Node Degree based Clustering for WSN

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ABSTRACT
Wireless Sensor Network (WSN) is widely used for monitoring and gathering data in an autonomous fashion. Since sensors are small and power constrained devices, it is the most important to minimize the energy consumption. We propose Node Degree Based Clustering (NDBC) for enhancing life time of heterogeneous wireless networks. In this paper, two types of sensor nodes, i.e., advanced and normal nodes are used. Advance nodes are having more energy than normal nodes. The advanced nodes are selected as cluster head based on its energy and node degree in the network. Normal nodes are used for sensing and data forwarding. Using NDBC we have reduced communication cost among sensor nodes used for transmitting and receiving the messages for cluster head selection. Simulation results show that by selecting the optimum position of cluster head on the basis of density, the consumption of energy for communication is minimized. It also increases the overall lifetime compared with the existing schemes.

KEYWORDS
Clustering, density, degree, efficiency, lifetime, WSN.

1. INTRODUCTION
With recent advancement in Micro Electro Mechanical System (MEMS) technologies, low-cost and low-power wireless micro sensor nodes have become popular. The Wireless sensor network consists of tiny sensor nodes. Sensor nodes form an ad hoc distributed network to collect the information on the surrounding environment. It is widely used in both the military as well as civil applications such as target tracking, surveillance, security management. It can also be used for sensing of physical environment in terms of temperature, humidity, light, sound, vibration etc. Each sensor node consists of four basic units: sensing unit, processing unit, radio unit, and power unit. Sensor nodes are capable for monitoring, controlling and sensing. The sensor network can provide a fine global picture of the target area through the integration of the data collected from many sensors [1].

We propose NDBC, a distributed clustering scheme which considers energy, node Degree and topological features of a heterogeneous WSN. NDBC provides an efficient solution to handle large scale networks using high energy advance nodes which can work as cluster head. By use of advance nodes in NDBC, it reduces number of packets for communication amongst sensor nodes to select cluster heads, thereby network lifetime increases. NDBC is fast and scalable and it achieves a good distribution of cluster heads within the network. Furthermore, as advance nodes are energy-constrained, they frequently receive data from normal nodes and aggregate it. The aggregated data is forwarded to base station.

2. BACKGROUND DETAILS
The sensor nodes have limited power and cannot be easily recharged or replaced when the battery power runs out. The limited energy at each node affects the lifetime of the entire network. As a result energy efficiency becomes important criteria for the protocols and algorithms developed for WSN. Various network architectures and protocols have been developed for organizing the energy to function efficiently [2,3,4,5]. Many clustering schemes have been proposed in recent past. Low Energy Adaptive Clustering Hierarchy (LEACH) [6], is one of the most recognized cluster based protocol. LEACH selects cluster heads dynamically and frequently by a round mechanism and it allows different nodes to become cluster heads at each round. However, the scheme cannot guarantee a good cluster distribution. Power Efficient Gathering in Sensor Information Systems (PEGASIS) [7], is an extension of LEACH, in which all nodes are organized as a chain and each node transmits data to its nearest neighbor. Both LEACH and PEGASIS require strict time synchronization mechanisms. The Hybrid Energy-Efficient, Distributed (HEED) [8], clustering protocol uses a hybrid criterion for cluster head selection. It considers the residual energy of each node and a secondary parameter, such as the node's proximity to its neighbors or the number of its neighbors. The clustering process terminates in O (1) iterations and does not depend on the network size. M. Gerla et. al. has proposed the Highest-Degree scheme [9]. In this method, node with the maximum number of neighbors is chosen as a cluster head and any tie is broken by the unique IDs. In Energy Efficient Clustering with Self-organized ID Assignment (EECSIA) [10], a network first selects the nodes in the high-density areas as cluster heads and then assigns a unique ID to each node based on local information. In addition, EECSIA periodically updates cluster heads according to the nodes residual energy and density. This method is independent of time synchronization. It does not rely on the nodes geographic locations. Simulation results show that the scheme performs well in terms of cluster scale and number of nodes alive over rounds.

