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Dynamic Power Control Clustering Wireless Sensor Networks Based on Multi-Packet Reception

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Abstract

Objectives: A new method of cluster head election based on Energy Evaluation Factor (EEF) using multi-packet reception technology is proposed in clustering the Wireless Sensor Networks (WSN) to improve the performance and makes the network efficient and increases lifespan of the network. **Methods:** First EEF is calculated initially for clustering the WSN, the transmission power ranges of the CH elected in each group is calculated and adjusted considering the count of Cluster Head (CH) in elected in the area of interest as second, and thirdly we determine the distance from the sink to CH and its residual energy to implement interference cancellation algorithm in sink using transmission power levels. **Findings:** Simulation results show that this power control strategy can reduce the energy consumption of sensor nodes and increase network throughput, which can greatly improve network lifetime. **Improvements:** The authors believe that their findings will be useful guidelines for moving forward with successive interference cancellation research in WSNs.

Keywords: Cluster Head (CH), Multi-Packet Reception (MPR), Signal to Interference Noise Ratio (SINR), Successive Interference Cancellation (SIC)

1. Introduction

Recent advancements in the sensor technologies, the transmission power of the sensor nodes can be adjusted depending upon the distance with other nodes and based upon the applications to achieve energy conservation and prolong the lifetime of the network. Multi-packet reception technology is achieved using physical layer technologies like orthogonal Code Division Multiple Access (CDMA), *Multiple-Input And Multiple-Output* (MIMO)[1] etc.

Multi-packet reception[2,3] is the capability of the nodes to decode the signals from a number of sensor nodes concurrently rather than treating them as noise. In this era of wireless communication the mutual interference between the signals leads to loss of the information in data packets and even wastage of bandwidth. Due to broadcast nature of the signals, multiple signals from the multiple transmitters arrive at the receiver as a single composite signal. In this case when we consider the conventional wireless network signal reception model, the receiver decodes a single signal and rest of them are considered as a noise .The solution can be achieved with Successive Interference Cancellation (SIC) algorithm. Successive interference cancellation is the best method to achieve multi-packet reception .The received powers from the various transmitters can be found using Friss power transmission model.

As shown in the Figure 1 illustrates a simple wireless network consisting of multiple sensor nodes, gateway and internet. For each group of sensors nodes named as Cluster contains a CH, which collects and forwards the received data from the member nodes. CH will forward the data in single hop or multi-hop relaying techniques to the faraway Base Station (BS) or sink node. Based on the processing power of CH, the CH nodes can either sends a single data streamed to BS after data aggregation, and multiple data packets based on CH capabilities. And this CH role is circulated based on cluster head rotation techniques proposed by researchers to achieve uniform energy dissipation in the participating nodes.

In[4] proposed the basic distributed clustering algorithm Low Energy Adaptive Clustering Hierarchy (LEACH) which is structured in terms of rounds and the CH selection

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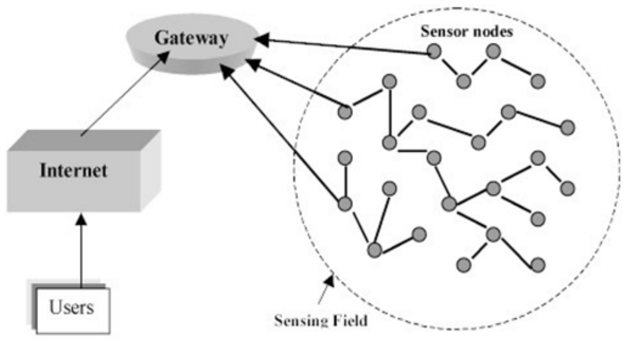


Figure 1. A simple wireless sensor network

occurs based on the threshold condition. In[5] proposed Hybrid Energy Efficient Distributed (HEED) clustering Protocol in 2004.It is an iterative process and introduces the concept of back up cluster heads for CHs selection process. In[6] proposed the Energy Efficient Hierarchical Clustering Algorithm (EEHCA) uses the distance and angle between nodes and cluster heads and even concept of backup cluster heads for CHs selection process. In[7] proposed Power-Efficient GAthering in Sensor Information Systems (PEGASIS), introduces the concept of chaining in the sensor nodes. S-EECP and M-EECP[8] cluster heads election occurs based on weighted probability based on ratio between remaining energy and average energy of the network. In[9] proposed the Threshold Sensitive Energy efficient sensor network protocol[9], where the cluster heads transmits the data packets based on the hard and soft threshold values.

