Cluster Head Recovery Mechanism for Hierarchical Protocols

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Abstract

Due to the big and essential role played by the cluster head in hierarchical protocols of wireless sensor network, it consumes an amount of energy more than the member nodes of the cluster. Therefore, the hierarchical protocols usually suffer from a packet loss due to frequent cluster head failure during the data transmission. This decreases the communication reliability in wireless sensor network applications. Errors caused by data loss inevitably affect the data analysis and subsequent decision making. This paper introduces, the Low-Loss Low-Energy Adaptive Clustering Hierarchy Centralized Protocol (LLEACH-C); LLEACH-C provides a cluster head recovery mechanism, which recovers the cluster head's death during the protocol round operation. This is a missing mechanism in LEACH-C protocol, the protocol that is one of the most popular in hierarchical protocols. The simulation results showed that, LLEACH-C succeeds in decreasing the data packet loss by on average 43% over LEACH-C, and in increasing the lifetime of the network by on average 69.3% more than VLEACH, the protocol that also proposes a mechanism for cluster head death recovery. Furthermore the behavior of the LLEACH-C, in both of the End to End delay and Throughput, are analyzed and compared to VLEACH.

Keywords: *Wireless sensor network, Clustering, Hierarchical protocols, LEACH-C, VLEAH, Packet loss.*

1. Introduction

To establish the connection between the physical world, the computing world and human society, a new class of short-range wireless communication networks has appeared to facilitate the needs of monitoring and controlling the physical environment especially in remote and unreachable areas. These networks are called Wireless Sensor Networks (WSNs). It can be used in wide-range of applications like Agriculture [1], Medicine [2], Military [3], Intelligent Buildings [4], Natural Disasters discovery [5], Traffic control [6], etc. A WSN generally consists of a large number of small and smart Sensor Nodes (SNs), SN contains one or more sensors, embedded processors, limited memory, low-power radio, and is normally operated with AA battery or coin cell, they are capable of monitoring a desired event in a particular geographical area, processing this event related data, and sending it to a remote location which is called Base Station (BS) using a certain routing protocol. Due to the small size of sensors, they cannot be equipped with large power supplies, thus small batteries are used to provide their energy. Battery replacement is impossible in most applications. Therefore designing an energy-aware routing protocol is considered to be one of the most significant challenges for these networks because most of the sensor's energy is consumed by the communication process when sending data from SN to the sink. By summarizing routing challenges in WSNs [7], many ways for routing had been developed for energy optimization in WSNs [8-9]. They can be categorized into flat [10], hierarchical based (cluster based) [11] and location based [12]. Cluster-based routing algorithm has a better energy utilization rate compared with non-cluster routing algorithm. In hierarchical (cluster-based) routing protocols, SNs are divided to clusters each cluster has a leader which called Cluster Head (CH). Using this scheme reduces the energy consumption, during sending data to the BS, by decreasing the number of messages sent to the BS through data aggregation and fusion. Balanced distribution of energy consumption tasks among cluster nodes cannot be achieved, because the CH has many energy consuming tasks. CH tasks are (i) overhearing Member Nodes (MNs) for the round time, (ii) creating Time Division Multiple Access (TDMA) scheme and broadcasting it to all MNs to use it in a communication process, (iii) Setting up communication channels between itself and all MNs, (iv) receiving data from all MNs, and (v) aggregating the received data and sending them to the BS that might be remotely located. On the other hand, MNs have only two tasks, data sensing and sending data to CH then sleeping till next time slot. This unbalanced energy distribution tasks cause CH to consume its energy faster than other MNs, and may fail during the round whereas, other MNs are alive and sensing data. If the CH fails during the round, the collected data from MNs will be lost because it will never reach the BS. Also MNs consume their energies for sensing the surrounded environment while there will be no actual data transmission, so the entire cluster will be useless. Which means that the CH represents a single point of failure for the cluster.

This paper proposes a new cluster head recovery mechanism over LEACH-C protocol, this mechanism recovers cluster head before failure to save the collected data from being lost.

The rest of this paper is organized as follows: Section 2 overviews the related works. Section 3 discusses the LEACH-C protocol as a base for LLEACH-C. Section 4 discusses the LLEACH-C in details. Section 5 represents LLEACH-C system model, Section 6 views the performance evaluation for LLEACH-C, and finally section 7 represents the conclusions and future work.

