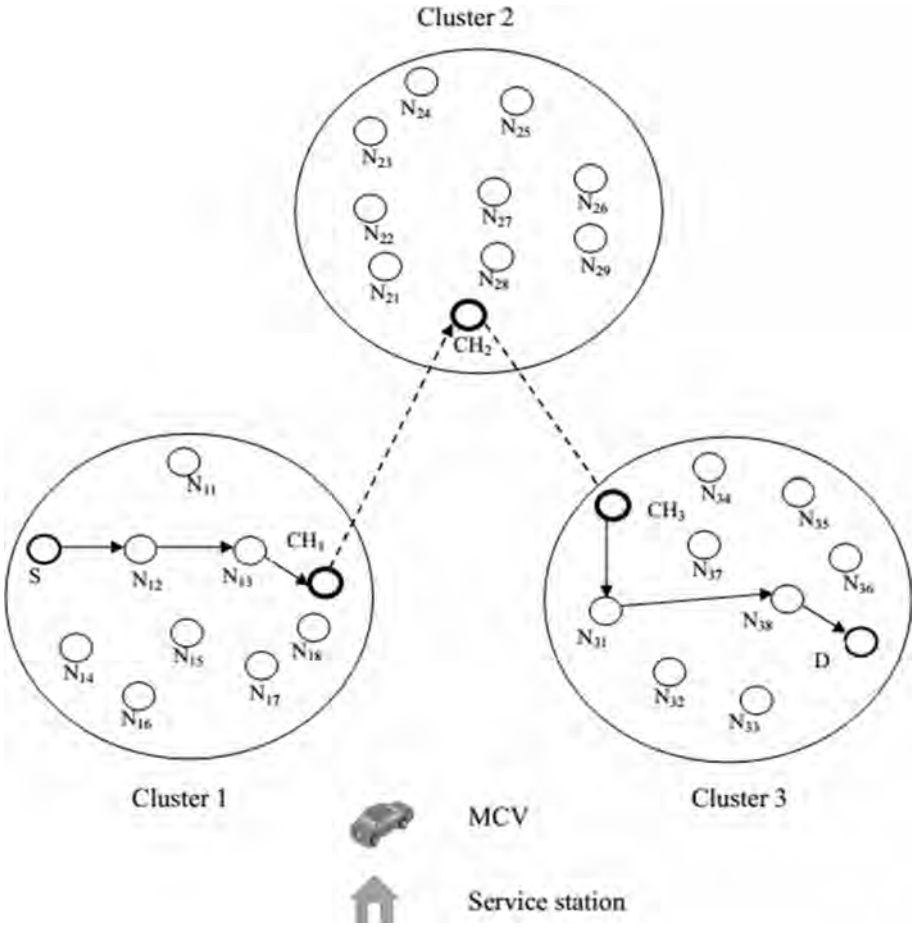

Fig. 2 Cluster-based routing

After this process, a node possibly will misplace its energy stage in the route. Therefore the CH confirms the energy stage of every node in the route and itself also. Suppose, if the energy stage of every node is obtained from the highest and the least threshold value, then the CH verifies the particular requirement to be revived.

$$T_{\max} > E_{res_i} > T_{\min} \tag{5}$$

Suppose, if the CH convinces that situation, then it sends Charge Request (C-REQ) to the mobile charging vehicle (MCV) at a service location.

$$CH \overset{C-REQ}{\longrightarrow} MCV$$

In this network, MCV recognizes the position ID for the entire nodes. Here, the MCV progress to the CH and establish to charge after getting the demand from the CH. Suppose, if charging is completed, then MCV takings to the service location. Moreover, if a non-CH

Algorithm 1

1. *Initializes each and every one nodes in a cluster*
2. *Keep informed Information Table (IT) and Neighbor Table (NT) of each node in a cluster*
3. *Approximation degree of the node s* (N_S)*, sum of distance between s and s'* (T_S)*, average residual energy of the node* (E_{res_s}).
4. *In conclusion, compute the Rank metric* ($Rank_s$) *value of the node.*

$$Rank_s = \alpha * N_s + \beta * E_{avg_s} + \gamma * \left(\frac{1}{T_s}\right)$$

