A Novel Cluster-based Energy Efficient Routing in Wireless Sensor Networks

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***Abstract*—Recent development in electronics and wireless communications has enabled the improvement of low-power and low-cost wireless sensors networks. Wireless Sensor Networks(WSNs) are a combination of autonomous devices transmitting locally gathered information to a so-called sink node by using multi-hop wireless routing. One of the most important challenges in WSNs is to design energy efficient routing mechanism to increase the network lifetime due to the limited energy capacity of the network nodes. Furthermore, hot spots in a WSNs emerge as locations under heavy traffic load. Nodes in such areas quickly drain energy resources, leading to disconnection in network services. Cluster based routing algorithms in WSNs have recently gained increased interest, and energy efficiency is of particular interest. A cluster head (CH) represents all nodes in the cluster and collects data values from them. To balance the energy consumption and the traffic load in the network, the CH should be rotated among all nodes and the cluster size should be carefully determined at different parts of the WSNs. In this paper, we proposed an cluster based energy efficient routing algorithm (CBER), CBER elects CH based on nodes near to the optimal cluster head distance and residual energy of the nodes. In WSNs energy is mostly consumed for transmission and reception, it is a non linear function of transmission range.In this paper, the optimal cluster head distance which links to optimal energy consumption is derived. In addition, residual energy is considered in the CH election in order to increase the network lifetime. Furthermore, the energy consumption of being a CH is equally spread among the cluster members. Performance results show CBER scheme reduces the end to end energy consumption and prolong the network lifetime of multi hop network compared to the well-known clustering algorithms LEACH and HEED.**

Keywords - MANETs, Clustering, Energy efficiency, Wireless Sensor Networks, and Routing.

I. Introduction

Typical sensor nodes are able to carry out sensing, data processing, and communicating components, making it feasible for a wide range of promising applications, such as: environmental monitoring (e.g., humidity,temperature), disaster and health care areas providing relief, conferencing,file exchange, commercial applications including controlling product quality, military applications and managing inventory [1]. For these purposes, sensors are usually deployed densely and operated autonomously. Furthermore, sensor nodes are normally battery-powered, and left alone makes it quite challenging to recharge or replace node batteries. Hence, one of the important problems in WSNs is how to prolong network lifetime with constrained energy resource. If each and every node starts to transmit and receive data in the network, great data collisions and congestions will be experienced. Therefore, the nodes in WSNs will run out of energy very quickly. As a result, the energy of each sensor nodes being a major limitation.The research in data centric WSNs is concentrated on selection of network architecture and energy efficient data gathering, as a backbone of routing protocol and data aggregation mechanism, plays a important role in achieving it. All aspects, including protocols, architecture, algorithms and circuits, must be made energy efficient to prolong the network lifetime of the sensor node. At routing layer, the main purpose is to determine ways for energy efficient route and reliable forwarding of data from the source nodes to the sink to save energy consumption. We aims on the network level energy preservation protocols and algorithms in this paper. Due to different inherent characteristics of the WSNs that differentiates from other known networks such as cellular or mobile ad hoc networks makes very challenging for designing routing protocols. Furthermore, there may also be other critically-located sensors not necessarily close to data sinks, which carry the burden of relaying large amounts of data traffic, especially when multiple high-rate routes pass through these sensors. Such nodes are usually frequently chosen to be data relays by routing algorithms and may serve a large portion of the network traffic, due to their convenient locations. Thus, avoiding the failure of such nodes caused by early energy depletion is critical to ensure a sufficiently long network lifetime.

Routing algorithms can be widely classified into two categories . They are direct routing and indirect routing. In direct routing algorithms [2], [3] each nodes in WSNs directly forward the gathered data to the sink node. Contrarily, indirect routing algorithms [4], [5] are those clustering algorithm that creates different clusters of sensor nodes in WSNs. Clustering is suggested to WSNs due to its advantages of energy saving, network scalability and network topology stability [4]–[6]. Furthermore, clustering technique decreases the overheads occurred due to communication, thereby reducing interferences and energy consumptions among network nodes. In addition, clustering improves the efficiency of data relaying by decreasing number of nodes required to forward data in the WSNs, using data aggregation at CHs by intra cluster communication decreases overall packet loses. However, clustering algorithms have some disadvantages compared to other mechanisms, such as additional overheads during CH selection, cluster formation, and assignment process.