There are many ID assignment schemes use IDs to distinguish the nodes in the network. There are many algorithms generated to assign the ID either in a predefined manner or locally generated. C. Schurgers et. al. [11] utilizes a proactive conflict detection procedure for a general sensor network. When a node joins the network, it

first chooses a random physical ID and then informs to all neighbors periodically. By exchanging this kind of HELLO messages, 2-hop neighbor information is acquired from which ID conflicts can be resolved. H. B. Zhou et.al. [12] has proposed a method in which the nodes randomly choose an ID when is likely to be unique within a 2-hop neighborhood. No conflict resolution is performed until data communications are initiated. O.A.V. EL Moustapha [13] proposed a scheme that assigns globally unique IDs. It uses a tree structure to compute the size of the network and then unique IDs are assigned using the minimum number of bytes. However, this protocol has to use not only temporary ID and final ID but also sub-tree size, which results in high communication cost.

After going through above literature it appears that all normal nodes are intending to compete for becoming cluster head. During this process all nodes are degrading their energy in transmission and reception of packets. In the present paper only the few number of nodes are competing for becoming cluster head.

The rest of the paper is organized as follows: Section 3 describes the network model, energy consumption model and clustering objectives. Section 4 presents the NDBC in detail and analyzes its properties. Section 5 verifies the effectiveness of the NDBC via simulations. In Section 6, we conclude the paper with summary and possible directions for future work.

3. NETWORK MODEL, ENERGY CONSUMPTION MODEL AND CLUSTERING OBJECTIVES

3.1 Network model

Network model consist of N nodes in M x M network field as shown in Fig 1.

In our network model the following assumptions have been made for sensor nodes as well as the networks.

- The sensor nodes are randomly deployed or scattered in the network.
- There is one base station which is located at the centre of sensing field.
- Nodes are not aware of location.
- All nodes have similar capabilities in term of processing and communicating range. They are having equal significance. It arises the need for extending the lifetime of every sensor.
- The network is heterogeneous therefore energy heterogeneity is used. Two types of sensor nodes are deployed i.e. advanced nodes and normal nodes. Advanced nodes have more energy than normal nodes.
- In this network unique IDs are used for identification of advanced nodes as well as normal nodes so as to make

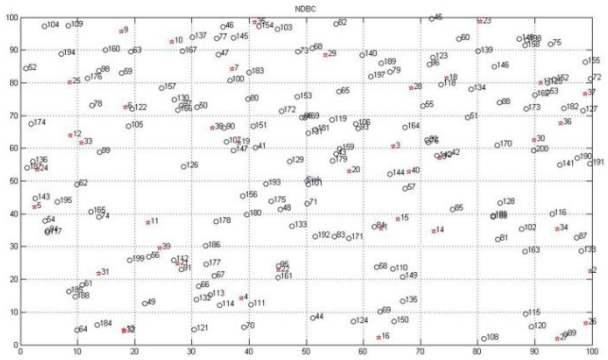

Fig. 1: Wireless Sensor Network

3.2 Energy Consumption Model

We use the same energy consumption model as suggested by A.P. Chandra Kasan et.al. [6]. Energy is consumed to serve: (i) digital electronics, 'E_{elec}' (depending on factors such as the digital coding, modulation and spreading of the signal) (ii) communication, E_{com}. In our work, both the free space (d^2power loss) and multi-path-fading (d^4power loss) channel models are used, depending on the distance d between the transmitter and receiver. $E_{com}= \varepsilon_{f\,s}$ assuming a free space model when $d < d_0$, while $E_{com}= \varepsilon_{mp}$ assuming a multi path model when $d \geq d_0$, where $\varepsilon_{f\,s}$and ε_{mp} are the amplifier energy factors for free space and multi path fading channel models, respectively d_0 is the threshold distance which depends on the environment.