Several protocols are proposed for power control-strategies[10-13] such as: COMPOW, CLUSTERPOW and BASIC. COMPOW will find out the minimum distance or range for the network connectivity and it uses transmitting power of equal value for all the nodes. Here we cannot adjust the transmission power of the nodes based on distance and applications. COMPOW is not suitable in the heterogeneous networks. The improved version of COMPOW is CLUSTERPOW where the transmission powers can be adjusted depending upon the destination nodes.

2. Proposed Work

In the WSNs the main problems are power management, improving lifetime and improving performance of the network. In case of the conventional signal reception model except the signals from the intended transmitter, the left over signals are treated as noise, it leads to loss of information. The two key problems of successive interference cancellation algorithm are successive interference rejection and concurrent reception of the signals, and main important fact is adjusting the transmission power of the cluster heads according to real time networking conditions. And finding out the best cluster head selection algorithm for efficient power management is also a great challenge. Adjusting the transmission power of the cluster heads as per real time networking conditions is the ongoing research theme in the wireless sensor networks.

2.1 Successive Interference Cancellation Algorithm

The SIC[14] algorithm is a unique way to achieve the multi-packet reception. This method receives and decodes the signals radiating from different transmitters, if and only if it satisfies the threshold condition of Signal to Interference noise ratio. The term SIC itself indicates that it cancels the interference between signals successively. The signal to interference noise ratio is the quantity which defines the theoretical upper bounds of channel capacity.

Let us consider the intended transmitter x and receiver y and σ^2 is the noise power. The threshold criteria of the signal to interference noise ratio for the intended transmitter x at the receiver y is stated as

$$\frac{P_{xy}}{\sum_{k \in N_y}^{k \neq x} P_{ky} + \sigma^2} \geq \delta$$

The transmission from x to y will be successful only if SINR at node y is greater than threshold δ where P_{xy} is the received power. Let us consider the set of signals $s_1, s_2 \dots \dots ., s_N$ which are having the powers $p_1, p_2 \dots \dots\ p_N$. Firstly we have to eliminate the signals of high strength in order to extract the desired signal. First and foremost step is to arrange the signals in ascending order. It is mathematically stated as follows:

$$p_1 \leq p_2 \leq p_3 \dots \dots \dots .. \leq p_N$$

Where N refers to number of the signals arrived from multiple transmitters. Considering the signal of strongest power and then testing the signal to satisfy threshold of SINR. Based on the above condition the strongest power signal will be decoded and completely eliminated from the residual set of signals, and then it chooses the sub strongest signal from the residual signals and continues the iterations and so on until the rest of the received signals do not satisfy the threshold condition.

2.2 Power Controlled Clustering Algorithm

In the sensor networks each sensor will be able to communicate with other sensors if they are within the radio communication range. To have the communication with the sensors which are not within the range can be achieved with the formation of distributed clusters. Clustering plays a vital role in energy savings in the wireless network. There are various clustering protocols like LEACH, HEED, S-EECP, M-EECP. LEACH is the basic algorithm for cluster head election. The proposed model includes the cluster head election based on energy evaluation factor.

Assuming *P* number of sensor nodes which are randomly distributed in the monitoring field will divide into *M* number of clusters and each cluster includes *P*/*M* number of nodes. The proposed scheme includes cluster head election based on present energy associated with the nodes. The energy evaluation factor evaluates the energy of each node in the cluster to become the cluster head.

