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ENERGY EFFICIENT CLUSTER HEAD SELECTION CRITERION IN WIRELESS SENSOR NETWORK

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ABSTRACT

Wireless sensor network is a network of nodes, which transmit data hop by hop to the Base Station .The process of transferring data in the network consumes energy, as the result the nodes energy gets depleted. Minimizing energy dissipation and maximizing network lifetime are among the central concern when designing applications and protocols for sensor network. One of the energy efficient technique is clustering .In this paper, we try to formulate and prove that for improving efficiency in a cluster based network further, a real time situations like losses could be considered. Thus, by considering this, cluster head selection could be done more efficiently which can ultimately leads to increase in network lifetime.

KEYWORDS: Cluster Head, Distance, Energy, Network Lifetime

INTRODUCTION

A sensor network consists of a large number of sensor nodes densely deployed in a region of interest, and one or more data sinks or base stations that are located close to or inside the sensing region. The sink sends queries or commands to the sensor nodes in the sensing region while the sensor nodes collaborate to accomplish the sensing task and send the sensed data to the sink. Meanwhile, the sink also serves as a gateway to outside networks, for example, the Internet. It collects data from the sensor nodes, performs simple processing on the collected data, and then sends relevant information (or the processed data) via the Internet to the users who requested it or use the information. The sensor nodes in the network are called as *motes* or *smart dust,* as they contain radio transceiver and are battery powered.

In WSN, energy conservation is a critical issue that has been addressed by substantial research works [1] [2]. A clustering technique has been proven particularly energy efficient in sensor networks [3] [4]. The nodes form clusters which include one cluster head and the cluster members. Cluster heads (CHs) has the capability to process, filter and aggregate the data sent by sensors belonging to their cluster, thus reducing network load and alleviating the bandwidth [6]. These cluster heads then send data to the base station through single hop or multi-hop. Thus in clustered network data transmission is classified into two stages: intra-cluster communication and inter cluster communication. It is shown in [5] that multichip inter-cluster communication mode is more energy efficient because of the characteristics of wireless channel.

Energy Consumption Model

In this paper, we use a simplified energy model proposed in [7]. In this for a distance of d units both free space (d^2 power loss) and the multi path fading (d^4 power loss) channel models has been used depending on the distance between the transmitter and the receiver. If this distance is less than a threshold, the free space (*fs*) model is used; otherwise, the multi path (*mp*) model is used. Thus, to transmit an *L*– bits message over a distance *d*, the radio expends (1):

$$E_{tx}(L,d) = \begin{cases} L * E_{elec} + L * \varepsilon fs * d^2 & if\ d \le d_0 \\ L * E_{elec} + L * \varepsilon mp * d^4 & if\ d \ge d_0 \end{cases} \quad (1)$$

Where E_{elec} is the energy dissipated per bit to run the transmitter or the receiver circuit, εfs and εmp depend on the transmitter amplifier model used, and d is the distance between the sender and the receiver.

To receive an *L* bit message the radio expends

$$E_{RX} = L * E_{elec}$$

RADIO PATH BASICS

Radio signal path loss [8] is a particularly important element in the design of any radio communications system or wireless system. The radio signal path loss will determine elements of the radio communications system in particular the transmitter power, and the antennas and their gain, height and general location. These losses can also affect other elements such as the required receiver sensitivity, the form of transmission used and several other factors. As a result, it is necessary to understand the reasons for radio path loss, and to be able to determine the levels of the signal loss for a give radio path. The signal path loss can often be determined mathematically and these calculations are often undertaken when preparing coverage or system design activities. These depend on knowledge of the signal propagation properties.

Signal Path Loss Basics

The signal path loss is essentially the reduction in power density of an electromagnetic wave or signal as it propagates through the environment in which it is travelling.

There are many reasons for the radio path loss that may occur:

Free Space Loss: The free space loss occurs as the signal travels through space without any other effects attenuating the signal it will still diminish as it spreads out. This can be thought of as the radio communications signal spreading out as an ever increasing sphere. As the signal has to cover a wider area, conservation of energy tells us that the energy in any given area will reduce as the area covered becomes larger.

Absorption Losses: Absorption losses occur if the radio signal passes into a medium which is not totally transparent to radio signals. This can be likened to a light signal passing through transparent glass.

Diffraction: Diffraction losses occur when an object appears in the path. The signal can diffract around the object, but losses occur. The loss is higher the more rounded the object. Radio signals tend to diffract better around sharp edges.

Multipath: In a real terrestrial environment, signals will be reflected and they will reach the receiver via a number of different paths. These signals may add or subtract from each other depending upon the relative phases of the signals. If the receiver is moved the scenario will change and the overall received signal will be found vary with position. Mobile receivers (e.g. cellular telecommunications phones) will be subject to this effect which is known as Rayleigh fading.

Terrain: The terrain over which signals travel will have a significant effect on the signal. Obviously hills which obstruct the path will considerably attenuate the signal, often making reception impossible.

Buildings and Vegetation: For mobile applications, buildings and other obstructions including vegetation have a marked effect. Not only will buildings reflect radio signals, they will also absorb them.

These reasons represent some of the major elements causing signal path loss for any radio system.

Predicting Path Loss

One of the key reasons for understanding the various elements affecting radio signal path loss is to be able to predict the loss for a given path, or to predict the coverage that may be achieved for a particular base station, broadcast station, etc. Although prediction or assessment can be fairly accurate for the free space scenarios, for real life terrestrial applications it is not easy as there are many factors to take into consideration, and it is not always possible to gain accurate assessments of the effects they will have.

Despite this there are wireless survey tools and radio coverage prediction software programmers that are available to predict radio path loss and estimate coverage. A variety of methods are used to undertake this.

Free space path loss varies in strength as an inverse square law, i.e. 1/(distance)^2, or 20 dB per decade increase in distance. This calculation is very simple to implement, but real life terrestrial calculations of signal path loss are far more involved.

CLUSTER BASED ROUTING PROTOCOLS PROTOCOLS

There are two kinds of clustering schemes. The clustering algorithms applied on homogeneous networks are called homogeneous schemes, and the clustering algorithms applied on heterogeneous networks are referred to as heterogeneous clustering schemes. It is difficult to devise an energy-efficient heterogeneous clustering scheme due to the complicated energy configuration and network operation.

Thus most of the current clustering algorithms use homogeneous schemes, such as LEACH [7], PEGASIS [9], and HEED [10].The cluster-heads have to spend extra energy for aggregating data and performing long-range transmission to the distant base station. As in LEACH, the protocol selects cluster heads periodically and drains energy uniformly by role rotation. Each node decides itself whether or not to be a cluster- head distributed by a probability [11].

In CCPAR [12] (clustered chain based power aware routing) utilizes the periodic assignments of the cluster head role to different nodes based on highest residual battery capacity for ensuring the even dissipation of power by all the nodes.

In DCR [13](Distributed Chain Routing) protocol the selection criteria for a nodes to be selected as cluster head is based upon two parameters i.e. residual energy and distance from the base station.

In DEEAC [14],the main criteria is to choose a node with high residual energy and greater hotness value to be selected as cluster head .Hotness factor is the relative hotness of the node with respect to the network.

In [15], as an improvement over LEACH to ensure even load distribution over the whole network, additional parameters have been considered to optimize the process of cluster head selection. So, Leach's stochastic cluster head selection algorithm has been extended by adjusting the threshold factor as

$$T(n) = \frac{p}{1 - p(r \bmod 1/p)} \frac{E_{residual}}{E_{initial}} k_{opt} \qquad (2)$$

Where $E_{residual}$ is the remaining energy of the node and $E_{initial}$ is the initial energy of the node before the transmission.

