An improved Energy Efficient Communication Protocol (IEECP) for Wireless Sensor Networks

Shailendra Mishra, Mayank Singh

Abstract*: The wireless sensor networks have been experiencing exponential growth in the past decade. A Wireless Sensor Network provides low cost solutions and consists of several sensors distributed across a geographical area. In many commercial and industrial applications, it often needs to monitor and collect the information about the environment conditions (temperature, humidity, vibration, acceleration etc.) by using sensor networks. This paper aims to resolve issues relating to excessive multi-hoping from one node to another. Proposed addressing can be used for signal spreading and de-spreading and minimize power usage. The proposed protocol is compared with the two existing protocols namely Tree Routing and Enhanced Tree Routing. The simulation results show that the proposed protocol has the low hop-count compare to TR and ETR, also it consumes less power and energy in finding paths and transmitting data to the sink node compare to TR and ETR protocols.

Index Terms*: Wireless sensor network, Energy Efficient Hope Count Protocol, Tree Routing, Extended Tree Routing, Non-Orthogonal Variable Spreading Factor Technique.

I. INTRODUCTION

Wireless Sensor Network (WSN) has less bandwidth, short range and small data processing capability, while traditional networks have large range, more storage capacity and more data processing capability. A sensor network has slow processing devices. Now days a wide variety of applications make utilization of wireless sensor networks. Therefore, we need more efficient protocols and algorithms for routing, communication and data security [1]. Main challenges of WSN are physical constraints, fault-tolerance, ad-hoc wireless deployment, scalability, Quality of Service (QoS), unattended operation, un-tethered and data security. Physical constraint like battery power, storage and computational power are commonly known to a sensor network. Since sensors are supplied with the limited battery power, therefore energy consumption is main design constraint to a protocol and it depends on network size as well as routing algorithms. [2].

Due to physical constraints like physical damage or lack of power supply a sensor node may fail, so the protocol must accommodate changes like node failure, topology changes etc. [3]. The battery backup of sensor node is limited so network cycle as well as throughput of network is low [4].

Revised Manuscript Received on December 22, 2018.

Shailendra Mishra, Computer Engineering Department, College of Computer & Information Sciences, Majmaah University, Saudi Arabia

Mayank Singh, School of Electrical, Electronics and Computer Engineering, University of KwaZulu-Natal, Durban, South Africa

Consumption of energy in WSN has been optimized by cross-layer design method, using this it is easily know about the network nodes, also cross-layer design method improves the network performance [5].

The deployment of sensors can vary from hundreds to thousands or to more, as per the application need. Thus, the protocols must be scalable enough to respond and operate with such large number of sensor nodes [6]. In some scenario, sensors once deployed can work for a longer time without any human intervention. Hence, the nodes themselves should be reconfigurable, adaptable to the new topology changes. The sensors have a fixed source of energy and have no external power supply; therefore, they must be optimally used for processing and communication. Since sensor networks work on low bandwidth, data security becomes a key issue as well as key parameter in WSNs [3].

The energy consumption, QoS and overall performance of a routing protocol depends on the architectural model and design of the sensor network. Energy plays a vital role in designing a network infrastructure and route processing for data transmission. In a large sensor network, duplicate data generation by different sensor nodes is a common problem. The problem is resolved with the help of aggregation function [7].

The aggregation function eliminates duplicate data, by using functions such as min, max, suppression and average. As WSN is deployed in hostile areas such as battle fields, forests etc. The data collected is highly significant therefore; protection of the data is one of the major concerned. The communication protocols should incorporate security features for data transmission. Depending on the application type, the sensor network topology can be designed statically or dynamically [8].

The static architecture has a fix path from each sensor node to the sink node and thus consumes less energy, bandwidth etc. In deterministic approach, data routing, topology implementation and network management is easy and predictable, while in case of self-organizing sensor networks the sensor nodes themselves are responsible for topology management, data forwarding and network management [2]. Hence, the protocols implementation, to carry-out different tasks in the above two approaches are different.

Data Delivery models in WSN are demand driven. When a request is generated by a user it is processed instantly and result is produced.

The power optimization in clustering approach aims to extend the clustered wireless network life time by making economical and efficient use of battery power supply [9]. Section 1 gives an introduction of WSN, purpose and significance of this research. Section 2 gives the related work study (literature survey) for various power optimization methods and energy efficient communication protocol. Section 3 discussed about proposed system model for power optimization. Section 4 gives information about topological structure, energy consumption model and data collection strategy for the protocol. A comparative analysis of the results of the proposed protocol (IEECP) and TR and ETR protocol has been discussed. Further, it is interpreted that the new protocol is superior to the existing protocol. In the last, Conclusion and future scope of the work is presented followed by reference presenting the clarity of the philosophy of the research.

II. Related work

The nodes in WSN dynamically self-organize their network topology based on varying network conditions, rather than having a preprogramed network topology. Although, a WSN is having good characteristics, it has some limitations like the storage capacity, power consumption and limited processing. These limitations and the special architecture of sensor nodes lead to the development of energy efficient and secure communication protocols. Number of researchers have proposed different power saving strategies based on different approaches. The survey is broadly categorized in three areas i.e. power management based, cyclic approach and motion-based approach.

