Energy and Round Time Estimation Method for Mobile Wireless Sensor Networks

NAJMA ISMAT*, REHAN QURESHI*, AND MUMTAZ-UL-IMAM*

ABSTRACT

Clustered WSN (Wireless Sensor Networks) is a hierarchical network structure that conserves energy by distributing the task of sensing and data transfer to destination among the non-CH (Cluster-Head) and CH (Cluster Head) node in a cluster. In clustered MWSN (Mobile Wireless Sensor Network), cluster maintenance to increase at a reception at the destination during communication operation is difficult due to the movement of CHs and non-CH nodes in and out of the cluster. To conserve energy and increased data transfer to the destination, it is necessary to find the duration after which sensor node's role should be changed from CH to non-CH and vice-versa. In this paper, we have proposed an energy independent round time scheme to identify the duration after which re-clustering procedure should be invoked for changing roles of sensor nodes as CHs and associated nodes to conserve energy and increased data delivery. This depends on the dissemination interval of the sensor nodes rather than sensor node's energy. We have also provided a complete analytical estimate of network energy consumption with energy consumed in every phase of a around.

Key Words: Mobile Wireless Sensor Network, Round Time, Cluster, Cluster-Head Rotation.

1. INTRODUCTION

WSN is a collection of SN (Sensor Nodes) either deployed, implant, or worn by the nodes or entities that can move. Movement of SN makes efficient use of energy and performs better channel utilization and low latency [1,2]. The positive impact of node mobility in WSN is that it provides better network coverage by covering those are as that areas not covered with random deployment of SN [3]. MWSN application scenarios may include battlefield surveillance, disaster management, patient monitoring, animal behavioral studies, studying and monitoring seismic activities and underwater habitat, etc. Due to the nature of the application area and mobility of SN, clustering solutions available for static WSN are not applicable on MWSN.

Regardless of that the SN are stationary or mobile in a sensing field, the performance of WSN is measured in terms of energy consumption, reliability and network survival time [4-6]. The SN battery in general cannot be charged or placed once its operational and due to that the power management schemes and battery consumption methods determine the network life [7,8]. So, for increasing the network life, it is necessary to adopt methods that

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may conserve energy, for example, restricting network wide transmission of data and control packets, avoiding retransmission of lost packets by maintaining reliable connection between sender and receiver. Studies have shown that clustering methods are cost effective in terms of energy, scalability, fault tolerance, reduces latency, and decreases communication costs [9-13].

Communication in clustered networks takes place in rounds, which reduces the overall network energy usage and increases network life. Energy is conserved by changing the role of the SN as CH and as non-CH node in every round. This change in role of SN in every round distributes energy consumption among all the nodes. However, in many schemes round time is dependent on SN initial or residual battery power. So, if it is dependent on initial battery power it means that an increase in initial battery power increases the round duration. If round time is dependent on residual energy, then when CH battery passes the threshold limit, re-clustering procedure is invoked. The frequency of re-clustering increases with the decrease in CHs battery power and it further affects the network life. In any case, the round time is large at the beginning of network operation, forcing CHs to stay in their role for longer periods, which results in early depletion of their power. The overall result is non-uniform distribution of energy consumption that adversely affects the network's life time. In addition to the above mentioned drawbacks, we have also noticed that most of the energy estimation methods found in the literature for clustering protocols only consider the energy consumed in data transfer operation and it ignores the energy spent in exchange of control packets for network setup and management. This results in an inaccurate estimation of consumption of energy during network operation.

In this paper, we have presented new energy independent round time estimation method that determines when SN role should be changed from CH to non-CH node and

conversely. The energy independent round time estimate shows that increase in SN initial battery power does not affect the cluster round time. An analytical estimate, for complete network energy consumption has also been given that includes energy consumed in exchange of data as well as control packets. The rest of this paper is organized as follows: Section 2 briefly discusses the previous work done in this area. Our proposed energy independent round time estimate is discussed in section 3. A mathematical expression for energy estimation is derived in section 4. Evaluation of our proposed work along with the discussion on the results are presented in section 5 and section 6 concludes the paper.

