A Cluster-Chain based Routing Protocol for Balancing Energy Consumption in Wireless Sensor Networks

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Abstract

Wireless sensor networks have recently emerged as an important computing platform. Energy conservation and maximization of network lifetime are commonly recognized as a key challenge in the design and implementation of wireless sensor networks. Clustering provides an effective method for prolonging the lifetime of a wireless sensor network. In this paper, we propose an Energy Efficient Cluster-Chain based Protocol (ECCP) for wireless sensor networks. The main goal of ECCP is to distribute the energy load among all sensor nodes to minimize the energy consumption and maximize the network lifetime of wireless sensor networks. ECCP organizes sensor nodes into clusters and constructs a chain among the sensor nodes within cluster so that each sensor node receives from a previous neighbor and transmits to a next neighbor. Furthermore, ECCP improves the data transmission mechanism from the cluster heads to the base station via constructing a chain among the cluster heads. Simulation results demonstrate that our proposed protocol significantly outperforms LEACH, CBRP and PEGASIS in terms of network lifetime, stability period, instability period, energy savings, balancing energy consumption among sensor nodes and network throughput.

Keywords: *Wireless sensor network, Clustering protocol, Energy efficient, Chain based routing*

1. Introduction

Rapid technological advances in micro-electro-mechanical systems (MEMS) and low-power wireless communication have enabled the deployment of large scale wireless sensor networks. The potential applications of sensor networks are highly varied, such as environmental monitoring, target tracking, and battlefield surveillance [1,2,3].

Wireless sensor networks have composed of hundreds of sensor nodes which sense the physical environment in terms of temperature, humidity, light, sound, vibration, etc. The main task of sensor node is to gather the data and information from the sensing field and send it to the end user via base station [2,4].

Energy conservation and maximization of network lifetime are commonly recognized as a key challenge in the design and implementation of wireless sensor networks [5,6]. Clustering provides an effective method for prolonging the lifetime of a wireless sensor network [1]. Using a clustering approach, sensors can be managed locally by a cluster head, a node elected to manage the cluster and be responsible for communication between the cluster and the base station. Clustering provides a convenient framework for resource management. It can support many important network features within a cluster, such as channel access for cluster members and power control, as well as between clusters, such as routing and code separation to avoid inter-cluster interference.

Moreover, clustering distributes the management responsibility from the base station to the cluster heads [7].

There are several cluster based protocols proposed by many authors. All those methods have their own advantages and disadvantages. In this paper, we propose an Energy Efficient Cluster-Chain based Protocol (ECCP) for wireless sensor networks. The main goal of ECCP is to distribute the energy load among all sensor nodes to minimize the energy consumption and maximize the network lifetime of wireless sensor networks. Proposed protocol organizes sensor nodes into clusters and forms a chain among the sensor nodes within cluster so that each sensor node receives from a previous neighbor and transmits to a next neighbor. Cluster heads are elected based on residual energy of nodes, distance from neighbors and the number of the neighbors of nodes. ECCP also adopts chain based data transmission mechanism for sending data packets from the cluster heads to the base station. Through simulation contrasted with previous works, we show that our approach can outperform in network lifetime, stability period, instability period, energy consumption, throughput and communication overhead.

The rest of this paper is organized as follows: Section 2 provides an overview of related work. Section 3 describes assumption and radio energy dissipation model. Our proposed scheme ECCP is described in detail in Section 4. The simulation results and related analysis will be illustrated in Section 5. Finally, in section 6 conclusion of the paper is presented.

2. Related Work

During the last few years, many energy efficient clustering protocols have been proposed for wireless sensor networks to prolong the network lifetime. We review some of the most recent work in different views of clustering.

LEACH [8, 9] is the first and most popular energy efficient hierarchical clustering algorithm for wireless sensor networks that was proposed for reducing energy consumption. The operation of LEACH is divided into rounds which each round consists of two phases, the set up phase and the steady state phase. In the set up phase, cluster heads are selected and clusters are organized. In the steady state phase, the actual data transmissions to the base station take place. After the steady state phase, the next round begins. During the set up phase, every sensor node elects itself as cluster head with some probability and broadcasts its decision. The remaining sensor nodes receive the broadcast from one or more cluster heads and make their association decision based on minimum communication cost. Since the role of cluster head requires more handling of data than non-cluster head nodes, energy of the cluster head node is dissipated at higher rate than ordinary sensor nodes. To balance the over all energy consumption across the network, the role of the cluster head is rotated among all sensors. The LEACH protocol is energy efficient but the expected number of clusters is pre-defined. Another disadvantage of LEACH is that it does not guarantee good cluster head distribution and assumes uniform energy consumption for cluster heads.

