Comparative Study of BCDCP protocols in Wireless Sensor Network

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ABSTRACT
A wireless sensor network (WSN) consists of low power multifunctioning sensor nodes which operate in an unattended environment with limited computational and sensing capabilities. Once deployed, the small sensor nodes are usually inaccessible to the user, and thus replacement of the energy source is not feasible. Therefore, energy efficiency is a key design issue that needs to be enhanced in order to improve the life span of the network. The sensor nodes communicate with each other via various Routing Protocols. Base-Station Controlled Dynamic Clustering Protocol (BCDCP) is a hierarchical routing protocol that distributes the energy dissipation evenly among all sensor nodes to improve network lifetime and average energy savings. In this paper, we discuss and compare BCDCP and the different types of BCDCP-based protocols.

General Terms
Routing protocols, QoS, wireless sensor network, hierarchical routing

Keywords
WSN, hierarchical routing protocols, BCDCP, QoS

1. INTRODUCTION
Wireless sensor networks consist of thousands of low-power sensor nodes that are normally deployed in an unattended environment which once deployed are usually inaccessible to the user. These sensor nodes have limited sensing and computational capabilities. Thus, replacement of energy is not feasible. Recent developments in WSN have made the sensor nodes small in size and low in cost. Hence, energy efficiency is a key design issue that needs to be enhanced in order to improve the life span of the network. Several network layer protocols have been proposed to improve the effective lifetime of a network with a limited energy supply. Most of the attention, however, has been given to the routing protocols since they might differ depending on the application and network architecture [[1], [2]].

Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding. The sensor nodes are used in different applications such as military and security, environmental monitoring, automobile industries, patient health monitoring, constructions, etc. [[3], [4], and [5]].

2. HIERARCHIAL ROUTING PROTOCOLS
The routing protocols are classified as data-centric, hierarchical, location based, network flow based and quality of service (QoS) based.

Data-centric protocols are query-based and depend on the naming of desired data, which helps in eliminating many redundant transmissions. Hierarchical protocols aim at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Location based protocols utilize the position information to relay the data to the desired regions rather than the whole network. The routing approaches based on general network-flow modeling and protocols that strive for meeting some QoS requirements go along the routing function.

In hierarchical-based routing, also known as cluster-based routing, different roles are assigned to sensor nodes. Energy-intensive tasks are assigned to nodes that are more powerful in terms of energy reserve, while more energy relaxed roles are proclaimed by weaker nodes. Hierarchical-based routing is prominent for achieving empirically good and promising results in terms of network lifetime and energy savings. This is attributed to the fact that, as means of reducing data traffic and consequently minimizing the amount of energy dissipated, hierarchical based routing protocols perform local data processing and aggregation as early as possible.

Minimizing spatial separations between non-cluster head nodes and the CH in each cluster is a rather critical influential factor in cluster-based routing protocols. The fact that only CH nodes are required to transmit signals to the far BS, highlights the leverage of small transmit distances traversed by most nodes in the network (i.e. non-cluster-head nodes). However, being a CH is associated with performing energy-intensive tasks; which makes it more apt to quickly draining its energy. Once a CH dies, all nodes belonging to the cluster lose communication ability and are considered virtually dead. In addition, if other CHs are engaged in inter-cluster communication with the CH in question, they also, along with their entire cluster, lose communication ability [15].

3. HISTORY OF BCDCP PROTOCOL

3.1 LEACH

Low-energy adaptive clustering hierarchy (LEACH) is a protocol architecture for micro sensor networks that combines the ideas of energy-efficient cluster-based routing and media access together with application-specific data aggregation to achieve good performance in terms of system lifetime, latency, and application-perceived quality. LEACH includes a distributed cluster formation technique that enables self-organization of large numbers of nodes, algorithms for adapting clusters and rotating cluster head positions to evenly distribute the energy load among all the nodes, and techniques to enable distributed signal processing to save communication resources. The results showed that LEACH can improve system lifetime by an order of magnitude compared with general-purpose multi hop approaches [6].