2. RELATEDWORK

Several round time estimation methods are proposed in research literature. These methods can be categorized as fixed, dynamic or adaptive estimation schemes. LEACH [14] a very popular distributed clustering solution for WSN and its round time is calculated from sensor nodes initial battery power, and the average energy consumed by CH and non-CH nodes in a round. Sensor nodes change its role from CH to non-CH role from CH to non-CH node in every round is to distribute energy consumption among all nodes. In [15] the round time scheme is adopted from HEED [16]. The clustering process is divided into phases. Nodes are selected as CH in the in the first round of the setup phase. CH with residual energy within the threshold continues to be the CH in the next round. The re-clustering procedure is invoked when residual energy reaches the threshold energy. In [17] a hybrid cluster rotation strategy given. At the start of the network operation, SN have ample amount energy, so energy-driven rotation strategy is used which is dependent on the residual energy of the CH. So, with network operation residual energy decreases and more energy are consumed in frequent CH election and re-construction of topology. When residual energy drops

to a certain threshold, it switches to time-driven method which is a dependent node density, energy status and fixed when the number of rounds determined at the start of the network. LEACH-F [18,19] is a dynamic, adaptive round time estimation method for fixed cluster networks has been proposed. In these schemes the duration of a round is determined from SN current energy. In each round elected CH sends current energy to the BS to calculate round time and broadcast it back to the SN. In [20] an adaptive scheme, where round time is calculated from the number of active nodes in the network. When the number of active nodes goes down to certain threshold number, round time is fixed to avoid frequent re-clustering.

Number of authors have proposed energy consumption estimation methods for distributed clustered networks. LEACH [14] protocol, which has been discussed widely by the research community lacks a complete energy estimation model. It estimates energy based on data transmitted in steady state phase and does not calculate the energy spent in exchange of control packets for cluster setup. For estimating the energy consumed for data transfer from SN to CH and from CH to sink in steady-state phase free space and two-ray ground propagation models are used. In [21] the authors have found the energy consumed in the setup phase of cluster formation and named it as overhead energy. The overhead energy includes energy consumed in sending and receiving control packets for cluster formation and energy consumed in node association with the CH and broadcast of TDMA schedules. WSN DEEC (Distributed Energy-Efficient Clustering) for heterogeneous [22] have calculated the network energy consumption of heterogeneous networks, but they have not considered the energy expenditure of the setup phase. DEEC gives the ideal estimates of the network life to compute the projected expenditure of energy by each node. In EERP (Energy Efficient Routing) and Clustering for MWSN [23], surplus energy of a SN is calculated. This estimation

includes energy consumed in sensing, generating, transmitting, receiving and in standby mode. It does not consider the energy consumed in the exchanging control packets for the topology setup. In [24] energy usage estimation technique (LCEFCM) is presented, which computes the energy consumed in setup and steady-state phases of the Fuzzy C-Means clustering. It calculates the energy consumed by each CH and CM in setup and steady-state phase so around. In [25] energy estimation using the M/M/1 queuing model has been proposed. They have estimated the energy consumption by the non-CH nodes, CH nodes and the sink node in steady-state phase. The energy consumed by the node depends on number of receiving packets, reception energy, probability of node in idle state and the energy consumed in idle state.

3. ENERGY INDEPENDENT ROUND TIME

Clustering is a hierarchical topological scheme, where one complete communication operation takes place in around. Each round lasts for certain duration after which CH role changes to common sensing node. Due to this mechanism of change of roles in around, it is also known as CH rotation. Round time plays a very important role in the maintenance of topology as well as increasing the life time of the SNs [17].

The important factors that can affect the performance of clustered wireless sensor networks and its lifetime is its battery power, energy consumption model and round time. A round can be defined as the time interval during which network topology is created and data packet exchange takes place between SN and their CH and the data sink. The operations performed in a round, can be divided into two main phases, namely: *setup* phase and *steady-state* phase. Cluster creation takes place in *setup* phase and transmission of sensed data to its intended destinations takes place in *steady state* phase. Network

topology is recreated at the start of every round by changing the roles of the CH to non-CH node and vice-versa. The network lifetime also depends on round time, as it symbolizes the duration for which some SN are acting as CH. The SN that acts as CH consumes more energy than common sensing node whose only job is to sense certain phenomena at regular intervals. CH not only performs the task of sensing but also acts as transit data hub for its cluster member to forward their sensed data to the sink. Shorter duration round means clustering procedure initiation frequency is high, which also consumes energy because of the frequent initiation of the setup phase. Longer duration round means early drainage of energy of those SN that are acting as CHs and thus compromising on network life.