5. *If* $Rank_m > Rank_{m+1}$

   $Rank_m = CH$

   Or else, go step 2

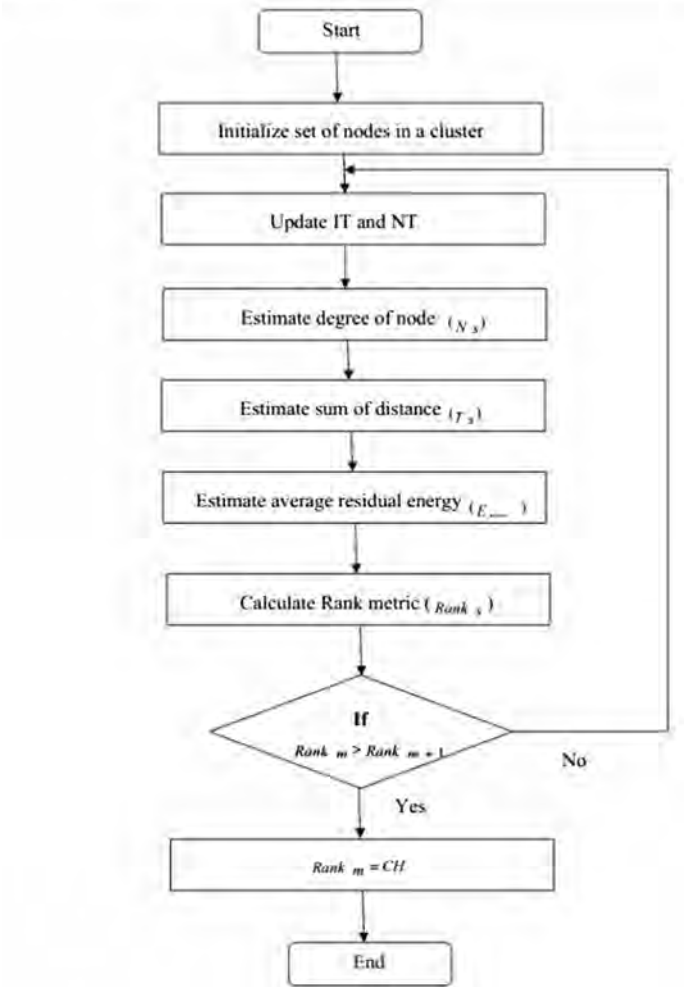

Fig. 3 Flowchart of Algorithm 1

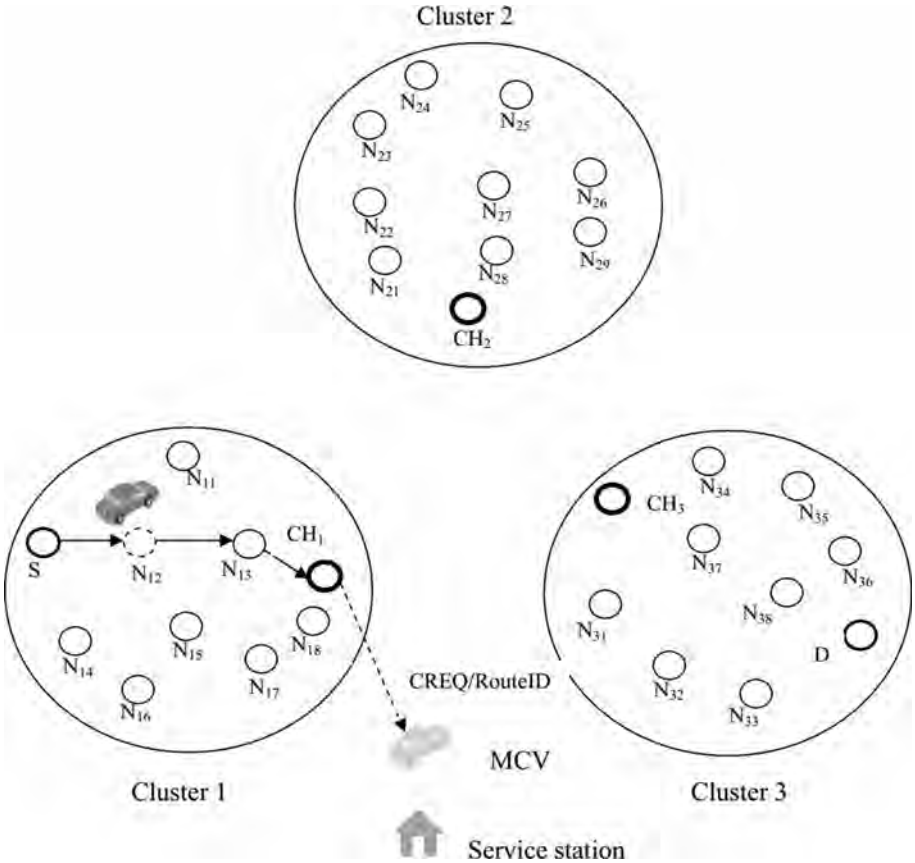

Fig. 4 Cluster-based wireless energy transfer (CWET)