In all above methods, cluster head selection is done by assuming zero attenuation/interference in a network. As a consequence, the results are not very accurate. In order to avoid this, it's always better to consider some losses in the network due to interferences. We have discussed in the next section that by considering base station power while selecting cluster head based on distance and energy (homogeneous assumed) ,the result comes out to be more appropriate

PROPOSED APPROACH

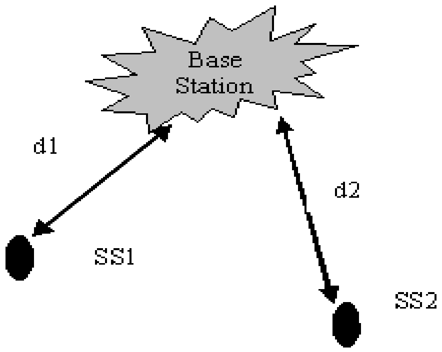

Figure 1: A Network Designed with Two Cluster Head Nodes Having Signal Strength SS1 and SS2 at a Distance of d1 and d2 Respectively

In this figure 1, SS1 and SS2 are the signal strength of node 1 and node 2.d1 is the distance of node 1 from the base station and d2 is the distance of a node 2 from the base station.

We can calculate path loss (PL) factor as

PL1=SS1-Pb // Pb is the base station power

PL2=SS2-Pb (3)

Case 1: Considering same path loss factor in both the nodes

i.e.

PL1 = PL2

SS1-~~Pb~~ = SS2-~~Pb~~

SS1 = SS2

The results shows when path loss in both the nodes is same, the signal strength turned out to be equal.

Case 2: If path loss in node 1 is greater then path loss in node

i.e.

PL1 > PL2

Path loss factor (PL) can be defined as sum of free space (FSL) path loss and loss due to multipath fading (MFL) or interferences i.e.

PL1 = FSL1+MFL1

PL2 = FSL2+MFL2 (4)

In this case if we assume, distance of node 2 is greater than distance of node 1 from the base station i.e. d2 > d1 (as shown in diagram) .Then

FSL1 < FSL2,

as free space path loss factor directly depends on distance.

As discussed above, if PL1>PL2 than interference in node 1 should be greater than node 2. So,

MFL1 >MFL2

This implies that MFL1 must be > MFL2.As path loss factor in case of node 1 is more thus SS2 > SS1.Base station will choose node 1 as a cluster head node although multipath fading effect in node 2 is more.

Case 3: *C*onsidering equal distances i.e. d1=d2

From equation 2

PL1-PL2 = ~~FSL1~~+MFL1~~-FSL2~~-MFL2

PL1-PL2=MFL1-MFL2

This equation implies that if multipath fading effect is more in path 2, the path loss will be negative. It will be better to choose node 1 as cluster head node.

Case 4: Considering d2>d1, SS1>SS2

If d2>d1, implies FSL2>FSL1

If MFL1>MFL2 (discussed case 2)

If SS1>SS2 then

PL1>PL2

From equation 2

FSL1+MFL1>FSL2+MFL2

Also, from equation 1

SS1-Pb > SS2-Pb

This equation implies that instead of considering Signal strength and Energy only as a selection criteria for a node to become as a cluster head from the base station. It is better to consider base station power as (SS-Pb) for selecting a node as cluster head from the base station.

We can even prove these results by considering a distance

d1 = x units (say) and d2 = x + y units.

Since PL α d

SS1= Pb - (PL1+A1) (From 3)

SS2 = Pb- (PL2+A2)

SS1-SS2= Pb-PL1-A1-Pb+PL2+A2=PL2-PL1+ (A2-A1)

This equation implies

$$(SS1\text{-}SS2)\ \alpha\ (PL2\text{-}PL1)$$
$$\alpha\ (A2\text{-}A1)$$

Here, A1 and A2 are the attenuation of the node 1 and node 2 from the base station.

Considering Different Cases in Different Scenario

Case 1

If d2 > d1 implies PL2>PL1

Value of (SS1 –SS2) > 0 i.e. SS1 > SS2

Or SS1-SS2 = x + (A2-A1)

Or x+ (A2-A1) > 0

Or A1-A2>-x or A1-A2 < x

This implies that SS1 of node 1 will be more only when path loss of node 2 will be more and multipath fading of node 2 will be more.

$$A1\text{-}A2 < PL2\text{-}PL1$$

Thus, we will choose node 1 only though its signal strength (SS1) is coming more if **attenuation A1 of node 1 is less** although PL2>PL1.

