Performance analysis of Zigbee WDSN using clustering protocol and STR algorithm

R.Maria Brigitta
Department of Electronics Engineering
School of Engineering and Technology
Pondicherry University
Puducherry-605 014, India
mbrigitta07@gmail.com

P.Samundiswary
Department of Electronics Engineering
School of Engineering and Technology
Pondicherry University
Puducherry-605 014, India
samundiswary_pdy@yahoo.com

***Abstract* — In recent years, wireless networking plays a prominent role because of its easy installation and flexibility. Among the various wireless domains, Zigbee based Wireless Dynamic Sensor Networks (WDSN) pose a good support to the dynamics that arise when the nodes are induced with mobility. In the Zigbee based Wireless Dynamic Sensor Network (WDSN), major consideration is on utilizing the energy efficiently among the mobile nodes. Various techniques are used to attain energy efficiency in Zigbee WDSN. Among them, clustering the nodes is one of the best methods, since they aim at reducing the energy dissipation and increasing the life span of the network. Hence, in this paper, the performance of Zigbee WDSN using clustering scheme is done by considering the nodes with mobility and compared with performance of Zigbee WDSN using non clustering technique. The proposed work is summarized as follows: the network is deployed as clusters and the remaining energy of the node is determined by utilizing clustering protocol. In each cluster, the clustering protocol opts for the node with the maximum remaining energy as the head of that cluster. Then STR algorithm is utilized to route the sensed data from the member nodes to the cluster head. Hence, the clustering technique and STR, route the information through the shortest path paving the way for enhanced average residual energy and Packet Delivery Ratio (PDR). The simulations are done by using ns2 and performance metrics such as average residual energy and PDR are computed and analyzed for non clustered and clustered method.**

Keywords—Zigbee; WDSN; clustering; residual energy; STR.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) are utilized for different applications such as remote environment monitoring, military, surveillance etc [1-4] in order to sense physical parameters such as temperature, pressure, humidity etc. Wireless Sensor Network can be defined as a network with massive number of tiny, less expensive sensor devices that have the capability to detect; measure and interact with other devices in order to collect local information and to make an overall decision about the physical ambience. The sensor network consists of sensor field, sensor nodes, sink and task manager as illustrated in fig 1.

Sensor field is the field wherein the sensor nodes are positioned. The sensor nodes are the essential components in the sensor network. These are responsible for gathering the data and then forwarding the same to the sink. Sink is the point of data gathering and its task is to receive; process and store the data from other sensor nodes.

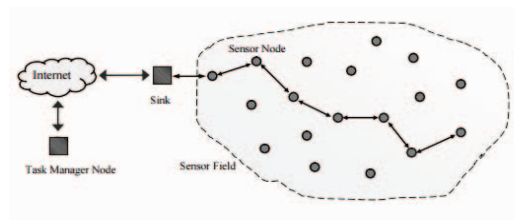


Fig. 1. Components of Sensor Network

The centralized control point within the network is the task manager whose purpose is to draw the information from the network and distribute control information back into the network.

A small variant of WSN is WDSN wherein the nodes are mobile in nature. Since the nodes are dynamic; various features such as network formation, capability to organize and reorganize, discerning the route and handling the communication among the mobile nodes have to be considered. These features are supported by Zigbee based WDSN [5]. IEEE 802.15.4 is the IEEE standard that defines the physical layer and MAC layer for Low-Rate Wireless Personal Area Networks (LR-WPANs). LR-WPANs are otherwise known as Zigbee networks. Zigbee technology is very widely used as they are easy to install, reliable, self configurable and self healable networks. Zigbee protocol defines the upper layers for the IEEE 802.15.4 standard as illustrated in fig 2.

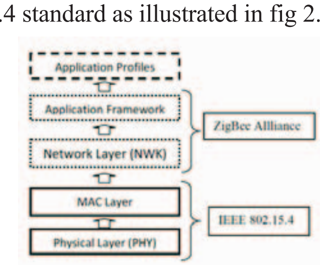


Fig. 2. Zigbee protocol stack

The network layer defined by Zigbee supports multiple hop transmissions-receptions and also routing between the mobile sensor nodes. Zigbee based WDSN have the following benefits:

- Zigbee protocol cuts down the energy drawn by the nodes, as they make the nodes to enter into a sleep state when the sensor nodes do not transmit or receive/remain idle for a prolonged time.
- The nodes in WDSN require constant restructuring and reformation of routes and topology. Zigbee protocol has inherent functionalities for discerning the network and for routing the information among the nodes.

In the Zigbee based WDSN, the sensor nodes are mobile and the energy consumed by the mobile nodes varies with the distance. The Received Signal Strength Indicator (RSSI) algorithm is used to calculate the distance from the strength of the received signal. The RSSI is best suited for communication through wireless media. In the RSSI algorithm, the strength of the received signal is inversely proportional to the squared distance between the transmitter and the receiver. Hence it can be used for measuring the wireless link quality. The RSSI can be effectively used to identify the packet reception rate in the wireless network. In order to analyze the packet reception rate using RSSI, a threshold level is maintained. If the calculated received signal strength value overlaps with the threshold region, then the number of packets received successfully will be less. On the other hand, if the calculated received signal strength value does not overlap with the threshold region, then the number of packets received successfully will be high indicating a better network performance.

WSNs pose several advantages but they do suffer from few limitations [6-11] and also few authors have proposed several protocols for existing WSN networks [12]. Hence in this paper an effort is made to tackle a limitation which is of major consideration in WDSN (i.e) energy consumption. This paper utilizes a technique which could effectively cut down the energy drawn by the nodes and also enhances the Packet Delivery Ratio (PDR). The rest of the paper is summarized as follows: Section II discusses the existing work. Section III presents a detailed description of proposed work. Section IV analyzes the performance of proposed work through simulation results. Finally, Section V concludes the paper.

II. Existing Work

The existing work considers Zigbee based WDSN with non clustered technique. For routing the packets among the nodes in Zigbee wireless network, various routing schemes such as ZTR (Zigbee Tree Routing) and STR (Shortcut Tree Routing) have been proposed. ZTR is proposed for Zigbee devices that are limited in their resources. It routes the packets on a multi hop routing path from source to the destination. ZTR suffers from a serious limitation. That is, even when the destination node is at one hop distance, the packets will be routed to destination only on a parent child relationship. To overcome the limitation of ZTR, STR protocol is proposed. The merits of ZTR are retained in STR but it identifies the neighbor node as its next destination node by discovering the nodes that are at 1-Hop distance.

The existing work utilizes Shortcut Tree Routing (STR) algorithm [13] to route packet among the nodes. STR algorithm intends to reduce the cost incurred for routing while routing the packets between the source and the destination. The STR algorithm is utilized to identify the optimal next hop node that has the least remaining hop counts to the destination. The key features of STR include; low memory consumption and no route discovery overhead.

In the existing work, total number of mobile sensor nodes considered for simulation is 125 and they are deployed randomly. Each node has an initial energy of 5J. The existing work performance is analyzed through metrics such as average residual energy and PDR by differing the number of nodes from 25 to 125 and range from 45m to 125m.

III. Proposed Work

The proposed work aims at enhancing the performance of existing work by introducing the clustering technique. Among the various protocols proposed for WSNs, hierarchical protocols [14] outperform other protocols since they augment the network lifetime, reduce the energy dissipated by the sensor nodes and cut down the number of communication messages among the sensor nodes. Hierarchical protocols are cluster based protocols (i.e) the sensor nodes in the network are grouped into clusters. Low Energy Adaptive Clustering Hierarchy protocol (LEACH) [15] is an example of hierarchical protocol. It effectively cuts down the energy consumed by the nodes in the network. In the LEACH protocol, the node with least energy consumption is made to be the cluster head of that particular cluster.

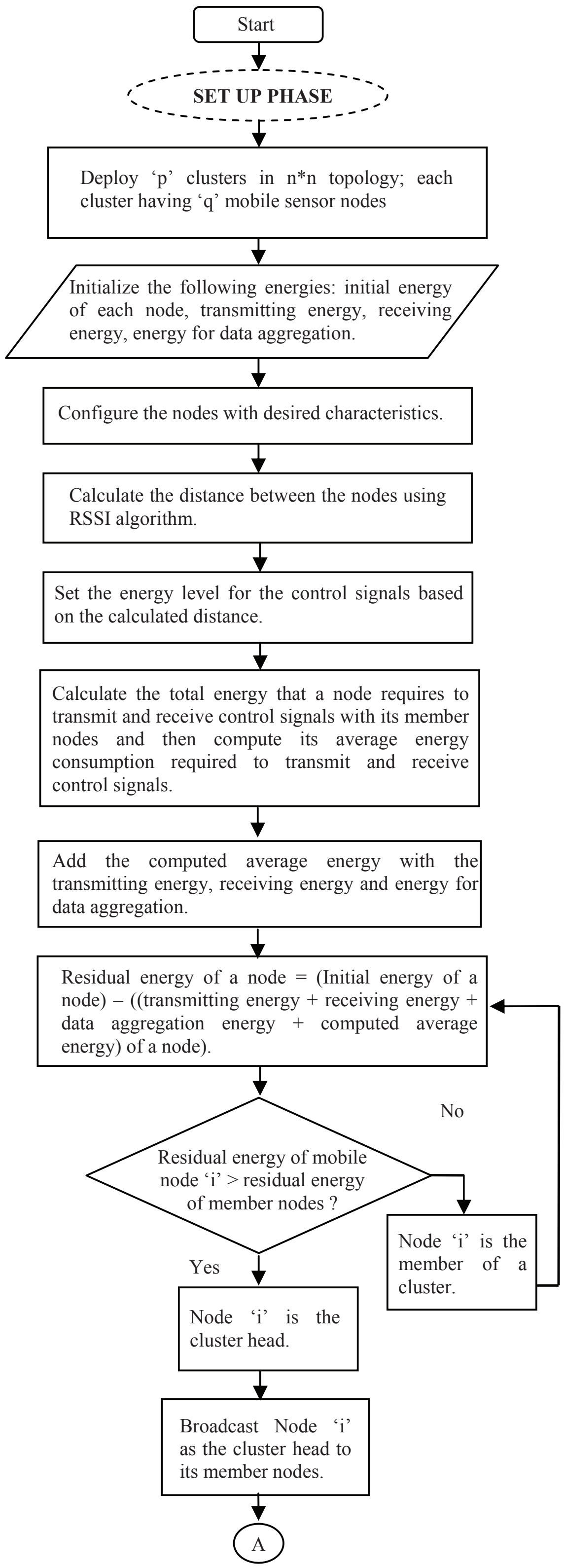
Among various LEACH protocols such as Centralized-LEACH, Modified LEACH, Multi hop LEACH, Two level LEACH, Vice LEACH etc, Optimization Low Energy Adaptive Clustering Hierarchy (O-LEACH) [16] finds an alternate way to cut down the energy required by the sensor nodes for establishing communication. In the O-LEACH, the sensor node with the highest residual energy is chosen as the cluster head of that particular cluster.

In the proposed work, the O-LEACH protocol is modified and utilized. The proposed work is carved up into two phases, namely the set up phase and the steady state phase. During the set up phase, the nodes are grouped into clusters and the cluster head is chosen by computing the residual energy of the nodes. Next, during the steady state phase, the information from the member nodes is passed on to the cluster head by utilizing STR algorithm. Since the shortest path is chosen for routing the

978-1-5090-3716-2/17/$31.00 ©2017 IEEE

packets between the member nodes and the cluster head, the energy is utilized efficiently.

The algorithm implemented in the proposed work is envisaged in the form of flowchart shown in fig 3.



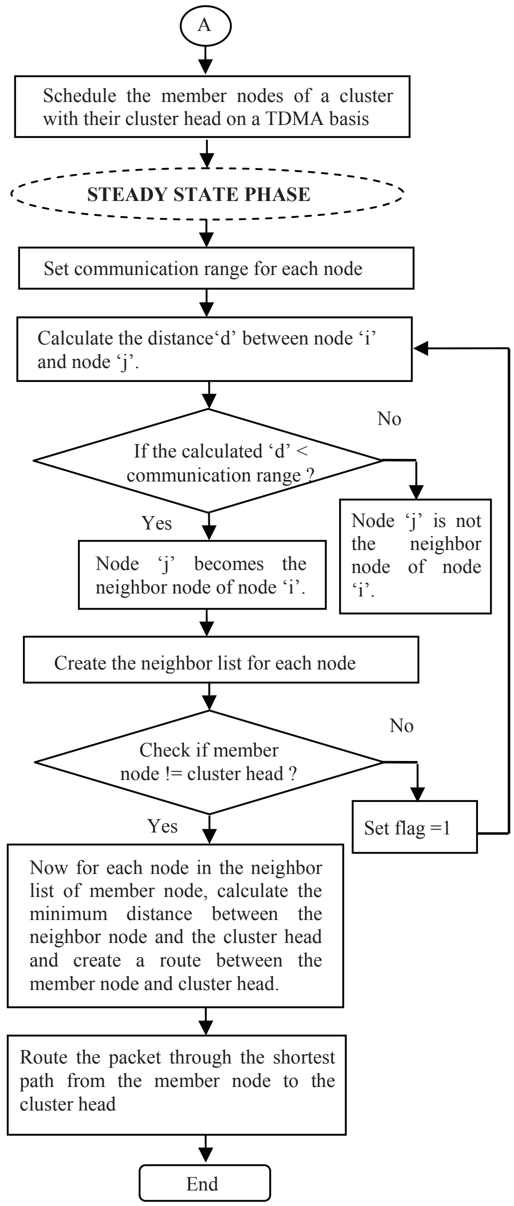


Fig 3. Flowchart to describe the set up phase and steady state phase of proposed work.

IV. SIMULATION AND RESULTS

The proposed work is developed and analyzed through simulations. The simulations are done using ns2 and the performance metrics such as average residual energy and PDR are evaluated and analyzed.

In the simulation, average residual energy and PDR are computed and analyzed for different values of nodes from 25 to125 and range from 45m to125m. The parameters used for simulation are tabulated in Table I.

TABLE I. SIMULATION PARAMETERS

Sl. No.	Parameter	Value
1	Number of nodes	25,50,75,100,125
2	Number of clusters	1,2,3,4,5
3	Number of nodes in each cluster	25
4	Topology	1600*1600 (m^2)
5	Initial Energy of a node	5 J
6	Transmission range	45m to 125m
7	Speed of the node	2m/s
8	Mobility Model	Column mobility
9	Simulation time	60s
10	Energy for transmission	0.7 J
11	Energy for reception	0.9 J
12	Energy for data aggregation	5 nJ/bit/signal
13	MAC protocol	IEEE 802.15.4

In the simulation scenario, the mobile sensor nodes are deployed in 1600 x 1600 m^2 region. The scenario without clusters and with clusters is depicted in fig 4 and fig 5 accordingly.

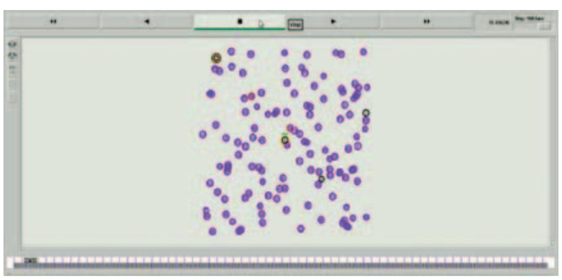


Fig. 4. NAM output of Zigbee based WDSN with 125 mobile nodes (non clustered network).

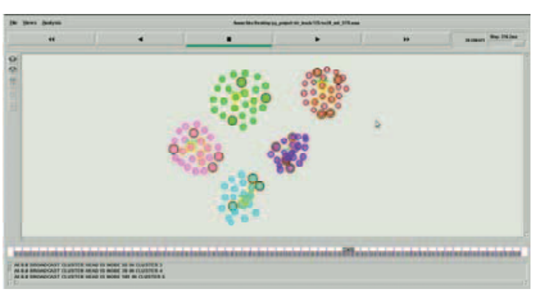


Fig. 5. NAM output of Zigbee based WDSN with 125 mobile nodes (clustered network).

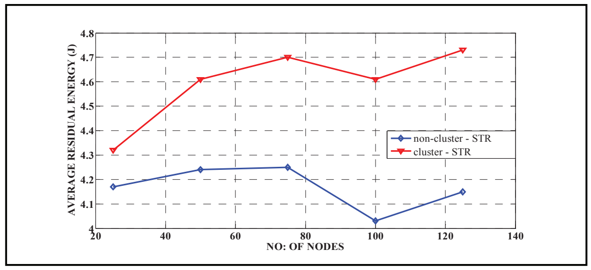


Fig. 6. Number of nodes vs Average Residual Energy (J).

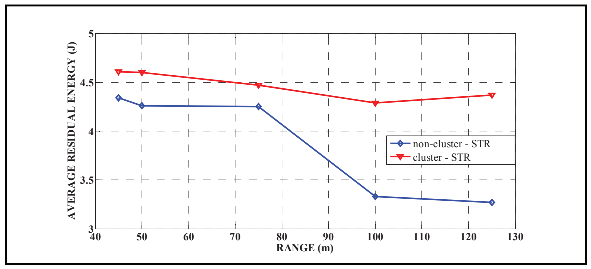


Fig. 7. Range (m) vs Average Residual Energy (J).

The variation of average residual energy (J) with respect to the number of nodes from 25 to 125 and range from 45m to 125m is depicted in fig 6 and fig 7 respectively. From Fig 6, it is noted that the average residual energy for the network using clustering technique and STR algorithm is higher than that of the network without using clustering technique and STR. In the network without using clustering technique and STR, as the number of nodes is increased from 25 to 125, the packets tend to be routed through the longest optimized path from the source node to the sink using STR. Thus the energy consumed by the nodes increases leading to a decrease in the average residual energy. But in the network using clustering technique and STR, the transmit distance of nodes is reduced. So, when the number of nodes increases, the cluster heads pull together the data from the member nodes and pass it on to the sink. Hence, the energy drawn by the nodes is reduced and average residual energy is increased. Also from Fig 7, it is observed that average residual energy decreases as the range increases in case of network using non cluster technique as well as with network using clustering technique. The reason behind the decrease in average residual energy is that, as the range increases, the nodes tend to be scattered, leading to decrease in the average residual energy.

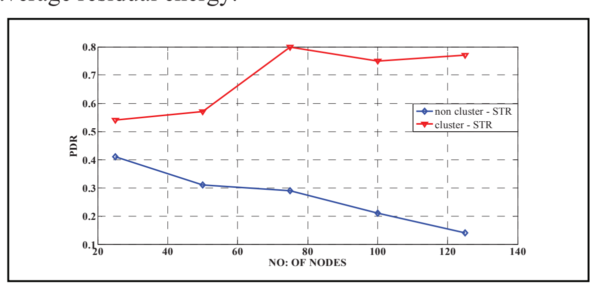


Fig. 8. Number of nodes vs PDR.

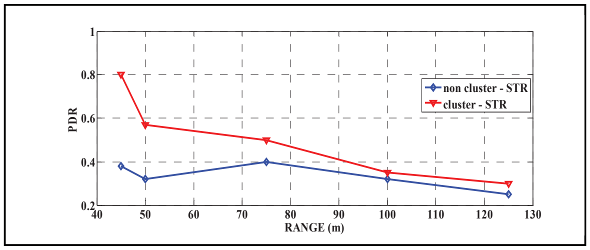


Fig. 9. Range (m) vs PDR.

The variation of PDR in accordance with the number of nodes from 25 to 125 and range from 45m to 125m is illustrated in fig 8 and fig 9 respectively. From Fig 8, it is portrayed that as the number of nodes increases, the PDR decreases in case of non-cluster and STR technique whereas the PDR increases in case of cluster and STR technique. In the non-cluster and STR technique, the nodes are deployed randomly and mobile in their nature. Thus when the number of nodes increases, the packets tend to traverse through a longer route to reach the sink. So there is a lesser probability to receive the packet successfully leading to a steady reduction in the PDR. But in case of cluster and STR technique, even when the number of nodes increases, the nodes are organized as clusters having small transmitted distances and the information is passed to the sink through the cluster head. Thus, by using the clustering technique the longest route taken by the packet from the member node to reach the sink is mitigated, which in turn enhances the PDR. From Fig 9, it is illustrated that as the range increases the PDR decreases in both cases. This is because as the range increases, the nodes are liable to be more dispersed; leading to a decrease in the PDR. Here also cluster-STR technique outperforms non-cluster and STR technique because the cluster head effectively aggregates the sensed data from the member nodes and passes it to the sink.

Thus the simulation results depict that the proposed technique surpasses the existing technique by enhancing the average residual energy and PDR.