3.2 PEGASIS

A protocol called PEGASIS (Power-Efficient GAthering in Sensor Information Systems) is a near-optimal chain-based protocol that minimizes energy. In PEGASIS, each node communicates only with a close neighbor and takes turns transmitting to the base station, thus reducing the amount of energy spent per round. The main idea which works here is to form a chain among the sensor nodes so that each node will receive from and transmit to a close neighbor. Gathered data move from node to node, get fused, and, eventually, a designated node transmits to the base station (BS). Nodes take turns transmitting to the BS so that the average energy spent by each node per round is reduced. Building a chain to minimize the total length is called a greedy chain approach. The simulation results showed that PEGASIS performed better than LEACH. The comparisons were made on the basis of performance of LEACH and PEGASIS with respect to energy and delay using extensive simulations for different network sizes. Results showed that PEGASIS protocol performed 80 or more times better than the LEACH protocol [[7], [16]].

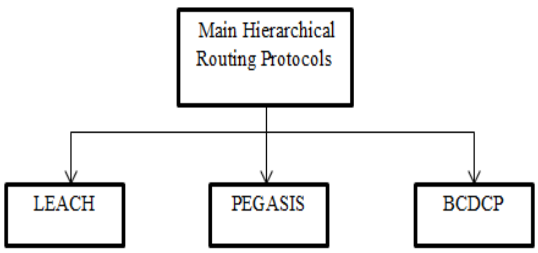


Fig 1: Hierarchical Routing Protocol

4. BCDCP

As an extension of LEACH and PEGASIS, a centralized cluster-based routing protocol, called Base-Station Controlled Dynamic Clustering Protocol (BCDCP) is a wireless sensor routing protocol with the base station being an important component with complex computational abilities which makes the sensor nodes very simple and cost effective. In BCDCP, energy intensive computation decisions are taken by the BS, which is assumed to be non-energy constrained and to be fully aware of the location of all sensor nodes in the network. BCDCP builds uniformly distributed clusters and does not get confined to a particular region in the network. It performs balanced cluster formation by balancing the size of the clusters.

BCDCP operates in two major phases: setup and data communication. During data-communication phase, each cluster head (CH) receives signals from the non-cluster-head members, and aggregates them before engaging in a multi-hop CH-to-CH routing path, constructed by applying minimum spanning tree (MST) algorithm. The MST technique applied in BCDCP connects all CHs on the basis of their spatial separation, so as to minimize the amount of energy dissipated for each CH. Upon constructing the MST, BCDCP randomly selects one of the CHs to be the one that forwards the data to the distant BS.

BCDCP provides drastic improvements over LEACH, LEACH-C and PEGASIS. It avoids direct transmission from each CH to the distant BS which yields substantial reduction in energy consumption. Also clusters are no longer isolated from each other, and so the death of one CH would have a profound effect on partitioning the network and causing other CHs, along with all the nodes in their clusters, to be virtually dead [[5], [7], [8]].

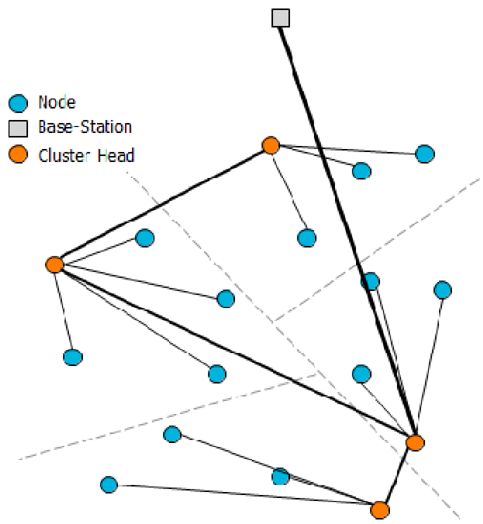


Fig 2: BCDCP protocol after Setup and Data Communication Phase

4.1 SETUP PHASE

i. Choose two most separated nodes from potential CHs
ii. Divide nodes based on proximity
iii. Balance clusters
iv. Iterate
v. MST connecting CHs
vi. Randomly choose one CH to forward to BS
vii. This distributes burden of routing to BS
viii. Create and distribute time division multiple access (TDMA) schedule