Route ID	S	**N_{12}** **(C_REQ)**	N_{13} N_{25}	CH_1

Fig. 5 Route ID of cluster 1

component in the route gratifies the above situation, then it sends Charge Request (C-REQ) to the cluster head.

$$non - CH \overset{C-REQ}{\longrightarrow} CH$$

Afterward, the CH sends the Route-ID among C-REQ to the MCV. After getting the message from the CH, the MCV shift the route from the basis node and recognize the node which is to be accusing. Suppose, if charging is completed, then MCV takings to the service location.

Overall Algorithm

1. *Cluster formation and cluster head selection*
2. *CH gathers information about the non-CH members in the cluster*
3. *Updates neighbor table of each node*
4. *The node with minimum hop count is selected as a next hop node for routing*
5. *If* $T_{min} > E_{res,i} > T_{th}$

   Node ^{i} *sends C-REQ to CH*

   CH sends Route-ID and C-REQ to MCV

   MCV charges the Node ^{i}

   Else

   Routing continued

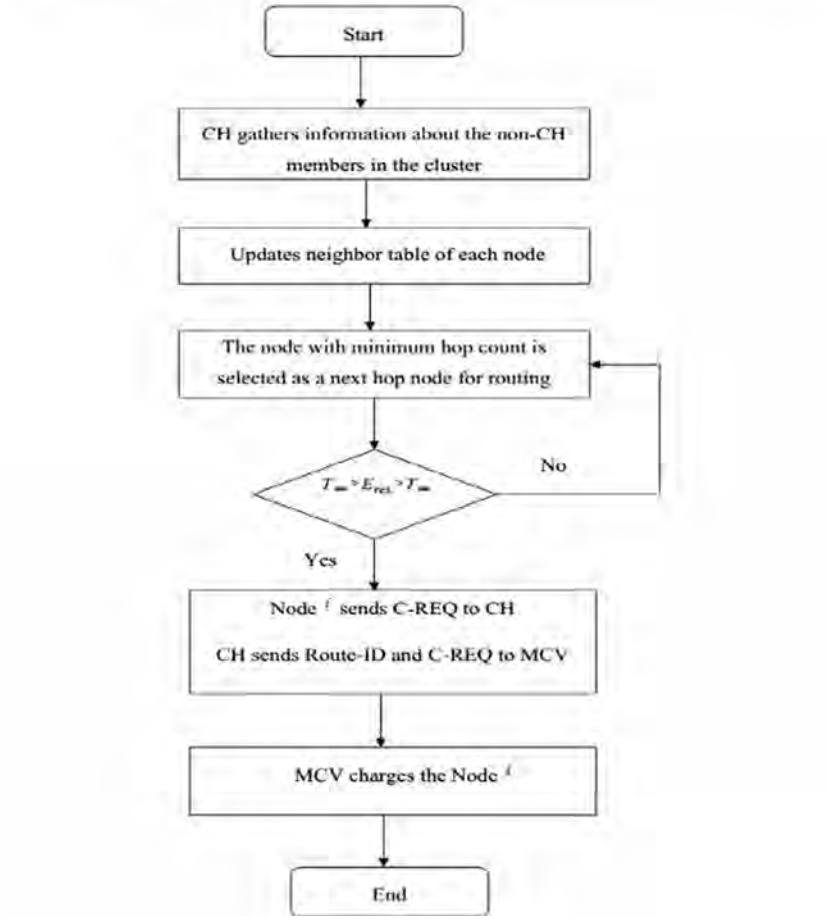

Fig. 6 Flowchart of overall algorithm

$$CH \xrightarrow{Route-ID/C-REQ} MCV$$

In Fig. 4, the node N_{12} is reducing its energy for conveying C_REQ to the CH_1. Afterward, the CH_1 sends the C_REQ among the Route ID to the mobile charging vehicle (MCV). After this process, the MCV shifts the route and recognize the node as to be accused. Here, Fig. 5 illustrates about the Route ID of cluster 1.