Clustering through formation of hierarchical WSNs helps in efficient use of limited energy of sensor nodes and hence improves network lifetime. Clustering has a potential impact on WSNs applications where a huge number of ad hoc sensor nodes are distributed for sensing purposes. In conventional clustering, the nodes in WSNs is divided into small groups called clusters and from each cluster one node is selected as CH which then grant other nodes to join to create the cluster. During information collection phase CH gathers information from all of its cluster members and after its aggregation forwards to the next adjacent CH and last to the sink node. While using conventional clustering, sensor nodes elected as CH are believed to absorb more energy as compared to other cluster members, due to their long range or multi hop transmissions to the sink node, and may lead to an irregular energy consumption of sensor nodes in the WSNs.This problem can be avoided by efficient rotation of CH nodes and provided a major breakthrough in cluster based data collection in WSNs. Furthermore, regular re-election of CHs within clusters depending on their remaining energy is a possible way to reduce the total energy consumption of every cluster. In addition, clustering scheme must be developed for various application scenarios to have capabilities like scalability, transmission coverage, prolonged lifetime, robustness, and simplicity [4]–[6].Furthermore, the hot-spot issue is a major concern around sink nodes where large amounts of data are merged. In fact, as the hop distance to a sink decreases, the traffic on CHs quickly intensify. Hence, there is an obvious relationship between the hop-distance to a sink node and the amount of data that has to be forwarded. This uneven energy consumption of the CH node can rapidly disconnect the entire WSNs if the communications are extended. Many proposals have concentrated on this problem. However, they have their own performance limitation. We proposed CBER algorithm aimed at prolonging the overall network lifetime and energy efficiency. With our scheme, the CH election depends upon the optimal cluster head distance and remaining energy of the sensor node.

The remainder of the paper is organized as follows. In Section 2, we continue with related work. Section 3, shows the energy consumption model. In Section 4, we derive the optimal cluster head distance. In Section 5, we propose the new scheme CBER. Section 6 shows the performance of the proposed scheme and we provide conclusions in Section 7.

II. Related Work

Many different approaches have been carried out to design feasible WSNs. Energy conservation is crucial to the prolong the network lifetime of WSNs. Many approaches for energy efficient routing have been proposed to reduce energy consumption. One alternative approach to conserve energy is using clustering technique [7]. In addition, when scalability is considered to be a major problem when network density is of hundreds and thousands of nodes then clustering is considered to be a useful technique. In various WSNs applications routing efficiency is considered important for energy efficiency, load balancing, and data fusion [8]. In this paper we are concern about CH selection schemes and discuss some of the associated schemes. In clustering, only CHs need to communicate with the sink node via multihop communication. Low Energy Adaptive Clustering Hierarchy [3] is a well known clustering algorithm in which the CH in cluster is periodically rotated among members to achieve energy balance. However, this scheme showed only partial success, it needs a new cluster formation process at every section. With cluster formation, in each cluster with random probability a new CH node is re-elected, and from the promising CH candidates, the optimal node should be adaptively optimized for minimum communication distances to the maximum number of one hop neighbors. This only produce worst suboptimal solution due to cluster re-election process, which results in the nodes to spend additional delay and energy. In addition, LEACH requires all CHs to perform single hop transmissions to the networks sink, thus it suffers from the cost of long-range transmissions. As a result, the CHs that are further away from the sink depletes their energy much earlier than others.

In EARACM [9] selects some overhearing nodes as CH nodes. This scheme adopted the multi-hop transmission to further minimize the energy absorption. Unfortunately, this benefit comes from sacrificing the resulting transmission delay and communication overhead since each CH node has to maintain the status of the other CH nodes. In EECS [10], during cluster formation it allocates only less number of nodes to the clusters with longer distances to the sink node. Nevertheless, it is still based on single-hop communication to the sink from the CHs and is not scalable to large-scale or high density networks. In addition, clusters farther away from the sink node is limited by small cluster size by using a weighted parameter in order to reduce the energy consumption for long distance data transmission to sink node. Simulations results show that EECS performs better compared to LEACH in terms of energy efficiency. However, it needs extra knowledge about the WSNs, such as communication distance between CHs and Sink node. Furthermore, this extra requirement adds overheads to all nodes due to data aggregation in the WSNs.

In [11], authors proposed a protocol called HEED where a node uses its two parameters communication cost between cluster members and remaining energy to probabilistically elect itself to become a CH. HEED is a multi hop clustering algorithm for WSNs. Remaining energy of each sensor node is used to probabilistically choose the first set of CHs, as usually performed in other clustering techniques. In [11], communication cost between cluster members shows the node degree or nodeâs proximity to the neighbor and is main parameter that decides whether to join the cluster. However, hot spot issue in HEED appears in areas that are close to the sink, as nodes in such areas need to relay incoming traffic from other parts of the network. Furthermore, knowledge of the whole WSNs is necessary to determine communication cost between cluster members. HEED is a distributed clustering mechanism in which CH nodes are picked from the WSNs. HEEDs CH selection parameter is a hybrid of energy and communication cost. In EEUC (Energy- Efficient Unequal Clustering) [12], the cluster sizes with longer distance from sink node is larger compared to the cluster sizes near to the sink node. This was proposed to save energy in communication between cluster members and CHs. However, extra overheads caused due to the additional data aggregation in all nodes degrades the efficiency of the network in a multihop environment. Furthermore, the energy of CH closer to sink node tend to deplete quickly, because they forward more data traffic compared to other sensor nodes.