2. Related Work

Many algorithms have been developed using clustering techniques in routing to increase the energy efficiency of the network [13]. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol[14], is the first hierarchical routing protocol proposed for WSNs since 2000. It has become one of the most well known energy efficient clustering algorithms for WSNs. The whole operation of LEACH is divided into rounds. Each round consists of setup phase followed by steady state phase. During set up phase clusters are formed by organizing SNs into clusters, each cluster has its own CH which has been selected randomly based on the threshold generated by the algorithm. Each CH sets up its own TDMA scheme which determines a certain Time Slot (TS) for each MN for data transmission in the next phase. In the steady state phase CHs aggregate the data received from their MNs and send the aggregated data to the BS by single hop communication. One of the major benefits of LEACH is reducing energy consumption than flat protocols. This is achieved by decreasing the number of transmissions to the BS through sending the aggregated data from CHs, instead of each node. Further, the MNs entered sleeping mode during the transmission phase until its predetermined TS is active. In spite of these benefits, there are many drawbacks in LEACH protocol such as (i) CHs are not uniformly distributed; as CHs can be located at the edges of the network, (ii) random CHs selection, which does not take energy consumption into consideration, (iii) small coverage area because it assumes that all nodes over the network that can communicate with each other, and are also able to reach the BS, (iv) CH will die faster than other cluster members because of unbalanced distribution of energy consumption tasks among cluster nodes.

Since LEACH has many drawbacks, many researchers tried to enhance the performance of the protocol. Some of these enhancements are briefly described in the following paragraph.

LEACH-C protocol [15-16] solves the CHs uniformly distribution issue; by using a BS central control algorithm to form the clusters, It differs from LEACH only in the cluster setup phase. LEACH-C uses an unlimited energy BS, when the network is initialized, all SNs send their energy level and positions to the BS, which in turn uses a centralized algorithm to select all CHs depending on the larger residual energy and non bordered positions, then sends a message to all nodes informing each of them with the CH responsible for each one, then the rest of the operation will be the same as in LEACH.

The main advantage of LEACH-C over the LEACH is the knowledge that the BS has about the entire network topology, which makes the selection of CH more efficient, more accurate, better distributed and less energy consuming. Consequently, LEACH-C enhances the entire network lifetime. However, the selected CH still represents single point of failure for the cluster.

To save the CH from being a single point of failure for the cluster, researches had presented an idea for back up the CH, by placing a Vice Cluster Head (VCH) to take the role of the CH in case of failure.

VCH idea had been applied for the first time for hierarchical protocols in [17] over the LEACH protocol. In the Vice Low Energy Adaptive Clustering Hierarchy (VLEACH) protocol, randomly selects any of cluster MNs to become a VCH after the CH failure, and takes the role of the CH. Although in VLEACH the CH is not a single point of failure, it still has the same drawbacks of LEACH as described above.

A new version of VLEACH called Improved V-LEACH protocol [18] was proposed to reduce the drawbacks of VLEACH by enhancing the CH selection process based on minimum distance, maximum residual energy, and minimum energy, also besides having a CH in the cluster, there is a VCH selected randomly to take the role of the CH when the CH dies. The main advantage of this protocol is to increase the steady state phase to reduce the reclustering process, thus increasing the network life time. The above mentioned protocols used the VCH for increasing the network lifetime, also many protocols had used the VCH in different ways to achieve different goals.

As in [19] the Energy-aware Data Gathering and Routing Protocol Based on Double Cluster-heads (EAGRDC) which used the VCH for sharing the energy consumption of CH. not for CH recovery. Also in [20] Multiple Cluster-Heads Routing Protocol (MCHRP) used two VCHs in two ways, one for sharing the energy consumption with the CH and the other for CH back up to achieve the load balancing in the cluster.

It should be obvious that, none of the previous ideas has paid attention to the packet losses caused when CH fails and VCH takes the designed role. This paper highlights the importance of VCH in loss reduction over the network.

3. Low-Energy Adaptive Clustering Hierarchy Centralized Protocol (LEACH-C)

LEACH-C enhanced both the poor CH selection in LEACH, and the LEACH network lifetime by using the BS central algorithm, which can determine better clusters than the distributed algorithm.

This section will describe LEACH-C protocol as a base for the proposed LLEACH-C protocol. LEACH-C operation is divided into rounds each round consists of a setup phase and a steady state phase.

3.1 Setup phase

Each SN sends information about its residual energy and location to the BS. Then BS uses its central algorithm to compute the average node energy, and any node having energy below this average cannot be a CH for the current round. The BS finds clusters using the simulated annealing algorithm. This algorithm attempts to minimize the amount of energy for the non-cluster head nodes to transmit their data to the CH, by minimizing the total sum of squared distances between all the non-cluster head nodes and the closest CH. Once the CHs and associated clusters are found, the BS broadcasts a message that contains the CH ID for each node. If a node's CH ID matches its own ID, the node is a CH; otherwise, the node determines its' TS for data transmission and goes to sleep until it is time to transmit data.