4 Results and Discussions

In this segment, the document is premeditated by NS2. To modernize their topology, every node is sending hello package to its adjacent node which is in its communication series. Here, the arrangement of topology has 40 nodes in surroundings system. The entire nodes are considered as dynamic nodes with identical energy stage at the establishment. The preliminary energy stage of every node is 100 Joules. The node among the highest quantity of adjacent node is chosen as a cluster head. The energy stage of cluster head is 200 Joules. The accusation rate of cluster head is 45 joules. Here, the two unsystematic produced WSNs are included 40 nodes. The sensor nodes are set up a square region as 1 km $\times$ 1 km. The least energy stage of the node is measured as 40 joules.The traveling speed of the WCV is considered as V and the value is 5 m/s. Figure 7 illustrates the topology arrangement of our anticipated method. Here, the 40 nodes are gathered as a cluster and the network encompasses one base location, WCV/MCV, and service location.

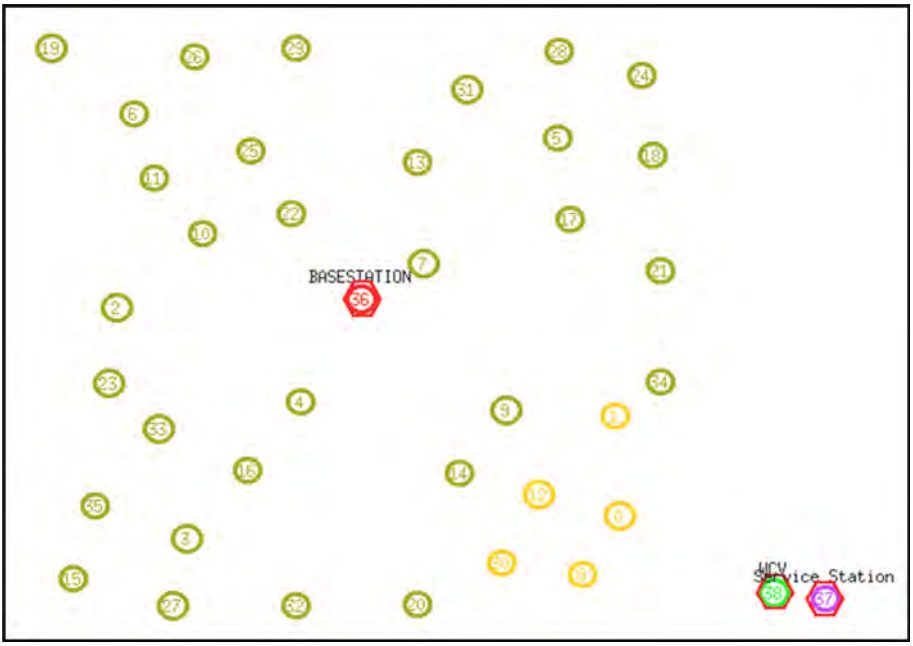

Fig. 7 Topology formation

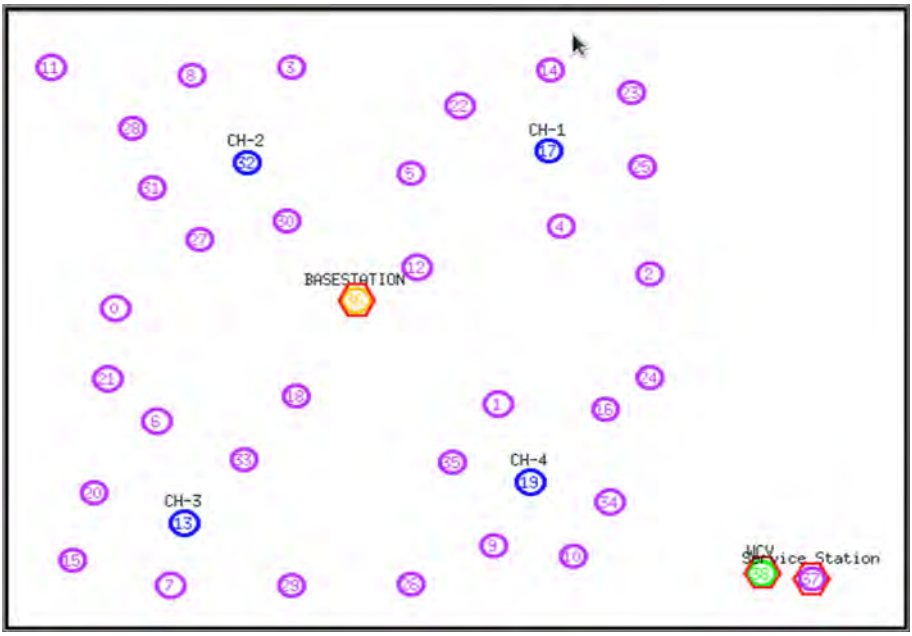

Fig. 8 Cluster head selection

Figure 8 illustrates about the computation of rank metric value for every node in a cluster. Here, the node among highest rank value is preferred as a cluster head (CH). So, we have preferred four cluster heads like CH-1, CH-2, CH-3, and CH-4.