The cyclic approaches mainly focus on Time-Division Multiple access based Media Access Control (TDMA MAC) protocol, staggered wakeup pattern, scheduled rendezvous scheme, link scheduling, messaging and hybrid protocols. Cyclic approaches suggest that contention free slot allocation is desirable to eliminate collision and to save energy. Static to dynamic time stamping needs minimum efforts. Sensing the medium and availability of additional antenna are a sort of overhead to the sensor network. Further, energy efficient node addressing is essential in routing network traffic. It can further have divided into power management based and Topology based energy saving scheme.

The power management protocols deal with Medium Access Control (MAC) and Sleep-Wake Up pattern. The major cyclic power management approaches are TDMA scheduling algorithm in WSN [10], Smallest collision free fixed time slot, minimize idle listening, Latency-Energy Minimization Medium Access (LEMMA)- an improved TDMA Approach [11], Contention Based MAC protocol Carrier-Sense Multiple Access (CSMA) [12], Power Aware Multi-Access with signalling (PAMAS) protocol [13], Hybrid of TDMA and CSMA protocol [14], Quorum Based Asynchronous wakeup protocol [15], Asynchronous wakeup mechanisms gives information about forecasted energy [16,17], Flooding timestamp messages [18] and Link scheduling algorithm [19]. TDMA scheduling algorithm in WSN support collision free fixed time slot and minimize idle listening. LEMMA is an improved TDMA approach, it minimizes latency, In Contention Based MAC protocol CSMA, collision avoidance through channel listening. Power Aware Multi-Access with signalling (PAMAS) protocol, uses two transceivers for messaging and controlling and avoid collision of data messages. Hybrid of TDMA and CSMA protocol, designed for one-hop neighbour, no consideration for topology change and synchronization.

In Quorum Based Asynchronous wakeup protocol, no guaranteed overlapped period in a cycle, include two steps wakeup prediction and neighbour discovery. In Asynchronous wakeup mechanisms, no need for slot assignment is required. Flooding timestamp compare Leader-timestamp and arrival-timestamps comparison and Link scheduling algorithm, provide slot length for all links.

Important features of cyclic approaches are smallest collision, free fixed time slot, minimize idle listening, minimize latency, collision avoidance through channel listening, nodes at different level of tree wake up different time, allow data aggregation, solar radiation as energy harvesting, time varying harvesting prediction model, lower average packet latency, fixed staggered scheme, use of spanning tree for time synchronization and node has wakeup schedule function, no need for slot assignment.

The major approaches based on network topology protocols are aggregation routing, enhanced tree routing, Connection Driven and location driven routing. In Aggregation Tree [20], root is sink and leaves are sensor nodes, it is a data gathering tree. An Aggregation Tree Protocol [19] follows a tree like structure for sink and sensor nodes deployment. Aggregation Tree is a data gathering tree that connects the base station node and all sensor nodes in a network. Root is the base station in the WSN and other nodes are located at the relaying or a leaf node. There can be more than one base station and each base station has its own tree.

Enhanced Tree Routing [21,45] avoids flooding network path search and use neighbour table to find shortest paths. An improvement to aggregation tree is Enhanced Tree Routing protocol, it avoids flooding, during searching the path, hence, save bandwidth and energy. A default Tree Routing (TR) protocol uses strict parent-child link for data forwarding. A tree-based topology is highly suitable for a moderate size network. The tree path from sensor node to the sink plays a critical role in energy consumption. Multi-hoping along a tree path is more energy efficient than single hopping.

Further, excessive multi-hopping in tree may cause early drain of energy of intermediate nodes in transferring its' own data and data forwarding. Connection Driven routing [23], elects coordinators for multi-hop routing and in location driven protocol [22], nodes are existing in two states active state and discovery state, root is selected based on rank-based election algorithm.

Data Oriented approaches works on data sensing impacts on sensor nodes. Major work in this area are adaptive sampling approach [24], it exploits temporal correlation between data.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

Adaptive sensing strategy [25], it exploits three approaches i.e. hierarchical sensing, adaptive sampling and model based active sensing. Model based data sampling [26], for prediction and uses computing model for sampling, Utility based sensing model [27], linear regression model is used to forecast sample. Hierarchical sampling [28], for low-power sensor and used for coarse-grain information, Probabilistic modelling [29] on data stream, uses two instance of model one at sink to answer query and other on source node to sense data, Correlation based scheme [30] uses dynamic estimation of frequency of signal and spatial correlation scheme [31,32] is back casting scheme, field need not to be sensed in uniform way.

Motion based approach were categories as mobile-sink and mobile-relay approach, in mobile-sink the sink node is moveable and can be repositioned to collect the data. In mobile-relay technique, data mule (Mobile Ubiquitous LAN Extension) is placed that reaches to every sensor nodes location to collect data. Major approach related to motion are discussed below.

In mobilizers approach [33] sensors are place to the device which are mobile like car, bus etc., a few nodes are mobile to keep connectivity using mobilizers, these sensors are place to the device which are mobile like car, bus etc., a few nodes are mobile to keep connectivity.

In message ferrying approach [34], ferry moves and collect data. In data mule approach [36], mules are people, vehicle etc., and access points collects data from it and use short range radio for data transmission [35]. Mobile sink approach [36], uses linear programming technique for optimized sink placement.