3.2 steady state phase

The steady-state phase of LEACH-C is identical to that of LEACH. The steady-state operation is broken into frames, where MNs send their data to the CH at most once per frame during their allocated TS using a minimal amount of energy. This allows the radio components of each MN to be turned off at all times except during its' TS. The CH must be awake to receive all the data from the MNs in the cluster. Once the CH receives all the data, it performs data aggregation. Thus, compressed data is sent from the CH to the BS at the end of its frame. This process is repeated till the designed number of frames per round is finished.

LEACH-C performance is better than LEACH because, it delivers about 40% more data per unit energy than LEACH, which enhances the total network life time.

Although LEACH and LEACH-C provide significant energy saving, they still suffer from loss of data packets due to frequent CH failure during the data transmission, because it represents a single point of failure for the cluster. This issue creates the main motivation of this research, how to save the collected data packets before the CH failure.

4. Low-Loss Low-Energy Adaptive Clustering Hierarchy Centralized Protocol (LLEACH-C)

This section describes in details the functionality of the proposed LLEACH-C protocol which is a modified version from LEACH-C. Section 4.1 represents the description of LLEACH-C. Section 4.2 explains the LLEACH-C operation.

4.1 Description of LLEACH-C

LLEACH-C is the first protocol that applies the idea of VCH Mechanism (VCHM) over LEACH-C protocol to achieve fault tolerance for the CH. It reduces losses by preventing the packets from being lost when the CH energy decreases.

As in hierarchical protocols, the LLEACH-C protocol divides the network into clusters, as shown in Fig.1(a), each cluster has a CH and VCH selected by the BS at the beginning of each round, CH responsibilities are overhearing, receiving, aggregating, and sending data to BS. Each frame consumes an amount of energy equal to EF reduced from the CH energy to complete the transmission to BS. For each frame received at BS, it tests the residual energy for each CH, if any CH has residual energy (ECH) lower than the EF required for the next frame like cluster X, the BS employs the VCHM, as shown in Fig.1 (b).

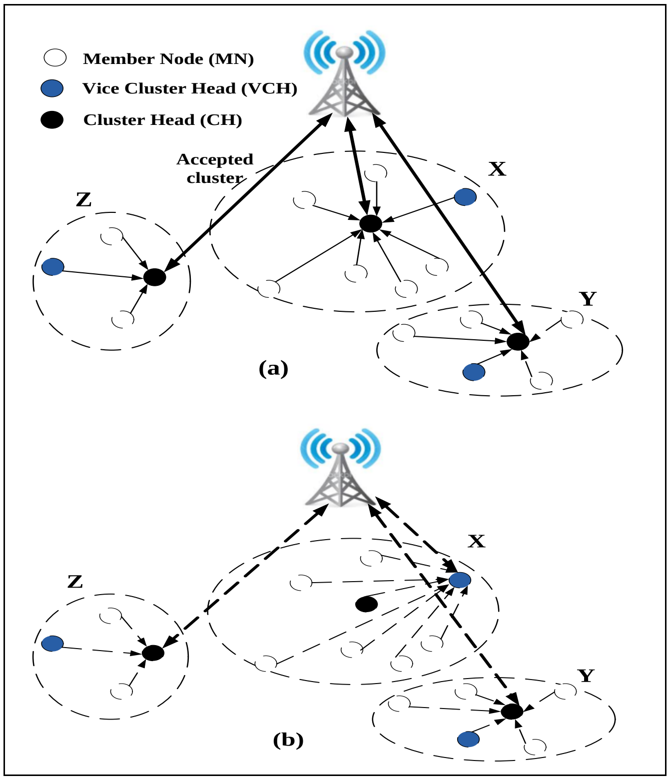

Fig.1 The network structure of LLEACH-C: (a) before applying VCHM, and (b) after applying VCHM on cluster X

4.1.1 Vice Cluster-Head Mechanism

Because of CH numerous responsibilities, its energy is consumed faster than MNs, therefore the probability of CH failure during the round is increased. Causing all cluster failure, accordingly loss of all collected data of that cluster. So to solve this problem, the VCHM had been proposed.

At the begging of each round, and during the setup phase the BS selects CHs and forming the cluster, after that it sorts MNs in each cluster according to the residual energy, and then selects the largest residual energy MN as a VCH. After that the BS sends a message to all nodes to announce their CH and VCH.

During the data transmission in the steady state phase, when the BS receives a frame, it tests the ECH for each CH, if any CH has ECH lower than the required energy for the next frame EF, the BS starts VCHM over that cluster by sending a message to all cluster nodes, informing them that the roles between CH and VCH are exchanged, therefore MNs establish a connection with VCH, CH becomes a normal MN and establishes a connection with VCH, and VCH will start overhearing, receiving, aggregating, and sending data to the BS till the end of the current round.