In Fig. 9, the cluster heads CH-1, CH-2 and CH-3 are diminishing its energy. Therefore, they have sent C_REQ to the MCV. The MCV establish to accuse the cluster heads. Suppose, if one non-CH element is diminishing its energy, then it conveys the C_REQ to the related CH. Afterward, the CH sends the C_REQ and Route_ID to the MCV. The non-CH element is recognized and accused through choosing the exacting route.

4.1 Performance-Based on Nodes

In this segment, the presentation of the anticipated method is anticipated for diverse nodes 8, 16, 24, 32 and 40. The Figs. 10, 11, 12, 13, 14 and 15 is illustrated about the package delay, delivery ratio, package drop, energy utilization, network lifetime and throughput of our anticipated method. Here, the anticipated cluster-related wireless energy transfer (CWET) is contrast by means of the obtainable method MWEC [14]. Figure 10 is illustrated about the package delay of our anticipated method. Suppose, if the quantity of node is augmented, then the packet delay of the network also augmented. But, the packet delay of our anticipated method is diminished to 68% in the contrast to the obtainable method. According to the arrangement of energy competent cluster, the chance of delay is very small in our anticipated process. Figure 11 is illustrated about the delivery ratio of our anticipated method. According to the rank-related cluster head choice, the delivery ratio of our anticipated method is augmented to 40% than the obtainable method. The Figs. 12 and 13 illustrates about the package drop and energy utilization of our anticipated method correspondingly. The related CH sends charge request to the MCV in the cluster, at the