LEACH-C [9] uses a centralized clustering algorithm. In each round of LEACH-C, a node needs to send its residual energy and location information to the base station. Based on the received information, the base station can uniformly distribute the cluster heads to the topology and adjust the size of each cluster. The base station also adjusts the probability of selecting cluster heads according to each node’s residual energy. The steady state phase of LEACH-C is identical to that of the LEACH protocol. Because of centralization, LEACH-C will cause high overhead.

In [9,10] LEACH with Fixed clusters (LEACH-F) has been proposed. The base station uses the same algorithm used in LEACH-C to form the clusters, then LEACH-F uses fixed clusters that are formed once in the first setup phase by the base station. The cluster head position rotates, and every node can become cluster head of its cluster. The fixed clusters do not allow new nodes to be added to the network, and the nodes performance is not affected by nodes dying.

PEGASIS [11] is a chain based power efficient protocol constructed on the basis of LEACH. Rather than forming multiple clusters, PEGASIS forms a chain from sensor nodes so that each node receives from and transmits to a neighbor and only one node is selected from that chain as leader node to transmit to the base station. PEGASIS eliminates the overhead caused by dynamic cluster formation in LEACH, and decreases the number of transmissions and receptions by using data aggregation although the clustering overhead is avoided. However, this achievement faded by the excessive delay introduced by the single chain for the distant node.

HEED [12] selects cluster heads randomly based on probability but it distributes cluster heads more uniformly across the sensor network by multiple iterations and smaller cluster ranges. The approach sets the probability of selecting cluster heads by each node's residual energy at the first iteration of each round, doubles the probability before going to the next iteration, and terminates the operation when the probability reaches 1. At any iteration, each node can become a cluster head with its own probability if hearing no cluster head declaration from its neighborhood.

Tang et al. [13] proposed a Chain-Cluster based Mixed routing (CCM) algorithm for wireless sensor networks. CCM, organizes the sensor nodes as a set of horizontal chains and a vertical cluster with only chain heads. Data transmissions in CCM proceed in two stages: chain routing and then cluster routing. In the first stage, sensor nodes in each chain transmit data to their own chain head node in parallel, using an improved chain routing protocol. In the second stage, all chain head nodes are grouped as a cluster in a self-organized manner, where they transmit fused data to a voted cluster head using the cluster based routing.

Zarei et al. [14] proposed a distributed and energy efficient protocol, called CBRP for data gathering in wireless sensor networks. CBRP clusters the network by using new factors and then constructs a spanning tree for sending aggregated data to the base station. Only the root node of this tree can communicate with the base station node by single-hop communication. The main drawback of CBRP is the much communication overhead due to many number of non-data messages exchanged between sensor nodes.

Bajaber and Awan. [10] proposed an energy efficient clustering protocol (EECPL) to enhance lifetime of wireless sensor networks. EECPL elects a cluster head and a cluster sender in each cluster. The cluster head is responsible for creating and distributing the TDMA while cluster senders responsible for sending the aggregated data to the base station. EECPL organizes sensor nodes into clusters and uses ring topology to send data packets so that each sensor node receives data from a previous neighbor and transmits data to a next neighbor. Upon receiving the aggregated data from previous neighbors, cluster senders transmit the aggregated data to the base station directly.

3. Assumption and Radio Energy Model

Assumption and radio energy model is described in this section.

3.1. Assumption

The following assumptions are made for our sensor network.

- There is a base station located far from the sensing field. Sensor nodes and the base station are all stationary after deployment.
- Nodes are location-aware, i.e. equipped with GPS-capable antennae.
- All sensor nodes are homogeneous and have the same initial energy supply.

  Radio channel is symmetric, i.e., the energy consumption for transmitting a message from one node to another is the same as on the reverse direction.

3.2. Radio Energy Model

We use the similar radio energy model described in [8, 9] for the communication energy dissipation. Equation (1) is used to calculate the transmission energy, denoted as $E_{Tx}(k, d)$, required for a k bits message over a distance of d.

$$E_{Tx}(k,d) = \begin{cases} kE_{elec} + k\varepsilon_{fs} d^2, d < d_0 \\ kE_{elec} + k\varepsilon_{amp} d^4, d \geq d_0 \end{cases} \qquad (1)$$

To receive this message, the energy required is as Eq. (2).

$$E_{Rx}(k) = kE_{elec} \qquad (2)$$

The electronics energy, E_{elec}, is the energy dissipated per bit to run the transmitter or the receiver circuit, and depends on factors such as the digital coding, and modulation, whereas the amplifier energy, $\varepsilon_{fs}d^2$ or $\varepsilon_{amp}d^4$, depends on the acceptable bit-error rate.