In Multi-hop routing protocol with unequal clustering (MR-PUC) [13] is a distributed clustering algorithm which function in three phases: cluster formation, routing between CHs and sink node, and packet transmission. Each node collects information from its neighbor nodes and elects a node with maximum remaining energy as the CH. The CHs closer to sink node have smaller cluster sizes to reduce the energy for heavy inter-cluster transmissions. However, Inter cluster multi-hop routing formation may cause an additional overhead. Hierarchical control clustering (HCC) [14] is proposed to save energy consumption and provide scalability. In [14], new cluster generation is started when the value of the original cluster head drops below a certain threshold. In [14], CH is elected based on the value assigned by the weighted factor to the cluster members in the cluster. Multi-tier clustering is formed using hierarchical control clustering. In [14], the algorithm was proposed to achieve various goals in different layers, such as: each sensor node will be part of a fixed number of clusters, connected clusters, and each cluster should have a maximum and minimum size constraint. However, the entire network must be traversed before it can be computed and since the spanning tree is a global data structure it is not a strictly localized routing protocol.

Algorithm for cluster establishment (ACE) [15] uses a protocol to cluster the WSNs in to constant number of iterations, where node degree is used as the critical parameter. In [15], one way of CH selection is when many nodes in its neighborhood do not belong to any cluster, then it elect itself as a CH. Furthermore, these number of iterations were enough to achieve a stable average cluster size. In Addition, the two functional components of ACE are generation of new clusters and migration of existing ones. However, when the communication cost requirements and energy consumptions are satisfying, then its hard to detect the number of iterations required to achieve it. Moreover, additional overheads are caused due to migratory mechanism in ACE. In Power-efficient and adaptive clustering hierarchy (PEACH) [16], cluster generation is performed by using overhearing characteristics of wireless communication to avoid additional overheads and support adaptive multi-level clustering. In WSNs, overhearing a node can recognize the source and the sink of messages transmitted by the neighbor nodes. In [16], it can remarkably reduce energy consumption of each node, increase the network lifetime, and is less affected by the distribution of sensor nodes compared with existing clustering protocols. In brief, total energy consumption in multihop data delivery in clustered WSNs should be analyzed comprehensively. Such an analysis should be based on an clustering protocol and energy-efficient data routing that prevent using network-wide broadcasts and reduces additional overhead. Furthermore, to affirm the load balance in a WSNs, this trade-off between the distance to the sink from source and the cluster size should be studied analytically, before setting up the network hierarchy.

III. Energy Consumption Model

In this paper we use a radio model proposed in [3] as radio energy model to measure energy consumption for proposed CBER algorithm. In [3], the radio model is a combination of three main models: transmitter, the receiver and the power amplifier. The energy consumed by the transmitter consists of transmitter circuitry and the power amplifier, and the energy consumed in receiver for receiving data consists of the receiver circuitry [3]. When a packet transmitted from a transmitter to a receiver, where the distance between them is d, the received signal power at the receiver is [17] :

$$p_r(d) = \frac{p_t G_t G_r \lambda^2}{(4\pi)^2 d^\beta Loss} \tag{1}$$

where G_r and G_t are respectively receiver and transmitter gains. Furthermore, $Loss$ represents any additional losses in the packet transmission and λ represents carrier wavelength .The propagation loss factor β, which is typically varies between 2 and 4. Hence, considering $G_t = G_r = 1$, and $Loss = 1$, the received signal power at the receiver is

$$p_r(d) = \frac{p_t \lambda^2}{(4\pi)^2 d^\beta} \tag{2}$$

To receive the data packets successfully, the received signal power at the receiver must be above a minimum threshold power (p_{thr}). Hence, the transmitter signal power at the transmitter must be above this threshold $\frac{p_{thr}(4\pi)^2 d^\beta}{\lambda^2}$. The energy absorbed by the transmitter is

$$E_t = (e_e + \frac{p_{thr}(4\pi)^2 R^\beta}{\lambda^2 d_r}) \times Packet = (e_e + e_a R^\beta) \times Packet \tag{3}$$

where $e_a = \frac{p_{thr}(4\pi)^2}{\lambda^2 d_R}$, which is considered as the $energy/bit$ absorbed in the transmitter RF amplifier, d_R is the transmit or receive data rate $(bit/second)$ of each network node, $Packet$ is the number of bits in the packet and e_e is the $energy/bit$ consumed in transmitter electronics. Hence, based on [18] the energy absorbed per second by a sensor node in three states can be calculated as follows:

$$\begin{aligned} &E_t = (e_e + e_a R^\beta) N_t \\ &E_r = (e_e) N_r \\ &E_l = e_l T_l = e_l(1 - T_t - T_r) = e_e d_R (1 - T_t - T_r) \end{aligned} \tag{4}$$