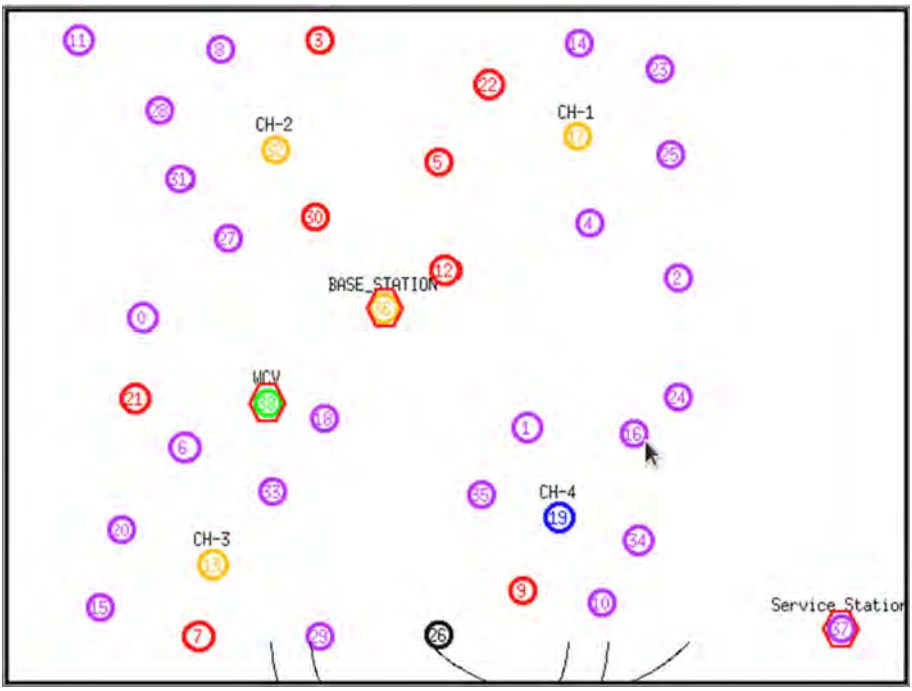

Fig. 9 Power transfer to nodes

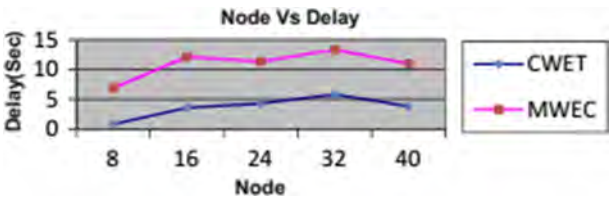

Fig. 10 Node versus delay

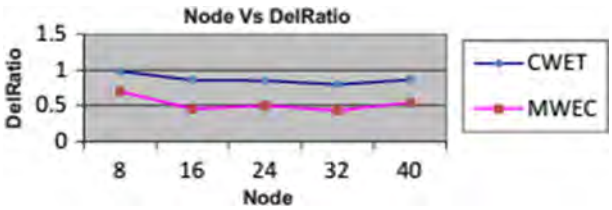

Fig. 11 Node versus delivery ratio

same time as a node in the route is diminishing its energy. Afterward, the MCV accuses the node earlier than it misplaces its energy. Therefore the package drop and energy utilization of our anticipated method are diminished to 95 and 96% correspondingly than the obtainable method. The Figs. 14 and 15 is illustrated about the network lifetime and

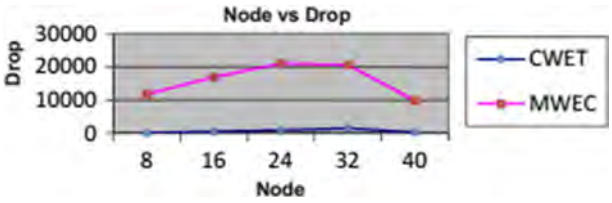

Fig. 12 Node versus drop

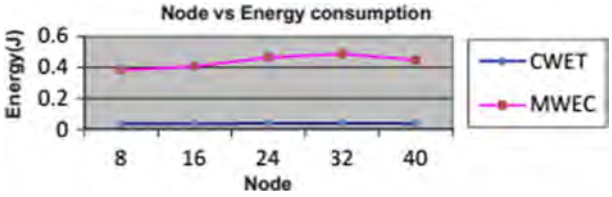

Fig. 13 Node versus energy consumption

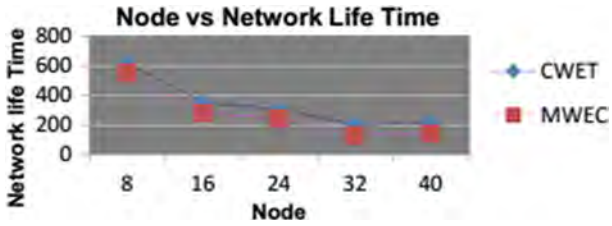

Fig. 14 Node versus network lifetime

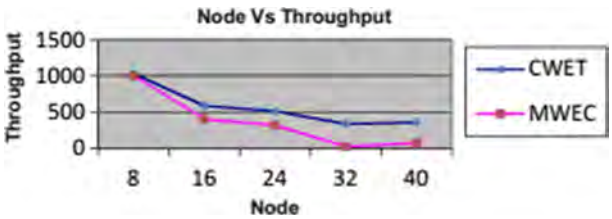

Fig. 15 Node versus throughput

throughput of our anticipated method. In this process, our anticipated method is augmented to 32 and 34% than the obtainable method.

5 Conclusion

In this document, we proposed cluster-related wireless energy transfer and our method are replicated by means of the network simulator NS2. Here, the sensors of the network are gathered as a cluster and the cluster head for every cluster is preferred by the help of rank-related weight metrics value. The choice of the node among a least hop count is used to take place the routing. Suppose, if a node in the cluster is exhausted its energy, then the cluster head sends the charge request to the MCV for to accuse the node. Our simulation consequences are illustrated about the network lifetime of our anticipated method.