From Equation (2), one can see that receiving data is also a high overhead procedure. Thus, the number of transmission and receiving operations must be cut to reduce the energy dissipation.

4. Details of the Proposed Protocol

In conventional clustering protocols [8, 9, 12], cluster heads manage the member nodes and collect data from them. Each cluster head collects data from the member nodes, aggregates the data, and then sends the aggregated data to the base station. Since the cluster heads have responsibility for the collecting, aggregating, and sending data to the base station, they drain energy much faster than the member nodes, reducing the network lifetime. Some of the clustering protocols [8, 9, 12, 14] periodically recluster the network in order to distribute the energy consumption among all sensor nodes in a wireless sensor network. These protocols suffer from cluster formation overhead. They consume more energy due to the cluster formation overhead. In static clustering protocols, clusters are formed once forever and role of the cluster head is rotated among the nodes in a cluster. Static clustering eliminates the overhead caused by dynamic cluster formation but the fixed clusters do not allow new nodes to be added to the network, and the nodes performance is not affected by nodes dying. In PEGASIS that is chain based routing protocol for wireless sensor networks, is formed a chain among the sensor nodes so that each node will receive from and transmit to a close neighbour.

PEGASIS significantly induces a much longer data transmission delay because of large number of hops in a long chain.

In order to avoid this situation, we propose an Energy Efficient Cluster-Chain based Protocol (ECCP) for wireless sensor network to maximize the network lifetime and reduce the energy consumption and communication overhead. The operation of the ECCP protocol is organized into rounds. Each round of this protocol consists of the following phases.

1 Clustering phase

2 Chain formation phase

3 Data transmission phase

In our proposed protocol, due to reduction of clustering overhead, clustering phase is not performed in each round. Sensor nodes use residual energy levels to select new cluster heads for next round. If any sensor node dies in cluster, the cluster head sends a message to base station and informs it that the sensors should hold the clustering phase at the beginning of the upcoming round. After that, the base station sends specific synchronization pulses to all nodes. When each node receives a pulse, it prepares itself to perform clustering.

4.1. Clustering Phase

Clustering phase consists of two stages.

4.1.1. Cluster Head Election: In ECCP, each node maintains a neighborhood table to store the information about its neighbors. In the clustering phase, each node broadcasts a message which contains information about its current location (possibly determined using a GPS receiver) and residual energy using a non persistent carrier-sense multiple access (CSMA) MAC protocol within radio range r. All nodes within the radio range of one node can be seen as the neighbors of the node. Each node receives the message from all neighbors in its radio range and updates the neighborhood table. After receiving the message, each node computes the distance to its neighbors and computes its weight using Eq. (3)

$$Weight_i = RE_i * \sum_{j=1}^{numberofneighbors} \frac{1}{dist^2(v_i, v_j)} \tag{3}$$

Where RE_i denotes residual energy of node *i* and *dist* (v_i, v_j) is the distance node *i* to node *j*. Each node broadcasts its weight using a non persistent CSMA MAC protocol within a radio rang r and the node with highest weight among its neighbors is selected as cluster head.

4.1.2. Formation of Cluster: Each cluster head broadcasts an advertisement message (ADV) which contains the node's ID and a header that distinguishes this message as an announcement message using a non persistent CSMA MAC protocol and invites the other nodes to join its cluster. Depending on the signal strength of the advertisement messages, each node selects the cluster head it will belong to and sends a join-request message (Join-REQ) which contains node's ID and the cluster head's ID back to the chosen cluster head using a non persistent CSMA MAC protocol.

Because of much overhead of clustering phase, the phase is not performed in each round. If any sensor node dies in cluster, the cluster head sends a message to base station and informs it that the sensor nodes should hold the clustering phase at the beginning of the next round, otherwise sensor nodes use residual energy to select new cluster heads for next round.

4.2. Chain Formation Phase

This phase is divided into Chain formation within clusters and Chain formation among cluster heads.

4.2.1. Chain Formation within Clusters: When the clusters formed, the cluster head creates a chain between sensor nodes within cluster so that each sensor node receives data from a previous neighbor, aggregates its data with the one received from its previous neighbor and transmits aggregated data to a next neighbor. The chain within cluster is formed in the order from the furthest to the nearest node from the cluster head. Once the chain construction within the cluster is complete, the cluster head creates the TDMA schedule, which specifies the time slots allocated for each member of the cluster. After that, cluster head sends the chain of sensor nodes and TDMA schedule to sensor nodes within its cluster.