4.2 LLEACH-C Protocol operation

LLEACH-C achieves a good performance in fault tolerance by avoiding the CH from being a single point of failure for the cluster, when its energy decreases to a level lower than the energy required for the next frame.

LLEACH-C operation is divided into sequenced rounds; each round as shown in Fig.2 consists of two main phases, setup phase and steady state phase.

4.2.1 Setup phase

This phase is subdivided into three phases, base station cluster formation phase, cluster send/receive phase and TDMA scheme phase as shown in Fig. 3. In the cluster formation phase each node sends its ID, current location, and current level of residual energy to the BS, then the BS uses its central algorithm to select the CHs according to their remaining energy levels, the selected CHs are 5% of alive nodes. This approach has been concluded by authors of [10] to obtain the optimal number of CHs for energy minimization. Before sending the cluster information to the nodes, the BS needs to select VCHs for each cluster, by sorting each cluster MNs descendingly according to their remaining energy, and selecting the largest energy MN as a VCH. While in cluster send/receive the BS sends message to all nodes, and announces their corresponding CH and VCH.

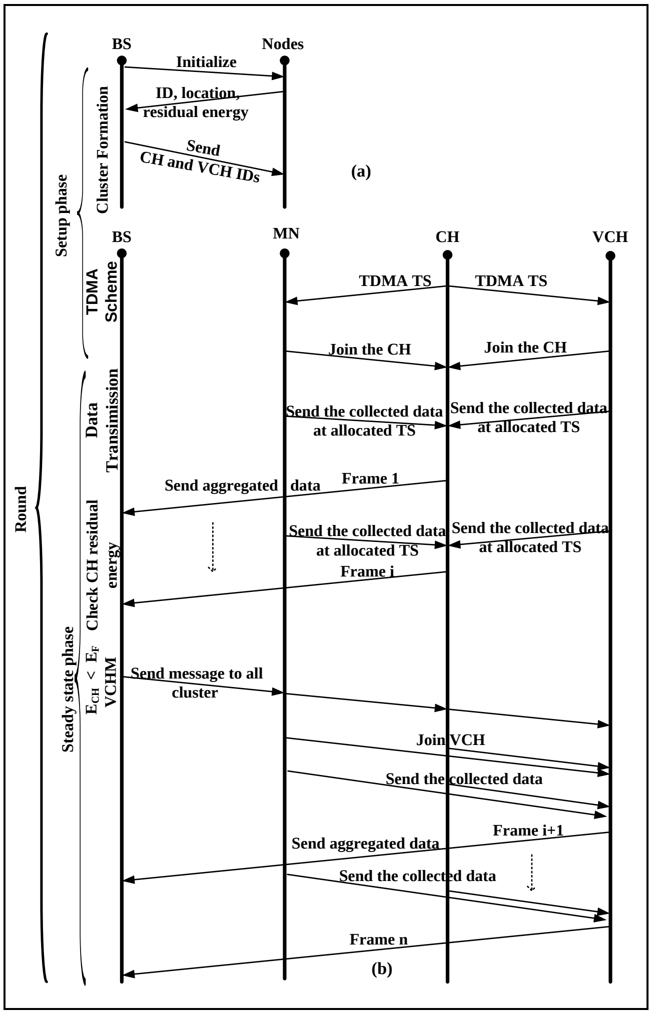

Fig.2 LLEACH-C protocol Round: (a) Round initialization (b) Round operation

These messages contains CH_{ID} and VCH_{ID}, when a node receives this message it compares its own ID with the received IDs, if it matches with the CH_{ID} the node will become a CH, else if it matches with the VCH_{ID} the node will become a VCH, otherwise, the node will be a MN and will establish the connection with the corresponding CH.

Then TDMA schema phase starts, by the CH creating the TDMA schema. Fig.4 (a) shows the TDMA schema Time Slots (TS), TSs are equals to no. of MNs + VCH + 2, CH arranges TDMA scheme as follows, (i) TSs for MNi, (ii) TS for VCH, (iii) the last two TSs are assigned to CH Data Aggregation (CH_{DA}) and CH Data Sending (CH_{DS}).

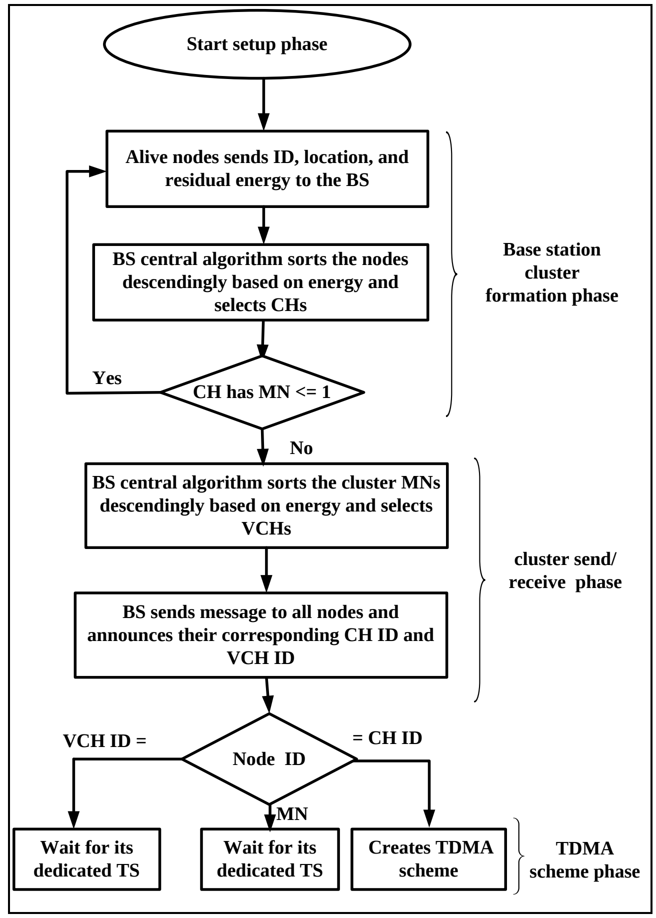

Fig.3 LLEACH-C set up phase flow chart

During the steady state phase when the BS decides to employ the VCHM over a certain cluster, instead of creating a new TDMA the VCH uses the same TDMA already created, but only exchanges the last three TSs between himself and CH, as shown in Fig. 4 (b), that is as a result of exchanging the roles between them.

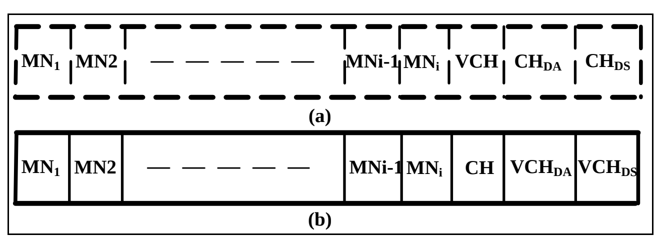

Fig. 4 LLEACH-C TDMA Scheme (a) before applying VCHM (b) after applying VCHM.

Then the CH announces its TDMA scheme by a message, sends it to its MNs containing the allocated TS for each one. When MNs receive this message each node knows its allocated TS for data transmission and goes to sleep until it is time to transmit data. Once the clusters are formed and TDMA schemes are constructed and distributed, the steady state phase is started.

4.2.2 Steady state phase

All MNs through the network sense the surrounding environment to collect required data and send it to the corresponding CH, once the CH receives packets from all MNs; it aggregate the collected data in one packet and sends it to the BS. As shown in Fig. 5.

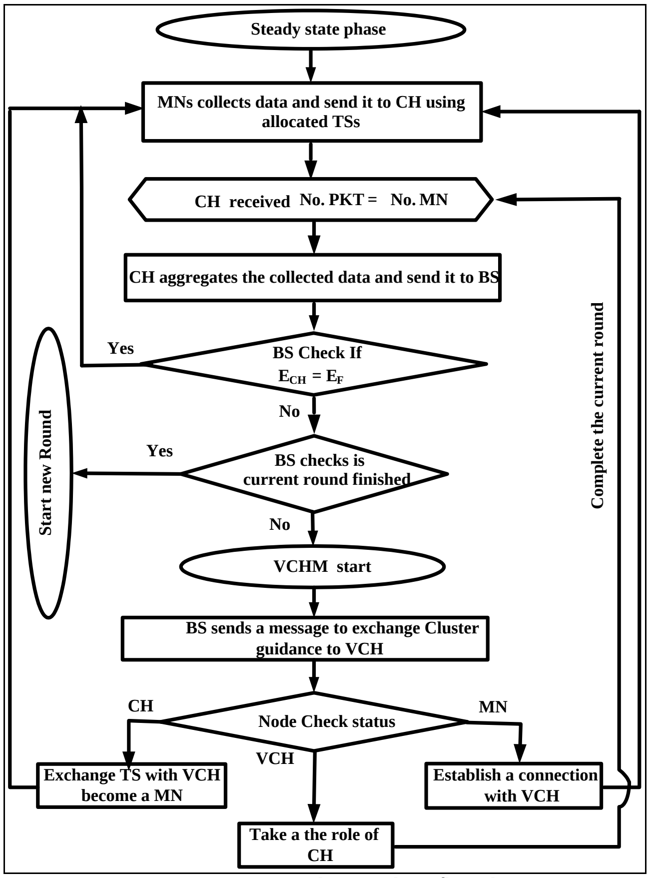

Fig. 5 LLAECH-C steady state phase flow chart

During data transmission, the VCHM at the BS central algorithm checks the residual energy for each CH, if the ECH for a certain CH is larger than EF, the VCHM confirms that this CH is able to send in the next frame, otherwise, the BS starts to employ the VCHM to save the next frame from being lost. The VCHM starts by sending a message from BS to the cluster that suffers from the above condition, to exchange the roles between the CH and VCH, till the end of the active round, the CH becomes a MN under the leadership of VCH.

Then the CH and VCH exchange the allocated TSs for each of them, as described above.

5. LLEACH-C System model

This section describes in details the assumptions of LLEACH-C system model. Section 5.1 explains the proposed network model in designing the protocol. Section 5.2 describes the adopted radio model in the protocol operation. Section 5.3 views the VCHM.

5.1 Network Structure for LLEACH-C

N sensor nodes are assumed to be randomly distributed in 1000*1000 square areas and periodically collect data. LLEACH-C network has the following design assumptions: (i) sensor nodes and BS are immobile after deployment and the BS is located far from all sensors, (ii) all nodes in the network are identical and have limited energy with an identifying ID, (iii) all nodes are able to reach BS and can communicate with each other, (iv) CHs perform overhearing, receiving, aggregating, and sending of data to the BS, (v) propagation channels are symmetric; that is the energy consumption of sending data from node A to node B equals to the consumption from node B to node A, (vi) all nodes are sensing the surrounding environment in a fixed rate and send data periodically to CH, and finally (vii) all nodes start with the same energy level and the BS has unlimited energy resource.

5.2 Radio Signal Propagation and energy consumption Model

LLEACH-C use a simple energy model as in LEACH-C, Where energy dissipation 50nJ/bit for both transmitter ETx-elec and receiver ERx-elec to run the radio electronics and the energy dissipated in the transmitter amplifier in a free-space channel εfs = 10pJ/bit/m2. Thus to send an (I-bit) message over a distance d the energy consumed by the radio can be calculated as:

$$\mathbf{E_{TX}\ (I,\ d) = E_{TX\text{-}elec}\ (I) + E_{TX\text{-}amp}\ (I,\ d)\ E_{TX}\ (I,d) = I{*}Eelec + I * \varepsilon_{Fs} {*}d2} \quad (1)$$

To receive this message at destination the energy consumed by the radio can be calculated as:

$$\mathbf{E_{Rx}\ (I) = ER_{TX\text{-}elec}\ (I) = Eelec * I} \quad (2)$$

5.3 Vice Cluster Head Mechanism VCHM

VCHM computes the $\mathbf{E_F}$ required from each CH, during the data transmission in steady state phase, by the following equation:

$$\mathbf{E_F = E_{DR} + E_{DA} + E_{DS}} \quad (3)$$

Equation (3) explains the components of $\mathbf{E_F}$. Where $\mathbf{E_{DR}}$ is the CH consumed energy for data receiving, $\mathbf{E_{DA}}$ is the CH consumed energy for data aggregation, and $\mathbf{E_{DS}}$ is the CH consumed energy for data sending to BS.

For any CH has MNs and receives packets of I data bits (PKT (I)), equation (3) can be expanded as follows:

$$E_F = E_{elec} * I * MN + P_{KT}(I) * E_{DA} * MN + I * E_{elec} + I * \varepsilon_{Fs} * d^2 \quad (4)$$

Equation (4) is the criteria for the VCHM activation. Because when the BS received a frame, the VCHM compares the E_{CH} for each CH, with the calculated E_F for that cluster, if $\mathbf{E_{CH} < E_F}$, the VCHM will exchange the roles between the CH and VCH.

6. Performance evaluation for LLEACH-C

The LLEACH-C simulation model is built by using OMNET++ discrete event Simulator [21], to evaluate its performance from the point of view of the packet loss and network lifetime.

6.1 Simulation parameters

The values of the used parameters in the simulation are listed in Table.1.