References

1. Park, G., Rosing, T., Todd, M. D., Farrar, C. R., & Hodgkiss, W. (2008). Energy harvesting for structural health monitoring sensor networks. *Journal of Infrastructure Systems, 14*(1), 64–79.
2. Chang, J., & Tassiulas, L. (2004). Maximum lifetime routing in wireless sensor networks. *IEEE/ACM Transactions on Networking, 12*(4), 609–619.
3. Giridhar, A., & Kumar, P. R. (2005). Maximizing the functional lifetime of sensor networks. In *Proceedings of ACM/IEEE international symposium on information processing in sensor networks* (pp. 5–12). Los Angeles, CA.
4. Shi, Y., & Hou, Y. T. (2008). Theoretical results on base station movement problem for a sensor network. In *Proceedings of IEEE INFOCOM* (pp. 376–384). Phoenix, AZ.
5. Bulusu, N., & Jha, S. (Eds.). (2005). *Wireless sensor networks: A systems perspective, Chapter 9*. Norwood, MA: Artech House.
6. Jiang, X., Polastre, J., & Culler, D. (2005) Perpetual environmentally powered sensor networks. In *Proceedings of ACM/IEEE international symposium on sensor networks* (pp. 463–468). Los Angeles, CA.
7. Kansal, A., Hsu, J., Zahedi, S., & Srivastava, M. B. (2007). Power management in energy harvesting sensor networks. *ACM Transactions on Embedded Computing Systems, 6*(4), 32.
8. Liang, W., Ren, X., Jia, X., & Xu, X. (2013). Monitoring quality maximization through fair rate allocation in harvesting sensor networks. *IEEE Transactions on Parallel and Distributed Systems, 24*(09), 1827–1840.
9. Xie, L., Shi, Y., Hou, Y. T., Lou, W., & Sherali, H. D. (2013) On travelling path and related problems for a mobile station in a rechargeable sensor network. *ACM Transactions MobiHoc'13*, July 29–August 1, 2013.
10. Wang, C., Li, J., Ye, F., & Yang, Y. (2013). Multi-vehicle coordination for wireless energy replenishment in sensor networks. In *IEEE Proc*.
11. Peng, Y., Li, Z., Zhang, W., & Qiao, D. (2011). Prolonging sensor network lifetime through wireless charging. In *Proceedings of IEEE RTSS, 2010*.
12. Madhja, A., Nikoletseas, S., & Raptis, T. P. (2016). Hierarchical, collaborative wireless energy transfer in sensor networks with multiple mobile chargers. *Computer Networks, 97,* 98–112.
13. Xu, W., et al. (2016). Efficient scheduling of multiple mobile chargers for wireless sensor networks. *IEEE Transactions on Vehicular Technology, 659,* 7670–7683.
14. Xie, L., & Shi, Y. (2012). Multi-node wireless energy charging in sensor networks. *IEEE Transactions, 23*(2), 437–450.
15. Shi, L., et al. (2014). The dynamic routing algorithm for renewable wireless sensor networks with wireless power transfer. *Computer Networks, 74,* 34–52.
16. Lin, C., et al. (2016). Gtcharge: A game theoretical collaborative charging scheme for wireless rechargeable sensor networks. *Journal of Systems and Software, 121,* 88–104.

M. Dhurgadevi obtained her Bachelor's degree in Information technology from Anna University. Then she obtained her Master's degree in Computer Science and Engineering from Anna University. Currently she is working at K.S.R. Institute for Engineering and Technology, Tiruchengode, Tamilnadu, as Assistant Professor and working towards her Ph.D. in the area of Wireless Sensor networks. She is having 10 years of experience in teaching. She had published 8 papers in various national conferences and 10 papers in international conferences. She has published 7 books. Her research interests include data structures, Wireless networks, and Artificial intelligence. She is life member in ISTE.

Dr. P. Meenakshi Devi received her B.E. degree in Kongu Engineering College, Perundurai, in 1993 and M.E. degree in Thiagarajar College of Engineering, Madurai, in 2003, and the Ph.D. degree from the Anna University, Chennai, India. Currently, she is working as a Professor and Head in the department of Information Technology, in KSR Institute for Engineering and Technology. She is guiding 3 research scholars. She has published 30 papers in national and international journals. She has published 5 books. Her area of interests includes Information Security, Watermarking, Cryptography and Computer Networks. She is life member in ISTE.