Multiple mobile station approach [37], uses more than one mobile sink station. Distributed protocol [38], uses greedy maximum residual energy approach. Proximity selection based on high traffic rates, it considers mobility and routing together [39] and two-tier data dissemination approach [40] used for efficient data delivery to multiple mobile stations, it uses grid structure for forwarding the data.

The important issues identified in the literature survey are listed below.

- Transmission system in a sensor network consumes more power as compared to data processing [41,42].
- Excessive multi-hoping in dense sensor network causes early drain of energy for sensors near to the sink node.
- Mobility of devices makes significant effect on power consumption.
- Placing of mobile sink more than a specific number can increase cost of sensor network deployment.
- A scheme is needed to identify shortest path from source node to a sink node using neighbour table.
- MAC protocols like: ALOHA and CSMA sends a packet whenever they are generated, hence, causes lot of congestion.
- A systematic addressing scheme is needed to address a particular node in the network.
- Mobility of devices must be energy efficiently. The movability of the sink is limited to certain feasible sites; it helps in reducing excessive multi-hopping to minimum especially in tree-based sensor network.

III. Proposed Wireless Sensor Network Structure for Power Optimization

To obtain power optimization in wireless sensor network, we proposed a node-addressing scheme with reduced length. Availability of mobile sinks are apart from fixed sink. The main sink node in tree network is fixed and other base stations are mobile. The mobile bases are located at feasible location from the fixed sink node.

The mobile base station is located at the centroid for each region. The architecture helps in reduction of excessive, parent-to-child multi-hoping in a dense sensor network. The sensors in this topology sense facts from the environment and forward it to nearby mobile sink. The mobile sink considerably having more energy than sensors, further forward collected data to the fixed fusion sink node as shown in fig.1. Mobile sinks can only be placed at feasible location of the sensor network.

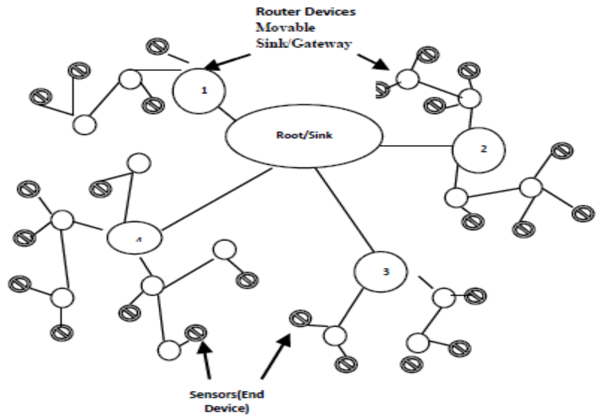

Figure 1. Proposed Tree Structure of IEECP with a fixed root/sink node and mobile sinks

In proposed network structure shown in Fig.1 to increase the life time of end devices (sensors), we propose to employ more than one base station in the network. In proposed network structure, there are more than one base station, because the sensor which are near to the sink node need to forward data coming from other nodes, in addition to delivering their own data. To share the medium with minimum interference the proposed MAC scheme is Non-Orthogonal Variable Spreading Factor Technique (NOVSF). The count of the mobile base station in the network is determined by a special method called Non-Orthogonal Variable Spreading Factor Technique (NOVSF) [43].

Fig.2 shows a tree like architecture for NOVSF code with spreading factor 8. We have selected a Spreading Factor (SF-8) for analysis in a region of 500 x 500 m^2. The orthogonal codes generated by the fix base station, depending on the spreading factor, determine the size of the network. With spreading factor (SF) 8 the network can have 8 unique addresses assigned to mobile base stations. Mobile sinks further use these codes to assign addresses to the sensor nodes to uniquely identify them on the network.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

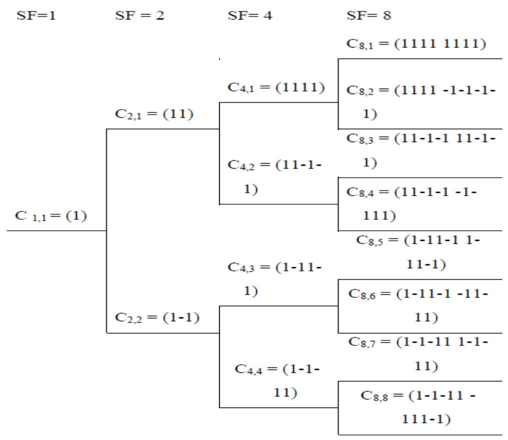

Figure 2. Tree architecture for NOVSF code with spreading factor 8.

Sensor Node Address Format is shown in fig.3. Example of Sensor Node Address Format is shown in figure4.

Movable Sink Address (Orthogonal Code)	Sensor Number (Sequence Number)

Figure 3. Sensor Node Address Format

8 bit		8 bit	
1111	1111	*0* 000	0001

Figure 4. Example Sensor Node Address Format

Proposed addressing scheme in mobile base station is shown in table 1.