The round time estimation methods can be categorized as fixed, dynamic or adaptive. Dynamic or adaptive schemes decide the duration of around from network statistics like remaining energy or number of alive nodes in a network. Dynamic or adaptive round time method given in [18-20] is applicable to networks where clustering is fixed and controlled by the base station. With dynamic, distributed clustering schemes adaptive round time is not applicable due its complexity of how to propagate network statistics and maintain same round duration among all the clusters. In fixed round time estimation scheme, base station decides the duration of a round and either provide priori information to SN at the time of deployment or propagate it in a network after deployment. Therefore, fixed round time estimation method is best suited for distributed clustered networks. In [14] authors proposed a ffixed round time estimation method for distributed clustering schemes. The drawback of this scheme is that it depends on SN initial battery power shown in Equation (1). The measure obtained from Equation (1) is approximately 20 seconds and with the assumption that SN initial energy ($E_{initial}$) is 2 Joules (J) t_{frame} is the total frame time and 9mJ is the value obtained from number of

frames per round. The main drawback of this scheme is increasing initial battery power increases round time, which means SN acting as CH are active for longer duration and thus consuming more energy and compromising on network life. Therefore, it is always good to provide a parameter that are perceptible for the realistic evaluation of the scheme.

$$r_t = t_{frame} \times \frac{E_{initial}}{9mJ} \tag{1}$$

In this work, we have proposed a new round time estimation method that is independent of SN initial battery power. It is the extension of the proposed VGDC protocol [25]. Our proposed estimation method does not consider any energy parameters, rather it depends on the size of the transmitted packet *m bits*, data rate R as:

$$r_t = t_{setup} + t_{steady} \tag{2}$$

In the setup phase, clustered topological setup takes place, where clusters are formed before the transmission of data. In this phase four different types of control packets are exchanged between CHs and common SN. The time taken in setup phase as in Equation (3) consists of broadcasting of CH contention message t_c, transmission time of CH broadcast advertisements t_{adv}, time taken for the transmission of join request message t_{join}, and time taken by TDMA schedule broadcast messages t_{tdma} from CHs to its member nodes.

$$t_{setp} = t_c + t_{adv} + t_{join} + t_{tdma} \tag{3}$$

The transmission of sensed data take place in steady-state phase and time taken t_{steady} can be found from the time consume in transmission of m-bit message t_{df} over a communication channel that has a data rate of R bits per second, N_c number of nodes in a cluster and dissemination interval ($D_{interval}$).

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$$t_{steady} = N_c \times t_{df} + \alpha \times D_{interval} \qquad (4)$$

The constant α can have a value based on the number of times data is disseminated by the SN during a round. It also signifies how long a node can act as cluster-head without draining its energy so not to compromise on network life.

Now, t_{df} is given as:

$$t_{df} = \frac{m}{R} \qquad (5)$$

Also,

$$N_c = \frac{N}{k} \qquad (6)$$

For the sake of simplicity assuming that t_c, t_{adv}, t_{join}, and t_{tdma} takes the same amount of time as the time taken by m-bit message to transmit over R Mbps supported communication channel t_{df}.

Now, solving Equation (3) and substituting the results and 4 in Equation (2), we have a CH round time r_t:

$$r_t = \left(\frac{N}{k}\right) \times \left(\frac{m}{R}\right) + \alpha \times D_{interval} + t_{df} + t_{df} + t_{df} \qquad (7)$$

So, cluster-head rotation or round time t_r is given as:

$$r_t = \left(\frac{N}{k}\right) \times \left(\frac{m}{R}\right) + \alpha \times D_{interval} + 3 \times \left(\frac{m}{R}\right) \qquad (8)$$