Case 2

If SS1< SS2 (say)

i.e. x + (A1-A2) < 0

x > (A1-A2)

$$PL2\text{-}PL1 > A1\text{-}A2$$

If SS1 is coming less in Node 1 then although PL2>PL1 then attenuation factor comes out to be greater for node 1.So we will choose node 2.therefore ,It is always good to consider base station power along with node's energy and distance .

RESULTS

In order to prove the above approach, a simulation has been performed on MATLAB 7.0 .In this, a random network arrangement of three nodes (node 1, node 2 and the base station) is formed and the distance of each node from the base station is calculated using Euclidean distance formula.

We have considered the homogeneous network of nodes .Initially, node 1 and node 2 have equal energy, and the energy consumed is calculated based on their distance from the base station using first radio model. The node which consumes less energy will be selected (marked black).

Case 1

Considering ideal situation when there is no loss in the environment a node selection will be based on distance and the energy consumed by the node from the base station as shown in figure 2.

Statistics

Node 1	
Xd	13.071
Yd	81.876
E	0.000135
D	95.06

Node 2	
Xd	43.071
Yd	89.032
E	0.000354
D	71.308

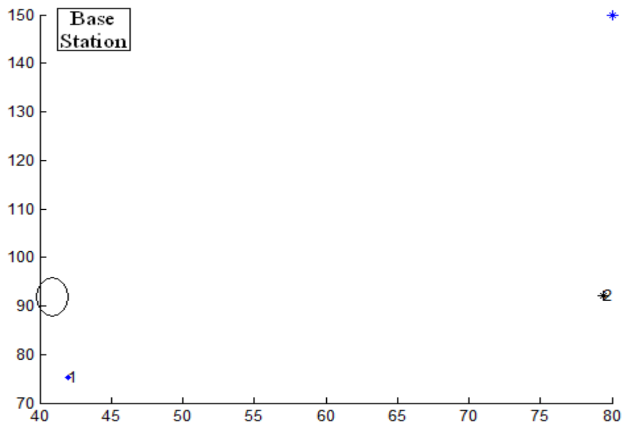

Figure 2: Node Selected Based on Distance from the Base Station (Lossless Assumed)

Case 2:

In real time situation when there is a loss due to multipath fading and others. Its is not appropriate that a node selection criteria should only be based on distance and energy .It is always better to consider losses due to multipath fading or interference or to consider base station power as shown in figure 3 .

Statistics

Node 1	
Xd	41.986
Yd	75.367
E	0.000475
D	83.757

Node 2	
Xd	79.387
Yd	91.996
E	0.00027
D	58.008

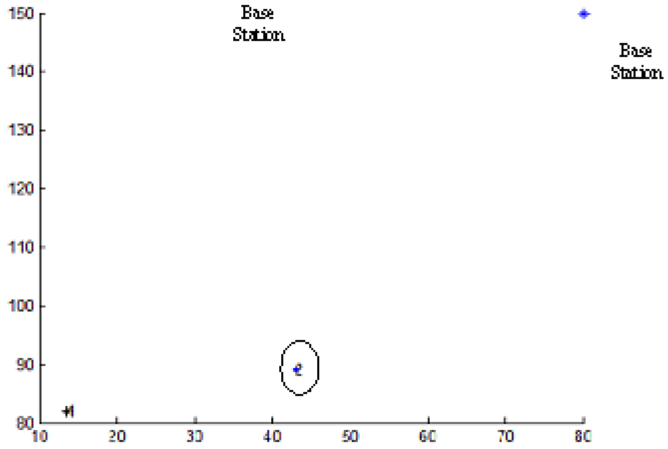

Figure 3: A Network Having Multipath Fading (Loss) in a Path 2, though the Distance from the Base Station of Node 2 is Less

CONCLUSIONS

In this paper, we came to the conclusion that it is good to consider losses due to fading or interferences in the network .The selection of a node which can be treated as a cluster head node of a cluster should not be based on energy and distance only but for getting an optimum solution it is desirable to consider losses also. This will enhance the network lifetime and even the energy consumption will be reduced. It is good to determine base station power, so that when a signal is received by the base station, the loss can be judged by subtracting the transmitted signal from the received one. In future, additional parameters like MAC layer concepts for selection of cluster head can be considered.

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