Table 1. Proposed Addressing scheme in mobile base station

S. No	**Mobile Sink/Gate way**	**Orthogonal Codes for Addressing**
1.	1	A=1111 1111
2.	2	B=1111 -1-1-1-1
3.	3	C=11-1-1 11-1-1
4.	4	D=11-1-1 -1-111
5.	5	E=1-11-1 1-11-1
6.	6	F=1-11-1 -11-11
7.	7	G=1-1-11 1-1-11
8.	8	H=1-1-11 -111-1

IV. IMPROVED ENERGY EFFICIENT COMMUNICATION PROTOCOL (IEECP)

Researchers have proposed several communication protocols for energy efficient communication. The survey reported in section 2, is broadly categorized in three areas: power management based, cyclic approach and motion-based approach. The aim of each approach is to save sensor's energy by implementing energy efficient addressing, topology creation, routing algorithms and data collection methods. As from literature survey, we have found that placing mobile sinks more than a specific number can reduce network performance as well as complexity of the network increases. Therefore, we intend to introduce moveable sink in the region, the count of which is controlled by some mathematical formulation. Further we intend to propose an addressing scheme refer to a node, that can also be used for signal spreading and de-spreading. Thus, we have proposed in this paper a different energy efficient addressing scheme, a network topology and energy efficient data collection method for tree-based sensor network. The proposed protocol follows the concept of tree routing protocols.

The scenario is based on the concept of inverted tree topology, where sink node is the root, mobile sinks are the branches and sensors are the leaves of the tree. The mobile sinks collect data from end node i.e. sensors and forward to fixed sink/root and can be repositioned at the feasible distance in a region where sensors are randomly deployed. A feasible distance is the centre place where the hop-count of sensors to sink node can be reduced to minimum. As we know the transmission power is related to distance, as short distance consumes less power and large distance consumes more power for a single bit transmission. The objective of the proposed protocol is thus to reduce the distance between sensors and sinks by reducing multi-hopped links for certain distances.

Non-Orthogonal Vector Spreading Factor (NOVSF) technique is used for dynamic addressing with small address size. The technique makes use of orthogonal codes and mobile sinks for data collection. The codes facilitate addressing and spreading of signal in a time-shared manner to provide data security and error correction mechanisms. The sensors have minimum overhead of path discovery when there is a change in the topology, otherwise they are assigned fixed time slots for data transmission without any data collision. The fixed sink node in this protocol generates the orthogonal codes and assigns them to the mobile sink nodes. Mobile sinks further use these codes for distribution among sensors in the region. Each mobile sink is having a unique orthogonal code and can support up-to 128 sensors.

In Basic Tree Structure [43] shown in fig. 5, nodes are forward the packets to its parent or child, so it consumes less energy, no need of searching the path.

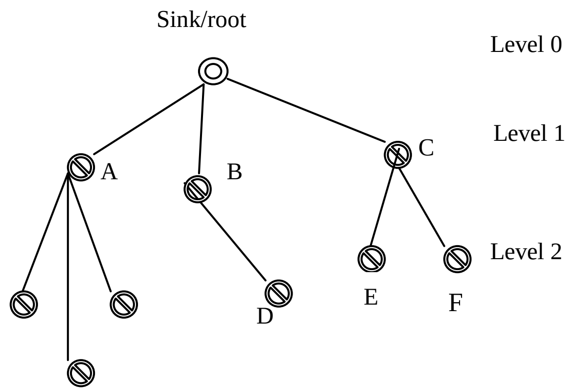

Figure 5. Basic Tree Structure

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

TR protocol is suitable for small network, it is complex and more energy consuming if we implement it in a large network. It works fast and efficiently when network size has no significance. By following the parent-child links it avoids flooding of synchronization message to the network hence, saves a lot of energy for WSNs but as the network grows, the hierarchy becomes large and complicated to handle. Moreover, the distance of the leaf node to the root node also increases causing large multi-hopping sequence to be followed. The problems identified in this protocol and removed in Enhanced Tree Routing (ETR) protocol.

In Enhance Tree Routing (ETR) [21] shown in Figure 6, nodes are forward the packets to its parent or child, as well as neighbour node can provide a minimum path link and that neighbour is selected as the next hop for packet forwarding.

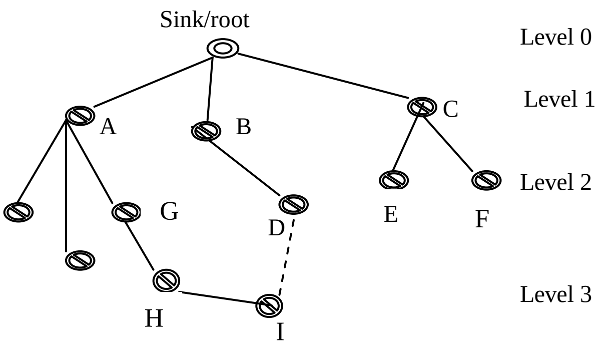

Figure 6. ETR Tree Structure

ETR protocol considers neighbour table for alternate path selection along with the traditional parent-child link. Though this causes the extra computation yet produces best shortest path from source to destination node. Moreover, it uses a fixed size, systematic addressing scheme for node address assignment. As the network density increases the possibilities of multiple shortest paths exist, hence, there are chances of frequent multi-hopping that leads to energy consumption for frequent short transmissions. The ETR protocol uses a systematic node addressing scheme for sensor node identification. It also considers neighbour table containing the information available for the nearby neighbours. The decision for path selection is based on comparison of the distance as identified by TR protocol and path selected from neighbour table. ETR protocol uses a fixed size addressing scheme for node identification. Nodes in sensor network thus have an extra work of shortest path selection. The behaviour of path selection in ETR in some of the cases is unpredictable. For a dense sensor network, the alternative path identification is a challenging and time-consuming task and consumes a lot of process cycle of sensors' processor and hence, energy. The frequent multi-hopping in ETR also causes more power consumption while forwarding data to the neighbour node.

