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A CLUSTERING-TREE TOPOLOGY ARCHITECTURE COMBINED WITH ENERGY PREDICTION FOR HWSN

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ABSTRACT

Designing an energy-effectiveprocedure to maximize the network lifetime in complex scenarios is a serious problem for heterogeneous wireless sensor networks (HWSN). Here, a cluster based control algorithm coupled with energy prediction (CBEP) is proposed for saving energy and guaranteeing network load balancing, while considering QoS parameters like link quality, packet loss rate. In CBEP, the average energy of the network is exactlyforetold per round in terms of the variance between the ideal and real average residual energy using central limit theorem and normal distribution mechanism, concurrently. Based on this, cluster heads are chosen by cost function (including the energy, link quality and packet loss rate) and their distance. The unselected normal nodes are then to join the cluster via the energy, distance and link quality. Also, a number of non-cluster nodes in each cluster are selected as relay nodes for transmitting data via multi-hop communication to reduce the load of each cluster-head and prolong the lifetime of the network. The simulation results show the efficiency of CBEP. As against with low-energy adaptive clustering hierarchy (LEACH), energy dissipation forecast and clustering management (EDFCM) and efficient and dynamic clustering scheme (EDCS) protocols, CBEP has longer network lifetime and receives more data packets at base station.

Index Terms - clustering, Heterogeneous wireless sensor networks (HWSN), energy valuation, multi-hop communication, topology control.

1. INTRODUCTION

Of late, wireless sensor networks fascinated lots of researchers because of its valuable wide applications and unique challenges. In the beginning study on wireless sensor networks mostly focused on technologies based on the homogeneous wireless sensor network in which all nodes have identical system resource. However, heterogeneous wireless sensor network is becoming more attractiveof late. And the output of researches [1], [2] depict that heterogeneous nodes can extend network lifetime and improve network reliability without significantly increasing the cost. A conventional heterogeneous wireless sensor networks comprises of a large number of normal nodes and a few heterogeneous nodes. The normal node, whose main tasks are to sense and issue data report, is low-cost and source-constrained.

The heterogeneous node, which offers data filtering, fusion and transport, is more costly and more talented. It may possess one or more kind of heterogeneous resource, e.g., improved energy capacity or communication expertise. They may be line powered, or their batteries may be substituted easily.Compared with the normal nodes, heterogeneous nodes may be configured with more powerful microprocessor and more memory. They also may connect with the sink node via high-bandwidth, longdistance network, such as Ethernet. The presence of heterogeneous nodes in a wireless sensor network can increase network reliability and lifetime.

Energy saving always is a crucial concern in sensor networks. Because some of situations might be very dangerous, for example, forest and building fire, volcanic mountain and underwater. Not everybody would like to change or recharge batteries of sensor nodes in the network. Thus, the most exciting design issue in sensor networks is limited and non-renewable energy provision. It is desirable to develop energy-efficient processing techniques that minimise power requirements across all levels of the protocol stack and minimise the amount of message passing for network control and coordination.
Heterogeneity of the network, the duplicate rate of the transmitted data, and the huge number of nodes may raise many opportunities for the design of routing protocols in sensor networks. Meanwhile, owing to vibrant process environments and the inherent limitation of various hardware and software resources, no single topology will always be best for all applications.
Since above differences, many new algorithms have been proposed for the routing problem in wireless sensor networks. To optimise energy consumption of routing protocols in wireless sensor networks, data aggregation and in-network processing, clustering technology, genetic algorithms and ant colony algorithms are employed in routing techniques proposed in the literature. Such techniques offer various possibilities for routing optimisation but also cause various problems.
Some of the problems faced by previous proposed algorithms are not taking into consideration other parameters like link quality, data loss rate, distance between cluster heads and other nodes, overloading of cluster heads. So in this paper, we try to consider these parameters too and design an energy efficient methodology for heterogeneous WSN to lengthen the lifetime of the network in both simple as well as complex scenarios.

In HWSN, predicting the energydepletion per round during the network lifetime and theactual lifecycle of network is much more difficult than homogeneousWSN. We propose CBEP algorithm for solvingthis problem in an effective way in terms of the predictabledifference between the ideal average residual energy and theactual average residual energy to calculate the average energyof network at the next round. The cluster heads are selecteddepending on the integrated cost function and their distance,while the clusters are formed by merging the factorsof the energy, distance and link quality.
As sensor networks interact with sensitivedata and/or operate in unfriendly unattended environments, it is crucialthat security concerns be addressed from the beginning of the systemdesign. But, due to inherent resource and computing restraints,security in sensor networks poses different challenges than traditional network/computer security.The untrustworthy communication channel andleft alone operation make the security defences even trickier.Indeed, aslisted out in [3], wireless sensors often have the processing featuresof machines that are years old, and the industrial focus isto reduce the cost of wireless sensors while maintaining comparable computingpower. Keeping this in mind, many scholars have begun to focus on thechallenges of maximizing the processing abilities and energy reserves ofwireless sensor nodes while also securing them against attackers.