4. ENERGY CONSUMPTION ESTIMATION

Clustered networks support hierarchical communication where the entire sensing and transfer of the sensed data to its intended destination is performed in sessions known as rounds. The rounds are further divided into sub-sessions according to their working. In the first sub-session network, topological setup takes place and in the second sub-session transfer of sensed data from SN to CH and then to sink is performed. These two sub-sessions of a around are named: setup phase and steady-state phase respectively. Energy consumed in setup phase is mostly due to exchange of control information. This consumption of energy is significant, but often ignored because the number of control packets exchanged between nodes in setup phase is much less than the data packets once topology is created. The control information exchanged in setup phase is for the topology creation, and once topology is created, data transfer of sensed data can be initiated. Most of the energy consumed by SN is in a steady-state phase where some are acting as a CHs and some as common SN involved in sensing task only. The transfer of sensed data between SNs and their CH and from CH to a data sink takes place in this phase, so energy consumption much higher in this phase than in setup phase.

The energy estimation methods of MWSN protocols [27-30] adopted the energy consumption model of [14], which only consider the energy consumed in the steady-state phase of a round. For an accurate calculation of utilized or consumed network energy, setup phase energy estimation is also necessary. In the setup phase cluster topology creation takes place for which control packets are exchanged between SNs. In this paper, we have proposed a complete network energy estimate that evaluates the energy spent on setup and steady-state phases of a round.

The energy consumed in each round can be found as:

$$E_r = E_{setup} + E_{steady} \qquad (9)$$

In setup phase clusters are formed by selecting nodes as CHs. The role of CH is to invite non-CH nodes to join its cluster by broadcasting cluster contention messages. After the completion of contention operation, sensor nodes elected as CH, broadcasts CH advertisement

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messages to non-CH nodes. During setup phase, non-CH nodes decide whether to become the part of the cluster by after receiving CH advertisements. They send join request to the CH if they decide to become cluster member. After receiving join request from the non-CH nodes, CH schedule data transfer operation among its members by issuing and broadcasting TDMA schedules. The energy consumed in setup phase is given as:

$$E_{setup} = E_{contention} + E_{CH\text{-}elec} + E_{tdma\text{-}sch} \qquad (9)$$

$$E_{setup} = E_{c\text{-}Bradcast} + E_{c\text{-}Recv} + E_{ADV\text{-}Broadcast} + E_{ADV\text{-}Recv} + E_{join\text{-}Req} + E_{Join\text{-}Recv} + E_{tdma\text{-}Broadcast} + E_{tdma\text{-}Recv} \qquad (10)$$

The measures $E_{contention}$, $E_{ADV\text{-}Broadcast}$, $E_{join\text{-}Req}$ and $E_{tdma\text{-}Broadcast}$ are given as:

$$E_{contention} = ((N \times p_{con}) \times E_{c\text{-}broadcast}) + E_{c\text{-}Recv} \times (N \times (1\text{-}p_{con})) \qquad (11)$$

$$E_{CH\text{-}elec} = kxE_{ADV\text{-}Broadcast} + (N - k) \times E_{ADV\text{-}Recv} + (N - k) \times Ej_{oin\text{-}Req} + E_{Join\text{-}Recv} \qquad (12)$$

$$E_{tdma\text{-}sch} = k \times E_{tdma\text{-}Broadcast} + (N - k) \times E_{tdma\text{-}Re\,cv} \qquad (13)$$

Assuming that data and control messages are of size m-bits, from [14], we have: Energy consumed in transmitting m-bit message is given as:

$$E_{tx}(m,d) = E_{elec}(m) + E_{amp}(m,d) \qquad (14)$$

$$E_{tx}(m,d) = E_{elect} \times m + E_{efriss\text{-}amp} \times d^2 : d < d_{crossover} \qquad (15)$$

$$E_{tx}(m,d) = E_{elec} \times m + E_{efriss\text{-}amp} \times d^4 : d >= d_{crossover} \qquad (16)$$

Energy consumed in receiving m-bit message is:

$$E_{rx}(m,d) = E_{elec} \times m \qquad (17)$$

Since, data and control messages are of equal size of m-bits, so the energy consumed in transmission of control and data messages is the same as given in Equations (14,15,17). The energy consumed in a broadcast operation

like $E_{c\text{-}Broadcast}$, $E_{ADV\text{-}Broadcast}$ and $E_{tdma\text{-}Broadcast}$ use an Equation (16) whereas sending a join request may use Equation (15) or Equation (16) depending upon the distance of the receiving node. The energy consumed in receiving CH advertisements, join requests and TDMA schedules by sensor nodes irrespective of being a CH or not determined using Equation (17).

