# Clustering Approach to Minimize the Consumed Energy in WSNs

# النظرية العنقودية لتقليل استهلاك الطاقة في شبكات الاستشعار اللاسلكية

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## Abstract

Saving energy or energy consumption represents the essential problem in the process of designing, deploying and operating any "wireless sensor networks" (WSN). Most of the available produced sensors depend on a "limited power supply" battery in all their operations. Most of the sensors can perform the process of sensing, "data processing" and "wireless communication". Sensors can achieve various duties in WSNs according to their wanted applications.

In most applications sensors are ordered into sets called clusters according to the network objective and its requirements. Clustering achieved many advantages, so it represents the first preferable approach in designing or improving any WSN. Each cluster includes one leader sensor node known as a "cluster head" (CH) and the other sensors known as member nodes. In most applications the sensor node with higher energy is preferred to be a CH to perform the process of data transmission and data processing while those with low energy are preferred to achieve the sensing task as cluster members. Simulation being the unique tool in evaluating and estimating the performance metrics of any new designed WSN.

In this study, a main effort is made to study the effect of clustering approaches on the WSNs consumed energy. Many clustering approaches is simulated and evaluated with a developed suggested clustering approach. Three approaches were suggested, built and simulated to estimate the WSNs lifetime with their important behaviors parameters. Net Logo (5.2.1) as "multi-agent programming language" is suggested to be the simulation tool in this study.

**Keywords:** WSN, Clustering, energy consumption, simulation.

**الخلاصة**

توفير الطاقة او استهلاكها هي المشكلة الاساسية في عملية تصميم ونشر شبكات الاستشعار اللاسلكي (WSN) ،فمعظم اجهزة الاستشعار المتاحة تعتمد على بطارية ذات قدرة محددة لتزويدها بالطاقة في كافة عملياتها. يمكن لجميع اجهزة الاستشعار اداء عملية معالجة البيانات، والاستشعارعن بعد و تناقل البيانات . كما ان اجهزة الاستشعار تؤدي واجبات مختلفة في شبكات الاستشعار اللاسلكي وفقاً للحاجة ونوع الشبكة. في معظم تطبيقات اجهزة الاستشعار اللاسلكية يتم ترتيبها على شكل مجموعات او عناقيد وفقاً لهدف الشبكة ومتطلباتها. حققت عملية العنقدة العديد من المزايا ولذلك اصبحت تمثل النهج والخيار الاول عند تصميم او تحسين شبكات الاستشعار اللاسلكي. كل مجموعة (عنقود) تحتوي على عقدة استشعار تسمى العقدة الرئيسية (رئيس المجموعة) والعقد الاخرى في المجموعة تسمى العقد الاعضاء. في معظم التطبيقات يفضل استخدام عقد الاستشعار ذات الطاقة العالية لتنفيذ عملية نقل ومعالجة البيانات في حين يفضل استخدام عقد الاستشعار ذات الطاقة المنخفضة لتحقيق مهمة الاستشعار وتعمل كاحد اعضاء المجموعة. المحاكاة هي الاداة الفريدة التي يمكن استخدامها في تقييم وتقدير مقاييس اداء وسلوك اي تصميم جديد لشبكات الاستشعار اللاسلكي. تناولت هذه الدراسة مناقشة تأثير اسلوب العنقدة على الطاقة المستهلكة في شبكات الاستشعار اللاسلكي. تمت محاكاة وتقييم العديد من اساليب العنقدة المتوفرة مع تطوير اسلوب عنقدة مقترح. تم اقتراح وبناء ومحاكاة ثلاثة اساليب لتقدير اعمار شبكات الاستشعار اللاسلكي مع جميع معلمات سلوكياتها. تم استخدام برنامج ال (Net Logo 5.2.1 ) كلغة برمجة" multi-agent " ليكون اداة المحاكاة في هذه الدراسة.

## 1. Introduction

A "Wireless Sensor Network" (WSN) represents a self- organized set of sensors deployed in a certain area to achieve certain task through radio communication links. Each sensor node can perform the process of sensing, data processing and exchanging information with others [1].