The time for receiving and transmitting the data traffic between the cluster is denoted by T_r and T_r respectively. Where N_t and N_r are the traffic data bits transmitted and received respectively. The equation (5) represents the value of T_r and T_r.

$$\begin{aligned} T_t = \frac{N_t}{d_R} \\ T_r = \frac{N_r}{d_R} \end{aligned} \tag{5}$$

The amount of time spent in one second for listening to the radio channel is represented as $T_l : T_l = 1 - T_t - T_r$, $(0 \leq T_l \leq 1)$, thus $0 \leq (1 - \frac{N_t}{d_R} - \frac{N_r}{d_R} \leq 1)$. Considering the static data traffic environment, where $N_t = N_r = N$, the value of N is represented in equation (6) as

$$0 \leq N \leq \frac{1}{2} \times d_R \times 1second \tag{6}$$

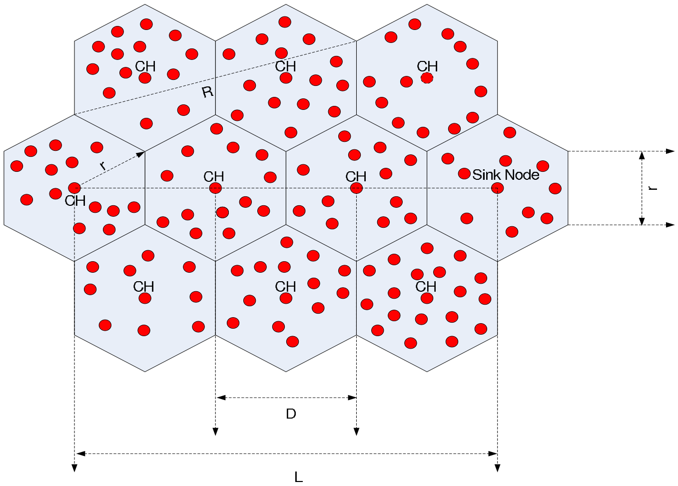

Fig. 1. Cluster based End-End Multihop transmission in hexagonal structure

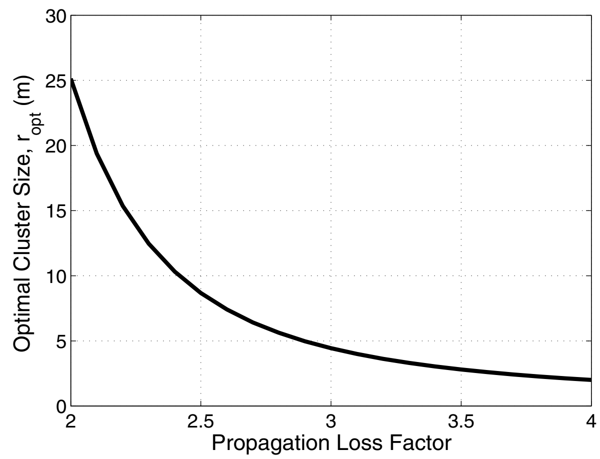

Fig. 2. Optimal cluster head distance r variation with β.

As a result, $\frac{1}{2} \times d_R bits$, represents the maximum amount of data that can be transmitted in each cluster per second, when nodes in the cluster don't listen to the radio environment and spend half a second for receiving the packets and another half for transmitting the packets. In simulations, we consider $d_R = 2.5 \times 10^5 bps$ [19], the maximum data that can be relayed in WSNs based on equation (6) is $1.25 \times 10^5 bits$ per second. Where the energy consumed for listening to the radio environment per second is represented as $e_l.e_e, e_a$, and e_l are obtained from the design characteristics of the transceivers. From [3] and [19], the specific values of e_e is: $e_e = 3.32 \times 10{-}7J/bit$. When $p_{thr} = 2 \times 10^{-9}w, d_R = 2.5 \times 10^5 bps, f = 2.4 \times 10^9 Hz$, and $e_a \approx 8 \times 10{-}11J/bit/m^2$.