The operations performed in steady state phase are: sensing of phenomena, processing of data sensed from sensing phenomena, transmission of processed data from node to CH and from CH to the sink. It is possible that there some nodes that are not the part of any cluster, transmit their sensed data directly to the sink. The energy consumption in steady-state phase is given as:

$$E_{steady\text{-}state} = E_{sensing} + E_{processing} + E_{tx\text{-}CH} + E_{rx\text{-}CH} + E_{tx\text{-}CH\text{-}BS} + E_{tx\text{-}Node\text{-}BS} \qquad (18)$$

The energy consumed in $E_{tx\text{-}CH}$, $E_{tx\text{-}CH\text{-}BS}$, $E_{tx\text{-}Node\text{-}BS}$ can be found from any of the Equations (17) or Equation (18), whereas $E_{rx\text{-}CH}$ can be obtained using Equation (19). Sensing energy $E_{sensing}$ and $E_{processing}$ is given by:

$$E_{sensing} = P_{sensing} \times t_{sensing} \qquad (19)$$

$$E_{processing} = P_{processing} \times t_{processing} \qquad (20)$$

So, the total energy consumed E_r is found by substituting the values of Equations (10,18) in Equation (9), we have:

$$E_r = E_{c\text{-}Broadcast} + E_{c\text{-}Recv} + E_{ADV\text{-}Broadcast} + E_{ADV\text{-}Recv} + E_{join\text{-}Req} + E_{Join\text{-}Recv} + E_{tdma\text{-}Broadcast} + E_{tdma\text{-}Recv} + E_{sensing} + E_{processing} + E_{tx\text{-}CH} + E_{rx\text{-}CH} + E_{tx\text{-}CH\text{-}BS} + E_{tx\text{-}Node\text{-}BS} \qquad (21)$$

5. EVALUATION OF THE PROPOSED SOLUTION

For obtaining the experimental proof of our analytical work we have implemented our proposed work with VGDC protocol [26] and compared it with LEACH-M and grid clustering protocols.

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For simulations sensor nodes are randomly spread and moving with a speed of 0-5 m/sec and 0-10m /sec in a sensing area of dimensions 150x150 and 200x200m. SN movement patterns are generated using a Bonn Motion Mobility pattern generator with different random seeds according to Gaussian-Markov model Symbols and their meanings used in this paper are shown in Table 1 and the summary of simulation parameters is shown in Table 2.

5.1 Effects of Round Time

To analyze the effects of round time, we have run simulations on VGDC protocol with different round times calculated from Equation (9) and evaluate data reliability at sink, network energy consumption and disconnection percentage of CH and its members. The round time values calculated from our work are 12, and 22 seconds when we

TABLE 1. SYMBOLS AND THEIR DEFINITION

Symbol	Definition
N	Number of sensor nodes
pcon	contention probability
k	Number of clusters
Nc	Number of nodes in a cluster
m	Packet size in bits
Dinterval	Dissemination interval
tdf	Time taken in transmission of m-bit message

TABLE 2. SIMULATION PARAMETERS

Parameter	Values taken in simulation
Sensing Field Dimensions	150x150, 200x200m
Node Density	90,160
Data Sink Location	Center of the sensing field
Initial Energy	100 J
Node Speed	0-5 and 0-10m/sec
Eelec	50 nJ/bit
Eamp	10 pJ/bit/m2
Etr	0.0013 pJ/bit/m4
Message Size (m)	400 bits