Table 1: simulation parameters

Parameters	***Value***
Field size (M ·M)	1000 · 1000
Initial energy of sensor node	0.5 J
Transmitter /receiver Electronics ETX and ERx (Eelec)	50 nJ/bit
Transmitter amplifier ε_{Fs}	0:0013pJ / bit /m2
The energy for aggregation EDA	5 nJ /bit/ signal
The data packet size	4000 bits

6.2 Results

The simulation results which were carried out to compare the performance of the LLEACH-C with both, LEACH-C as a base protocol, and VLEACH as a basic idea, are in sections 2, 3 and 4. In simulation, the number of the deployed nodes is increased from 100 to 1000 node with unit step 100. Most of the results obtained in this paper were obtained by averaging ten independent simulation runs, where each run uses a different randomly-generated topology of sensor nodes.

6.2.1 Packet loss

The packet loss is the failure of one or more transmitted packets to arrive to their destination. This event can cause noticeable effects in all types of digital communications. This paper cares to give attention to the packet loss due to the CH failure during the round.

Therefore this paper is concerned with reducing the losses caused by applying the VCHM over LEACH-C. Simulation results compare the LEACH-C average packet loss with the LLEACH-C average packet loss, to find out the loss reduction as a result of adding the VCHM.

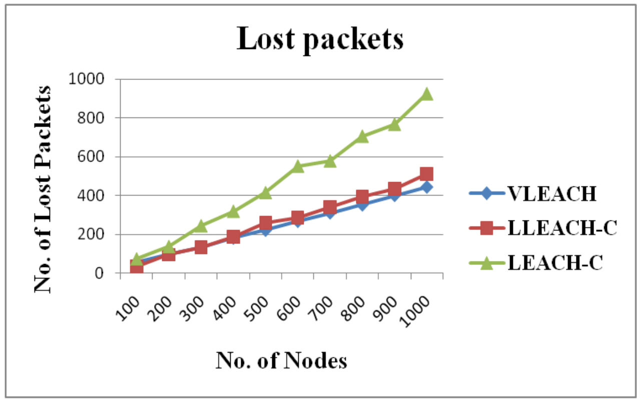

Fig.6 Average packet loss vs. number of nodes

Fig.6 demonstrates the average packet loss for LLEACH-C, VLEACH and LEACH-C. It is obvious that the average packet loss of LLEACH-C and VLEACH are approximately the same, because in both protocols there is a vice cluster head to take over in case of the CH failure, when this happens, it saves the collected data packets from being lost during the round, and thus solves the CH from being a single point of failure in the cluster. While in the LEACH-C, the packet loss increases dramatically as the number of nodes increases in the deployed area, which is due to the CH single point of failure problem, where; when the cluster head fails during the round, there is no recovery for its role, and all the data packets in the cluster are lost. It's clear that LLEACH-C has reduced the packet loss compared to that of LEACH-C by 43% on average, by applying the VCHM.

6.2.2 Network life time

The simulation calculates the network life time by counting the number of successive finished rounds till the last alive 10 nodes.

As shown in Fig. 7 the VLEACH lifetime is lower than LLEACH-C, by on average 69.3%, that is because the LLEACH-C uses a central algorithm, which creates optimal clusters, requires less energy for operation than the clusters formed using the distributed algorithm in VLEACH.

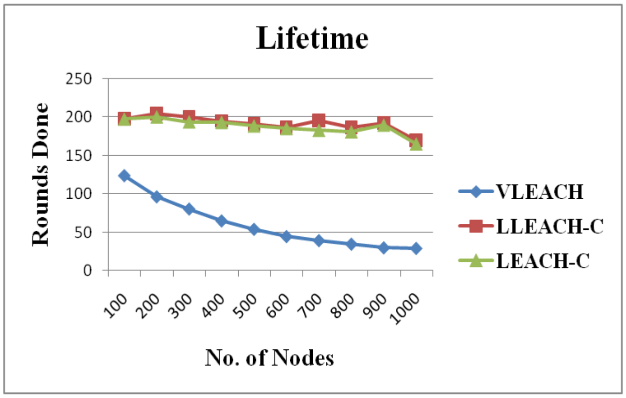

Fig.7 Network lifetime vs. number of nodes

Although the LLEACH-C reduces the packet loss of LEACH-C by approximately 43%, by applying the VCHM, the lifetime of both is the same, which means that the VCHM, saves the packets from loss, and does not consume extra network energy.

6.2.3 Throughput

The number of successive data bits received at the BS per second.