4.2 DATA COMMUNICATION PHASE

i. Using the TDMA schedule, nodes send data to the CH

ii. CH performs data fusion

iii. Compressed data is routed to the BS

Cluster head SCID	Time slot 1	Time slot 2	Time slot 3
Aa	Ab	ba	bb
Ab	Aa	ba	bb
Ba	Aa	ab	bb
Bb	Aa	ab	ba

Fig 3: Table of Schedule Creation using TDMA in BCDCP for a cluster with four nodes

4.3 BCDCP ADVANTAGES

i. Avoids direct transmission between each CH to distant BS – reduces energy consumption

ii. Clusters are not isolated – all region are covered

iii. Energy efficient – improves energy savings

iv. Network lifetime increases

v. Reduction of data traffic - minimizing the amount of energy dissipated

vi. Uses TDMA – avoids collision

vii. Uses MST – spatial distances lessened

viii. Load equally distributed between clusters in terms of energy – balanced cluster formation

5. BCDCP BASED PROTOCOLS

Though BCDCP protocol has its advantages over LEACH and PEGASIS protocol, it still had certain deficiencies. The below described protocols are various versions of BCDCP that are designed to overcome those deficiencies. Each protocol takes into consideration unique factors and proposes its different version.

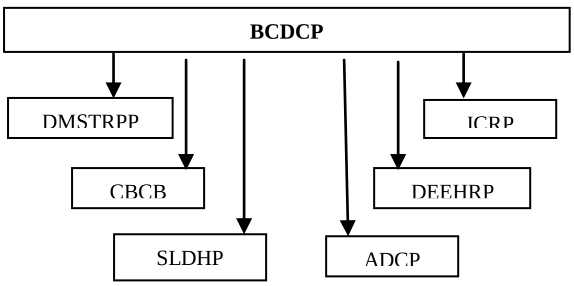


Fig 4: Various BCDCP based protocols

5.1 DMSTRP

Dynamic Minimal Spanning Tree Routing Protocol (DMSTRP) is an extended type of BCDCP protocol but operational for large network area. The main idea used here is to use MSTs to replace clubs in two layers of the network: intra-cluster and inter-cluster. If network area is large, clubs are not more effective than spanning tree to connect the nodes and so DMSTRP is an elegant solution for larger network area. DMSTRP protocol improves BCDCP by introducing MSTs instead of clubs to connect nodes in clusters. In each cluster, all nodes including CH are connected by a MST. CH being the leader then collects data from the whole tree. All CHs are connected by another MST and go on route towards BS. Trees produce less delay than clubs in wireless communication network. Results showed that DMSTRP excels LEACH and BCDCP in terms of both network lifetime and delay when the network size becomes large [9].

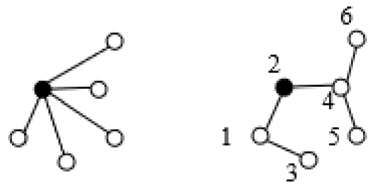


Fig 5: a) A club structure in BCDCP
b) A MST structure in DMSTRP [9]

5.2 ADCP

An Application Dependent Communication Protocol (ADCP) is based on the concept of Aggregation-aware Minimum Spanning Tree (AMST) which takes care of the aggregation capabilities of sensors and the corresponding application they have been deployed for. AMST when computed takes care of the data fusion scheme for the given application and thus develops a general protocol. An algorithm for AMST construction inspired from the Page Rank algorithm is developed. Simulations performed resulted that ADCP gives a higher network lifetime than other schemes such as LEACH, PEGASIS, BCDCP and PEDAP [10].

5.3 SLDHP

A Sink administered Load balanced Dynamic Hierarchical Protocol (SLDHP) is another hierarchical WSN routing protocol. It balances the load on the principal nodes. The sink has unrestrained energy and plays an important role of performing energy intensive tasks thereby increasing the energy efficiency of the sensors and its lifespan. In each iteration, the hierarchy pattern varies dynamically as it is based on the energy levels of the sensors. Outcome of this protocol includes substantial saving of the energy consumed by the nodes. Simulation results indicated significant improvement of performance over BCDCP [11].

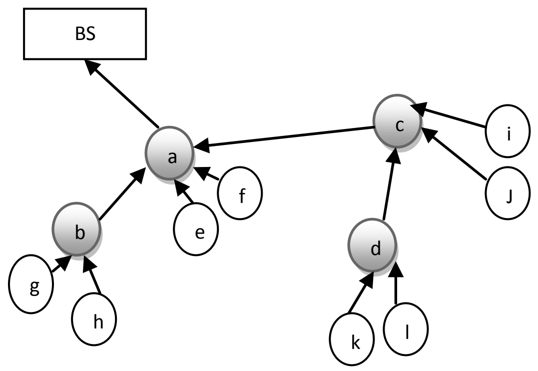
5.4 ICRP

Inner Cluster Routing Protocol (ICRP) is an algorithm routing protocol based on both BCDCP and LEACH protocols. It is a new hierarchical clustering algorithm that has the ability to create equal cluster with the same number of sensor like BCDCP method and then divided into small cluster with the same number of cluster like method in LEACH. In ICRP algorithm, the first step is deploying random of sensor node in field area, and then the sensor nodes will broadcast all information to the base station. The BS computes variables to find the most efficient energy called MER (Most of Efficient Energy Ratio). The sensor determines the cluster by a message sent from the BS and save all information in information table message.

This algorithm consists of three phases: initial, set-up and maintenance phase. The simulation results showed that this algorithm reduced the energy dissipation and prolonged the network lifetime when compared with BCDCP and LEACH [12].

5.5 DEEHRP

The death of one CH during a round in hierarchical routing protocols leads to virtual death of all the nodes in its cluster. In protocols having both inter- and intra- cluster communication, this effect cascades into other clusters inducing a set of similar effects and causing virtual death of nodes. This problem is referred to as domino effect. A centralized energy-aware routing protocol, called Domino effect- Evasive Energy-efficient Hierarchical Routing Protocol (DEEHRP) explicitly reduces the domino effect problem by handing over the role of a dying CH to another carefully selected node, called delegate directly before it runs out of energy. DEEHRP is an extension to the Energy-efficient Hierarchical Routing Protocol (EHRP). Extensive simulation results confirmed that DEEHRP outperforms the well-known Base-station Controlled Dynamic Clustering Protocol (BCDCP). In particular, it reduces energy consumption by up to 36% as compared to BCDCP [13].



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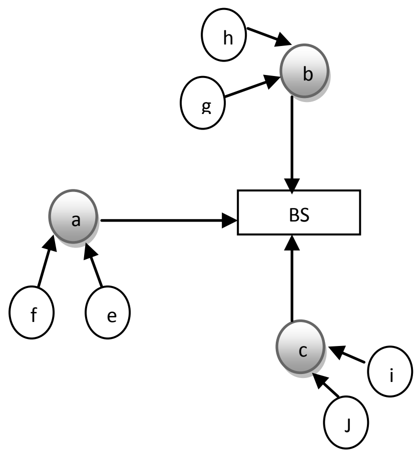

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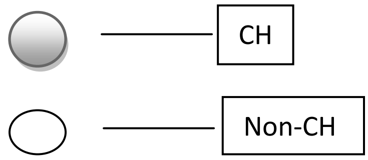

c)

Fig 6: Domino-effect problem in Hierarchical architectures

5.6 CBCB

A Centralized Border Node based Cluster Balancing (CBCB) protocol evenly distributes the load equally among the clusters to improve network lifetime. The main idea in CBCB is to maintain balanced number of sensor nodes among each cluster to prevent the overloading of CH, selection of CHs to cover the entire sensing area and use of multi-hop for head-to-head routing for forwarding the sensed information to remote BS. This protocol makes use of a BS with high energy in order to form clusters and discover the paths in routing, the CH rotation and to perform the different jobs which need intense energy. A comparison has been made between the performance of CBCB and other cluster-based approaches such as, LEACH, LEACH-C, BCDCP and PEGASIS. Simulation results indicated that the proposed CBCB protocol causes reduction in the overall energy consumption and improved network longevity [14].