The problems identified in TR and ETR is removed in Proposed IEECP protocol. IEECP protocol uses a NOVSF addressing scheme for node identification. IEECP on the other hand also reduces the frequent multi-hopping by placing a mobile sink to their nearest proximity of the sensor deployment.

V. SIMULATION RESULT

Results are obtained from simulation done in MATLAB. The snapshots of few network topologies in a region of 500 m by 500 m for the three protocols (TR, ETR and IEECP) for 65 sensor nodes are shown in Figure 7, to Figure 9. The figures are self-explanatory to depict the topological structure of the three protocols. It shows that with increase in density the possibility of multi-hoping increases significantly and thus ETR become more complex and energy consuming. IEECP on the other hand helps in reducing the complexity of the network to minimum and that of excessive multi-hoping.

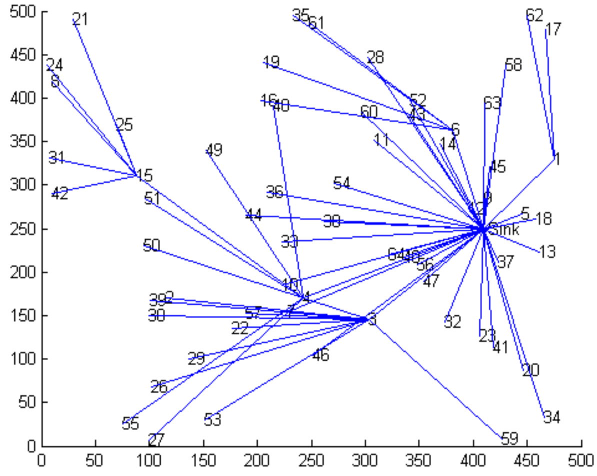

Figure 7. TR Topology (65 nodes)

The dark blue lines in the above figures (TR-Topologies) shows the strict parent-child path as followed by the tree routing protocol for packet forwarding in the dynamic topology. A data packet can opt for single hopping or multi-hopping sequence to reach the sink node.

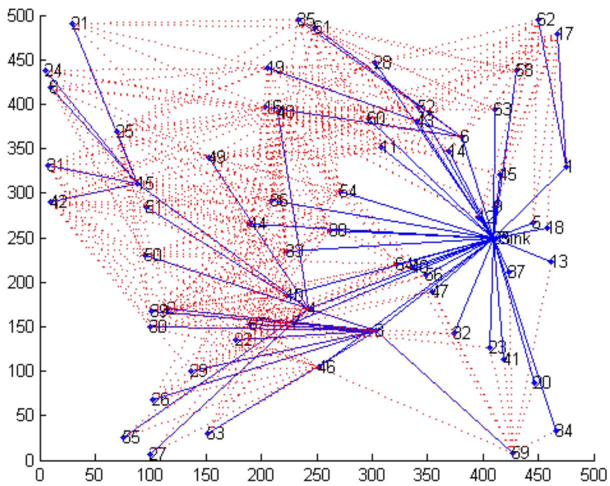

Figure 8. ETR Topology (65 nodes)

The dark blue lines in the figure 7. shows the strict parent-child path as followed by the tree routing protocol for packet forwarding in the dynamic topology and the red dotted lines are the alternative shortest path to reach sink nodes.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

A sensor sends data packets through the shortest possible path, if no path is identified the default path i.e. the traditional parent-child path as in TR is followed. A sensor node in ETR can adopt the shortest possible path by considering the neighbour table and can route a data packet to the sink node by following a sequence of multi-hops. However, it might be possible to forward the data packet to the destination by having only single or a few hops. ETR therefore, do not consider the probabilistic minimum path from source to sink to deliver data. In a dense network the excessive multi-hoping causes early drain of energy of intermediate sensor nodes that lies between sink node and the sensor node.

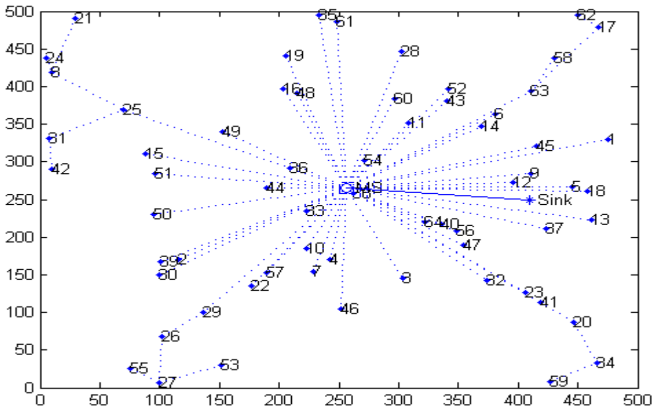

Figure 9. IEECP Topology (65 nodes) with one fixed sink and one mobile sink

The dark blue line in the figure 9, connects the fixed sensor node to the mobile sink station. The mobile sink collects the sensed data from the environment through the sensor in the range using fixed time multiplexing technique and forwards the accumulated data to the fixed sink node. The hop counts as can be seen from the above topologies are found to be reduced significantly if we place mobile sinks near to sensors density. Figure 10 and 11 shows the hop count of TR, ETR and IEECP for 50 and 65 nodes respectively. It is clear from the graphs that as the network density increases, more possibilities for multi-paths and hence, multi-hop routing increases. Therefore, TR become more complex in maintaining parent child links and ETR's computation for shortest path become typical and thus consume more power.