4.2.2. Chain Formation Among Cluster Heads: In this stage, the cluster heads send their location information to the base station. Based on the received information, the base station creates a chain of cluster heads and sends it to the cluster heads. In ECCP, the base station applies the greedy algorithm used in PEGASIS to make a chain among the cluster heads. The chain is formed in the order from the furthest to the nearest node from the base station, and nearer nodes have better opportunities to be the leader. All the cluster heads send the data to the leader node along the chain, finally the leader node transfers the collected data to the base station. Building a chain among the cluster heads can reduce energy consumption.

4.3. Data Transmission Phase

Data transmission phase is divided into several frames and sensor nodes transmit and receive the data at each frame. For gathering data in each frame, sensor nodes in each cluster transmit their data to their own cluster head using the chain based routing. The end node (furthest node) in a chain transmits data to the next neighbor in the chain. Each sensor node receives data from previous neighbor, aggregates with its own data, and transmits to the next neighbor in the chain. The data are transmitted in an alternative way until all data are transmitted to the cluster head node. Once the cluster heads receive data form previous neighbors in the latest frame of a round, data transmission among cluster heads are begun.

In this stage, leader node generates a token and then transmits it to the end cluster head node in the chain of cluster heads. Only the cluster head that has the token, can transmit data. Each cluster head aggregates its neighbor's data with its own data and transmits aggregated data and token to the next neighbor in the chain of cluster heads. Finally, the aggregated data are delivered to the base station by the leader node in the chain of cluster heads that has the shortest distance to the base station.

Figure 1 shows data transmission in ECCP.

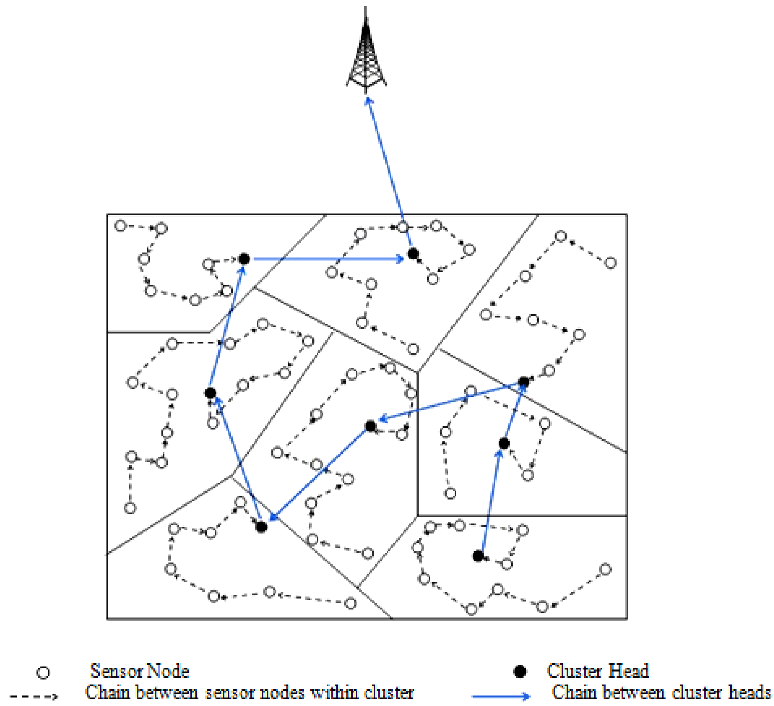

Figure 1. Data Transmission in ECCP

Since data transmission distances between cluster heads are more than data transmission distances between sensor nodes within the cluster, the cluster heads drain energy much faster than sensor nodes within cluster. In order to balance the energy consumption among all sensor nodes in the network, the cluster head's role should be rotated among the sensor nodes to prevent their exhaustion. ECCP uses the residual energy for cluster's rotation so that sensor node with highest residual energy in the cluster is selected as cluster head for next round. In the latest frame of a round; sensor node sends data to the next neighbor; also it sends its residual energy. Based on the collected information, the sensor node compares its energy levels with the energy level of previous neighbor and selects highest energy level and sends the information and aggregated data to the next neighbor. Once, the data are received by cluster head, the node with highest residual energy is selected as cluster head for next round.

