Using Nearest Neighbor Method and Subtractive Clustering-Based Method on Antenna-Array Selection Used in Visual MIMO in Wireless Sensor Network

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***Abstract*—Wireless Sensor Network (WSN) is combined with many sensor node (SN). Since SN is restricted to the communication range, the physical communication distances have to be considered during the network operation process. In this paper, we proposed to use Subtractive Clustering method to determine the sink node on a LEACH-based Two-tier network and after that, using Nearest-neighbor method(i.e. Single-linkage method) to select the suitable nodes to act as the visual Multi-input-multi-output (MIMO) antenna-array, which are used to multiple transmitting and receiving data. Previous study have shown successfully that HNN could be used to select the nodes to act as the antennas-array of MIMO, however, the method we proposed, Nearest-neighbor method, can reach the same result but less computational time. Although, HNN method is known for its quickly convergence speed during the network learning operation. However, HNN still have to take more time than the method we proposed. This study was based on LEACH to formulate the visual MIMO antenna-array. Finally, we will discuss the simulation result and indicate the effectiveness of the proposed method for the further study.**

Keywords—Sensor node (*SN*), MIMO, LEACH Protocol, HNN, Nearest-neighbor method.

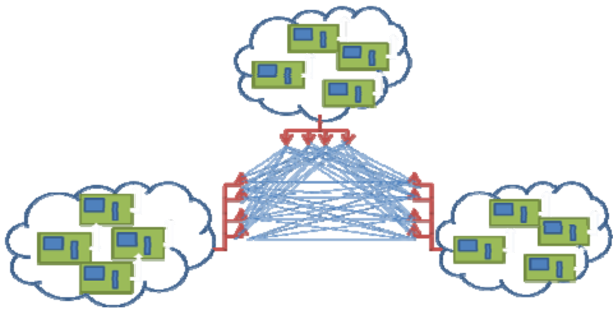

Figure 1 The concept of Virtual MIMO in WSN

1. INTRODUCTION

In WSN, a great number of *SN*s form a multi-hop network. Except for the other environmental affection on WSN, WSN is strongly affected by the data transferring paths, especially in highly density mesh network. A good multipath selection can prolong the lifetime of whole network of WSN. In this study, we examined the method which is used in virtual MIMO of WSNs [4] and proposed a Subtractive Clustering method to find a sink node for LEACH-based two-tier network and after that we proposed using subtractive algorithm to select the *SN*s to act as antenna -array. The MIMO and the space time coding techniques can both overcome the multipath fading and the diversity can enhance the power efficiency and also improve the utilization rate of frequency spectrums.[1]-[3]. However, for actualizing the real MIMO communications in WSN, the *SN* should be able to accommodate multiple antennas. Nevertheless, *SN* is limited to its size, cost and furthermore its energy. However, the dense sensor nodes can work together to act as a multi-antenna array through interchange of messages.

Restate, in this study, the network model is based on LEACH network. We proposed using Nearest Neighbor method to select the nearest *SN*s to act as antenna-array. MIMO technique in WSN is discussed in section 2, Subtractive and nearest neighbor method both are discussed on section 3, section 4 present the experimental result, and finally, conclusion is made in section V.

2. MIMO technique in Wireless Sensor Networks

Virtual MIMO system was proposed by [4] and used in wireless sensor networks. According to the real MIMO system, it can communicate at higher rate than the traditional SISO (single-in-single-out) system at the same transmission power budget. Real MIMO also can transmit the data through the multi antenna-array with only one channel. In other words, MIMO consumes less energy than SISO. In wireless sensor network, energy consumption is the most important issue, as the Quanquan [4] said that sensor cannot be able to accommodate the multiple antennas. Since sensor is restricted by its size, cost and the energy, we cannot set multiple antenna-arrays in a single sensor. Nevertheless, the clustered sensor nodes can jointly act as a multiple antenna-array, and communicate with other clustered *SN* to from a virtual MIMO system in WSN.

3. Use Subtractive clustering and Nearest-neighbor Method separately to find the Cluster head and sensors which act as multiple antenna-arrays

■ Subtractive clustering Method

Subtractive method was proposed by Chiu in 1994. Chiu suggested an improved version of the mountain method, which is proposed by Yager and Filev (1994) [5], referred to as the subtractive method. The main concept of subtractive clustering method is that it considered every data point, which is in 2 dimensional spaces, as a latent cluster centroid. Subtractive clustering method picks the centroid by judging from node with high density of data point, then excluding the nodes which are around the centroid for fear of being picked to act as centroid (Cluster head).