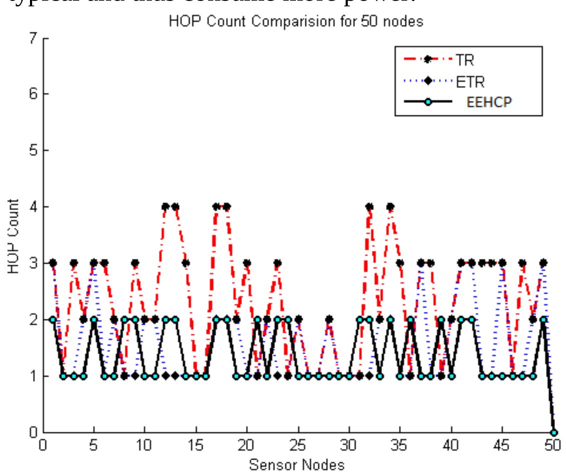

Figure 10. HOP count comparison for the three protocols (50 nodes)

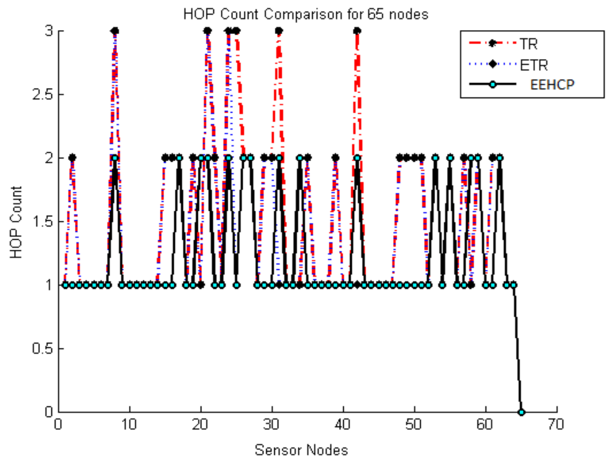

Figure.11.HOP count comparison for the three protocols (65 nodes)

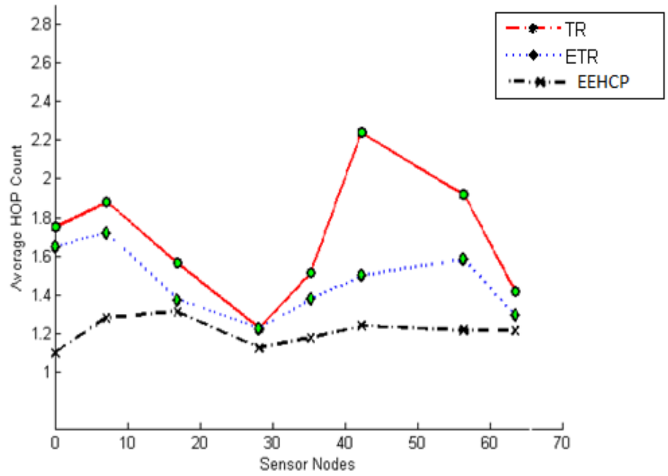

Figure 12. Average HOP counts and Number of sensors

Figure12. depict that IEECP has the lowest hop-count compared to TR and ETR protocol.

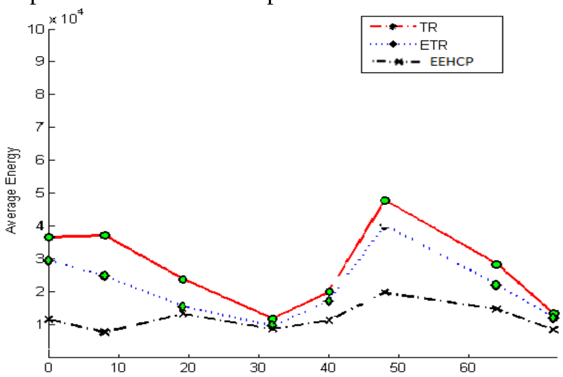

Figure 13. Average Energy consumption

Figure 13. shows that IEECP consumes less power in finding paths and transmitting data to the sink node compare to TR and ETR protocols.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

VI. CONCLUSION & FUTURE SCOPE

This paper aims to develop efficient hop count protocol and addressing scheme to resolve issues relating to excessive multi-hoping from one node to other. The proposed protocol (IEECP) is based on tree topology concept, where the fixed sink is working as root of the tree, moveable sinks are the branches of the tree and sensors are the leaves. By using NOVSF code, fixed sink node can identify its sender information.

IEECP is compared with the Tree Routing and Enhanced Tree Routing. IEECP comparatively consumes less power in finding paths and transmitting data to the sink node. It is evident from the simulation results that the IEECP protocol outperforms than the TR and ETR protocols and helps in reduction of excessive multi-hoping. TR and ETR hop counts show the same results while IEECP has less number of hop-counts. IEECP is found to reduce more energy efficient than TR and ETR protocols.