Each sensor node was mainly structured to contain a data processing unit, sensing unit, radio transmission unit and limited power battery. One of the main problems in WSN is the sensors lifetime due to its limited power battery. Any developed techniques in soft or hardware that helps in prolong the sensor lifetime is so vital and required [2].

Clustering approach is the process of arranging the network sensor nodes into non overlapping disjoint sets identified as clusters. Each cluster must assign one of its active members to be a Cluster Head (CH). There are many developed algorithms to create the clusters and to assign their CHs in WSNs. Member nodes in each cluster can only communicate through their CHs. Clustering process must be well selected to reduce the network communication energy. Sensors in WSN can communicate among each other or with a Base Station (BS). The main function of the CH is to gather and process the sensed data from all its cluster members and transmit it to the neighboring CH or to the BS [3].

All the developed clustering algorithms were aimed to minimize the energy consumed in order to increase the WSN lifetime. Energy consumption in WSNs relies heavily on the communication cost which is due to receiving, sending and data processing [4].

In WSNs clustering process improves the network scalability, improves the network "topology stability", saving energy, reduces the "communication overheads" and improves the network capacity. Transmitting data inside the cluster (among members and / or CH) is called "intra-cluster communication" while the process of transmitting data between CHs or from CHs to the BS is called "inter-cluster communication" [5].

## 2. Related works

Chunyao, et al., at 2013 suggested an improved version of the "LEACH Protocol" called "LEACH-TLCH". They used the same method in selecting the "cluster-head". If the current energy of the Cluster Head (CH) is being either lower than the average energy or its distance to the base station is greater than the average distance then this CH will be replaced by a sensor with maximum energy in a cluster. The CH must able to receive, fuse data and transmitting the collected data to the base station [6].

Praveen Dodwadmath and Aijazahamed Qazi at 2015 proposed a "cluster based mass-center" algorithm depend on rounds. Their algorithm was separated into two phases. They selected the cluster-head (CH) and the clusters structures in the first phase, while in the second phase; they dealt with the process of transferring among nodes. Their cluster based approach was used to minimize the energy consumption in WSN. The CH was selected based on the energy and the mass-center of the sensors. They found low consumption in nodes energy and significant increase in the network lifetime [7].

An improvement on the "LEACH protocol" was proposed by Thesiya Khushbu and Viraj Daxini at 2015 to reduce the nodes consumed energy. They suggested a cluster head selection approach based on certain threshold and the remaining energy on the sensor nodes. Their Simulation results present an improved in nodes working compared with the existing "LEACH protocol". The proposed approach was aimed to decrease the dissipated energy by changing the Cluster Head [8].

## 3. Clustering Process

The main objective of clustering is to form unordered objects in sets. Clustering always aims to separate the sensor nodes into various sets according to specific rules. It represents a process of collecting the sensor nodes into sets depending on specific shared parameters. Each set is called a cluster. One of its nodes must be selected to be the group leader or a cluster head (CH). The essential Parameters used in creating the clusters are the distance between sensor nodes, energy of sensor nodes, Base station location and other communication costs. All cluster members must exchange information through their CH only. Each CH must collect information about all members in its cluster and vice versa in order to form and keep appropriate processing management. LBF ("Load Balancing Factor"**)** can be used as an evaluation measure to the "well balancing" of the network CHs [4].

Each sensor node can be assigned as a cluster member or a cluster head. Clustering processes in WSNs can be gathered into distributed, centralized and hybrid depending on the control manners of clustering. In WSNs the clustering methods can be constant or variable convergence time. Clustering formation types in WSNs were also classified into iterative or probabilistic. Selecting the Cluster Head (CH) can be performed in adaptive, deterministic or random manner [9].

### 3.1 Clustering benefits

Clustering approaches have many additional advantages that improve the WSNs behaviors. The most important objectives and advantages of clustering are: Extra Scalability, reduction in energy consumption, improve the network Robustness, avoids Collision, minimizing Latency, Reliable Connectivity, prolong the network lifetime and improving its Quality of Service (QoS) [9].

### 3.2 Clustering Features

Clustering algorithms in WSNs depends on many features and factors. Some of these features are: the Clusters Number, Intra-cluster communication, inter-cluster communication, Cluster formation methodology, Cluster-head selection, Variability of Cluster (variable or fixed size) and Cluster Sizes [1].

## 4. LEACH protocol

"Low-Energy Adaptive Clustering Hierarchy protocol" denoted by (LEACH) represents a good approach in clustering routing protocols for WSNs. It randomly alternates the cluster heads in order to make certain energy load balancing. Its main objective is to assign CHs among sensors. LEACH operates in either a "steady-state" (SS) phase or a "setup" phase. Each Sensor node in a setup may be chosen in a random manner to be a CH or not. SS ensures delivering the collected data to the BS. This stage must be longer than the other stages to reduce the energy waste. LEACH aims to reduce the amount of the sent information by each node to reduce the energy consumption [6].

Randomness plays the main role in forming clusters in LEACH. The responsibility of any CH is to collect and fuse the data from its own entire cluster and then transmit it to the BS. The consumed energy by the process of transmission is greater than that consumed in the collection and fusion process. The CH will be died either when its current energy is being very low or the distance to the BS is too far [10].

In applying LEACH protocol the network creates many clusters and assigning a cluster head for each cluster. The main occupation of a CH is to gather data from its cluster member and transfer this data through other neighbor CHs or to the base station directly. Current WSNs were extended

to contain large number of sensor nodes deployed in large areas. Such number of nodes will form large number of clusters, so several of these CHs will being out of the BS coverage area (far) and can't be able to communicate directly with it. This represents one of the LEACH restrictions [11].

## 5. BREERA Algorithm

A new clustering algorithm entitled "Biased Random Energy Efficient (BREERA)" was firstly suggested by Mohamed, et al., at 2011. Their approach was based on the random walk algorithms. Improving the network energy consumption and its latency represented the main aim of their development study. BREERA improved the "Directed Rumor Routing" approach by eliminating the need for the "Hello" messages. It does not need any information about the sensor's global location. BREERA achieved an integral "load balancing property" among most of the available routing protocols. Its successful probability of transmitting messages from the source to the sink can be statistically analyzed depending on the random walk approach. Their results proved that this protocol is efficient in nodes energy consumptions. BREERA utilized the fundamentals of probability to offer an ability to each sent node to estimate its neighbor (within its transmission range) nodes energy values. This process will let the sent node avoid the unexpected failures by send its message to the neighbor in range node with the maximum energy [11].

## 6. Simulation setting

A suggested environment was designed and created using Net Logo (5.2.1) to perform the suggested simulation scenarios. This environment was built, simulated to be used in evaluating the WSN performance and observing its energy behaviour. Suggested transmission rate of 4 packets/second and 512 bytes for the message size were applied with a Random way point model as a mobility model in this environment. Three approaches were suggested, built and simulated to estimate the WSNs lifetime and their related behaviors.

In the first part of the first approach of this suggested environment, the effects of varying the node numbers (density) on the WSN performance was tested and evaluated while the second part tests and evaluates the effects of varying the sensor nodes speed. A suggested environment was created using Net Logo to simulate and test the mutual effects among its variables and parameters. Number of sensor nodes were randomly deployed and then clustered according to their locations and their transmission range. A cluster head for each cluster was also assigned randomly in the initial step. A base station was also located randomly in each run. This environment has an ability to communicate and transmit messages between cluster heads to the base station. Figure (1) shows a program screen snapshot for the Clustering process, Cluster heads and messages processing.

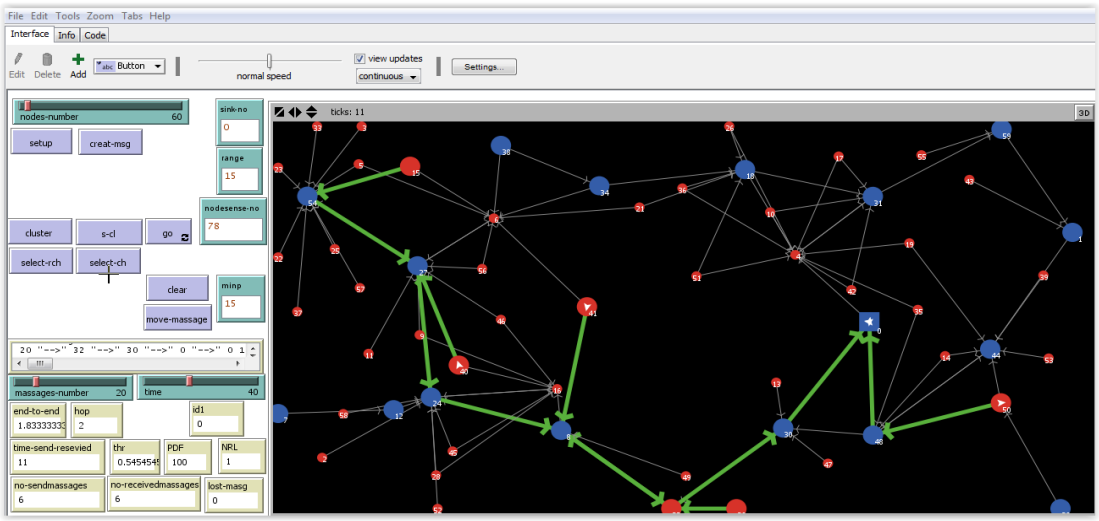


Figure (1): Clustering and messages processing between cluster heads.

Different number of sensor nodes (20, 40, 60, 80,100, 200,300 and 400) was used to test and evaluate the lifetime of this network by evaluating its Throughput, PDF, LBF and number of dead nodes. Nodes speed was suggested to be 0.5 m/sec and a simulation run time to be 40 sec. network area was suggested to be 100 x 100 $m^2$. In each run the simulation program was repeated 20 times for each number of nodes to reach close real results. The results were averaged to each deployed number of nodes in each run. Figure (2) summaries the average simulation trails results for each number of nodes.

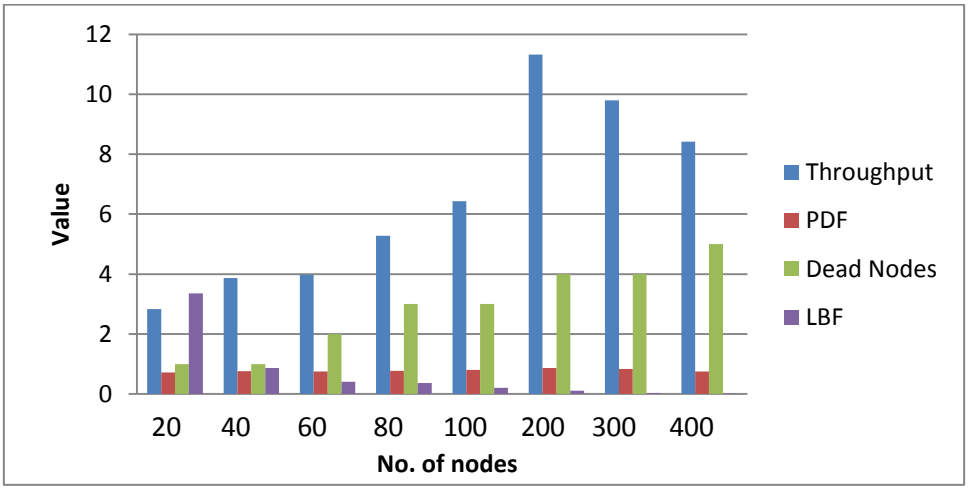


Figure (2): average simulation results for the variable number of nodes.

These results show that the best mount of the received data by the destination nodes was happened with the case of using 200 nodes. The throughput values are alternates due to node's movement, traffic overheads and link failures. The ratio of the received packets to the sent packets (PDF) was showed to be ranged in certain level and it is related to the throughput values. The number of the dead nodes was shown to be directly proportional to network size. Cluster heads were evaluated using the LBF values, which indicated a well balanced (highest one) with 20 nodes. The network energy consumption was increased with increasing its number of sensor nodes.

The second approach of the suggested environment in this study was utilized to estimate the effects of varying the nodes speed. A suggested 300 homogenous sensor nodes were distributed

randomly in a 100 x 100 $m^2$ area. The node speed was tested in three distinct cases: 0.5, 2 and random uniformly distributed with range of (0.5 - 2) m/sec and leaving the other network parameters without change. The developed algorithm makes the nodes clustering and assigns their cluster heads. The communication process between CHs was verified and observed visually to be valid. Figure (3) shows a developed simulation program snapshot.

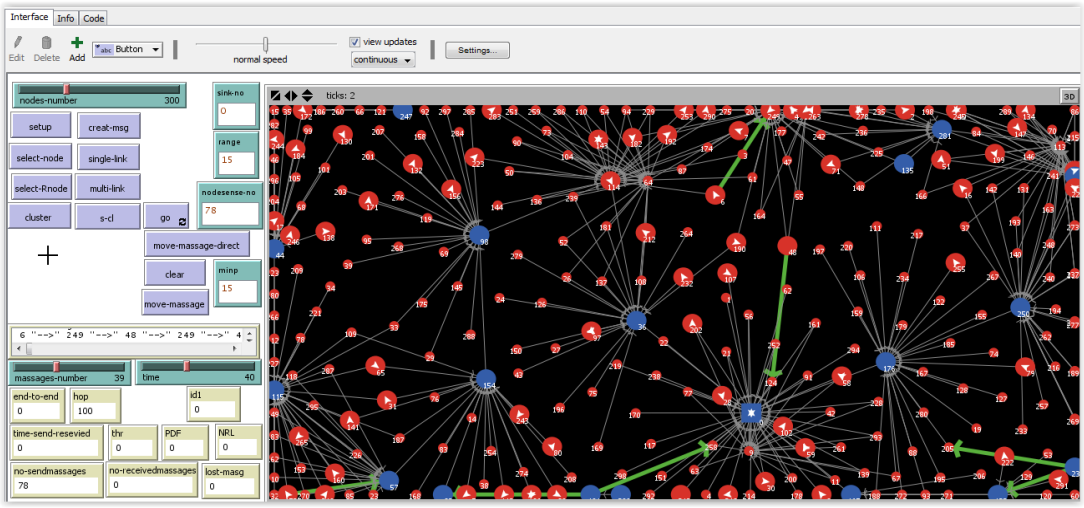


Figure (3): a second part simulation program snapshot.

The final average results showed an energy consumption of about 16235 energy units with 0.5 m/sec node's speed, 19706 energy unit with 2 m/sec node's speed and 15454 energy units with random node's speed. There is a clear effect of the clustering process and nodes speed on nodes energy consumption due to link failures and traffics.

The third approach of the suggested environment in this study was aimed toward the developing the clustering process. Most of the previous literatures indicated that clustering approach plays an important role in saving WSNs energy. Cluster head represents the guidance and the cluster controller among other cluster members in all the network activities. This approach focused on the possible suggested procedures in assigning and changing the CHs. A suggested developed Clustering approach can be proposed and implemented for the deployed WSNs initially. Figure (4) shows the main steps to perform the proposed clustering approach.

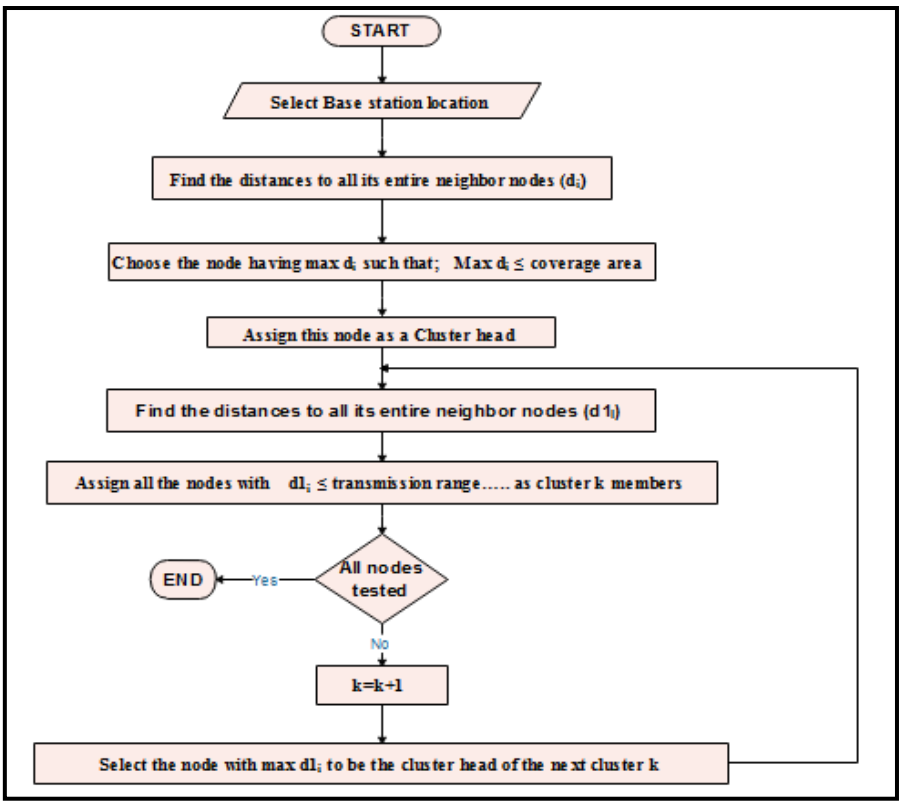


Figure (4): main steps in creating a developed WSNs clustering approach.

Net Logo (5.2.1) was used to create and implement the simulation environment for this clustering approach and Figure (5) shows a developed clustering program snapshot.

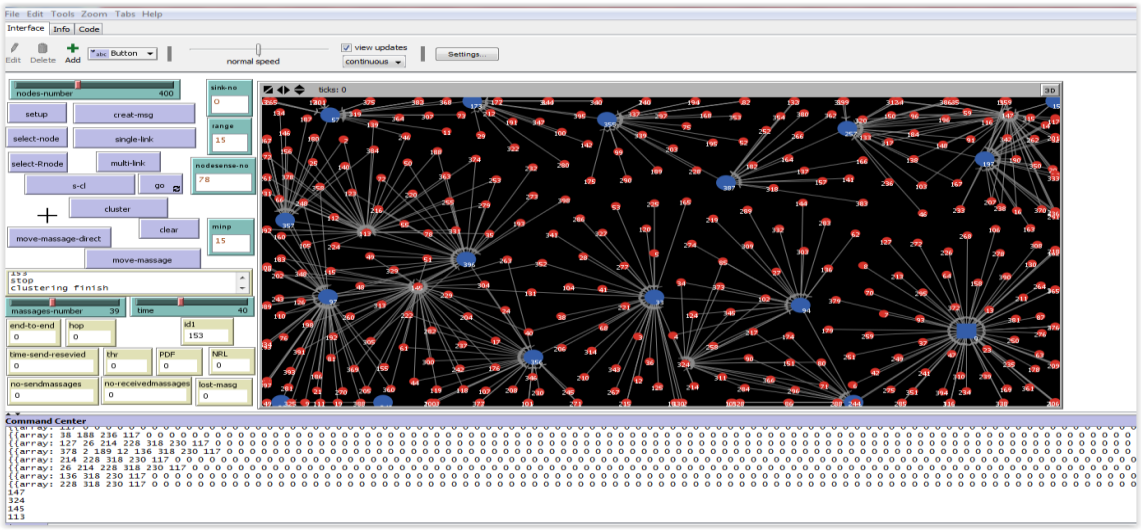

Figure (5): a developed clustering approach program snapshot.

After each epoch of time a check must be done on all cluster heads energy level values and to check whether certain nodes leaves its clusters and join another clusters or stay in its original cluster. In this study the epoch of time was selected as an exponential random variable with mean value equal to the nodes speed. When any CH energy level dropped to 0.4 of its initial value, a new cluster head forming process must be start. This process will re-assign this cluster head to be a

cluster member then comparing all the other cluster members' energy levels and select the highest value node to be the new cluster head and so on during the simulation run.

Four Hundred homogenous sensor nodes were deployed randomly in a square area of 100x100 $m^2$ dimensions. Nodes speed was suggested to be 0.5 m/sec with transmission range of 25 m. Nodes energy was settled to be 125 energy units with random multi hops.

Initial clustering, assigning of the CHs, ensuring possible communication and acceptable messages transmissions between clusters heads were tested initially in each of these 40 sec. simulation trails. Results showed tangible improve in the most of this network performance metrics. Figure (6) and (7) shows some of these related metrics.

Final results showed a clear reduction in the nodes wasted energy comparing with other clustering approaches. System Busy time means the total nodes transmitting and receiving times while by node utilization we means the percentage of time where the sensor node is being busy (either transmit or receive)

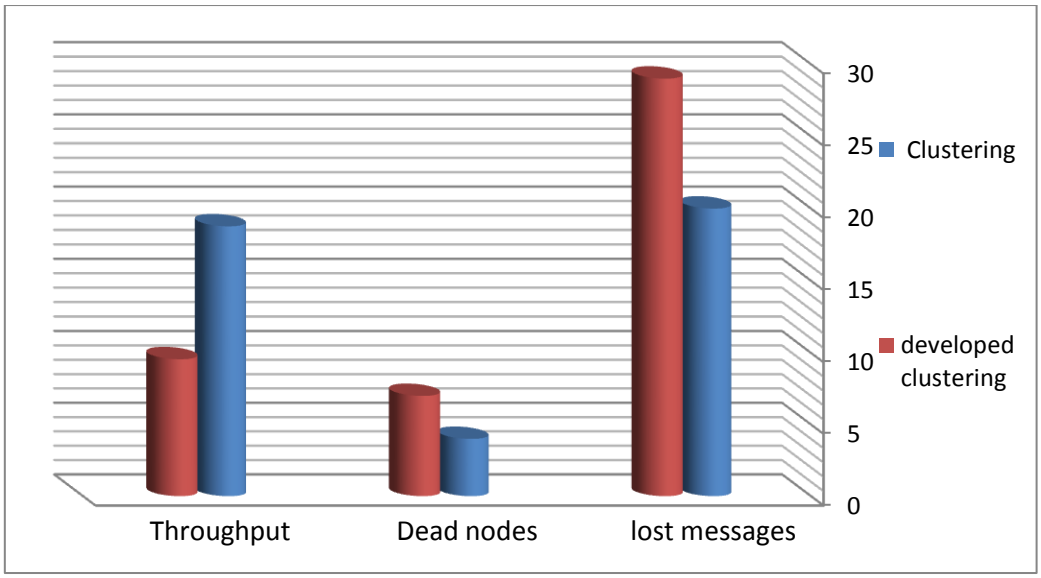


Figure (6): Throughput, Dead nodes and lost messages in two clustering approaches.

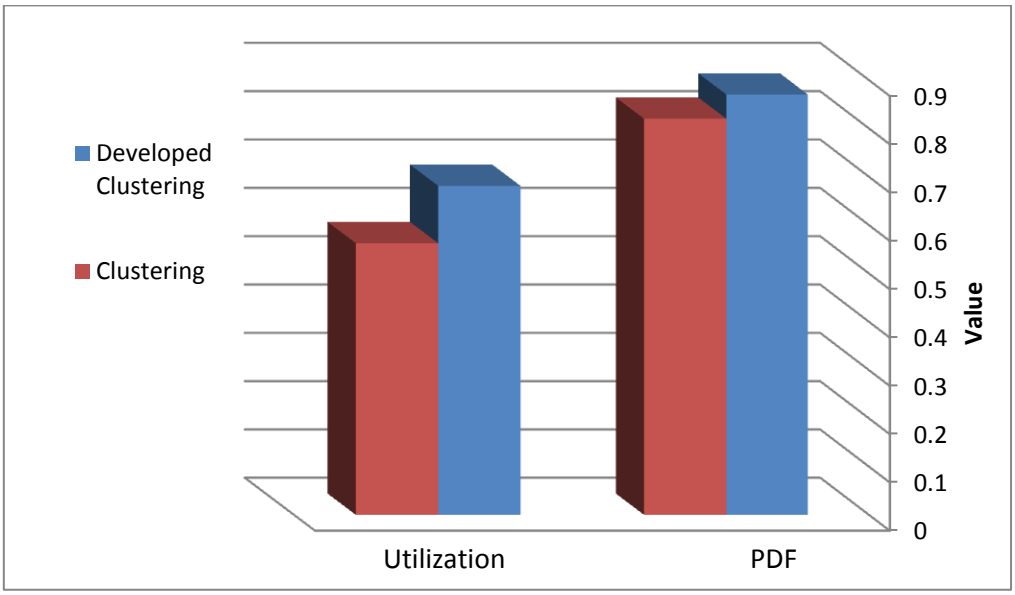


Figure (7): network utilization and PDF values in two clustering approaches.