EEF is ratio of each node's energy to average energy of the network. It is denoted mathematically as $\beta(j, r)$, where j is a sensor node and r is the round. The energy evaluation factor is directly proportional current energy with the nodes. The above factor gives the probability of node to be elected as CH. The higher energy nodes that are elected as CH aggregates the data and forwards to the base station in single transmission or multi-hop transmission based on distance to BS. Initially in the first round all nodes will be having same amount of energy, so the EEF factor will be unity .In the further rounds it will defined as ratio of current energy to the average energy of the cluster in the previous round. So the calculation of EEF depends on the energy in the previous round. The optimal number of cluster heads[15-17] among all the nodes in field is given by

$$G_{opt} = \frac{P}{M}$$

Finally the threshold can be defined for the CH election based on the energy of the nodes is defined below

$$\mathbf{T(j)} = \begin{cases} \mathbf{0} & ; \; j \notin K \\ \dfrac{G_{opt}\,\beta_{(j,r)}}{\mathbf{1} - G_{opt}\,\beta_{(j,r)}\left(rmod\left(\dfrac{\mathbf{1}}{[(G]_{opt}\,\beta_{(j,r)})}\right)\right)} & ; \; j \in K \end{cases}$$

Where k denotes the set of the nodes which have not become cluster heads in last $(1/G_{opt}\beta(j, r))$ rounds. The number of cluster heads is found from the mathematical relation

$$K_{opt} = \frac{\sqrt{\left(\frac{N}{2\pi}\right)\sqrt{\varepsilon_{fs}}}}{\varepsilon_{mp}}\frac{M}{d^{\alpha}}$$

Where ε_{fs} is amplification energy in free space model and ε_{mp} is amplification energy in multipath model. Here the sink can simultaneously receive packets from number of k cluster heads.

3. Simulation Results

Simulated results presented here are obtained using MATLAB 2012b for the simulation parameters as shown in Table 1. The distribution of the sensor nodes in the deployment area is carried out at two level hetero generous networks which consist of normal nodes and advanced nodes. These node types are differed based on their initial energies and the processing capabilities. Advanced nodes are having high power and processing capabilities compared to the normal nodes. Figure 2 illustrates the two level heterogeneous sensor networks of dimensions 150m × 150m and a base station.

Estimation of optimal number of clusters heads in the sensor network. The energy efficiency can be achieved by creating optimal number of clusters. Figure 3 shows the variation of optimal number of cluster heads with the number of nodes in monitoring area. From the graph we can conclude that the optimal number of the cluster heads increases with increase in number of deployed nodes in the monitoring field.

Figure 4 illustrates the variation of optimal number of the CHs versus the number of the sensor nodes. The increase in the optimal number of cluster heads increases

Table 1. Simulation parameters

Parameter	Value
No of nodes	100
Packet size	1000 bits
Initial energy	0.5 J
Size of network	100*100
Number of rounds	3000
Amplification energy in free space model (Efs)	10pJ/bit/m^2
Amplification energy for Multipath Fading Model (Emp)	0.0012pJ/bit/ m^2
Data Aggregation Energy (Eda)	5nJ

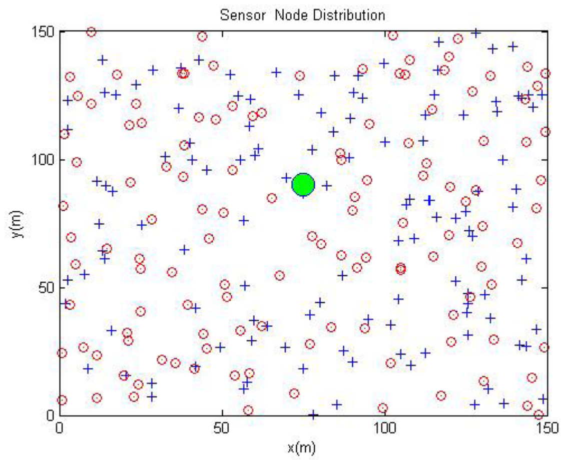


Figure 2. Two level heterogeneous sensor network

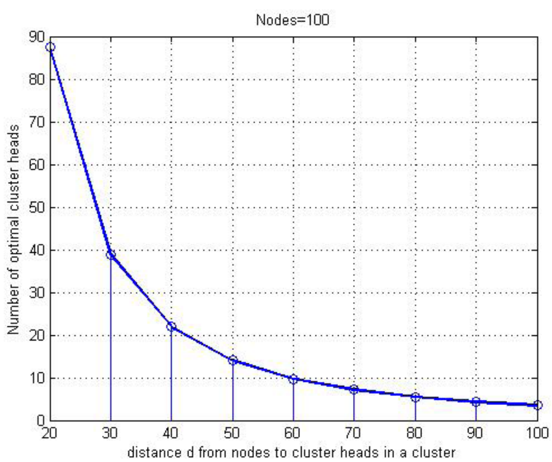


Figure 3. Variation of optimal number of cluster heads with distance

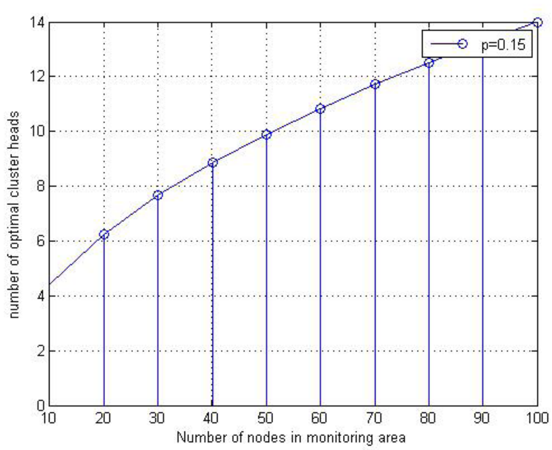
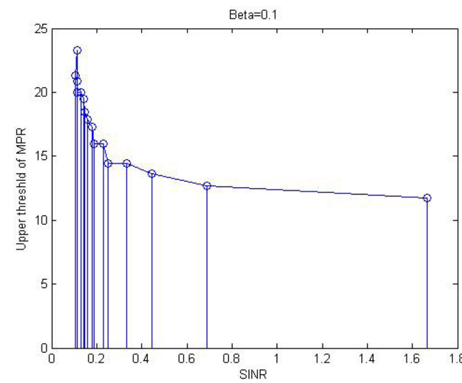
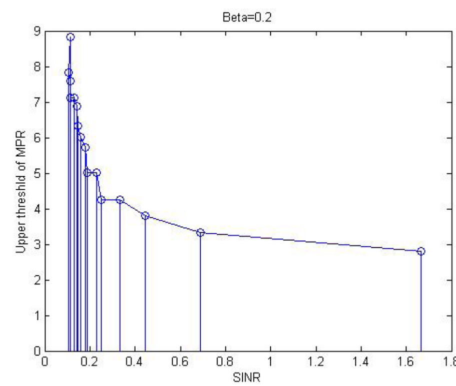


Figure 4. Variation of optimal number of cluster heads v/s number of nodes in monitoring area

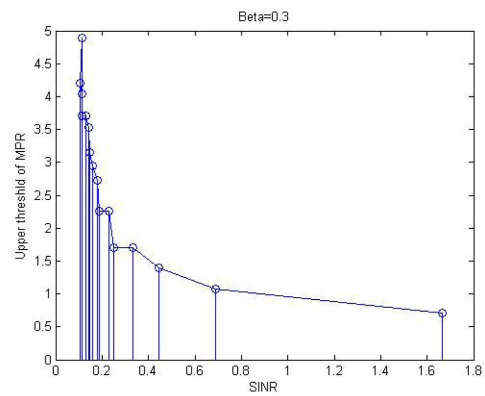
with the number of the nodes deployed in the monitoring area, and it shows the proportionality between them. The relationship between upper thresholds of MPR which defines maximum number of the packets that the receiver can be decoded with variation in signal to interference ratio, the number of the data packets depends on the threshold of SINR. Figure 5.a, 5.b and 5.c indicates the variation of multi-packet reception with SINR threshold.



(a)



(b)



(c)

Figure 5. **(a)** Variation of upper limit of MPR with SINR (β = 0.1). **(b)** Variation of upper limit of MPR with SINR (β = 0.2) **(c)** Variation of upper limit of MPR with SINR (β = 0.3)

Network throughput refers to the data rate or the number of the bits transmitted per unit time. The network throughput plays an important in defining the performance of the network. Figure 6 compares the network throughput and in comparison with theoretical throughput and the network throughput without any power control strategy. Considering N = 50 nodes, it can be concluded that the throughput using multi-packet reception technology is very close to the theoretical throughput value. So it shows an increase in the performance of the network.

In a wireless sensor network, initial energy will be same to all the nodes. As clustering is a dynamic process, the topology of the cluster changes continuously. The remaining energy associated with the network after changing the topology is the residual energy. Always the residual energy decreases with increase in time. Figure 7 displays the variation of the residual energy with variation in the simulation time.

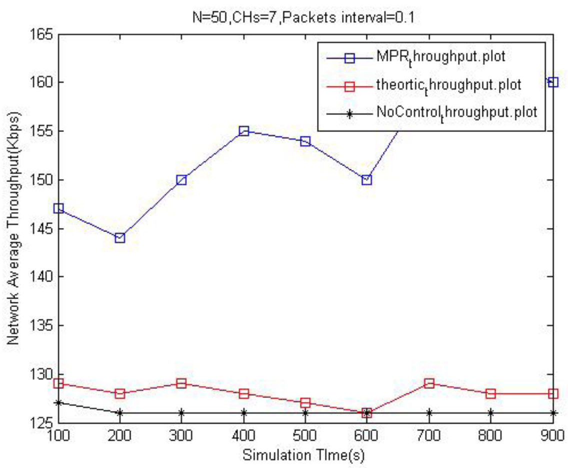


Figure 6. Network throughput *vs* simulation time

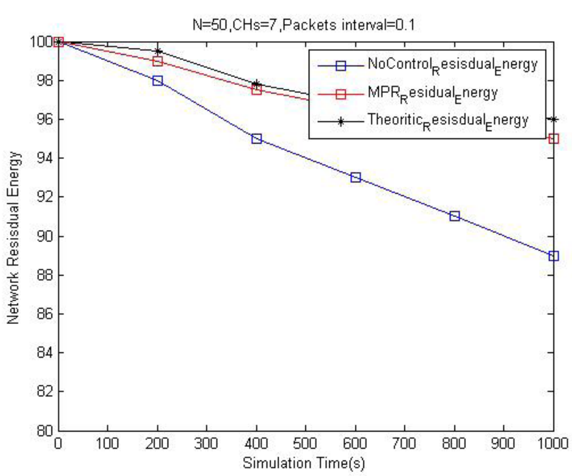


Figure 7. Variation of network residual energy v/s simulation time

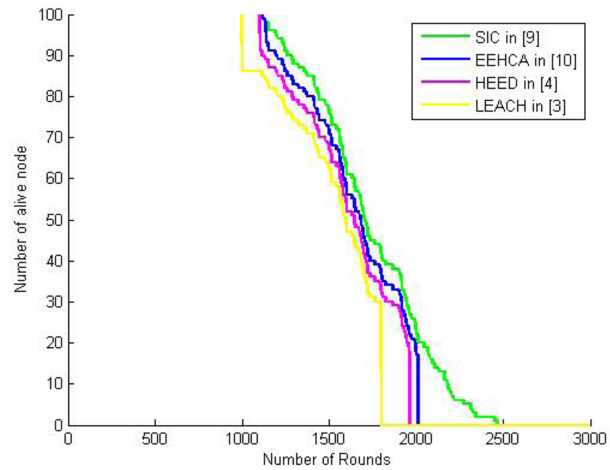


Figure 8. Comparison of lifetime of SIC algorithm with other protocols

In the sensor network the lifetime of a network is a crucial parameter. The lifetime of a network is the time till the last node of the network dies. Figure 8 shows the lifetime of the nodes with respect to other protocols.

4. Conclusion

The successive interference cancellation algorithm improves the performance of the system by decoding more number of the packets. Secondly, with the low value of threshold of SINR, the maximum number of the packets can be received and decoded. The performance can be increased by using multiple inputs multiple outputs, which works in a parallel fashion increases the rate and lifetime of network. Finally, the power control strategy increases the performance of the wireless sensor network.

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