Sensors in the network are free to send the sensed data to the mobile sinks by using these addresses. Sensors forward sensed data to the nearby mobile sink from which it has taken the address and specifically in the time slot assigned to it. Therefore, transmission energy is saved. Mobility of sink node supports dynamic topologies. Since spreading factor for network is fixed, the count of mobile sink is also restricted.

Wireless sensor networks are small, robust, scalable and cheap networks and are widely used in different areas of interest. Being small and powerful it has variety of rising application areas. Therefore, a continuous effort towards its growth and sustainability is required. Relating to it the future work identified as, finding the long lasting and self-generated power sources to the sensor network, applicability and manageability of the proposed protocol with the new areas, Finding and implementing the data security mechanisms to the sensor network by using proposed protocol.

REFERENCES

1. M. Edal Anand; K. Senthil Kumar; and R. Amutha (2013). Energy efficiency of cooperative communication in wireless sensor networks. International journal of data mining techniques and applications, (2), 300-314.
2. H. F. Chan; and H. Rudolph (2015). New energy efficient routing algorithm for Wireless Sensor Network. *TENCON 2015 IEEE Region 10 Conference*, Macao, 2015, 1-5.
3. Huili Jia; Xunli Fan; Kun Liu; and Yang Qian (2017). An Energy Efficiency Routing Algorithm for Wireless Sensor Network. *2017 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC)*, Guangzhou, 2017, 735-739.
4. H. KIM (2008). Multiple Sink Positioning and Routing to Maximize the Lifetime of Sensor Networks. *IEICE Transactions on Communications*, volume 91(B), 3499-3506.
5. Yu, Jun; Zhang; and Xueying (2015). A Cross-Layer Wireless Sensor Network Energy-Efficient Communication Protocol for Real-Time. *Journal of Sensors*, 2015(5), 1-13.
6. Vijayan, K; and Arun Raaza (2016). A Novel Cluster Arrangement Energy Efficient Routing Protocol for Wireless Sensor Networks. *Indian Journal of Science and Technology*, 9(2), 1-9.
7. Shinji Inoue; Noriyuki Masuda; and Yoshiaki Kakuda (2007). An Autonomous Method for Aggregating and Repairing Paths in Sensor Networks. *Eighth International Symposium on Autonomous Decentralized Systems (ISADS'07)*, Sedona, Arizona, USA, 526-533.
8. Basma M. Mohammad; El-Basioni; Sherine; M. Abd El-kader; and Hussein S. Eissa (2012). Designing a local path repair algorithm for directed diffusion protocol. *Egyptian Informatics Journal*, 13, 155-169.
9. Arain; Qasim Ali; Uqaili; Muhammad Aslam;Deng; and Zhongliang (2017). Clustering Based Energy Efficient and Communication Protocol for Multiple Mix-Zones Over Road Networks. *Wireless Personal Communications*, 95, 411–428.
10. S. C. Ergen; and P. Varaiya (2010). TDMA scheduling algorithms for wireless sensor networks. *Springer Wireless Network*, 16(4), 985–997.
11. Mario Macedo;Antonio Grilo; and Mario Nunes(2009). Distributed Latency-Energy Minimization and interference avoidance in TDMA *Wireless Sensor Networks. Elsevier Journal on Computer Networks*, 53, 569–582.
12. Bashir Yahya; and Jalel Ben-Othman (2009). Towards a classification of energy aware MAC protocol for wireless sensor networks. *Wireless Communication and Mobile Computing*, 9, 1572–1607.
13. Singh S.; and Raghavendra C (1998). PAMAS: power aware multi-access protocol with signaling for ad hoc networks. *SIGCOMM Computer Communications Review*, 28(3), 5–26.
14. Ephremides; and O. Mowafi(1992).Analysis of a hybrid access scheme for buffered user probabilistic time division. *IEEE Transactions on Software Engineering*, 8 (1), 52–61.
15. J. R. Jiang; Y. C. Tsang; C.S. Hsu; and T. H. Lai (2003). Quorum-Based Asynchronous Power-Saving Protocols for IEEE 802.11 Ad-Hoc Networks. *Proceedings of the 2003 IEEE-International Conference on Parallel Processing (ICPP'03)*, 257-264.
16. R. Zheng; J. Hou; and L. Sha (2003). Asynchronous wakeup for ad hoc networks. *Proceedings ACM Mobi Hoc*, USA, 35–45.
17. C. Vigorito;D. Ganesan;and A. Barto (2007).Adaptive Control of Duty-Cycling in Energy-Harvesting Wireless Sensor Networks. *Proceedings of IEEE Conference on Sensor, Mesh, and Ad Hoc Communications and Networks (SECON 2007)*, San Diego, 1-10.
18. M Maroti; B. Kusy;G. Simon; and A. Ledeczi(2004). The flooding time synchronization protocol. *Proceedings of ACM International Conference on Embedded Networked Sensor Systems*, Maryland, USA, 39-49.
19. S. Cui; R. Madan; A. Goldsmith; and S. Lall (2005). Joint routing, Mac, and link layer optimization in sensor networks with energy constraints. *Proceedings of IEEE International Conference on Communications, ICC 2005* Seoul, Korea, 2, 725–729.
20. Kilhung Lee (2008). An Energy-Aware Aggregation Tree Scheme in Sensor Networks. International *Journal of Computer Science and Network Security*, 8 (5), 51-57.
21. Wanzhi Qiu;Efstratios Skafidas; and Peng Hao(2009).Enhance tree routing for wireless sensor networks. *Ad-Hoc Networks, Elsevier*, 7, 638-650.
22. Y. Xu; J. Heidemann; and D. Estrin (2001). Geography-informed energy conservation for ad hoc. *Proceedings of ACM MobiCom*, Rome, 70–84.
23. S. Sharma (2008). Speed Aware Modified Span for Wireless Mobile Ad-hoc Networks. *Proceedings of Third International Conference on Digital Telecommunications IEEE Computer Society*, 53-58.
24. M. Basseville; and I.V. Nikiforov(1993).*Detection of Abrupt Changes: Theory and Application*. Publisher Prentice-Hall.
25. Jain; and J.Y. Chang (2004). Adaptive sampling for sensor networks. *Proceedings of 1st international workshop on Data management for sensor networks (DMSN 2004)*, Toronto, Canada, 10–16.
26. S. Goel, A. Passarella; and T. Imielinski(2006).Using buddies to live longer in a boring world. *Proceedings of IEEE International Workshop on Sensor Networks and Systems for Pervasive Computing (PerSeNS)*, Italy, 67-72.
27. P. Padhy; R. K. Dash; K. Martinez; and N. R. Jennings (2006). A utility-based sensing and communication model for a glacial sensor network. *Proceedings of Fifth International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS '06)*, Hakodate, Japan, 1353-1360.