V. Conclusion

In this paper, the performance of Zigbee based WDSN is analyzed using a clustering technique and its performance are compared with the existing technique. The simulation results portray that the proposed technique performs better than the existing technique by optimizing the performance metrics such as average residual energy and PDR.

References

[1] Akyildiz, I. F., Su, W., Sankarasubramaniam, Y., &Cayirci, E. "A survey on sensor networks". *IEEE Communications Magazine,* vol. 40, no.8, pp.102–114, 2002.

[2] Sheng, Z., Yang, S., Yu, Y., Vasilakos, A., Mccann, J., & Leung, K. "A survey on the IETF protocol suite for the internet of things: Standards, challenges, and opportunities". *IEEE Wireless Communications,* vol .20, no.6, pp. 91–98, 2013.

[3] Sarika Yadav, & Rama Shankar Yadav, "A review on energy efficient protocols in wireless sensor networks", *Wireless Networks,* vol.22, pp.335-350, 2016.

[4] Shen, C. C., Srisathapornphat, C., & Jaikaeo, C. "Sensor information networking architecture and applications". *IEEE Personal communications*, vol.8, no.4, pp.52–59, 2001.

[5] Thiago de Almeida Oliveira and Eduardo Paciencia Godoy, "Zigbee Wireless Dynamic Sensor Networks: Feasibility Analysis and Implementation Guide", *IEEE Sensors Journal*, vol. 16, no.11, June 2016.

[6] Wei, G., Ling, Y., Guo, B., Xiao, B., & Vasilakos, A. V. " Prediction-based data aggregation in wireless sensor networks: Combining grey model and Kalman filter". *Computer Communications,* vol. 34, no.6, pp.793–802, 2011.

[7] He, D., Chen, C., Chan, S., Bu, J., & Vasilakos, A. V. " Retrust: Attack-resistant and lightweight trust management for medical sensor networks". *IEEE Transactions on Information Technology in Biomedicine,* vol.16, no.4, pp.623–632, 2012.

[8] Song, Y., Liu, L., Ma, H., & Vasilakos, A. V. "A biologybased algorithm to minimal exposure problem of wireless sensor networks". *IEEE Transactions on Network and Service Management,* vol.11, no.3, 417–430, 2014.

[9] Liu, L., Song, Y., Zhang, H., Ma, H., & Vasilakos, A. "Physarum optimization: A biology-inspired algorithm for the steiner tree problem in networks". *IEEE Transactions on Computers,* vol. 64, no.3, pp.819–832, 2013.

[10] Sengupta, S., Das, S., Nasir, M., Vasilakos, A. V., & Pedrycz, W. "An evolutionary multiobjective sleep-scheduling scheme for differentiated coverage in wireless sensor networks". *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews,* vol.42, no.6, pp. 1093–1102, 2012.

[11] Xiong, N., Cao, M., Vasilakos, A. V., Yang, L. T., & Yang, F. "An energy-efficient scheme in next-generation sensor networks". *International Journal of Communication Systems,* vol.23, no. 9–10, pp.1189–1200, 2010.

[12] N. Vlajic, D. Stevanoic, and G. Spanogiannopoulos, "Strategies for improving performance of IEEE 802.15.4/Zigbee WSN's with path-constrained mobile sink(s)," *Computer Communication*., vol. 34, no. 6, pp.743-757, May 2011.

[13] Taehong Kim, Seong Hoon Kim, Jinyoung Yang, Seong-eun Yoo, Daeyoung Kim, "Neighbor Table Based Shortcut Tree Routing In Zigbee Wireless Networks", *IEEE Transactions On Parallel And Distributed Systems*, Vol. 25, No. 3, March 2014.

[14] Vishal Kumar Arora, Vishal Sharma, Monika Sachdeva, "A survey on LEACH and other's routing protocols in wireless sensor network", *Optik* vol.127, pp.6590–6600, 2016 .

[15] Payal Khurana Batra, Krishna Kant, " LEACH-MAC: a new cluster head selection algorithm for Wireless Sensor Networks", *Wireless Networks, vol.*22, pp.49-60, 2016.

[16] Salim EL KHEDIRI, Nejah NASRI, Anne WEI, Abdennaceur KACHOURI, "A new Approach for Clustering in Wireless Sensor Networks Based on LEACH", Procedia Computer Science, vol.32, pp.1180-1185, 2014.