IV. Optimal Cluster Head Distance

In an end-to-end multi-hop transmission considering a equal hexagonal cell, the best route between the source and sink node is the direct line between them, where intermediate nodes are properly deployed (the nodes exists whenever needed). As shown in Fig. 1, the data packet is transmitted from the source to the sink node, where L is the distance between them. Assume that the distance between each cluster head is D, m is the number of cluster heads and is derived as
$R = \sqrt{13} \cdot r$, $D = \sqrt{3} \cdot r$,

$$m = \frac{L}{D} = \frac{L}{\sqrt{3} \cdot r} \tag{7}$$

In this paper, we consider static traffic in the network. Network is considered to have static traffic when traffic rate following along the network is constant. In hexagonal cluster model, r represents the side of the hexagon and the optimal cluster head distance. While R is the maximum transmission range of node and the range should be such that two nodes located anywhere in adjacent cluster should be able to transmit and receive data. The energy consumed for the end-to-end multi-hop transmission based on the energy consumption model discussed earlier is:

$$\begin{aligned} E_i =& E_t + E_r + E_l, \\ =& (e_e + e_a R^\beta)N + (e_e)N + e_e d_R (1 - \frac{N}{d_R}), \\ =& (2e_e + e_a R_i^\beta)N. \end{aligned} \tag{8}$$

$$\begin{aligned} E_t =& m \cdot E_i, \\ =& \frac{L}{\sqrt{3}r}\left[2e_e + e_a\left(\sqrt{13}r\right)^\beta\right]N. \end{aligned} \tag{9}$$

In order to find the minimum energy consumption, we take the first derivative of E_t with respect to optimal cluster head distance, r, and let $\frac{d}{dr}(E_t) = 0$

$$\frac{d}{dr}(E_t) = \frac{L}{\sqrt{3}}\left(e_a N(\sqrt{13})^\beta(\beta - 1)r^{\beta-2} - \frac{2e_e N}{r^2}\right), \tag{10}$$

From equation (10) we can derive the value for r the optimal cluster head distance as:

$$\begin{aligned} r =& \frac{1}{\sqrt{13}}\left(\frac{2e_e}{(\beta - 1)e_a}\right)^{1/\beta}, \\ =& \frac{1}{\sqrt{13}}\left(\frac{2e_e \lambda^2 d_R}{(\beta - 1)p_{thr}(4\pi)^2}\right)^{1/\beta} \end{aligned} \tag{11}$$

By using correct transceiver parameters, equation (11) shows that the optimal cluster head location r, depends on the propagation loss factor β with values ranging from 2 to 4 and the network traffic. The relationship between propagation loss factor β and r is shown Fig. 2. In Fig. 2, the optimal cluster head distance and the side of the cell decreases when the propagation loss factor β increases while network traffic N is constant. Furthermore, there is a trade off between the number of cluster heads and energy consumed in each cluster head. Based on equation (8), when the number of cluster heads m is large, the size of the side of cluster becomes small, and then energy consumption is dominated by the fixed energy consumption of each cluster head. When the number of cluster heads is decreases, the size of the cluster side increases, and energy consumption is dominated by the cluster head because the energy consumed in the transmitter amplifier of each cluster head increases quickly.

V. CBER: Cluster Based Energy Efficient Routing

In this section, we explains the procedure of the CBER that is proposed in this paper. The CBER employ the self organization technique for routing and clustering of WSNs. Furthermore, here a network of homogeneous sensor nodes are considered. In the proposed scheme, each node has to perform the basic task of sensing the field parameters, form data packets, and communicate with the cluster head. Clustering in WSNs means partitioning nodes in network into different clusters. The network model considered in this paper is a hexagonal structure shown in Fig. 1 with source nodes and sink node. Sink node is constant and fixed for each simulation. Sensor nodes are homogeneous in nature, are assigned with a unique identifier and have same capability. They are able to function in an active or sleeping state. Nodes can use transmit power control to change the amount of power transmitted according to the distance of the receiver. In the CBER, each nodes shares information about the current energy state with only its one hop neighbors. The nodes of CBER will be in four different modes. The four modes are described as follows.

Cluster Head: While in CH mode, it gathers and aggregate information from its members and sends or receive message between the adjacent CHs or to sink node at regular intervals. In addition, it selects the next adjacent CH node where the data to be transferred. In hierarchical routing protocols, CHs are responsible for gathering, aggregating and forwarding the data to the sink. Thus, they are responsible for conveying the complete information of its cluster members. CH is then responsible to transmit this data towards the sink. There are two types of communication for CH, Intra cluster communication and Inter cluster communication. Intra cluster communication is between CH and its cluster members. Inter cluster communication is between CH and its adjacent CHs.