If any sensor node dies in cluster, the cluster head sends a message to the base station and informs it that the sensors should hold the clustering phase at the beginning of the upcoming round. After that, the base station sends specific synchronization pulses to all nodes. When each node receives a pulse, it prepares itself to perform clustering phase.

Figure 2 shows the pseudo code of the ECCP protocol.

Phase 1: Clustering phase
Each node broadcasts a message in the range r
Each node receives the messages from all nodes in the range r
Each node computes distance from all neighbors and updates neighborhood table
Each node computes CHSV

$$CHSV_i \longleftarrow Weight_i = RE_i * \sum_{j=1}^{numberofneighbors} \frac{1}{dist^2(v_i, v_j)}$$

if $CHSV_i$ > CHSV of all its neighbors nodes (all nodes in the range r)

```
    Node i acts as cluster head (CH)
    Clusterheads(i) ⟵ True
End
Each CH broadcast an adv_Msg in the range r
Each non-CH sends a Join_REQ to closest CH
Phase 2: Chain formation phase
If  clusterheads(i)= True
       Create a chain from its farthest node to its nearest node  in the cluster
       Sends the chain to its members of the cluster
       Send  (location i)  to the BS
        The BS creates a chain between  CHs and sends the chain to all CHs
       if distance (i,BS) < distance of all CH nodes to BS
                header(i) ⟵ True
end

Phase 3: data transmission phase
if  clusterheads (i) =FALSE
        node i aggregates its data with the data of  previous node and sends
       aggregated data and  Residual_Energy  to the next node in the chain
end
if  clusterheads(i) =TRUE
       if  header(i) = FALSE
             CH node i aggregates its data with the data of  previous CH node and sends
aggregated data  to the next CH node in the chain of CHs
     else
             header node i aggregates its data with the data of  previous CH node and sends
aggregated data  to the BS
     end
end
 During the data transmission phase
 ∀ node i:  if state(i) =dead
                           Alive_node(r) ⟵ Alive_node(r) -1
                  end
  if alive_node(r) = alive_node (r-1)   // r indicates cuurent round
                                                     // r-1 indicates previous round
         CH ⟵ the node i that has heighest Residual_Energy in each cluster
         Clusterheads(CH) ⟵ TRUE  // node i is cluster head
  else
         CH sends a message to BS to do clustering phase
         The BS broadcast the synch pluse in the network
          ∀ node j: if the synch pulse is received
                           The node j becomes ready to hold the clustering phase
                           for next round
                      end
 end
```

Figure 2. Pseudo Code of the ECCP

5. Simulation and Results

In this section, we evaluate the performance of ECCP via simulations. For evaluation, we used MATLAB and tested ECCP and other routing protocols, such as LEACH, CBRP and PEGASIS.

For performance comparison, we mainly take account of the following performance parameters:

- Network lifetime
- Stability period
- Instability period
- Load balancing
- Energy consumption
- Network throughput
- Communication overhead

5.1. Simulation Setup

We assume 100 sensor nodes are randomly scattered into the sensing field with dimensions 100 m × 100 m and a base station located at position (50,175). All sensor nodes periodically sense the environment and transmit the data to the next neighbors. Table 1 summarizes parameters used in our simulation.

Table 1. Simulation Parameters

Parameters	Value
Network size	(0,0) to (100,100)
Number of nodes	100
Base station location	(50,175)
Cluster radius r	20 m
Initial energy of nodes	0.3 J
Data packet size	500 Bytes
Broadcast packet size	25 Bytes
E_{elec}	50nJ/bit
ε_{fs}	100pJ / bit /m2
ε_{amp}	0.0013 pJ / bit /m2
d_0	87.7 m
E_{DA}	5 nJ/bit/signal

5.2. Simulation Results and Analysis

In this section, simulation results are described.

5.2.1. Network Lifetime, Stability Period and Instability Period: Stability period is defined as the time interval before the death of the first node. Instability period is defined as the time interval between the death of the first node and last node [15]. Without longer stability period, more information could not be able to collect from the sensor field even though the life time of the network is high. So prolonging the stability period is crucial for many applications [16].

Figure 3 shows the total number of nodes that remain alive over the simulation time. It also shows the time span from the first node dies to the last node dies in different routing protocols. Figure 4 shows the performance comparison of the network lifetime using FND and LND metrics. FND (First Node Dies) is defined as the time required for the first node to run out of energy and LND (Last Node Dies) is defined as the time required for the last node to run out of energy. Since more than one node is necessary to perform the clustering algorithm, the Last Node Dies represents overall lifetime of wireless sensor network when 90% of sensor nodes die.