assume that data is disseminated once and twice during a round respectively. For the sake of convenience, we named our protocol as VGDC-a when round time is 12 seconds and VGDC-b when round time is 22 seconds. The evaluated results have been compared with LEACH-M and grid clustering methods for which the round time is fixed to 20 seconds as given by [14]. The reason of fixing this value for the two protocols is that it depends on SNs initial energy. Increase in initial energy of a SN increases round time, which means nodes acting as CHs continues their role for longer duration. They consume more energy than non-CH nodes, so there is a possibility of an early death of a network. We have also calculated the energy consumed in setup phase and the effect of different round times on setup phase energy consumption and discussed it detail in 5.2.
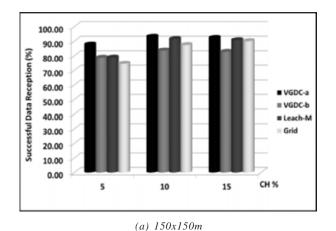
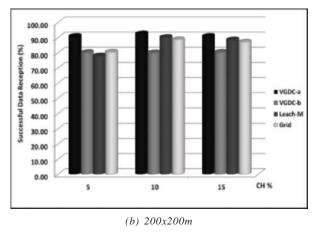### 5.1.1 Reliable Data Delivery

To evaluate the performance of our proposed round time estimate, we have calculated the percentage of data packets delivered to the sink and named it as reliable data delivery. This includes the data packets send to the sink by CHs and nodes that are not associated with any cluster and exchanged data directly to the sink. Each sensor node in our analysis disseminates 49 data packets during the complete simulation run.

Fig. 1(a-b) shows that round time affects the successful data delivery to its final destination when nodes are moving with a speed of 0 and 5 m/sec in sensing areas of 150x150 and 200x200m. At the sink data reception percentage increases with the decrease in round-time. The data reception percentage is approximately 88-93% for VGDC-a and 79-84% for VGDC-b for different number of CHs. For the same number of CHs LEACH-M data reception percentage is in the range of 78-92%. For grid clustering data reception at the sink is in between 74-90% for different cluster percentages.

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Similarly, for a nodal speed of 0 and 10 m/sec in the same sensing fields as shown in Fig. 2(a-b), VGDC-a has the highest reception percentage than VGDC-b, LEACH-M and grid clustering for the same cluster percentages. This means that shorter round time offers stable clusters in MWSN where sensor nodes are moving with low and high speeds. It is possible that longer duration of the round may cause member nodes or CH to move out of their cluster and may result in increasing the distance between sensor nodes, CH and sink.

LEACH-M gives a high data reception percentage at the sink irrespective of the round time. The reason is that, it follows the principle of LEACH protocol, that makes broadcasting of control and data packets to ensure delivery at the intended destination(s) at the cost of energy. Also, the number of packets send directly to sink by the nodes that have not been the part of any cluster is very high. Grid clustering shows higher data reception at the sink because each grid is considered as a cluster, therefore, complete cluster coverage is available throughout the sensing field.

5.1.2 Cluster Maintenance

By cluster maintenance, we mean that CH and SNs should maintain their association during a round irrespective of their movement in a sensing field. The nodes in a cluster is assumed to be associated with its CH if they are in the transmission range of each other. For this, we have
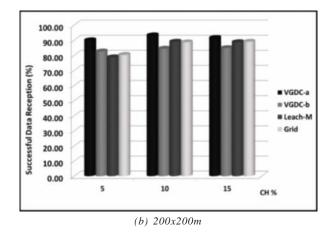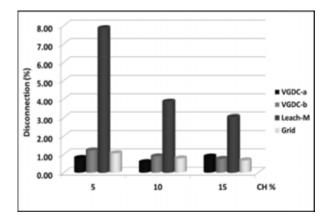

(a) 150x150m

(b) 200x200m

FIG. 1. DATA RECEPTION PERCENTAGE AT THE SINK WHEN NODE SPEED IS BETWEEN 0 AND 5 M/SEC

(a) 150x150m

(b) 200x200m

FIG. 2. DATA RECEPTION PERCENTAGE AT THE SINK WHEN NODE SPEED IS BETWEEN 0 AND 10 M/SEC

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calculated the disconnection percentage between them. It is obtained by taking the percentage of total number of times cluster-member or CH moves out from their cluster, with the distance between them is greater than their transmission range.