Cluster Member: A cluster member is a member that belongs to a particular cluster, it regularly transmits the collected information to its CH.

Dead Node: This is a state in which sensor node cannot operate anymore because its energy has been depleted completely or it has broken down. The node cannot either transmit or receive the data.In addition, the node is considered to be in this state when its residual energy (E_{res}) is below $0.005J$.

Isolated Node: This means node doesn't have any one hop neighbors either to transmit or receive the data. In this state, node is disconnected from the network.

Operation in CBER is divided into section. We perform energy aware clustering in sections and each section results in selection of different CH. One section means one end-to-end packet delivery. The CH is rotated among sensors in each section and distributes the energy consumption across the networks. CBER is divided into setup and steady transmission phase. The first phase is the setup phase, where members are classified into certain clusters and CH is selected for particular cluster. And the second phase is the steady set phase to transmit data. Data packets is transferred intra cluster between CM and CH in each partition level and inter-cluster between CH leaders in each partition level. In the first phase, setup phase, the hexagonal based cluster is formed and each members in the network is assigned to different clusters. The optimal size of each cluster side for $\beta = 2$ is found from Fig. 2. Then cluster is formed using optimal cluster side for mitigation the hot spot problem and balance energy consumption. This process is to make cluster with same size and number of cluster Members closer to the optimal cluster head distance. Furthermore, cluster member in each cluster finds the value of equation (12). Where in equation (12), N be the number of one hop neighbor of the sensor node,R_{ij} is the distance between node i and node j, r^i is the average distance from node i to all its one hop neighbors. For different cluster members they have different r^i values.

CH is decided based on remaining energy and optimum cluster head distance of node to mitigate hot spot problem. The CHs are selected by a rule of best candidate, which selects a sensor node with an optimal cluster head distance and has maximum remaining energy as a CH for the next section. The CBER algorithm decides the CH node as the node (within the cluster) that minimizes equation (13). In equation (13), r^i is the average distance to the one neighbor nodes and E_{res} is the remaining energy of the neighbors in the cluster. Intuitively, without taking into the energy balance, some sensor nodes may be selected more frequently as the cluster head nodes, and these nodes energy may be depleted out very quickly compared to other member nodes. Since r^i and E_{res} use different units, so they should be normalized and equation (13) shows the normalized form. The default energy capacity of each node (E_{cap}) is used to normalize E_{res} to define $E_{resnormalize}$; r^i is normalized with respect to the maximum distance between two nodes in anywhere in the cluster $2r$ to define $r^i_{optnormalize}$. The weight function α determines the relative importance placed on these two parameters. This is why it will be an effective way to choose the proper node as CH, combining each of system parameter with weighting factors chosen according application requirements. It means the nodes are decided to be CH depending on combined remaining energy (E_{res}) of node, and the optimal cluster head distance. This node uses the best combination of minimum energy needed to reach neighbors and with maximum residual energy. Therefore, CBER is higher in concept and efficiency as will be seen.

$$\sum_{j=1}^{N} \frac{R_{ij}}{N} = r^i \qquad \forall i = [1, N] \tag{12}$$

$$f(E_{res}, r^i) = \alpha \frac{r^i}{2r} - (1-\alpha)\frac{E_{res}}{E_{cap}} \tag{13}$$

Second phase is steady transmission phase, where intra and inter cluster multi-hop CH routing happens. In intra cluster routing, cluster member sends data to the CH in the same cluster. In inter cluster routing, the data aggregated by CH will be forwarded to adjacent CHs and later forwarded to sink node. The CH will operate at the range of R which is maximum distance between two adjacent cells in a hexagonal structure. In order to send neighbor information with all possible CH candidate within its cluster because CH has sent Next CH signals to optimal cluster head distance. Furthermore, the CHs create a route and select a final CH