It is clear from Figure 3 and Figure 4 that the ECCP has better performance than other protocols in terms of network lifetime, stability period and instability period. The stability period of the ECCP was prolonged than LEACH, CBRP and PEGASIS and the instability period was shortened for ECCP compared to LEACH, CBRP and PEGASIS. It means ECCP can better balance energy consumption in the network.

The ECCP has more alive sensor nodes than the other protocols at any time and ideally balance energy consumption of all nodes in the network. This is mainly because each sensor node receives data from the previous neighbor, aggregates with its own data and transmits to the next neighbor in the chain. ECCP also considers residual energy of nodes, distance from neighbors and the number of the neighbors of nodes to elect cluster heads in clustering phase.

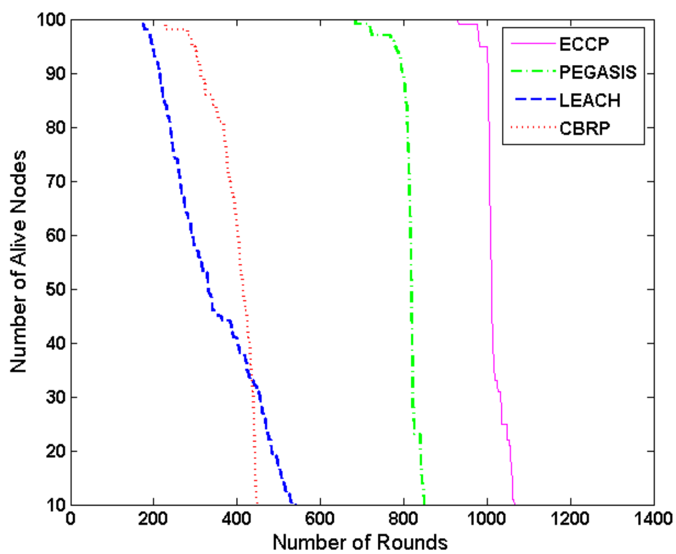

Figure 3. The Number of Alive Nodes over Round

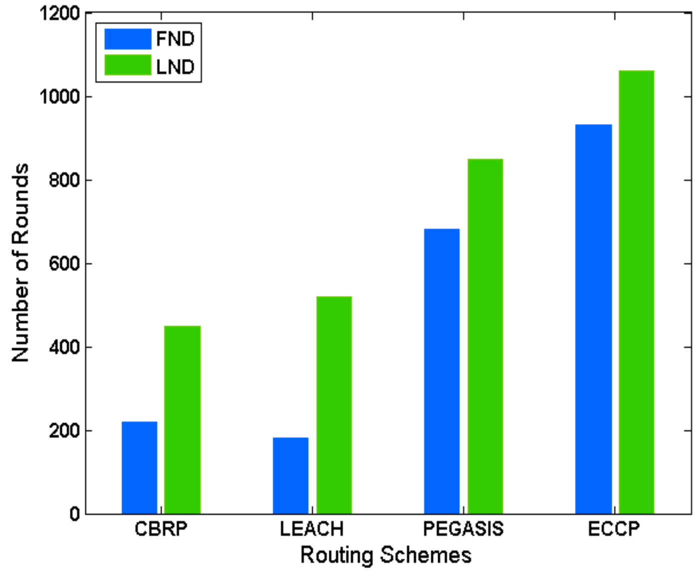

Figure 4. Performance Comparison of the Network Lifetime using FND and LND Metrics

5.2.2 Load Balancing: Load balancing is defined as the percentage of the total remaining energy of the network when the first node dies. Figure 5 shows the remaining energy of the network during the simulation runs. Table 2 shows the percentage of the total remaining energy of the network when the first node dies. If the parameter of a protocol is lower than other protocols, the protocol has better performance in terms of load balancing.

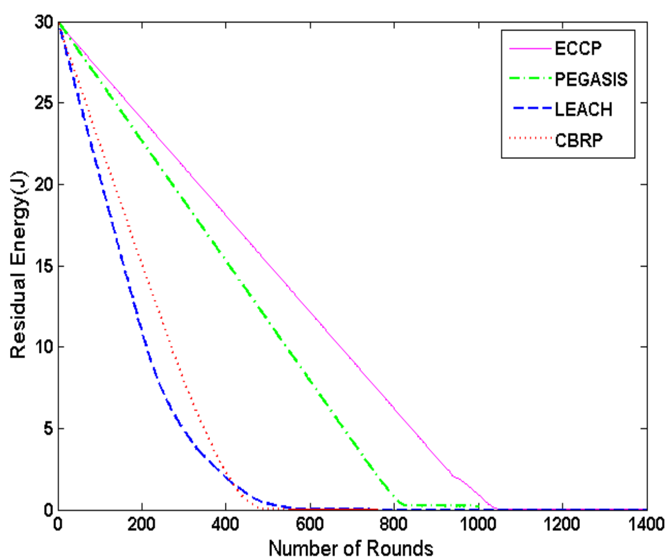

Figure 5. The Remaining Energy of the Network over Round

Table 2. The Percentage of the Total Remaining Energy of the Network when the First Node Dies

Routing Protocol	Remaining Energy
LEACH	42%
CBRP	43%
PEGASIS	14%
ECCP	8%

It is clear from Table 2 that our proposed protocol has better performance than other protocols in terms of load balancing.

5.2.3 Energy Consumption: Figure 6 demonstrates the energy consumed by all nodes during the simulation runs. It is obvious that ECCP uses much less energy compared to other protocols. The reduced energy consumption of ECCP is mainly due to the small transmit distances of most of the nodes as they need to transmit only to their nearest neighbors in the chain instead of transmitting directly to the far away base station or cluster head, which was the case with LEACH and CBRP. LEACH and CBRP also consume more energy due to the cluster formation overhead. Since ECCP does not perform clustering phase in each round, it reduces energy consumption of the network. ECCP also has better performance than PEGASIS. This is mainly due to the multiple chains are constructed in ECCP which causes the chains to have smaller length than the single chain in PEGASIS. This reduces the amount of data to be aggregated and propagated along the chain which results in more savings in the energy consumption of the nodes.

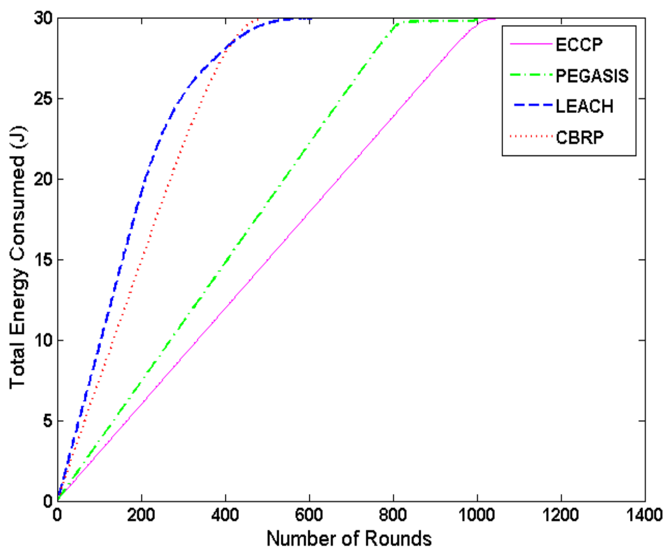

Figure 6. The Total Energy Consumption of the Network per Round

5.2.4 Network Throughput: Network throughput is defined as the total number of data packets received at the base station. Figure 7 and Figure 8 show that, the total number of data messages received at base station at the end of network lifetime in ECCP is greater than other protocols. Therefore, the proposed protocol has better throughput than other protocols. This is mainly due to ECCP increases the network lifetime.