2. RELATED WORK

Clustering arrangement is one of the most normal ways for topologycontrol in WSN. Maximum of cluster-based algorithms alwaysimplement data fusion scheme and practise clustering objectives[4]such as load balancing, fault-tolerance, growing connectivity,decreasing time delay, maximizing network longevity, etc. In thelast few years, LEACH[5] and its improved algorithms wereoffered as one of the most well-known distributed clusterbasedtopology control algorithm with scalability and energyconservation in WSN. However, it may not be suitable forheterogeneity because of its ideal network model[6].

Lately, fairly a lot of energy-oriented algorithms forHWSN are suggested. For example, EEHC (energy efficient heterogeneous clustered) algorithm is built on thethree-level network model in [7], which is comprised of supernodes, advanced nodes and ordinary nodes. EEHC applies thebest number of clusters computation method proposed inLEACH, and it selects cluster heads by residual energy ofnodes and weighted probability mechanism. Then the non-clusterhead nodes are attracted by the cluster heads to formclusters and the network begins to transmit data. Zhou etal.[8] suggesteda clustering protocol energy dissipation forecastand clustering management (EDFCM) based on the two-levelnetwork comprised of super nodes and ordinary nodes. Like EEHC, EDFCM also uses the same method of LEACH for calculating the best number ofclusters. Besides,a mathematical model of energy utilisation is proposed tocompute the weighted probability of node for selecting clusterheadby residual energy and the approximate average energyconsumption at the next round of network lifetime. Though,the estimated average energy consumption at the next roundof network is likely to cause deviation in real time because itis an ideal energy value.

Yet another efficient and dynamic clustering scheme (EDCS) wasproposed for multi-level heterogeneous wireless sensor networksin [9]. EDCS resolves the probability of nodeto be a cluster-head through guessing the mean residualenergy of the network in the next round by average energyconsumption forecast basedon ideal state and referencevalue of historical energy consumptionconcurrently. Similaruniversal gravitation was introduced to ensure non-clusterhead nodes join cluster in terms of gravitation during clusterformation.

Kuila et al.[10] proposed a load balancing methodbased on genetic algorithm. Sensor nodes are considered aschromosome number and the chromosomes are allottedto the corresponding gateway. Also, the standard deviationof load is utilized to decide whether the node is load balanced or not.

Dabirmoghaddam et al.[11] formulated an optimaluniform clustering (OUC) for extending the network lifetimeand firming the network scalability. In OUC, the commonproblem of optimal clustering with random cluster-headselection is demonstrated to be NP-hard. Sensor nodes formclusters in a distributed manner using a probabilistic clusterheadselection.

Our model on the other hand use more general network model with multilevelheterogeneous features, which means we need to take into account more complicated and real factors andcircumstances. As a clustering-tree topology control scheme, CBEPhas benefits both from the clustering and tree algorithms.Energy consumption can be estimated more precisely in eachround during the network lifetime, which results to be morepractical for cluster-head selection and cluster formation.

In addition, to evadeundue energy consumption from thecluster-head, several non-cluster head nodes are chosen to berelay node to further lessen the burden of each clusterhead.Due to these factor CBEP with multi-hop communication canhave longer lifetime.

3. HETEROGENEOUS WSN

A. HETEROGENEITY AND INFLUENCE ON WSN

Compared to homogeneous WSN, there are several special featuresin HWSN. Common types of heterogeneity inWSN are as follows

1) **Heterogeneity based on computational capability**: Different nodes have diverse capabilities to accumulate information or deal with growing events. Some super or advanced nodes have more

advanced processor and memory than other normal nodes. With high functioning hardware, these nodes which have powerful computational capabilities can provide more capability for data storage and complex data processing.

2) **Heterogeneity based on link**: similar to computational heterogeneity, the powerful electronic devices may have more channels, higher bandwidth and longer communication distance than normal nodes. So they can deliver reliable and robust data transmission network.
3) **Heterogeneity based on Energy**: It is the most significant and crucial point in these three common types of heterogeneity. Computational heterogeneity and link heterogeneity constantly results in consuming more energy than nodes in homogenous network so that their lifetime will be shorter. Energy heterogeneity can be represented as nodes that are supplied with different times of energy virtually.

But in homogeneous WSN, every node has the same computationaland transmission capability, initial energy, anddissipates equal energy per round. However, the practicalWSN is always comprised of multiple sensors which are givendissimilar processing abilities and initial energy. Every nodehas multi-level power selectionsso that it consumes differentenergy per round in the standard working time depending onits present power level. Also, the packet lossrate and link quality parameters should be taken into account for HWSN firstly as itcould easily exist in such a complex wireless situation.

More over interference can happen among nodes andclusters. So, HWSN with limitations isbetter suited for research and more approximated to actualnetwork.

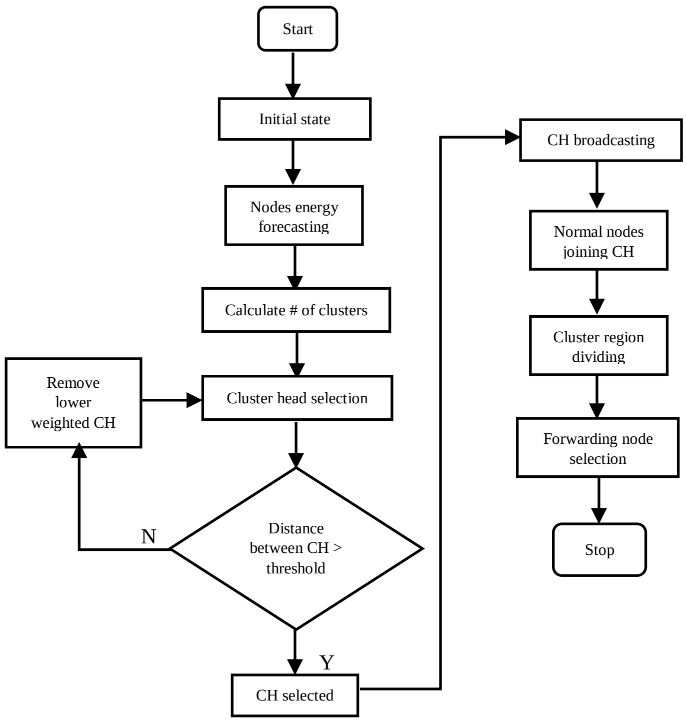

Fig. 1. The flow chart of CBEP algorithm.

B. NETWORK MODEL

1. N nodes in M x M square region that are different from each other.
2. Every node is given a different initial energy between two boundaries.
3. Packet loss rate and link quality rate are different too lying between 0 and 1.

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4. Only cluster heads are allowed to communicate with the base station directly.
5. Aggregation is done at cluster head.
6. RSSI is used to calculate the distance between nodes.
7. Interference can be reduced by using CSMA/CD at MAC layer.
8. The base station is located at the center of the region with abundant energy.

C. CBEP ALGORITHM

Our put forward algorithm CBEP aims to find an applicable way for HWSN to save energy consumption and extend the network lifetime. CBEP is mainly divided into four parts, i.e., network wise estimation of average energy, cluster-head selection, the cluster and tree formation within cluster.

PSEUDO-CODE OF THE CBEP ALGORITHM

Oblige: A HWSN is symbolised by graph G(V,E), N number of nodes, the rectangle region A of the HWSN, and e[r]is the residual energy of the network at r^{th} round.

1. G(V,E) is initialized with N and A;
2. calculate optimum number of clusters using nearest neighbour;
3. while there exists an alive node

   //Generate cluster heads
4. if $r \leq 2$ then
5. Calculate e[r];
6. else if $r \geq 3$ and $r \leq 10$
7. Generate randomly ε with length (10 - r);
8. Calculate mean with any three samples;
9. Calculate energy difference;
10. else
11. Calculate energy difference with its normal distribution;
12. end if
13. for i = 1 to n do
14. Calculate value of node(i) with cost function (link quality, packet loss rate and weighted coefficient)
15. end for
16. Sort the nodes' values in descending order;
17. Switch the first CH node(s) to cluster-head;

    //Generate cluster
18. while ((u, v) $\in$ E) and (i is not a cluster-head, j is a clusterhead)
19. Calculate distance between CH and normal nodes using RSSI and link quality metric.
20. if it is shortest for any v then
21. i becomes a member of cluster with j;
22. end if
23. end while

    // Generate tree in each cluster
24. for all u in the set of clusters
25. Divide cluster u into 8 parts;
26. Node v in each part becomes the relay node in terms of theshortest value
27. Connect the relay nodes with the shortest paths;
28. Connect the other nodes to v in each part;

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29. end for
30. if node i is dead
31. Calculate optimum # of clusters
32. end if
33. end while

4. SECURITY

RSA ALGORITHM

A technique to carry out a public key cryptosystemwhose security is based on the complexity of factoringlarge prime numbers was proposed in [12].RSA standsfor Ron Rivest, Adi Shamir and Leonard Adleman, whofirst openlyexplained the algorithm in 1977. Throughthis procedure it is possible to encrypt data and createdigital signatures.It was so effective that today RSApublic key algorithm is themost commonly used in theworld. The encryption scheme is as follows:

$$m^{ed} = m(\text{mod } n) \qquad (1)$$

foran integer m. The encryption and decryption schemesare presented below.

The decryption works as follows:

$$c^{d} = (m^{e})^{d} = m(\text{mod } n) \, (2)$$

The protection lies in the difficulty of calculating clear text am from a ciphertextcm^e mod n and public parametersn(e).

RSA ENCRYPTION

Input: RSA public key (n, e)
Plain text m∈ [0, n-1]
Output: Cipher text c
begin
1. Compute c = m^e mod n
2. Return c.
End

RSADECRYPTION

Input: Public key (n,e),Private key d,
Cipher text c
Output: Plain text m
begin
1. Compute m = c^dmod n
2. Return m.
end

5. EXPERIMENTS and RESULTS SIMULATION SETUP

Parameters	Value
Area	1000 x 1000 mts
# of nodes	100
Base station	500 , 500
Initial energy	10J
Energy boundaries	Lower – 10J Upper – 20J
MAC	802.11

Packet type	CBR
# of packets	1 per node per round
# of Cluster head	5
MAC type	CSMA / CD
Weighted coefficient	0.5
Distance between CH (Threshold)	70 mtrs

Due to the energy restriction, the lifetime is the one ofthe most significant performance measures to verify whether theproposed algorithm is useful. Moreover, similar with performance of energy, number of data packets received at the base station (throughput) isalso studied to evaluate our proposed procedure. As there are some sensitive parameters in CBEP whichshould be analysed cautiously because it may impact thesimulation results. The heterogeneity and real-world scenariosmake the experiments more complex. Therefore, we notonly discuss the impact of the distance, but also pay attention to the influence of link qualityand packet loss rate.

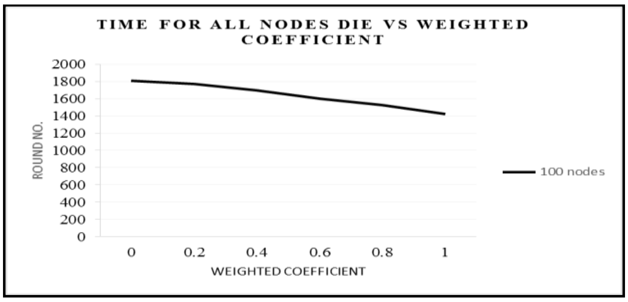

Fig 2. The time for all nodes to die under different weighted coefficient.

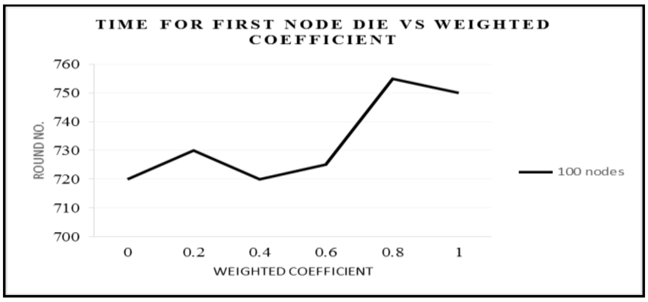

Fig 3. The time for the first node to die under different weighted coefficient.

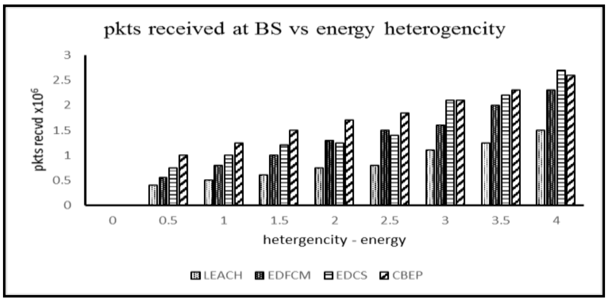

Fig 4. Packets received in BS (N = 100).

CONCLUSION

In this work, CBEP, a clustering-tree topology control system based on the energy forecast is proposed for heterogeneous wireless sensor networks. It answers the problem of energy depletion by taking into account the energy and link heterogeneity. The network mean energy at the next round is calculated by the difference between the ideal and the actual average energy, while the energy difference is computed by the central limit theorem and the normal distribution. The cluster-head is chosenbased on the cost which is estimated by the residual energy, link quality and packet loss rate. Moreover, the elected cluster heads are corrected by considering the distance between cluster heads, and also the residual energy and link reliability, etc., to help the cluster formation. Finally, CBEPhunts for the relay nodes within the cluster to transmit data to reduce the burden of the cluster-head.

Experiment results prove that CBEP is efficient forheterogeneous wireless sensor networks, and it outperforms LEACH, EDFCM and EDCS protocols with respect to lifetime and throughput.

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