28. D. Tulone; and S. Madden (2006). An energy-efficient querying framework in sensor networks for detecting node similarities. *Proceedings of 9th International ACM Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWIM06),* 291–300.
29. B. Kanagal; and A. Deshpande (2008). Online filtering, smoothing and probabilistic modeling of streaming data. Proceedings of 24th International Conference on Data Engineering (ICDE 2008), Cancun Mexico, 7–12.
30. N. Kim; S. Choi; and H. Cha (2008). Automated Sensor-specific Power Management for Wireless Sensor Networks. *Proceedings of IEEE Conference on Mobile Ad Hoc and Sensor Systems (MASS 2008),* Atlanta, Georgia, 305-314.
31. C. Alippi; G. Anastasi; C. Galperti;F. Mancini; and M. Roveri(2007). Adaptive Sampling for Energy Conservation in Wireless Sensor Networks for Snow Monitoring Applications. *Proceedings of IEEE MASS 2007,* Pisa, Italy,1-6.
32. R. Willett; A. Martin; and R. Nowak (2004). Back casting: Adaptive Sampling for Sensor Networks. *Proceedings of International Symposium on Information Processing in Sensor Networks (IPSN 2004),* 124-133.
33. I.F. Akyildiz; and I.H. Kasimoglu(2004).Wireless sensor and actor networks: research challenges", *Ad-Hoc Networks*, 2 (4), 351–367.
34. W. Zhao, M. Ammar; and E. Zegura (2004). A message ferrying approach for data delivery in sparse mobile ad hoc networks. *Proceedings of PACM MobiHoc 2004*, Tokyo, Japan, 97-102.
35. R.C. Shah;S. Roy;S. Jain; and W. Brunette(2003).Data MULEs: modeling a three-tier architecture for sparse sensor networks. *Proceedings of IEEE International Workshop on Sensor Network Protocols and Applications*, 30–41.
36. Z. M. Wang; S. Basagni; E. Melachrinoudis; and C. Petrioli(2005). Exploiting sink mobility for maximizing sensor networks lifetime. *Proceedings of 38th Annual Hawaii International Conference on System Sciences (HICSS'05),* Hawaii, 327-332.
37. S.R. Gandham; M. Dawande; R. Prakash; and S. Venkatesan (2003). Energy efficient schemes for wireless sensor networks with multiple mobile base stations. *Proceedings of IEEE Globecom 2003*, San Francisco, 377–381.
38. S. Basagni; A. Carosi; E. Melachrinoudis; C. Petrioli; and Z.M. Wang (2007). Controlled sink mobility for prolonging wireless sensor networks lifetime. *ACM Journal on Wireless Networks*, 112-117.
39. K. Akkaya; and M. Younis (2004). Energy-aware to mobile gateway in wireless sensor networks", *Proceedings of IEEE Globecom 2004 Workshops*, USA, 16–21.
40. H. Luo;F. Ye; J. Cheng; S. Lu; and L. Zhang(2005).TTDD: two-tier data dissemination in large-scale wireless sensor networks. *ACM Wireless Networks,* 11 (1–2), 161–175.
41. K Senthil Kumar; and R Amutha (2016). An Algorithm for Energy Efficient Cooperative Communication in Wireless Sensor Networks., *KSII Transactions on Internet and Information Systems*, 10(7), 3080-3099.
42. Kiran Vadde; and Hasan Cam (2004). A Code Assignment Algorithm for Non-blocking OVSF Codes in WCDMA. *Telecommunication Systems,* 25(3-4), 417–431.
43. Giuseppe Anastasi; Marco Conti; Mario Di Francesco; and Andrea Passarella (2009). Energy conservation in wireless sensor networks: A survey. *Ad Hoc Networks*,7(3) ,537-568

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication