TBEE: Tier Based Energy Efficient Protocol Providing Sink and Source Mobility in Wireless Sensor Networks

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Abstract

In resource constrained wireless sensor networks (WSNs) it is important to utilize energy efficiently. Data dissemination is mainly responsible for the consumption of energy in sensor nodes (SNs). The data dissemination protocols for WSNs should reduce the energy consumption of the SNs. Sink and source mobility is the major challenge for data dissemination protocols. In this paper, a Tier based Energy Efficient protocol (TBEE) providing sink and source mobility in WSNs has been proposed. TBEE protocol has been designed so that fewer SNs located nearer to the dissemination point (DP) respond to the sinks message for grid formation thereby reducing message overheads. TBEE exploits an improved approach of communication amongst the SNs so that the collisions are reduced. TBEE efficiently handles the movement of the sinks and sources in the network and reduces the overheads associated with their mobility. TBEE's performance was evaluated in different conditions and scenarios. Simulation results show substantial improvement by TBEE as compared with the other existing grid based approaches for most of the scenarios.

Keywords: *Wireless sensor Networks, Grid based data dissemination, TBEE.*

1. Introduction

WSNs are being used for applications such as agriculture, habitat monitoring, military surveillance, security intelligence and industry automation. The various challenges of WSNs are scalability, fault tolerance, hardware, power consumption, and topology change [1]. These challenges are to be dealt in order to provide better and efficient solutions for different applications of WSNs. Energy optimization is very important as it improves the life time of WSNs. Reducing energy consumption for extending the lifetime of WSNs is a challenging task [3].

The main purpose of data dissemination is not only to transmit information related to data or query; but also to reduce the overall energy consumption [4, 5]. A number of protocols have been proposed to achieve reliable data dissemination in WSNs. The direct data dissemination approaches are the fastest and easiest but are only feasible for static networks; where SNs have information of the other nodes. Single hop transmission used by direct data dissemination approaches is highly impractical for WSNs. Multi-hop data dissemination protocols support the cooperative effort of various SNs for data dissemination. SNs have a transmission range referred as the distance; where the signal strength remains above the minimum available level for a particular SN to transmit and receive data [6]. If two SNs are not capable of direct communication, they route their data through the intermediate nodes between them [7].

This paper mainly focuses on the mobility (sink and source) and energy efficiency for data dissemination in WSNs. In this paper, we have proposed a protocol namely tier based energy efficient protocol (TBEE) for static SNs where sinks and sources change their locations dynamically. The performance of TBEE has been analyzed and compared with two tier data dissemination protocol (TTDD) [2] and grid based data dissemination protocol (GBDD) [22]. The effect of the grid size on TBEE in terms of energy consumption has also been analyzed.

The rest of this paper is organized as follows: In Section 2, several related work are introduced. In Section 3, we present the analytical model with equations for energy and message overhead calculations. In Section 4, we present our proposed tier based energy efficient protocol. In Section 5, performance of TBEE has been analysed and compared with existing grid based data dissemination schemes. Section 6 is of conclusion.

2. Related Work

Energy efficient routing and data dissemination are the most highlighted research issues in WSNs these days. Sensor protocols for information via negotiation (SPIN) [8] is an important work that is based on the energy consumption and data dissemination in WSNs. Direct diffusion [9] is a data centric routing approach for data aggregation in WSNs. Gradient broadcasting (GRAB) [10] is a general scheme for collecting information where target or the user collecting the information is fixed. GRAB aims at rich data delivery in large WSNs. Low-energy adaptive clustering hierarchy (LEACH) [11] is a clustering based protocol to collect data from WSN. LEACH is an energy conserving protocol based on the clustering for aggregating the data to the CHs. Geographical multicast routing protocol (GMR) [12] routes data through the shortest path, but the location update messages are individually forwarded by a mobile sink to sources whenever there is movement in each sink. Region based data dissemination scheme RBDD [13] performs local flooding within group region; based on the current location of the mobile sink. All the sinks receive data without any location updates. It supports mobility for sinks that move in or out of their region. RBDD offers improved data dissemination and is energy efficient scheme for WSNs. Trajectory and energy-based data dissemination protocol (TEDD) [14] combines the concepts of trajectory based forwarding with the power levels of SNs to calculate forwarding paths. When a SN receives a data packet, it decides (based on its location) whether the data packet should be forwarded. The data dissemination system adapts dynamically on the left over energy of the SNs. Due to the limited processing capacity and energy of SNs, TEDD is not quite easy to implement. Hierarchical cluster based data dissemination (HCDD) [15] scheme organizes SNs into a hierarchical structure, so that each SN has to locally exchange the information with its immediate neighboring nodes. HCDD builds single or multiple hierarchical structures to support multiple source nodes. HCDD avoids the increasing overhead of route discovery if the number of source nodes increase. HCDD is scalable for the large scale WSNs.

Virtual grid concept is simple to implement as compared to cluster based schemes for WSNs. It not only reduces storage requirements but also reduces the energy consumption of SNs. TTDD [2] is the scheme that works on the moving sink (the number of sinks may vary). This scheme utilizes the square virtual grid paths for data dissemination instead of using all the SNs of the whole sensor field. TTDD reduces energy consumption of the whole network. TTDD always maintains square virtual grid paths instead of using the shortest possible path, which is a diagonal path. Geographical and energy aware routing scheme (GEAR) [16] utilizes the geographical location information to route queries or data to any specific region in the wireless sensor field. If the locations of the sources are known, this scheme saves energy by limiting the flooding to that geographical region. Geographical adaptive fidelity scheme (GAF) [17] builds a geographical grid to turn off sensor nodes for minimizing the energy consumption. GAF grid is pre-determined and well synchronized in the complete wireless sensor filed, whose cell size is determined by the communication range of SNs. Distance vector multicast routing protocol (DVMRP) [18] supports data delivery from multiple sources to multiple destinations and faces similar challenges of TTDD. Energy Efficient Data Dissemination protocol (EEDD) [19], addresses the issues of target and inquirer mobility and energy conservation. EEDD improves the network lifetime by adopting a virtual-grid-based two-level architecture to schedule the activities of SNs. Data dissemination with ring based index [20] scheme collects, processes and stores sensed data at the nodes close to the detecting nodes. The location information of these storing nodes is pushed to some index nodes, which act as the rendezvous points for sinks and sources. A Diagonal-based TTDD (A-TTDD) [21] approach adopted the diagonal structures for data dissemination, so that energy consumption is reduced. Grid based data dissemination scheme (GBDD) [22], is a dual radio based grid construction scheme; which exploits dual radio mode of a sensor node to for data dissemination. Grid construction is initialized by the sink appearing in the sensor field when no valid grid is present. Any sink appearing during valid grid period shares existing grid and thus obviate the need to construct new grid. GBDD disseminates data diagonally across the grid using high power radio transmission mode in order to conserve energy.

3. Analytical Model

Assuming that N location aware SNs (coordinates known to each SN) are uniformly distributed over an area A (as shown in fig. 1). Sink & Source are mobile, whereas SNs are static. Sink and SNs have transmission range R. Sink sends a query message to all the SNs within its transmission radius (R) (as shown in fig. 4). There may be K_i moving sinks in the sensor field (where i=1, 2, 3, 4….).The sink moves with an average speed S. Each node transmits d data packets in time period T, of size *PackLEN*. If there are n SNs in a cell, then there will be $\sqrt{n}$ SNs on each side of the cell. Let the grid size be $\alpha \times \alpha = \alpha^2$, where α is the distance between the crossing points of the grid.

The sensor nodes can be arranged into a grid structure as shown in figure 1. Sink initiates the grid formation by broadcasting an election message and its coordinates. SNs in area πR^2 around the sink will be receiving this message.

If only those sensor nodes which falls in radius greater than $R/2$ from the sink respond to sinks message; then other SNs will be conserving their energy. The area ($A_{respond}$) in which SNs respond to sink's election message is given by Eq. (1) and is shown in figure 2. The area ($A_{respond}$) whose nodes will respond (as shown in fig. 2 is given by Eq. (1).

$$\begin{aligned} A_{respond} &= \pi(R)^2 - \pi(R/2)^2 \\ &= \pi\,[R^2 - R^2/4] \\ &= \pi\,[3R^2]/4 \\ &= \pi[\sqrt{3}/2\ R]^2 \qquad (1) \end{aligned}$$

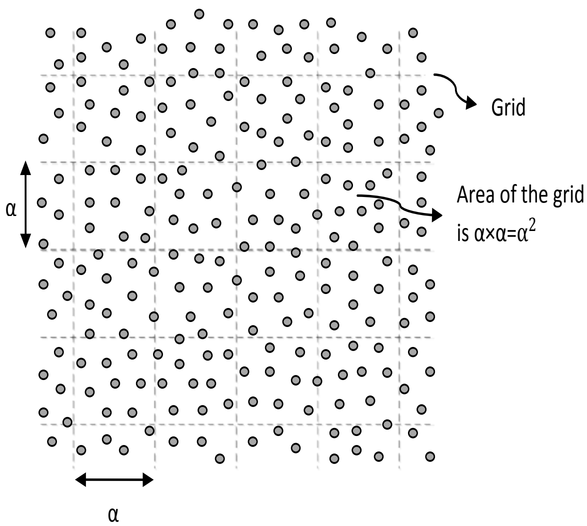

Fig. 1 Grid structure for area α×α=α².

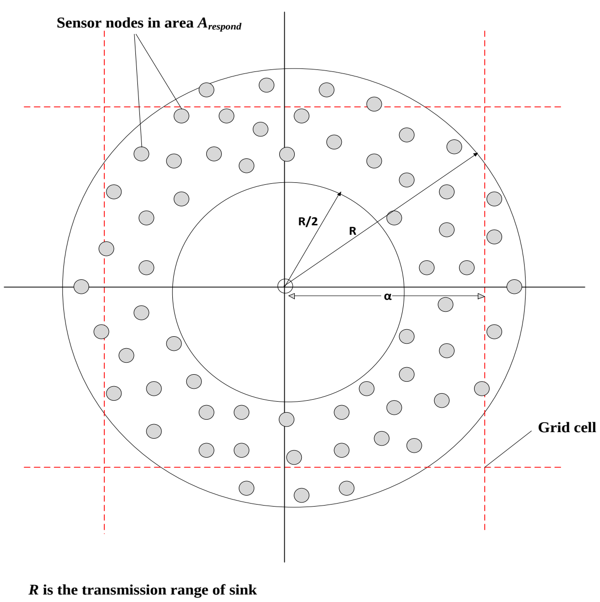

Fig. 2 Area ($A_{respond}$) in which SNs respond to sink's election message.

3.1 Energy Consumption

Assuming, initial energy of a SN is $E_{i,initial}$, $E_{i,sense}$ is per bit sensing energy consumed by a SN, $E_{i,Tx}$ is the transmission energy consumed per bit, $E_{i,Rx}$ is the receiving energy consumed per bit and $E_{i,process}$ is the processing energy consumed per bit by a SN, then the total energy consumed ($E_{i,Total}$) by a SN at particular instant of time is given by Eq. (2).

$$\begin{aligned} E_{i,Total} = {} & (b(E_{i,sense})) + ((p)(n)(E_{i,Rx})(PackLEN)) + \\ & ((m)(E_{i,Tx})(PackLEN)) + \\ & ((k)(E_{i,process})(b+((p)(n)(PackLEN))) \qquad (2) \end{aligned}$$

SN which will act as dissemination nodes (DNs) will be responsible for transmitting the packets received from the non-dissemination nodes towards the sink. Assuming, $E_{i,DN}$ is the energy consumed by a DN at any particular time and $E_{i,LN}$ is the energy consumed by a non-dissemination node at any particular time. Energy consumption of $E_{i,DN}$ and $E_{i,LN}$ at particular instant can be derived from Eq.(3) and is given by Eq.(4) and Eq.(5). DN will be consuming energy in sensing, receiving from non-dissemination nodes, processing the received and sensed data and in transmission of packets towards the sink. Energy consumption of non-dissemination nodes is less as compared to DNs as they will only consume energy in sensing and transmitting packets to DN.

$$E_{i,DN} = E_{i,Total} \qquad (3)$$

$$E_{i,LN} = (b(E_{i,sense})) + ((p)(E_{i,Tx})(PackLEN)) \qquad (4)$$

Where, b is the number of bits sensed by the SN, p is the number of data packets sent by a SN to DN, n is the number of SNs from which DN is receiving packets, m is the number of data packets sent by the DN, k is the number of data packets processed by the DN and $PackLEN$ is the data packet length.

3.2 Communication overhead

Assuming a rectangular sensor field of area A in which there are $n = \frac{N\alpha^2}{A}$, SNs in each cell and $\sqrt{n}$SNs on each side of cell. The data packet has a unit size and the messages have comparable size L. Assuming that there are k sinks in the sensor field moving with an average speed S. Sink receives d data packets from the source in the T time period. Further assuming that the sink traverses m cells, where the upper bound of m is $1+\frac{ST}{\alpha}$ and if m=1, then the sink is stationary. Sink updates its location m times as it traverses m cell and receives $\frac{d}{m}$ data packets between two successive locations.If sink updates its location by flooding a query locally to reach its nearby dissemination nodes only(as explained in section 4.4 for TBEE) then overhead for the query (without considering query aggregation) is nL, where nL is the local flooding overhead. The overhead for k mobile sinks is then *km (nL).*

If WSN consists of N SNs, then for updating a mission additional overheads for TBEE (as explained in section 4) are NL and $\frac{4NL}{\sqrt{n}}$ (for grid formation). The total communication overheads for TBEE are given by Eq. (5)

$$CO_{TBEE} = NL + \frac{4NL}{\sqrt{n}} + kmnL \qquad (5)$$

The total communication overheads of TTDD [2] is given by Eq. (6)

$$CO_{TTDD} = NL + \frac{4NL}{\sqrt{n}} + kmnL + kc(mL + d)\sqrt{2N} \qquad (6)$$

The comparison of TBEE and TTDD in terms of communication overhead can be done considering a scenario where a sensor network consists of N=10,000 SNs, there are n=100 sensors in a TBEE grid cell. Suppose c=1 and L=1, to deliver d=100 data packets. For the stationery sinks, m=1 and suppose there are two sinks (k=2), then $\frac{CO_{TBEE}}{CO_{TTDD}} = 0.33$. If sinks are mobile then ratio of communication overhead is, $\frac{CO_{TBEE}}{CO_{TTDD}} \rightarrow 0.4142$, as m $\rightarrow \infty$. The above comparison shows that TBEE has less communication overheads as compared to TTDD, hence is more energy conserving.

4. TBEE: Tier Based Energy Efficient Protocol

TBEE has been designed for WSNs where the nodes know their respective coordinates. Sink initiates the process of grid formation by sending an election message. Along with election message sink sends the calculated coordinates of DPs, which are virtual cross-section points of the grid. Nodes on receiving election message calculate their respective distance from DP (to which they are closest) and respond to sink with their coordinates and their respective distance from the closest DP. Sink elects the nodes closet to DPs as dissemination nodes (DNs) by sending an appointment message. Later subsections and scenarios explain the working of TBEE.

4.1 Grid Construction

TBEE has been designed for WSNs where transmission range (R) of nodes and sink are same. All the nodes in the area πR^2 from a particular sink or other node will receive their transmission. Sink node calculates DP in all four direction at distance α $(\left(\frac{3R}{4}\right) < \alpha < R)$. The location of DPs will be $(x \pm \alpha, y \pm \alpha)$. Grid formation is initialized by sink by broadcasting an election message along with its coordinates and mathematically calculated DPs (of all the four directions). SNs which are in the radius of R/8 of DP upon receiving this message; calculate their respective distance from DPs. SNs respond to sink by broadcasting their coordinates and the calculated distance from DPs. Sink elects dissemination nodes (in all four directions) which are closest to DPs by sending an appointment message along with coordinates of the nodes. If there are two or more SNs, who have same distance from the dissemination point then anyone of them can be elected as DN. Similarly, appointed DNs will further elect other DNs in entire sensor field. The appointment of new DN by another DN is shown in figure 3. SNs which fall in radius less than R/8 from DP upon receiving election message transmit their calculated distance from DP and their coordinates. The node (A) closest to DP is appointed as DN. A virtual grid is formed by appointment of DNs throughout the sensor field.

TBEE can construct grids of size α, which is much larger than the transmission radius R, by appointing intermediate DNs (IDN). The process is similar to appointing DNs by the sink. The Sink broadcasts an election message for the formation of IDNs. The SNs which fall in the radius greater than $\frac{3R}{4}$ and within the distance $\frac{R}{8}$ from the intermediate dissemination point (IDP) will respond to the message by sending their coordinates distance from the IDP (as shown in figure 4).

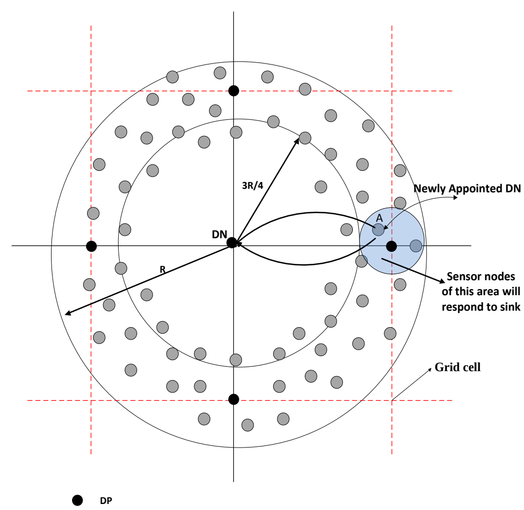

Fig. 3 Appointment of dissemination node during grid formation.

The Sink node will appoint an IDN within its transmission radius. Sink node sends the coordinates of DPs while appointing the IDNs. The SNs can communicate with sink either through DNs or IDNs. The IDNs calculate whether the dissemination point is within their transmission range or not. If DP is not in the transmission range of the IDN it further appoints another IDNs till DN is not appointed. The Sink node will communicate to the DN through IDNs. While the grid is being constructed, the appointment of DNs in the direction where the DN has already been appointed is efficiently handled by TBEE. As shown in figure 5, A, B, C and D are the DNs formed by the DN, P. Now DN, B will broadcast the election message for further formation of new DNs. When this election message is received by the previously formed DN i.e. P, it sends a message to B notifying it it's coordinates (that it is the DN already appointed in that particular direction). SNs of remaining three directions will send their coordinates to B and B appoints the remaining DNs.

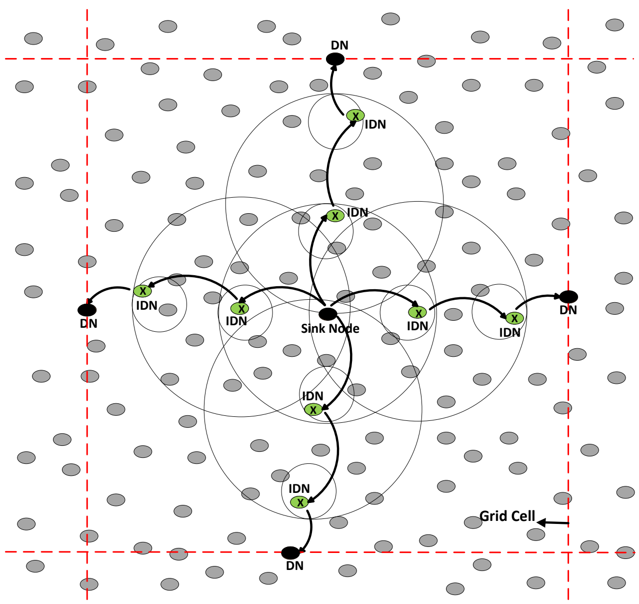

Fig.4 The formation of the grid when the value of α is much larger *R*.

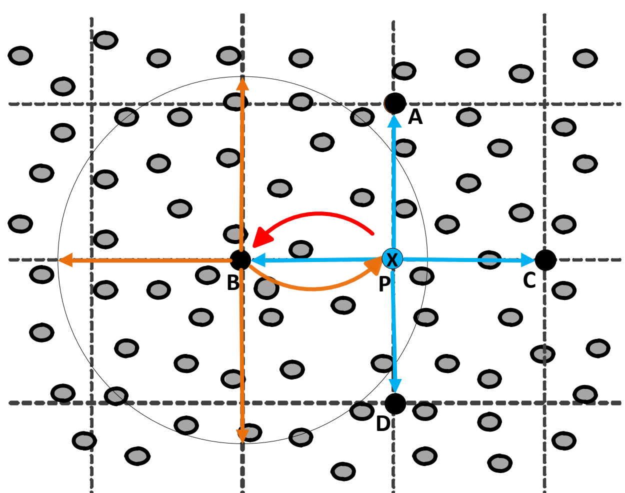

Fig. 5 Formation of the dissemination nodes.

4.2 Grid Termination

TBEE stops grid formation when the grid is formed for whole of the sensor field. As shown in figure 6, B is the DN and P is the DP. B broadcasts an election message for the further appointment of DNs. The nodes in the area $\frac{R}{8}$, from DP will respond to the election message by B. Since there are no SNs in that area of P (SNs which lie in the dark circled area have to respond to the B), B will not receive any message from that particular directions DP. The grid formation will be terminated in that particular direction by B but grid formation will continue in other directions. The SNs in that particular direction associate with B for sending their packets to sink.

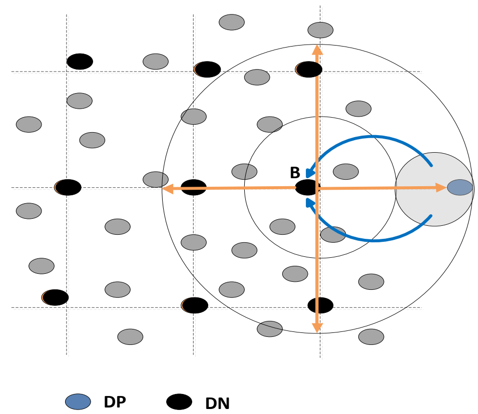

Fig. 6 Grid termination at the border.

4.3 Scenario 1: Grid maintenance with multiple sinks

The grid will be formed by TBEE as explained earlier but in case of a new sink that appears at any place in the network, the new sink will not construct its grid but will use the previous existing grid. The new sink will broadcast a message for the formation of its DNs. As shown in figure 7, DNs A, B, C and D formed by sink 1are in transmission range of sink 2, so upon receiving the message will respond to the election message of sink 2, intimating it about their status. Sink 2 will terminate the process of grid formation and will use grid formed by sink 1. Initial grid formed will be used by another new sinks for their data dissemination.

In case, when the DNs of the initial grid are not in transmission range of another sink then it will appoint its own DNs initially. New grid formation will continue in the direction where the DNs of previous grid are not in the transmission range of DNs of new grid. DNs of new grid will terminate the grid formation if it has at least two DNs of previous grid are in its transmission range. As shown in figure 8, E, F, G and H are the DNs appointed by sink 2.

When E broadcasts election message, A and B will respond to it by intimating their status. The grid formation is terminated by E. Similarly the grid formation will be terminated by other DNs formed by sink 2. Sink 2 will make use of grid formed by sink 1 through its DNs for data dissemination.

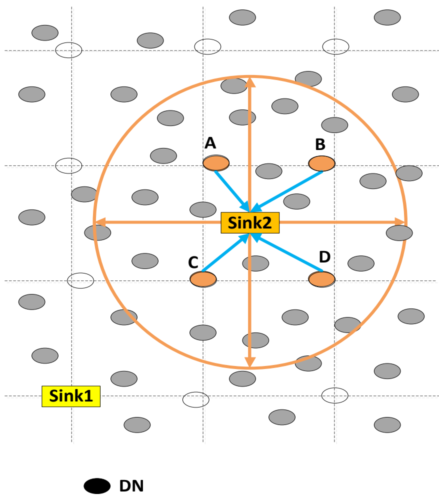

Fig. 7 Grid structure when multiple sinks exist.

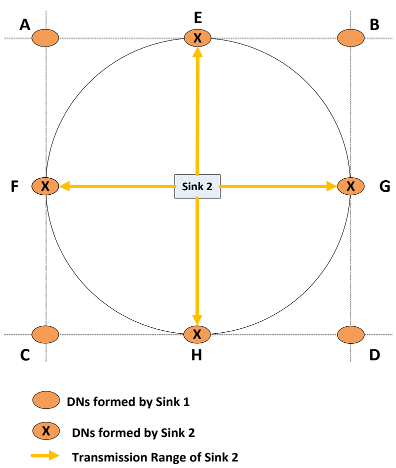

Fig. 8 Grid formation by sink 2.

4.4 Scenario 2: Grid maintenance when DNs reach threshold value of energy

The data dissemination will be through DNs; hence they will be consuming more energy as compared to other SNs (as given by Eq. (3) and Eq. (4)). In order to increase the life time of the network at DN upon reaching a threshold value of their energy (fifty percent of the initial energy), send an election message to SNs along with the coordinates of DP (since; it can be different than DN's coordinates) and coordinates of DNs which are in its transmission range. The nodes which are within the distance $\frac{R}{8}$ from the DP and at least two DNs are within their transmission range respond to this election message by sending their coordinates and the energy level to the electing DN. If the energy level of nodes is more than that of the electing DN, node with maximum energy level is appointed as DN. In case more than one node reports the same maximum energy level; appointing DN appoints any one of them as DN. The new DN will elect IDNs for the DNs which are not in transmission range of new DN. The appointment of new DN and IDNs are intimated to the sink by the new DN. If no SN responds to the election message of DN, then DN continues till it reaches another threshold level (seventy five percent of initial energy). DN if upon reaching this threshold level is unable to appoint new DN, it sends a re-election message to sink. A new grid formation is initiated by the sink.

4.5 Scenario 3: Movement of sinks

When sink is mobile it appoints SN nearest to it as DN. If the newly appointed DN is within transmission range of DNs(in all four directions) then it will not appoint any IDN otherwise it will appoint IDNs in the directions, whose DNs are not in its transmission range. As shown in figure 9, nearest node Sink 1is appointed as DN and is within the transmission range of its neighbouring DNs. Sink 1 moves from its initial location to new location; it comes under the transmission range of DN, A. Sink 1 will use A for data dissemination. If while moving sink is not in transmissions range of any DN it will appoint the IDNs in all four directions to communicate with the nearest DN. Similarly, Sink 2 appoints DN, C (as its nearest node). Now as it moves from its previous location to new location, it comes under the transmission range of DN, D.

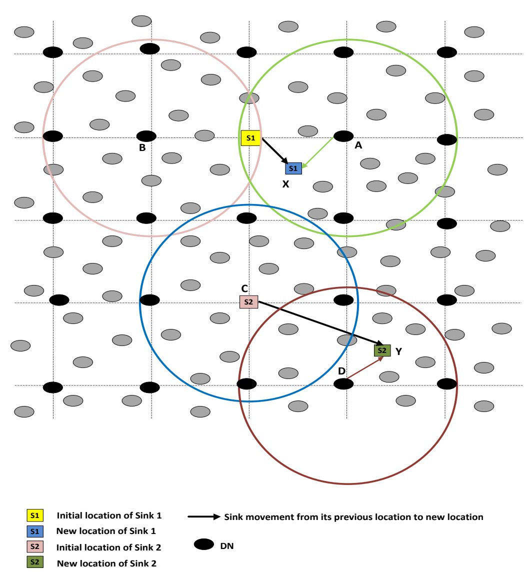

Fig. 9 Movement of sinks to new location.

4.6 Scenario 4: When source is mobile

TBEE can handle the mobility of source since every SN has a DN through which it transfers data diagonally towards the sink. As shown in figure 10 suppose the source is mobile the nodes sensing it will transmit the sensed data through their DNs towards the sink. In figure 10, when source moves to a new location all the data generated by the source will be transferred to sink through the DN, E of the grid.

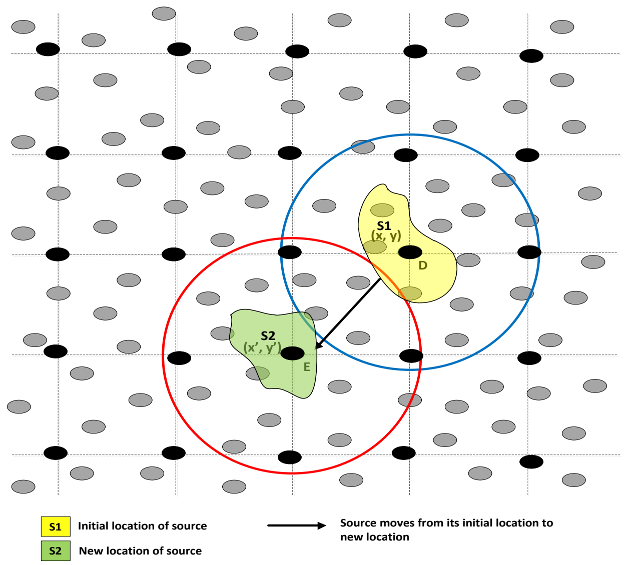

Fig. 10 Data dissemination by mobile source.

4.7 Scenario 5: Communication of SNs to the querying DN

TBEE is able to handle queries efficiently and avoids collisions so that retransmissions are avoided. Whenever sink wants information from some of the SNs the data is routed through a DN towards the sink. As shown in figure 11, SNs, S1 to S7 transmit their sensed data towards the sink through to DN, B.

SNs upon receiving query to send their sensed data wait for a guard time t_g before attempting to transmit anything. After the guard time expires or the channel is free, each SN will wait for a random listening time t_L before transmitting their data. The guard time t_g is to ensure that SNs reliably estimate the channel as either busy or idle. The additional random listening time t_L is to prevent nodes attempting to transmit their information at the same time. Suppose S1 sends RTS (Request to Send) message to B. The other SNs will be listening to the message will sense that the channel is busy. B will send CTS (Clear to Send) message to S1. Then, S1 will exchange the DATA & ACK (acknowledgement) packets with B; thereafter channel is free for further communication by other SNs. This above stated scheme of TBEE prevents collisions; hence energy consumption for retransmission is conserved.

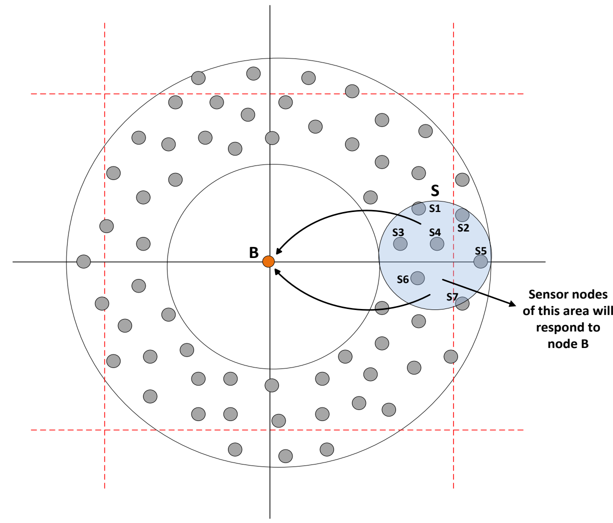

Fig. 11 Communication of SNs with node B.

5. Performance Evaluation & Simulation Results

Performance of TBEE was evaluated through simulations. Omnet++ an event based simulator was used for simulations. Simulation metric, parameters and evaluation methodology have been described in sub-section 5.1. The effect of various factors such as number sinks, varying number of sources and grid cell size on the performance of TBEE was evaluated. Performance of TBEE was compared with GBDD and TTDD.

5.1 Simulation metric, parameters and evaluation methodology

Same simulation parameters were taken for comparing TBEE with GBDD and TTDD. The SN's transmitting, receiving and idling consumption of power were taken as 0.66 W, 0.395 W and 0.035 W respectively. The simulations were performed with sensor field of 200 SNs, which are uniformly deployed in a 2000 X 2000 m^2 field. Packet length of query packet was considered as 36 bytes & each data packet was considered to be of 64 bytes. Various parameters used for simulation are given in table 1.

Two metrics were used to evaluate the performance of TBEE protocol. Our first evaluation metric is total energy consumption by SNs in transmitting and receiving queries and data. Energy consumption by nodes in idle state is not considered as it does not reflect energy consumption in retrieval of data packets. Second, evaluation metric is the average delay which is defined as the average time taken by packets to reach sink from the source. It was averaged overall between source-sink pairs

Table 1. Simulation Parameters

Parameters	***Value***
Transmitting power of a SN	0.66 W
Receiving power of a SN	0.395 W
Idling consumption of a SN	0.035 W
Number of SNs	200
Area in which SNs are deployed	2000 X 2000 m^2
Query packet size	36 bytes
Data packet size	64 bytes
t_q	50 µs
t_L	100µs

5.2 Effect of number of sources and sinks on total energy consumption

The impact of variable number of sources and sink on total energy consumption has been evaluated for TBEE. There is varying number of sinks and sources to study and evaluate the effect on total energy consumption. Figure 12, shows the total energy consumption for the varying number of sinks with a single source. Results show that as the number of sinks increase the energy consumption also increases. Results of figure 13show the total energy consumed by the three protocols for the varying number of sinks with 8 sources. The total energy consumption increases as compared to the results of figure 12. The results of figure 12 and 13 show that the total energy consumption increases as the number of sources increase for all the three protocols but TBEE consumes less energy when compared with TTDD and GBDD.

5.3 Effect of number of sources and sinks on average delay

Figure 14 and figure 15 shows the average delay for varying number of sinks with single source and 8 sources respectively. It can be seen from the figures that average delay increases as the number of source increase. Average delay for GBDD is less as compared to TTDD and TBEE. This average delay is less for GBDD because SNs use high power radio for diagonal transmission of data towards the sink. The energy consumption of nodes is more if they use high powered radio for transmitting packets to a longer distance. There is an improvement by TBEE in terms of average delay when compared to TTDD.

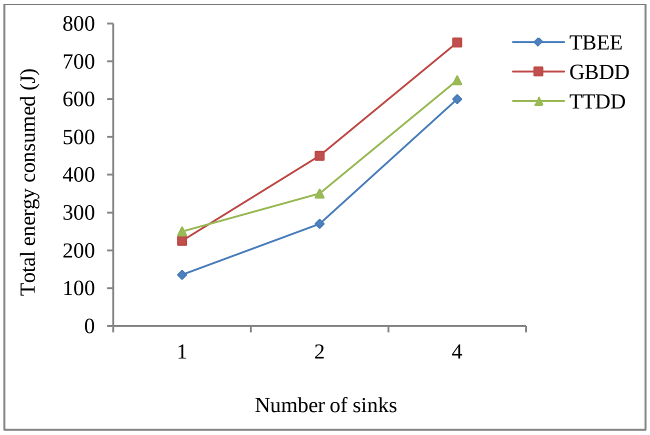

Fig.12 Total energy consumption for varying number of Sinks with single source.

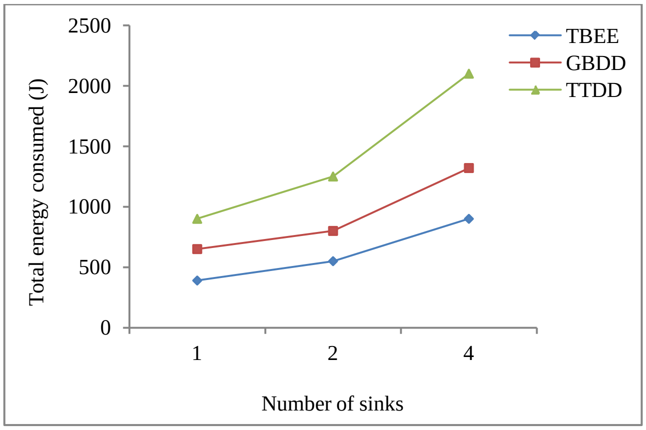

Fig.13 Total energy consumption for varying number of sinks with 8 sources.

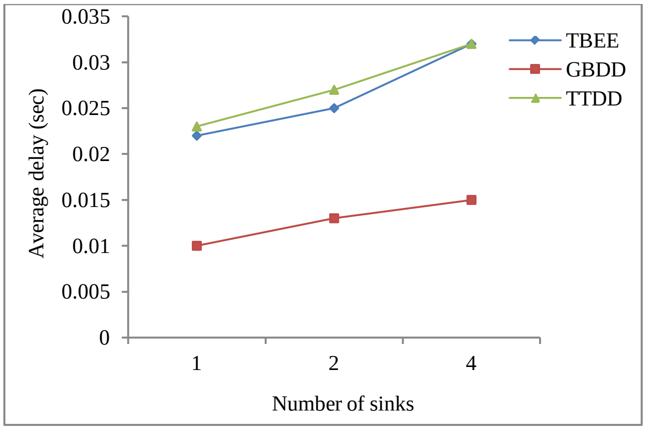

Fig.14 Average delay for varying number of sinks with single source

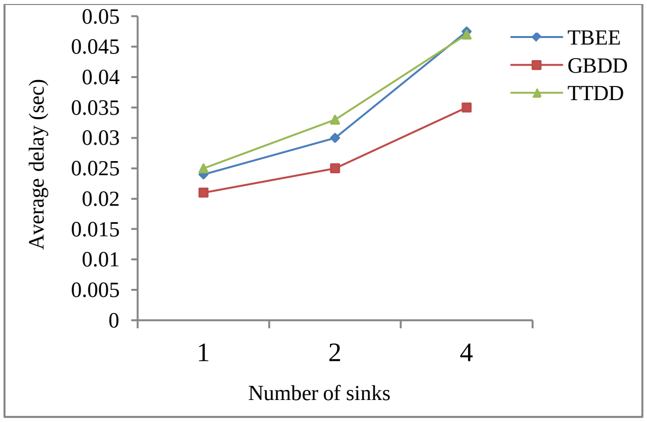

Fig.15 Average delay for varying number of sinks with 8 sources

5.4 Effect of Sink mobility on total energy consumption

Figure 16, shows the total energy consumption for mobile sink with varying speeds. If the speed of the sink is less the energy consumption is also less. As the speed increases the total energy consumption increases though energy consumed by TBEE is less as compared to TTDD and GBDD. This is because TBEE appoints less number of new DNs and makes use of the previous DNs.

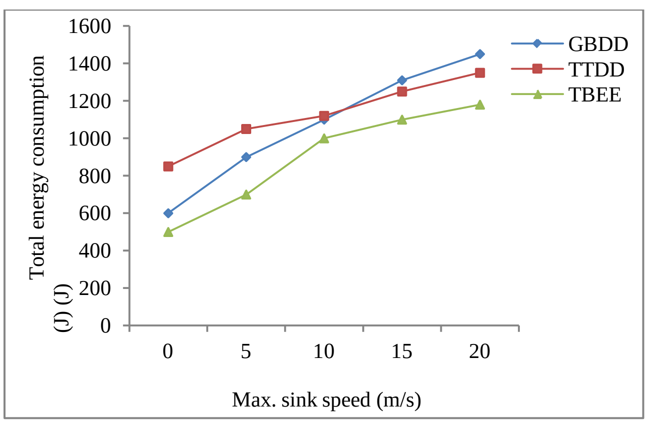

Fig.16 Total energy consumption for sink moving with varying speed

5.5 Effect of Cell Size α

The effect of cell size (α) on average energy consumption in the WSN for TBEE and TTDD is shown in figure 17. The results were obtained for1000 SNs deployed in the 6200 X 6200 m^2 sensor field. The nodes were placed evenly at 200 m distance with single source and sink. The cell size was varied from 400 m to 1800 m with an incremental step of 200m. Results show the average energy consumption of TBEE is less as compared to TTDD. The reduction in average energy consumption is more till the cell size is 1200 m, thereafter there is no significant reduction in the average energy consumption by TBEE. This results show that TBEE's energy consumption is effected by the grid cell size of the grid.

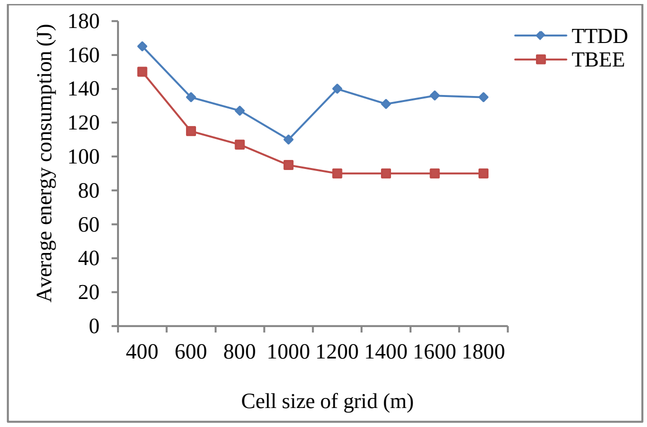

Fig. 17 Average energy consumption for varying cell size.

5.6 Effect of transmission radius for election message on TBEE.

The SNs which fall in a particular area from DP respond to election message. This reduces the overall energy consumption in a network. Results of figure 18 show average energy consumption of nodes for varying radius for communication in response to election message by sink. When the radius is $\frac{R}{2}$ from DP energy consumption is most but as the radius is reduced, the energy consumption also reduces because less nodes respond to the election message. Energy consumption is constant when the radius is further reduced from $\frac{R}{6}$, because the nodes are uniformly deployed and further reduction in radius does not reduce the number of nodes which respond to the election message.

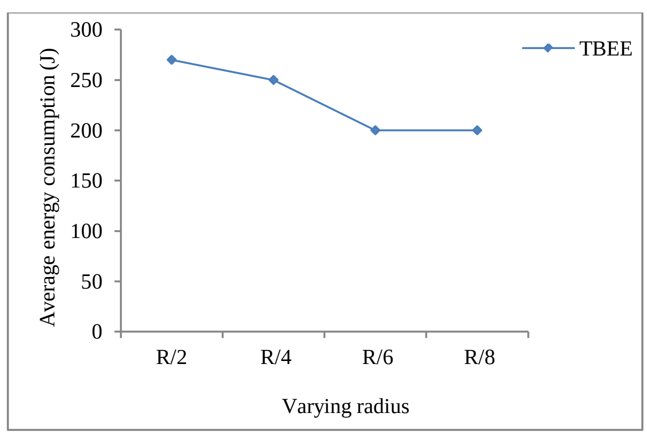

Fig.18 Average energy consumption of nodes for varying radius of communication to election message.

6. Conclusion

Virtual grid is quite useful and beneficial for the communication and data dissemination for the wireless sensor networks. Network lifetime can significantly be increased by reducing the transmission of packets. Our proposed protocol namely TBEE is energy efficient and is capable of handling sink and source mobility in wireless sensor networks. TBEE initially forms a virtual grid for the whole network. Grid formation is initiated by the sink and other sinks in the network use the previously constructed grid, which significantly reduces the energy consumption of the nodes. Mobility of the sinks and sources is efficiently managed by the message exchange and path discovery through the nearest dissemination nodes. Simulation results for TBEE show that when fewer nodes are located nearer to the dissemination points then the energy consumption is reduced. When the cell size of the grid is much larger as compared to transmission range of sensor nodes, the overall energy consumption in the network is reduced significantly by TBEE. Significant improvements in the simulated results are shown by TBEE when compared with TTDD and GBDD.

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