The Subtractive cluster function at data point (i.e. sensor node, *SN*) x_i is defined as

$$D_i = \sum_{j=1}^{N} \exp\left(-\frac{\|x_i - x_j\|^2}{(r_a/2)^2} \right) \quad (1)$$

where r_a represent the radius of each *SN*, and $\|x_i - x_j\|^2$ is the square of distance between x_i and x_j. If we assume all the *SN*s have the same r_a, and all r_a equal to 1, then we could simply the Equ. (1) as

$$D_i = \sum_{j=1}^{N} \exp\left(-4\|x_i - x_j\|^2 \right) \quad (2)$$

Let D_1* be the maximum value of the Subtractive clustering function, which is expressed as follow:

$$D_1^* = Max[D(x_i)] \quad (3)$$

and let x_i be the data point whose Subtractive clustering value is D_i . Restatement, in this study, we assume it is only one cluster head in the environment of WSN. Therefore, we find one cluster head (centroid) from 2D wireless sensor network by the scheme of Subtractive clustering method.

■ Nearest Neighbor Method

Nearest-neighbor method (also called “single-linkage”) is a method of calculating distances between clusters in hierarchical cluster analysis. The distance between two clusters is composed as the distance between the two closest elements in the two clusters.

Mathematically, the Nearest neighbor method function could be described as follows:

$$D(X,Y) = \min(d(x,y)) \quad (4)$$

where $d(x,y)$ is the distance between elements $x \in X$ and $y \in Y$. X and Y are two sets of elements(i.e. clusters). The clusterings are assigned sequence numbers 0, 1, …, (n-1) and $L(k)$ is the level of the kth clustering. A cluster with sequence number *m* is denoted (*m*) and the proximity between clusters (*x*) and (*y*) is denoted $d[(x),(y)]$.

The algorithm is composed of the following steps [8]:

1. Being with the disjoint clustering having level $L(0)=0$ and sequence number m=0.

2. Find the least dissimilar pair of clusters in the current clustering, say pair (x), (y), according to $d[(x),(y)]=\min d[(i),(j)]$ where the minimum is over all pairs of clusters in the current clustering.
3. Increment the sequence number $m= m+1$. Merge clusters (x), (y) into a single cluster to form the next clustering m. Set the level of this clustering to $L(m)= d[(x),(y)]$.
4. Update the proximity matrix, D, by deleting the rows and columns corresponding to cluster (x) and (y) and adding a row and column corresponding to the newly formed cluster. The proximity between the new cluster, denoted (x, y) and old cluster (k) is defined as $d[(k), (x,y)]=\min d[(k), (x)], d[(k), (y)]$.
5. If all objects are in one cluster, stop. Else. Go to step 2.

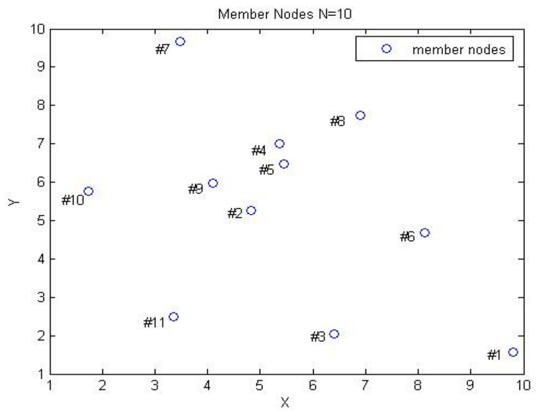

Figure 2.1 Randomly generated the 10 *SN* onto the 2D plane

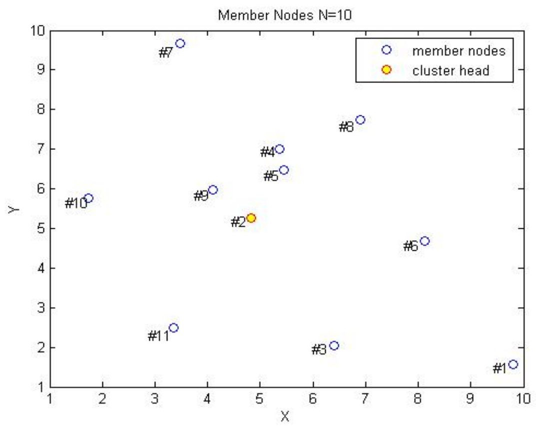

Figure 2.2 Through the Subtractive Clustering Method to find the suitable cluster head.