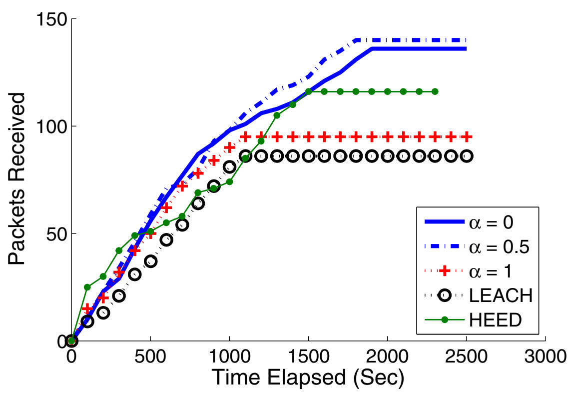

Fig. 3. Comparison of data received by sink node

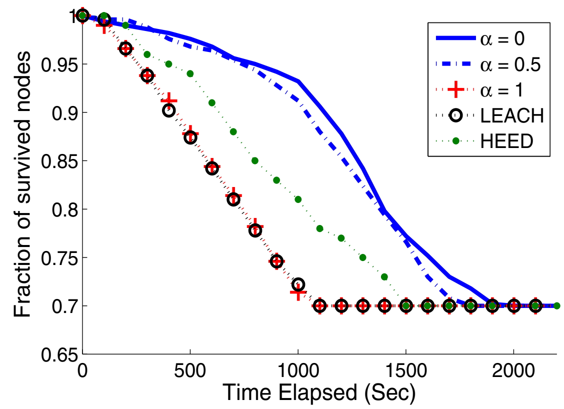

Fig. 4. Comparison of network lifetime

for relaying to the sink and sends messages to the sink. The 'Final CH' is the cluster head node that have next hop as sink node. Forwarding of messages through the route can reduce energy consumption compared to the direct transmission of messages from all CHs to the sink. During the creation of route for inter-cluster routing, the CHs carry out their duties while transforming into the following three modes while relying on different roles.

Initial mode: When Inter cluster routing phase starts,all CHs are initialized as the initial state.

Route broadcasting mode: This is a mode where the signals are broadcasted to establish an inter-cluster route.

Route established mode: In this mode, routes are established from its own routes and those of its neighbors.

In this paper, we compare the CBER algorithm with the LEACH [3](Low-Energy Adaptive Clustering Hierarchy) and HEED algorithm in terms of the network lifetime and through put.

VI. Simulation Evaluation

In this section, we evaluate the performance of our proposed algorithm (CBER) using MATLAB. In simulations, we assumes an error free physical layer links and ideal MAC layer. In this paper, we consider the each node's energy consumption as the summation of energy consumed in the transmission and reception of data packets per section. We compare CBER with LEACH and HEED. The results obtained from simulations are average of several tests. The simulation parameters are given in Table II, in which the parameters of radio model are the same as those in [3].

TABLE I
Measurments from simulation

	$\alpha = 0$	$\alpha = 0.5$	$\alpha = 1$	$LEACH$	$HEED$
Lifetime (s)	1900	1800	1045	1081	1500
Packets	140	143	95	86	116

We first obtain the optimal cluster head distance (r) from equation (11) (r = 25.06 m for n = 2). When α is set to the optimal value, it will prolong the network lifetime. In Fig. 4, its shows the network lifetime based on various values of α from 0 to 1. The measurements obtained from simulation are shown in Table I. In this paper, we define the lifetime of the network as the time duration before a fraction of nodes run out of energy, and the results from Fig 4 shows the efficiency of each algorithm. For instance, when the definition of lifetime of network is 30% of nodes completely depletes its energy, the ratio of the lifetimes of network (calculated in loops between 0 until the 30 event) under various algorithms is: HEED:LEACH:CBER($\alpha = 1$):CBER ($\alpha = 0.5$):CBER($\alpha = 0$) = 0.78:0.56:0.55:0.94:1. It shows the CBER algorithm (when $\alpha = 0$) has better performance in network lifetime when analyzed with LEACH and HEED. Furthermore, the 30% nodes referred to above corresponds to 70% "fraction of survived nodes" in Fig. 4. Since LEACH does not take into consideration of the residual energy of nodes, the network lifetime decreases drastically compared to the other algorithms. Therefore, data packets received by sink node using LEACH should be compared. From Fig 3, before the network disconnection with the CBER ($\alpha = 0.5$) algorithm, the sink node received much more data packets than the other algorithms. In Fig. 3, the received data with CBER($\alpha = 0.5$ and 0) increases more quickly than the other two protocols.

TABLE II
Parameters of Simulation

Propagation factor (β)	2
Network length	$2000m$
Simulation time (t)	$0.02sec$
Number of nodes (N)	1500
Energy capacity of nodes (E_{cap})	$2j$
Optimal cluster size (r)	$25.06m$
Min threshold power (p_{thr})	8×10^-15w
Carrier frequency (f)	$2.4 \times 10^4 Hz$
Data Rate (d_R)	$2.5 \times 10^5 bps$

VII. Conclusion and Future work

In this paper, we proposed the cluster based energy efficient routing algorithm (CBER) to extend the network lifetime, and simulation results are compared with the previous cluster based routing algorithms LEACH and HEED. The proposed CBER algorithm selects the CH node as the member (within the cluster) that minimizes the value of $[\alpha \frac{r^i}{2r} - (1-\alpha)\frac{E_{res}}{E_{cap}}]$. Furthermore, this CH node is the node that has the best residual energy and requires the minimum energy to be reached by the cluster members. In addition, weight parameter α decides the relative importance placed on these two parameters. The results from simulations show that the CBER algorithm has best efficiency in terms of both data packets received by sink node and the network lifetime.