5.6.1 GENERAL ALGORITHM FOR CBCB ROUTING PROTOCOL

A general algorithm is proposed for the working of CBCB routing protocol. Here are the following steps:

Step 1: Select the total number of nodes to be deployed to form an adhoc sensor network as ‘N’.

The node Si is symbolized by its i-th value and corresponding set of sensor nodes S= {s1, s2, s3, ….sN} where mod S = N and N represents the total number of sensor nodes deployed.

Step 2: Select the deployment area for the sensor nodes. Also fix the location for BS

Step 3: Let the optimal number of nodes in a cluster be ‘k’.

‘k’ can be any value from the maximum limit being 5% of remaining nodes i.e. 5% of all sensor nodes can become CH.

$$k = \frac{remaining\ nodes}{optimal\ CH}$$

Step 4: The cluster count begins initially with 0.

Step 5: Check condition for cluster count is less than or equal to ‘k’.

a) If cluster count <= k

- Select 2 border nodes among the unclustered nodes as BN1 and BN2
- Form 2 clusters with ‘k’ nearest nodes to BN1 and BN2 i.e.

cluster A = BN1 + (k-1) sensor nodes closest to BN1

cluster B = BN2 + (k-1) sensor nodes closest to BN2 respectively

where BN = border nodes

b) If cluster count not equal to k

- Select CH for all clusters
- Create MST where all CH are connected with each other to find a routing path which consumes minimum energy for each CH
- Select a forwarding CH (FCH) node to forward data to the distant BS
- Data transmission (each node to respective CH based on schedule creation ID)

Step 6: When CH receives all data from the nodes then performs data fusion to BS by FCH through the CH-to-CH routing paths and then fused data is transmitted to BS

Step 7: If a node doesn't die, we select CH for all clusters again i.e. step 5 b).

Step 8: If node dies, then

Remaining nodes = remaining nodes – dead nodes

Step 9: These steps are repeated until remaining nodes to form clusters becomes 0.

6. CONCLUSION AND FUTURE WORK

From the protocols reviewed, BCDCP protocol outperforms both LEACH and PEGASIS but still has certain drawbacks. It is a clustering based routing protocol which makes use of BS having a large energy to create clusters. The concept of BCDCP is to form balanced clusters such that the load on cluster head is balanced throughout the network. When sensor nodes and cluster heads are deployed in large number more amount of energy is dissipated for intra-cluster and inter-cluster transfer of data. Thus, creating an imbalance in terms of the intake of energy leads to decreasing the network lifetime.

These drawbacks of BCDCP are overcome by these following surveyed protocols. DMSTRP uses MSTs in replacement of club structure of BCDCP thereby becoming more feasible for larger network area and increasing energy efficiency over BCDCP routing protocol. ADCP uses Aggregation-aware Minimum Spanning Tree (AMST) which focuses on aggregation capabilities of sensors and the corresponding application they have been deployed for thereby developing a general protocol to route instead of MST routing in BCDCP and hence gave better results. SLDHP uses a sink structure which performs all the energy intensive tasks as it has unrestrained energy therefore increasing the network life span. ICRP is a protocol that has the ability to create equal cluster with the same number of sensor like BCDCP method and then divided into small cluster with the same number of cluster like method in LEACH and overall resulted in better results than both these protocols. DEEHRP explicitly reduces the domino effect problem which is present in those hierarchical routing protocols which have both inter- and intra- cluster communication. It reduces energy consumption significantly over BCDCP routing protocol. CBCB is a routing protocol in which the vital operations are carried out by the BS which performs intense computation to form clusters which contain approximately balanced count of sensor nodes in every cluster for maintaining the load giving better results than BCDCP.

Future trends include a performance evaluation and a check on the quality of service (QoS) metrics with a comparison of BCDCP and CBCB hierarchical based routing protocols that may prove which protocol is more efficient. The performance of these routing protocols will be analyzed using various metrics: Sensor nodes alive, Lifetime of the network, energy efficiency, network load, throughput, packet drop, energy consumption and end-to-end delay characteristics of both algorithms.

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