Thus, it transmits an l bit message with distance d, the radio expends as follows:

$$E_{\mathrm{TX}}(l,\mathrm{d}) = \begin{cases} lE_{elec} + l\,\epsilon_{fs}\,d^2, & d > d_0 \\ lE_{elec} + l\,\epsilon_{mp}\,d^4, & d > d_0 \end{cases} \qquad (1)$$

To receive an $l-$ bit message, the radio expends

$$E_{RX}\,(l) = lE_{elec} \qquad (2)$$

In our simulations, the typical parameters are set as: E_{elec}= 50nJ/bit, $\varepsilon_{f\,s}$= 10pJ/bit/m^2, ε_{mp}= 0.0013pJ/bit/m^4. In addition, the energy for data aggregation is set as E_{DA}= 5nJ/bit.

3.3 Clustering objectives

The proposed clustering approach is directed by two fundamental requirements: energy conservation and degree. Let CH be the set of all cluster heads in the network. Our goal is to select the optimum number of advance nodes as cluster head so that each node in the network belongs to a cluster. A node in NDBC may be in one of the four possible states: cluster head, 1-hop member node (an immediate neighbor of a cluster-head), 2-hop member node (an immediate neighbor of a 1-hop member node) and unclustered node (not a member of any cluster). In the proposed scheme, each node can relay its data within 2 hops to the cluster head and assigns its unique ID based on local information. In NDBC algorithm, only fraction of nodes (advanced node) are becoming cluster head. In NDBC, clustering is completely distributed. Each advanced nodes interacts with the neighbor normal nodes to form clusters. This scheme is better than central controlled schemes because it reduces the amount of central coordination and enables the node to act independently. The advanced nodes make their own

decision according to their schedules. Also the clustering process will occur within a fixed time interval.

4. THE NDBC

Let P be the set of all advanced nodes (P_n) and normal nodes (P_m) deployed in the region of interest. A normal node P_{m_i} is considered to be a neighbor of advanced node P_{n_i} ,if P_{m_i} lies within the radio range of P_{n_i} , where

P_{n_i}, $P_{m_i} \in P$. We define Node Degree (P_{n_i}) as the total number of neighbors of advanced nodeP_{n_i}, then:

$$\text{Node Degree}\,(P_{n_i}) = \text{count}\,(\{P_{m_i} | \text{dist}\,(P_{n_i}, P_{m_i}) < R_c\,,\ \ P_{m_i} \in P, P_{m_i} \neq P_{n_i}\}) \quad (3)$$

Where dist (P_{n_i}, P_{m_i}) represents the distance between node P_{n_i} and node P_{m_i}, R_c stands for node radio range and count stands for the number of elements in a finite set. In NDBC, no GPS or other location-awareness mechanism is available. We therefore use Node Degree to compare the density of nodes in the network. It is to be noted that each normal node belongs to exactly one cluster. The minimization of clusters *number* with full coverage is exactly equivalent to maximization of the average cluster *size* while maintaining a full coverage. We would like to select the advance nodes deployed in dense areas as cluster head.

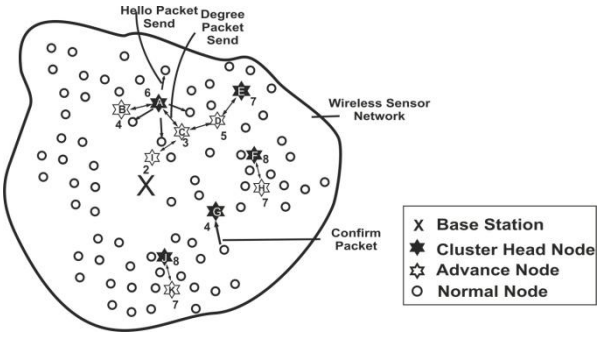

Fig. 2: Clustering Model of NDBC

In many cases, the nodes distributed in sparse regions or at the edge of the network cannot directly communicate with cluster heads due to limitation on their radio ranges. There are tradeoffs among connectivity, energy usage, and communication latency. In our work, communication between a cluster head and a node beyond the radio range of the cluster head is achieved through intermediate nodes (1-hop member nodes) which provide relaying service. Four different messages in the clustering process are defined as follows:

- DEG-MSG: Sent by each advance sensor node to its neighbors advance sensor node to indicate its Node Degree.
- STATE-MSG: Sent by each sensor node to its neighbors to indicate its current state.
- JOIN-MSG: Sent by an unclustered node to notify the cluster head/1-hop member node that it wants to be a 1-hop member node/2-hop member node.
- ABDICATE-MSG: Sent by each cluster head to notify its member nodes of its unwillingness to serve as the cluster head in the next round.

4.1 Detailed NDBC Algorithm

4.1.1 Cluster formation phase

At the start of the scheme, all nodes advanced and normal are unclustered. Each advanced node broadcasts an update packet of HELLO MESSAGE to its neighbors within the range R_C at a random time between 0 and a certain upper bound $T_{max.}$ After getting the received packets from normal nodes, every advanced node calculates its node degree. The delay of node P_{n_i} is given by $T_{P_{n_i}}$, given as

$$T_{P_{n_i}} = \alpha e * 1/\text{NodeDegree}(P_{n_i})) \quad (4)$$

Where α is a given constant to ensure $0 < T_{Pm} \leq T_{max}$. After that, every advanced node sends DEGREE MESSAGE to its neighbor advanced nodes and checks the node degree with in time T_{max} and $T_{max} + T_{Pn}$. If the node degree of neighbor advanced nodes is less than its own, it will choose a 2 m byte, m is a constant that needs to be selected carefully in practice according to the scale of the sensor network, random integer as its ID and announces itself as a cluster head and then advanced node will send a STATE MESSAGE to its neighbors node to indicate its status as shown in fig 2. As in equation (4), the node delay time is an increasing function. It means a node with the larger node degree among its neighbors .i.e. in a denser area, will have more probability to be selected as a cluster head. If the node degree of any advanced node is less than its any neighbor's advanced node, it will work as normal node. If normal node will receives a cluster head state message from the advanced node and not belonging to any other cluster than it will send a confirm message to advance node. Now the normal node becomes a 1 hop node. It will create its own ID and send a state message to its neighbors within their region. If an unclustered node receives a state message from a 1 hop member node, it will declare itself as a 2 hop member node. The 2 hop member node also chooses its own ID, which is m byte random integer added at the end of the selected 1 hop member nodes ID. It may rarely happen that two sensor nodes within a same cluster choose the same random number. This conflict can be solved through the cluster head by giving one of the nodes a different ID. Thus, at the end of this phase every node has its locally unique ID and knows which cluster it belongs to.