Fig. 3(a-b) and Fig. 4(a-b) shows the disconnection percentage between CH and its member nodes when they are moving with speeds between 0, 5 and 10 m/sec respectively. VGDC-a outperforms VGDC-b, LEACH-M and grid clustering for all speeds, sensing dimensions and CH percentages by providing better cluster maintenance strategy.

For node movement speed between 0 and 5m/sec as shown in Fig. 3(a-b) VGDC-a disconnection percentage

ranges between cluster members and their CH is in between 0.7-1.2% in 150x150m area and is between 0.7-1.0% for 200x200m area. Similarly, for LEACH-M this value is in between 3-8% in 150x150m and 5-14% for 200x200m sensing field size. The disconnection percentage value is increased for VGDC-b, but does not exceed 1.2% for all sensing field dimensions, which is still much less than LEACH-M. Fig. 4(a-b) compare the disconnection percentage of the three said protocols when nodal speed is 0 and 10 m/sec. Again, VGDC-a and VGDC-b outclass LEACH-M, and its disconnection percentage is maximum 7% compared to 21% of LEACH-M.

(a) 150x150m

(b) 200x200m

FIG. 3. CH-NODE DISCONNECTION WHEN NODE SPEED IS BETWEEN 0 AND 5 M/SEC

(a) 150x150m

(b) 200x200m

FIG. 4. CH-NODE DISCONNECTION WHEN NODE SPEED IS BETWEEN 0 AND 10 M/SEC

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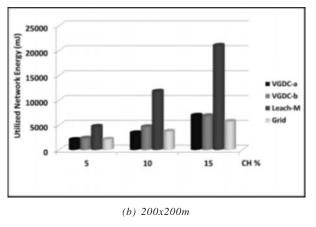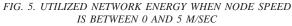
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The disconnection percentages of VGDC and grid clustering protocols is approximately equivalent. Gird clustering protocol is slightly better than VGDC, in grid clustering because each grid is assumed as a cluster where as in VGDC one or more grids are within the cluster coverage depending on a gird size. In VGDC sensor nodes associates itself with the CH based on the cost metric which is the weighted sum of average received CH speed and distance from the SNs. The CH with the minimum or least cost is selected as its CH by the node and they associate themselves with it for the current round to send their data to the sink. Therefore, it is highly likely that if CH or its member relocates itself during a round it may still be within the communication range of each other.
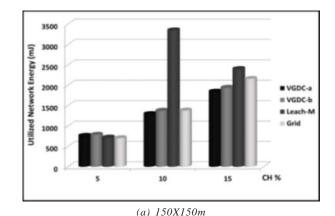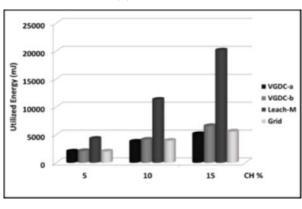
5.2   Network Energy Consumption

For the analysis of energy usage, we have calculated the utilize network energy by noting down the energy spent in sensing, processing transmission and reception of control and data packets. In Figs. 5-6 we have compared the network energy consumed by the three said protocols with nodal speeds of 0-5 m/sec, and 0-10 m/sec respectively.

Energy spent by VGDC-a and VGDC-b protocol is better than LEACH-M for all CH percentages, sensing field dimensions and speeds except for 5% clusters in 150x150m where it is slightly higher.

Due to location awareness, SNs in VGDC either CH or non-CH compute their current distance from data sink and transmit data with signal strength equivalent to carry