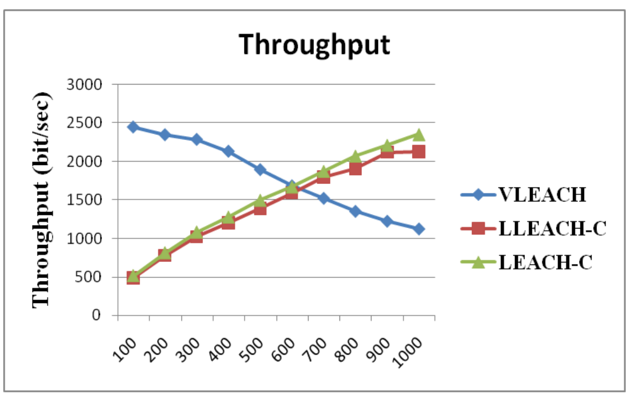

Fig.8 Throughput vs. number of nodes

Fig.8 demonstrates the average throughput for LEACH-C, LLEACH-C and VLEACH. From Fig.9, it is obvious that the throughput of LEACH-C and LLEACH-C are approximately the same, in both the throughput increased with the increase in number of deployed nodes, due to the increments of generated data packets. On the other hand, the throughput of VLEACH decreases with the number of deployed nodes. That is because VLEACH shows the worst performance of the three in lifetime as has been demonstrated before. Accordingly the number of data packets will be affected by this collapse in lifetime values. Therefore in large networks the LEACH-C and LLAECH-C perform better than VLEACH in throughput values.

6.2.4 End to end Delay

The time taken for a packet to be transmitted across a network from source to destination.

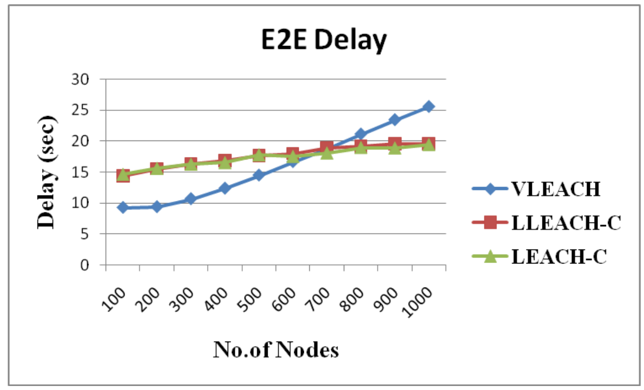

Fig.9 End to End delay vs. the number of nodes.

Fig.9 demonstrates the end to end delay for LEACH-C, LLEACH-C and VLEACH; it's obvious that the end-to-end delay of both LEACH-C and LLEACH-C is increased slowly with the increments of deployed nodes, due to a few increments of clusters members, which increases the required time from CH for overhearing and data aggregation. While in VLEACH the end-to-end delay increases rabidly with the number of deployed nodes, due to the increment of nodes density per cluster, that is because of the distributed algorithm applied for node choice in clusters, which may result in non uniform sized clusters. This problem increases the required time from CH for overhearing, and thus its failure will be accelerated and a new VCH will be chosen, and the overall network delay will increase. Therefore with large networks, LEACH-C and LLAECH-C protocols perform better end-to-end delay than VLEACH.

7. Conclusions and future work

High loss applications in WSN, suffer from degradation in network performance, caused by packet loss during the network operation, which makes the whole system unreliable, accordingly a lot of applications can bear occasional packet loss only with a certain upper bound of allowable packet loss, this paper addresses this important issue.

Generally, WSNs involve a large number of sensors ranging in hundreds or even thousands. Clustering is an effective mean for managing such high population of nodes. LEACH is one of the most popular clustering algorithms for WSNs, but its centralized version LEACH-C is able to deliver more effective data than it, even though cluster formation is more expensive, because the centralized algorithm can use network topology information to form good clusters that require less energy for operation than the clusters formed by distributed algorithm in LEACH.

Therefore this paper has proposed the VCHM mechanism for cluster head recovery to prevent the cluster head from being a single point of failure, this is done by selecting the biggest energy MN in the cluster as a VCH, to take the role of CH when its energy is not enough to finish the round, that reduces the packet loss occurred during the network operation.

Thus this paper cares about studying the performance of LEACH-C, before and after applying the VCHM to become LLEACH-C, also comparing the performance of LLEACH-C with the VLEACH, which applies the CH recovery over LEACH, in packet loss, network lifetime, End-to-End delay and throughput.

Simulation results showed that LLEACH-C offers improvements over LEACH-C in loss reduction by approximately 43%, while saving the same lifetime. Also it performs better lifetime compared to the VLEACH by on average 69.3%, with the same loss reduction, for large networks both of LAECH-C and LLEACH-C perform lower end-to-end delay than VLEACH, and higher throughput.

Renewable energy sources are the next hope to increase the WSNs lifetime, energy harvesting is the process by which energy is derived from natural resources, captured, and stored for small, wireless autonomous devices, like sensor nodes in WSN. Adding solar cells to sensor nodes gives them a continuous energy source, this leads to strengthening the lifetime of the nodes as well as the network. Studying the system performance after adding the solar cells is the goal for the future work.

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