CBER creates additional overhead of control packets during the end-to-end packet transmission and unbalanced utilization of nodes near sink. Our next step is to improve clustering algorithm to minimize the overhead of control packets and efficient utilization of nodes near sink. Furthermore, to implement in dynamic traffic scenario with adjustable hexagonal structure based on the cluster size.

REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," *Computer Networks*, vol. 38, no. 4, pp. 393 – 422, 2002.

[2] Aboobeker, Wei Feng, and Jaafar M.H Elmirghani, "Energy-efficient geographic routing in ad-hoc wireless networks," *London Communication Symposium*, Sept 2009.

[3] W. R. Heinzelman and A. C. H. Balakrishnan, "Energy-efÃÂ¨Ãcient communication protocol for wireless microsensor networks," *in Proceedings of HICSSâÃÃ´00*, vol. 2, pp. 4 –7, jan 2000.

[4] S. Hongchi B. Yin and Y. Shang, "Analysis of energy consumption in clustered wireless sensor networks," *in Wireless Pervasive Computing, 2nd International Symposium on,*, Feb 2007.

[5] H. Chan and A. Perrig, "Ace: An emergent algorithm for highly uniform cluster formation," *Proc. 1st Euro. Wksp. Sensor Networks,*, pp. 154 –71, Jan 2004.

[6] A. Manjeshwar and D. P. Agarwal, "Apteen: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks," *Proc. Int'l. Parallel and Distrib.Proc. Symp*, pp. 195 –202.

[7] J.N. Al-Karaki and A.E. Kamal, "Routing techniques in wireless sensor networks: a survey," *Wireless Communications, IEEE*, vol. 11, no. 6, pp. 6 – 28, dec. 2004.

[8] C. Intanagonwiwat, R. Govindan, D. Estrin, J. Heidemann, and F. Silva, "Directed diffusion for wireless sensor networking," *Networking, IEEE/ACM Transactions on*, vol. 11, no. 1, pp. 2 – 16, feb 2003.

[9] Sangho Yi, Geunyoung Park, Junyoung Heo, Jiman Hong, Gwangil Jeon, and Yookun Cho, "Energy aware routing based on adaptive clustering mechanism for wireless sensor networks," pp. 1115–1124, 2005.

[10] Guihai Chen Mao Ye, Chengfa Li and Wu.J., "Eecs: an energy efficient clustering scheme in wireless sensor networks," *Performance, Computing, and Communications Conference,IPCCC 2005*, pp. 535 – 540, april 2005.

[11] O. Younis and S. Fahmy, "Heed: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," *Mobile Computing, IEEE Transactions on*, vol. 3, no. 4, pp. 366 – 379, oct.-dec. 2004.

[12] Chengfa Li, Mao Ye, Guihai Chen, and Jie Wu, "An energy-efficient unequal clustering mechanism for wireless sensor networks," in *Mobile Adhoc and Sensor Systems Conference, IEEE International Conference on*, nov. 2005, p. 8604.

[13] Bencan Gong, Layuan Li, Shaorong Wang, and Xuejun Zhou, "Multihop routing protocol with unequal clustering for wireless sensor networks," in *Computing, Communication, Control, and Management, 2008. CCCM '08. ISECS International Colloquium on*, aug. 2008, vol. 2, pp. 552 – 556.

[14] S. Banerjee and S. Khuller, "A clustering scheme for hierarchical control in multi-hop wireless networks," vol. 2, pp. 1028 –1037 vol.2, 2001.

[15] H. Chan and A. Perrig, "Ace: an emergent algorithm for highly uniform custer formation," *Lecture Notes in Computer Science*, 2004.

[16] Sangho Yi, Junyoung Heo, Yookun Cho, and Jiman Hong, "Peach: Power-efficient and adaptive clustering hierarchy protocol for wireless sensor networks," *Computer Communications*, vol. 30, pp. 2842 – 2852, 2007.

[17] P.M Shankar, *Introduction to Wireless Systems*, John Wiley and Sons, 2001.

[18] M. Bhardwaj, T. Garnett, and A.P. Chandrakasan, "Upper bounds on the lifetime of sensor networks," vol. 3, pp. 785 –790 vol.3, 2001.

[19] Bolian Yin, Hongchi Shi, and Yi Shang, "Analysis of energy consumption in clustered wireless sensor networks," feb. 2007.