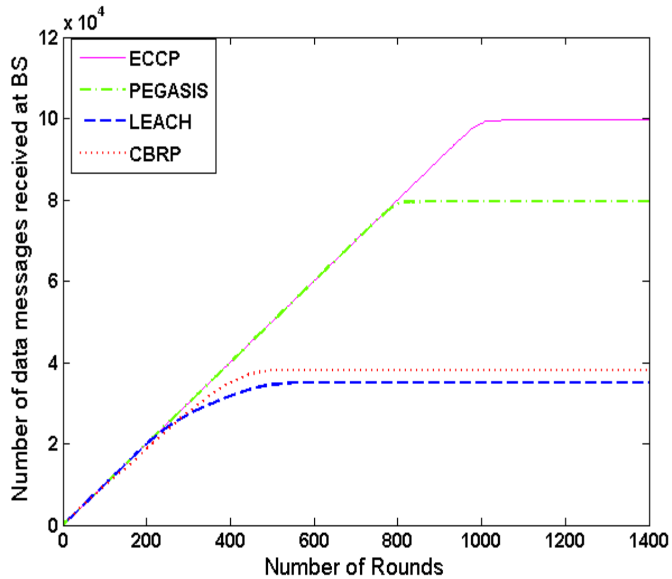

Figure 7. Number of Data Messages Received at Base Station over Round

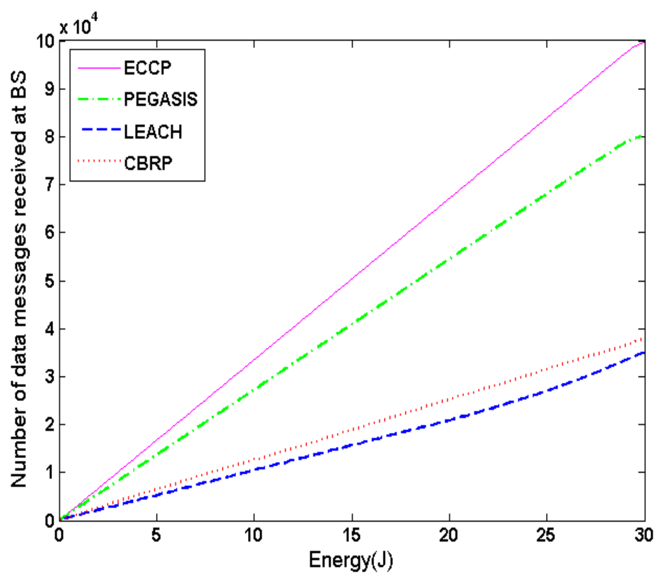

Figure 8. Number of Data Messages Received at Base Station over Energy

5.2.5 Communication Overhead: Communication overhead is defined as the total number of non-data messages transmitted during transmitting 10000 data messages. Lower value of the overhead indicates better protocol. Figure 9. clearly shows that ECCP has the minimum control overhead over all the protocols. LEACH and CBRP suffer from cluster formation overhead. They consume more energy due to the cluster formation overhead. Additionally, each sensor node transmits data to its cluster head even if the cluster head resides farther from the base station. CBRP also needs to send extra control messages to make the final selection of cluster head in each round, thus it has more overhead than other protocols. Since ECCP does not perform clustering phase in each round and uses the residual energy for cluster head's rotation, it reduces a large amount of communication overhead.

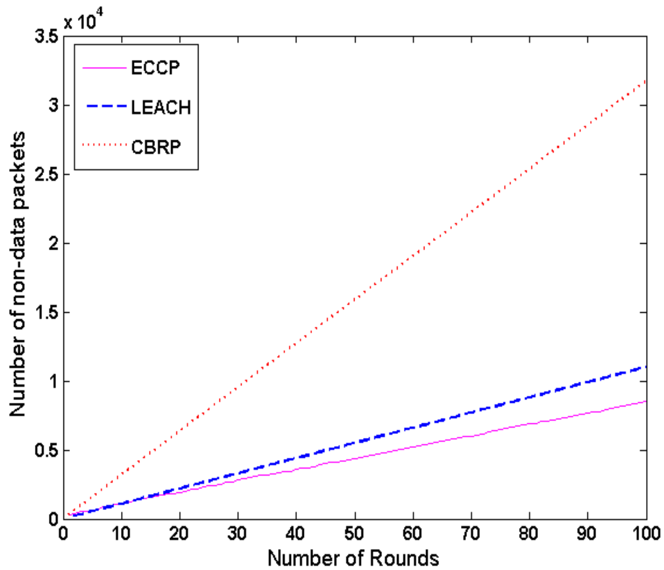

Figure 9. Communication Overhead

In summary, the above results show that ECCP can extend network lifetime, balance energy, reduce energy consumption, increase number of data messages received at base station (throughput) and reduce communication overhead.

6. Conclusion

In this paper, we proposed ECCP, a novel Energy Efficient Cluster-Chain based Protocol for wireless sensor networks that aims at maximizing the network lifetime and stability period and balancing energy consumption among sensor nodes. ECCP organizes sensor nodes into clusters by using multiple metrics and constructs a chain among the sensor nodes within cluster so that each sensor node receives from a previous neighbor and transmits to a next neighbor. ECCP also adopts chain based data transmission mechanism for sending data packets from the cluster heads to the base station. By chaining the nodes in each cluster and using a separate chain for the cluster heads, ECCP offers the advantage of small transmit distances for most of the nodes and thus helps them to be operational for a longer period of time by conserving their limited energy. We evaluated the performance of ECCP by comparing it with LEACH, CBRP and PEGASIS. The simulation results show that ECCP is more efficient in terms of network lifetime, stability period, instability period, balancing energy consumption among sensor nodes, energy consumption and the amount of data received at base station than other protocols.

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