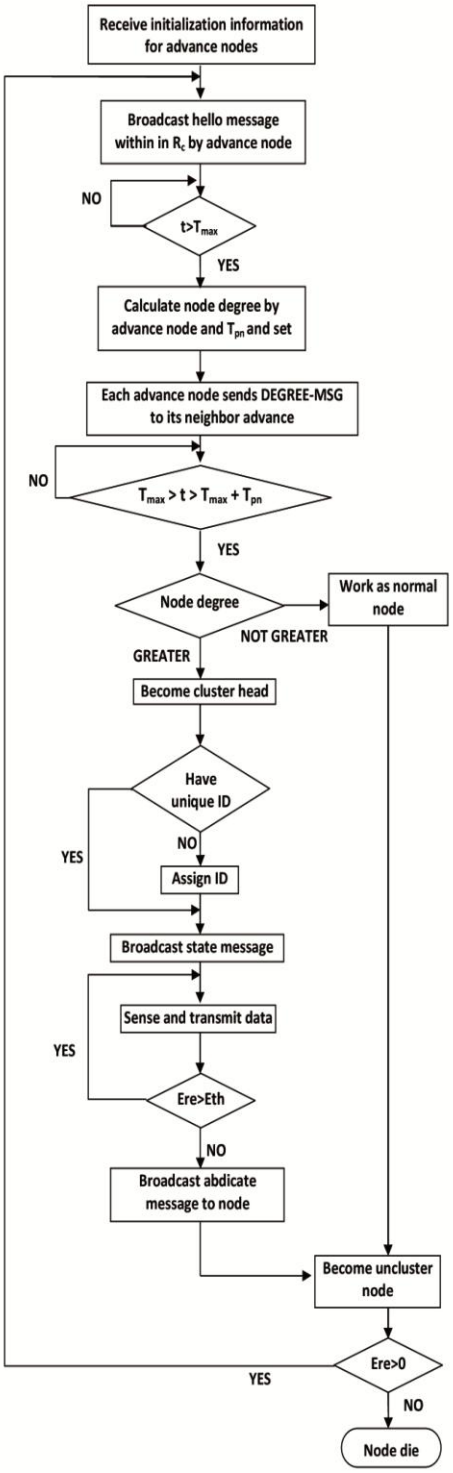

Fig. 3: The flow chart of NDBC for Advanced Nodes

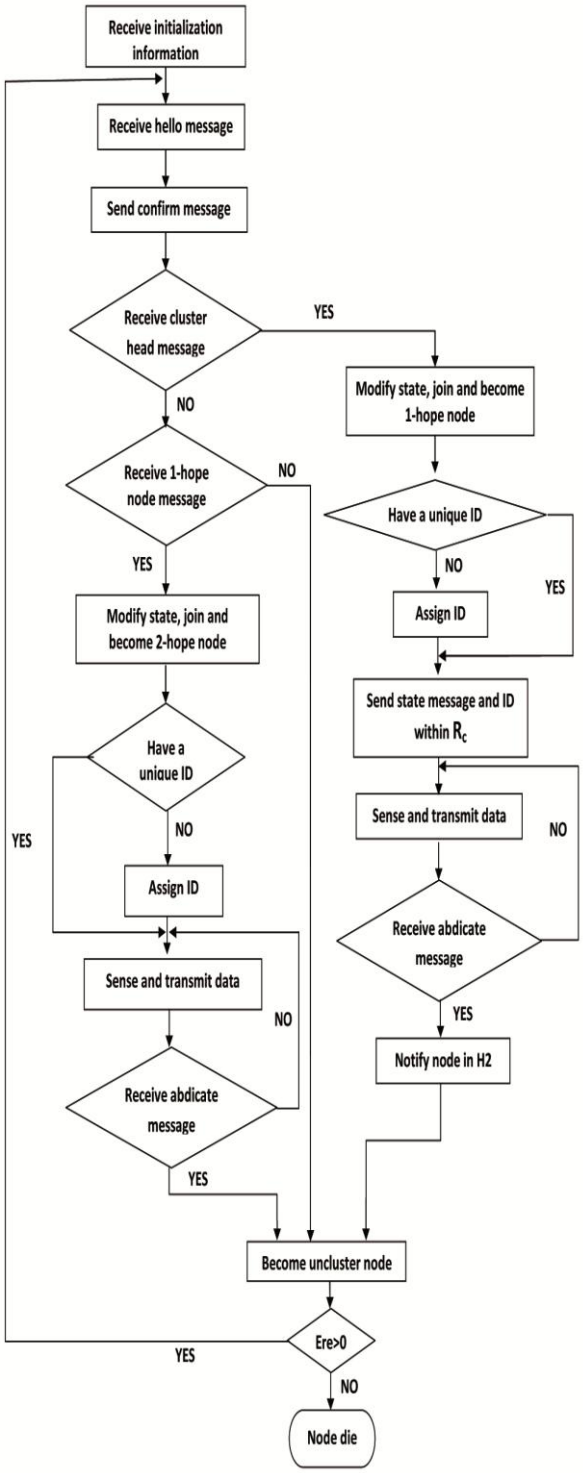

Fig. 4: The flow chart of NDBC for Normal Nodes

4.1.2 Cluster head migration phase

Note that the ID of cluster head is same as its 1-hop members IDs without the last m bytes, similarly the 1- hop member nodes IDs are same as its members' IDs without the last m bytes. Therefore it is not necessary for the cluster head to store the information of nodes belonging to another cluster. For a given cluster, let S_1 be the set of all 1-hop member nodes and S_2 be the set of all 2-hop member nodes.

When the TDMA schedule is executed by all nodes in the cluster, each 2-hop member node in S_2 (denoted by S_2i) starts transmitting the sensing data to the 1-hop member node during its allocated transmission slot. Then each 1-hop member node in S_1(denoted by S_1j) aggregates all the received data and sends them to the cluster head (denoted by CH_k). Assume the distance among the nodes in a cluster is less than d_0. The energy dissipation follows the free space model. The energy consumption for S_2i and S_1j is shown as following:

$$E_{S_{1i}} = l \times E_{elec} + kl \times \varepsilon f s \times dist^2(S_{1i}, S_{1j}) \quad (5)$$

$$E_{S_{1j}} = l \times E_{elec} \times count\ (M2 - hop\ (S_{1j})) + l \times E_{DA} \times (count(M2 - hop(S_{1j})) +) + l \times (E_{elec} + \varepsilon fs dist^2(S_{1j}, CH_k)) \quad (6)$$

Where l is the length in bits in each data message, S_2i M2−hop (S_1j), S_1j ∈ M1−hop (CH_k). M2−hop (S_1j) denotes the set of all members of S_1j, and M1−hop (CH_k) denotes the set of all 1-hop members of each cluster head CH_k.

Finally, the cluster head aggregates the data from the 1-hop members and transmits the final aggregated data to the base station. Assume the distance to the base station is greater than d_0, therefore the multi-path model is used as given in equation (7). Otherwise it follows free space model as given in equation (8). The energy dissipated in CH_k is:

$$E_{CH_k} = l \times E_{elec} \times count\big(M1 - hop(CH_k)\big) + l \times E_{DA} \times \big(count\big(M1 - hop(CH_k)\big) + 1\big) + l \times (E_{elec} + \varepsilon mpdist^4(CH_k, BS)) \quad (7)$$

$$E_{CH_k} = l \times E_{elec} \times count(M1 - hop(CH_k)) + l \times E_{DA} \times (count(M1 - hop(CH_k)) + 1) + l \times (E_{elec} + \varepsilon mpdist^2(CH_k, BS)) \quad (8)$$

Where dist (CH_k, BS) is the distance between CH_k and the base station. We introduce the energy threshold E_{th} for each cluster head to decide whether to continue to serve as a cluster head in the next round. If the residual energy, E_{re} of the current cluster head is below E_{th}, It will be replaced by one of its neighbor advance node having node degree maximum among its neighbor advance nodes. It will work as a normal node in the next round. The flow chart of the algorithm shown in fig 3 and 4 for clustering process.

5. SIMULATION AND ANALYSIS

We have simulated the wireless sensor networks in MATLAB environment in 100x100 fields. The table 1 shows the basic simulation parameters used.

Table 1: Simulation parameters

Parameter		Value
Network size		(100m x100m)
Node number		200
BS Position		(50m, 50m)
Initial energy	Normal Nodes	2 J
	Advanced Nodes	4J
E_{th}		1 J
d_0		87m
$\varepsilon_{f\,s}$		10pJ/bit/m^2
ε_{mp}		0.0013pJ/bit/m^4
Message Size (l)		4000 bits
T_{max}		500ms
R_c		20m

5.1 Network lifetime

It is the time interval from the start of operation of the sensor network until the death of the last alive node. We observe the performances of NDBC, EECSIA, LEACH and Highest Degree for number of node alive over number of rounds in the network as shown in fig 5. In case of NDBC lifetime is more as compared to others.