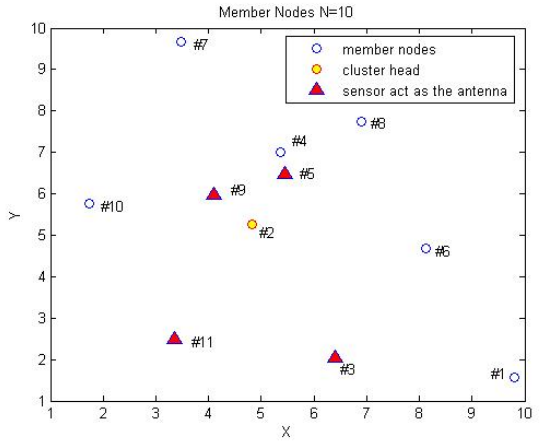

Figure 2.3 Based on Nearest Neighbor Method to find nearest sensors to act as antenna. (We assume four sensors being picked to act as the multiple-antenna)

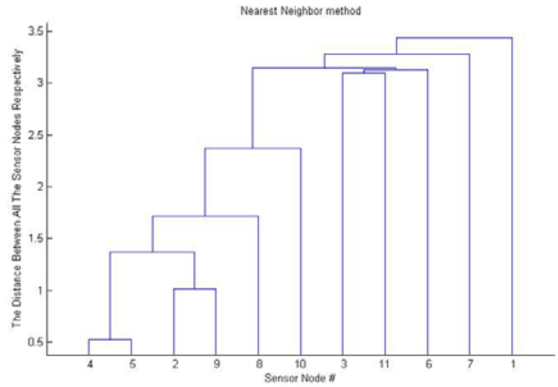

Figure 2.4 The distance among each sensor nodes.

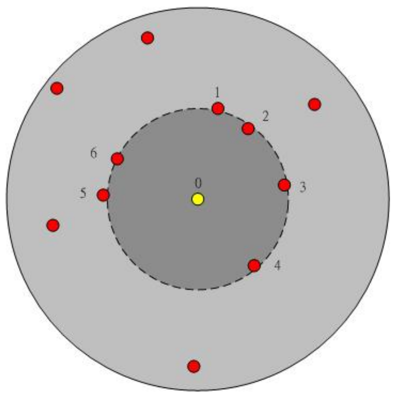

Figure 3 Visual MIMO antenna-array selection method based on Leach two-tier network.

Besides the above mentioned methods, we also provide another method which is used to decide which sensor should be picked up to form a polygon-shaped antenna-array. Here we define ε≧1(m). εis a threshold value of distance which is used to confirm there is enough space between antennas. The object of this step is to make sure antenna-array is not too closer among each other.

However, Quanquan [4] mentioned that, in MIMO system, the distance between the antennas should be larger than a certain value which is determined by the wavelength. Therefore, the cluster head should avoid choosing nodes with similar d_i.(d_i is the distance between *SN #i* to cluster head) In Figure 3, assuming that node 0 is selected to act as a cluster head, and *SN* #1, #2, #3, #4, #5, and *SN* #6 are having the same distance d_i, and they cannot be chosen to act as antenna array synchronously [4], [7]. Nevertheless, some of them can participate in the group of antenna-array because of enough distance between them (ε≧1). In [4], author defined that *SN* should be equal or more than 2 (if we pick *SN* =2 to act as antenna-array, it just can form a line segment.). However, we want antenna-array which our method selected can form a polygon, and we want polygon could cover the four different directions around the cluster. Therefore, in our method, each network model we simulated was forced to select 4 *SN*s to form a polygon around the cluster head. For instance, in Figure 3, *SN* #1, #3, #4, and *SN* #5 are selected to act as an antenna-array. Accordingly, we have differed antenna selection method from the previous study [4].

4. Experimental result

In this paper, we provide a subtractive clustering method to find the suitable cluster head for wireless sensor network and also provide the Nearest-neighbor method to determine which sensor could be act as an antenna to from a multi-antenna MIMO system. Shuguang, Goldsmith and Bahai [9] demonstrate that in short-range applications, especially when the data rate and the modulation scheme are fixed, SISO systems may outperform MIMO systems as far as the energy efficiency is concerned. However, by optimizing the constellation size, we could extend the superiority of MIMO systems in terms of energy efficiency down to very short distances.

Quqnquan [4] mentioned that HNN can be implemented in hardware components such as capacitor and resistors. However, HNN cannot always reach the optimal solution, and time-consuming on processing is also a drawback of HNN. Therefore we proposed a Nearest Neighbor method to find the nearest sensors to act as the

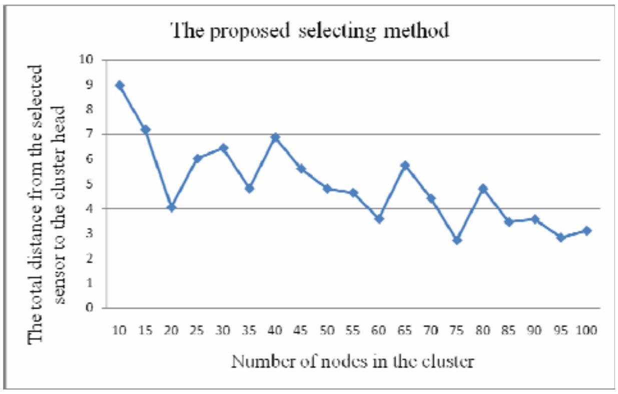

Figure 4 four sensors are selected to act as a antenna-array and form a polygon around the cluster head.