## 7. Conclusion

The design of robust, long life, effective and scalable WSNs represents a great challenging task. Clustering approach can helps in exceeding most of these challenges. It improves the network lifetime, helps in optimal utilization of network resources, minimizing the energy consumption, develop the network load balancing and increase the network lifetime management. Clustering approach helps in managing the WSN by allowing to only minimum number of sensor nodes to join the wireless channel and transmit or receive information at each time. When the energy level of certain sensor reached its minimum value, the sensor node informs all its neighbors in the cluster in order to let other sensor node perform its duty due to it's an ability to communicate with others.

Number of dead nodes is shown to be directly proportional with the network size. In this case the CH became responsible for the increased number of its cluster members, so the number of intra-communication will increased which results in increasing amount of its consumed energy.

When the nodes speeds increased, number of dead nodes will increase also due to the rapid change in clusters forming. Related throughput increased also due to the probability approach. Average PDF increased due to the shortening path toward the sink.

## References

[1] Kiranjit Kaur and Sandeep Waraich; " Energy Efficient Wireless Sensor Networks based on Clustering Techniques";International Journal of Computer Applications(0975 – 8887) Volume 119 – No.11, June 2015.

[2] Barra Touray and Princy Johnson; "Biased Random Energy Efficient Routing Algorithm (BREERA)"; International Journal of Engineering Science and Technology (IJEST), Vol. 4 No. 06 June 2012.

[3] Barra Touray and Princy Johnson; "Biased Random Energy Efficient Routing Algorithm (BREERA)"; International Journal of Engineering Science and Technology (IJEST), Vol. 4 No. 06 June 2012.

[4] Tushar D. Maheshwari; "Selection of Efficiently Adaptable Clustering Algorithm upon Base Station Failure in Wireless Sensor Network", a Master Dissertation submitted to the department of Computer Engineering and Information Technology- College of Engineering, Pune, India, 2012.

[5] Amjad K.Abu-Baker; "Energy-Efficient Routing ion Cluster-Based Wireless Sensor Network: Optimization and Analysis";Jordan Journal of Electrical Engineering(JJEE),Vol.2,No.2, 2016.

[6] Chunyao FU, Zhifang JIANG, Wei WEI and Ang WEI; "An Energy Balanced Algorithm of LEACH Protocol in WSN"; International Journal of Computer Science (IJCSI) Issues, Vol. 10, Issue 1, No 1, January 2013.

[7] Praveen Dodwadmath and Aijazahamed Qazi, "Cluster based Routing Algorithm to Minimize Energy Consumption in WSN", International Journal on Recent and Innovation Trends in Computing and communication, Volume: 3, Issue: 5, 2015. http://www.ijritcc.org.

[8] Thesiya Khushbu and Viraj Daxini,"Novel Clustering Approach to Reduce Energy Consumption in Wireless Sensor Network based on LEACH", International Journal of Computer Science and Mobile Computing (IJCSMC), Vol. 4, Issue. 6, June 2015.

[9] Xuxun Liu; " A Survey on Clustering Routing Protocols in Wireless Sensor Networks"; Sensors , 12; 2012. www.mdpi.com/journal/sensors.

[10] Amandeep Kaur and Amit Grover;" LEACH and Extended LEACH Protocols in Wireless Sensor Network, A Survey"; International Journal of Computer Applications, Volume 116 – No. 10, April 2015.

[11] Barra Touray, Jie Lau and P. Johnson; "Clustering-Biased Random Algorithm for Load Balancing (C-BRALB) in Wireless Sensor Networks"; Int. J. Intelligent Systems Technologies and Applications, Vol. 12, No. 1, 2013.