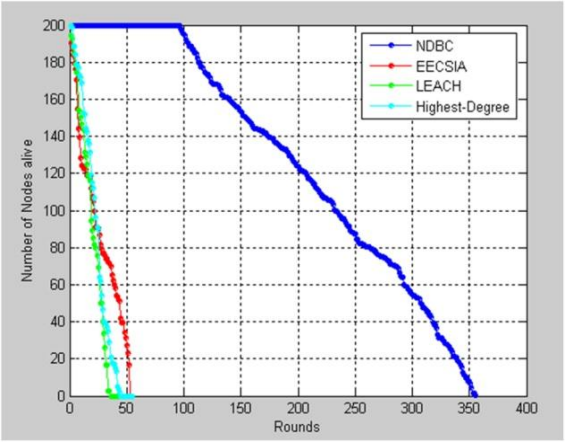

Fig. 5: Number of nodes alive over rounds

5.2 Normal nodes alive over advanced nodes

In this case we have calculated the number of normal nodes alive if number of advanced nodes varies for fixed 300 rounds. But after some time, numbers of nodes are alive is decreasing due to advance nodes threshold as shown in fig 6. Table 2 shows the percentage of alive normal node varied with the advanced node.

Table 2: Normal Nodes alive over advanced nodes

%Advanced Node	Normal node Alive
0.05	10
0.1	20
0.2	34
0.3	46
0.4	50

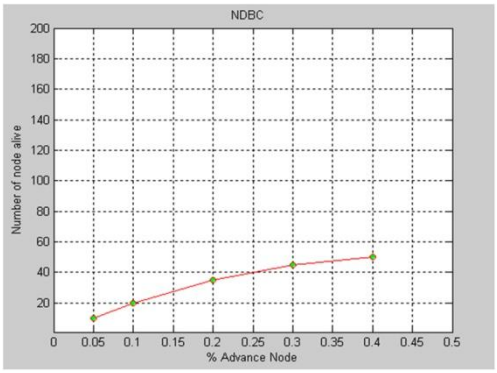

Fig. 6: Number of nodes alive over advanced nodes

5.3 Stability period

It is the time interval from the start of network operation until the death of the first sensor node. We also refer to *this period as stable region. In this parameter advanced* nodes are deployed with two times more energy than normal nodes. The first node dies after 56 rounds when we use the percentage of advanced nodes as 0.05 as shown in table 3. On increasing number of advance node stable region is also increasing, as shown in fig 7.

Table 3: Stability period

%Advanced Node	First Node Die
0.05	56
0.1	81
0.2	103
0.3	108
0.4	112

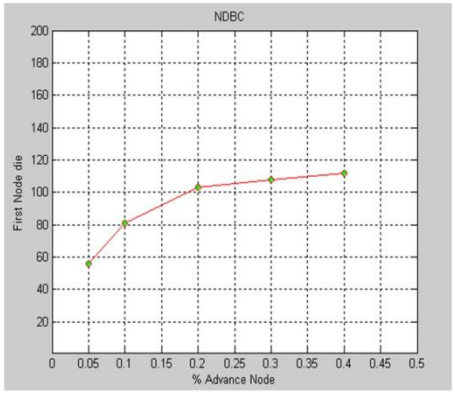

Fig. 7 : First node die over Advance Nodes

6. CONCLUSION AND FUTURE WORK

This paper presents NDBC, a distributed energy efficient clustering approach based on its energy and node degree for the selection of cluster head. We have decreased the overall communication cost for selecting cluster-head and thereby it increases overall network lifetime. The present simulation gives better results than EECSIA LEACH and Highest Degree.

The future scope will be to extend the NDBC with mobile nodes.

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