(a) 150x150m

(b) 200x200m

FIG. 5. UTILIZED NETWORK ENERGY WHEN NODE SPEED IS BETWEEN 0 AND 5 M/SEC

(a) 150X150m

(b) 200X200m

FIG. 6. UTILIZED NETWORK ENERGY WHEN NODE SPEED IS BETWEEN 0 AND 10 M/SEC
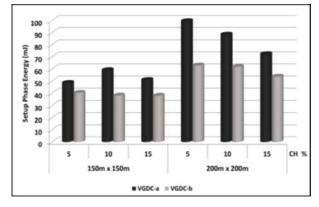
data to that distance which conserves energy. In contrast to this, in LEACH-M for the transmission of control and data packet network wide broadcasts are done that result in better reception percentage of data packets at the sink but increased energy consumption.
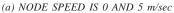
The Grid clustering consumes more energy than VGDC-a protocol when nodes are moving with speed of 0, 5 and 10 m/sec. This is because stable clusters are maintained with small round time and CH-node association criteria of VGDC. Grid clustering shows slightly better results in contrast to VGDC-b when node speed is 10 m/sec because when nodes are moving with high speed it is possible that nodes may move in and out of the grid during a round.
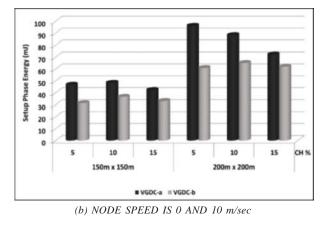
Also, in grid clustering each grid is a cluster so communication cost does not exceed the by setup phase is 1-6% for different cluster percentages in area of 150x150m shown in Fig. 6(a-b). The setup phase length of the sides of a grid. In VGDC the cluster radius comprises of one or more grid depending on grid size, so the communication cost may get increased.
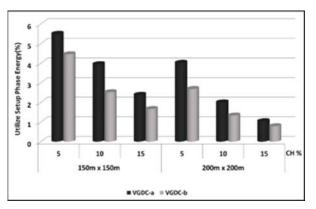
5.2.1 Setup Phase Energy Expenditure

The effects of round time can further be analyzed with the energy consumed in the setup phase and the percentage of the utilized energy spent by the setup phase during communication. Smaller round time invokes cluster formation procedure more often and this causes an increase in the setup phase energy consumption. Fig. 7(a-b) shows the energy consumed in the setup phase VGDC-a and VGDC-b for sensing field sizes of 150x150 and 200x200m area with node mobility between 0, 5 and 10 m/sec. Setup phase energy expenditure is high for VGDC-a and less for VGDC-b. For 5% clusters setup phase energy expense is high, as compared to 15% clusters. This is because an increasing number of clusters increase the likelihood that sensor nodes are close to their nodes are moving with speed between 0, 5 and 10 m/sec respectively. The total energy consumed

energy consumption percentage is in between 5-6% for VGDC-a when cluster percentage is 5. The percentage of setup phase energy expense decreases with the increase in the number of clusters. The setup phase energy expenditure of utilized energy for the sensing field size of 200x200m shown in Fig. 8(a-b). This value ranges from 4-5% low cluster percentage, but decreased with the increase in the number of clusters. Limiting the broadcast messages, transmission distances within the grid and within sensor node's transmission range, shows that VGDC protocol minimizes the energy consumed in the setup phase of a round. It also shows that invoking re-clustering procedure more often increased the energy usage, but at the same time increases the percentage of reliable transfer of data to its intended destination, by maintaining connectivity among CHs and associated SNs.
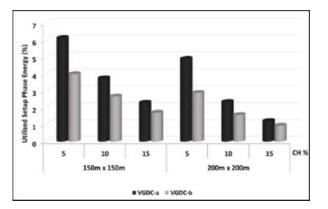

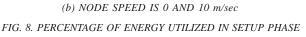*(a) NODE SPEED IS 0 AND 5 m/sec*

(b) NODE SPEED IS 0 AND 10 m/sec

FIG. 7. ENERGY CONSUMED IN SETUP PHASE

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(a) NODE SPEED IS 0 AND 5 m/sec

(b) NODE SPEED IS 0 AND 10 m/sec

FIG. 8. PERCENTAGE OF ENERGY UTILIZED IN SETUP PHASE

6. CONCLUSION

To conserve energy and increased data reliability, we have presented an energy independent round time estimation scheme for MWSN. Our proposed considers time taken by data and control packets to transmit to the destination, data dissemination interval and number of times data are disseminated in a round. This minimizes the possibility that round time expires while nodes are sending data to the destination. It also shows that smaller round time invokes clustering procedure more often but gives better data reliability in between 87-94%. Shorter round time results in the creating more stable clusters by maintaining connectivity between CH and its member nodes. We have also given the analytical estimate of setup phase energy and proves that invoking clustering

procedure more often means smaller round time consumes more energy in setup phase. It also shows that even with smaller round time the total percentage of energy consumed in setup phase is not more 6% from the total utilize network energy.

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