antenna-array as shown in Figure 2.3. In Figure 2.1, we randomly placed the sensors on x-y coordinate. Figure 2.2 showed the cluster head was chose by Subtractive Clustering method. In Figure 2.4, we noticed that sensor #4 and #5 were formed one small cluster with normalized distance 0.5, and so does sensor #2 and sensor #9 with normalized distance 1. (All the distance was normalized in Figure 2.4)

In Figure 4, we observed that with the increasing number of sensor nodes deployed on the environment of WSN, the method we proposed to find a cluster head and sensors act as antenna-array are having the tendency toward decreasing of distance among the selected sensors and cluster head.

5. Conclusion and Discussion

In order to compare with the method proposed by Quanquan [4], we have the same definition on the network format. Our work is based on LEACH protocol and without loss of generality, we consider the condition as proposed by Quanquan in which the sensors are fixed and can communicate with each other in the cluster. Through the local communication, there is used to share the information among *SN*, and to form a antenna-array.

Since Quanquan's method used HNN, an artificial intelligence method, on selecting the SN to act as antenna-

array, but HNN is a time-consuming method. When the WSN environment become larger, it may become unworkable or cost a lot of computation time. There is way their maximums of simulated SNs are confined at 30. In Figure 4 we can notify that even though our random deployment of SNs on the 10x10(m) environment cause the vibration through the increasing number of SNs, we can predict that with the number of SNs increasing, the distance among the selected 4 *SN*s and cluster head could reach the minimum. Therefore, the method we proposed consumed less energy as the sensor nodes increase.

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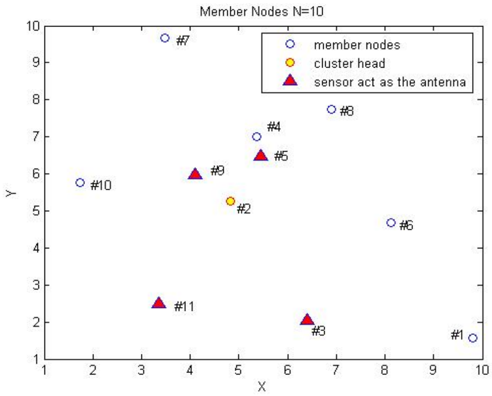


Figure b.1 Member node #= 10 (Unit: meter)

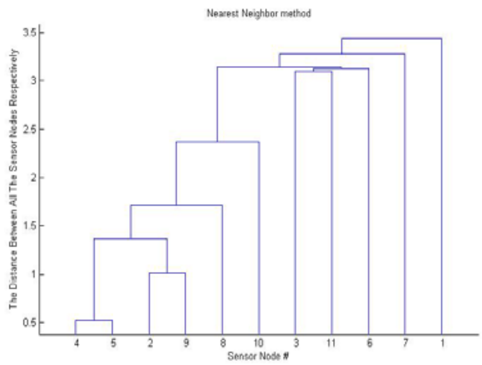


Figure b.2 The distance between all the sensor nodes.

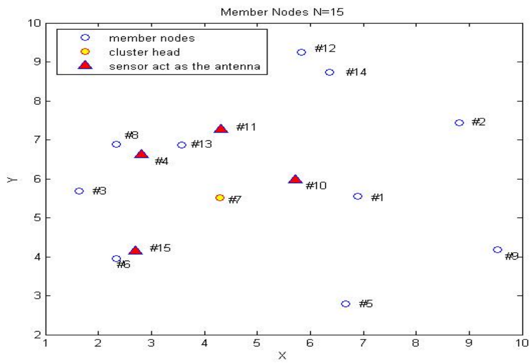
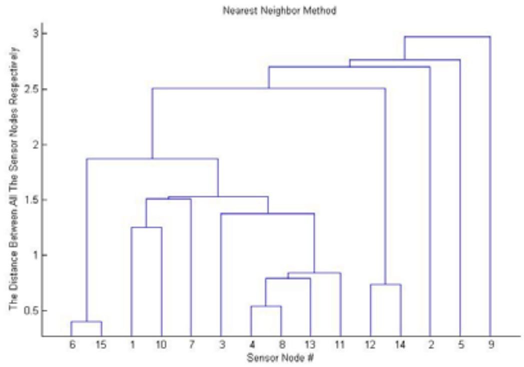


Figure c.1 Member node #= 15 (Unit: meter)



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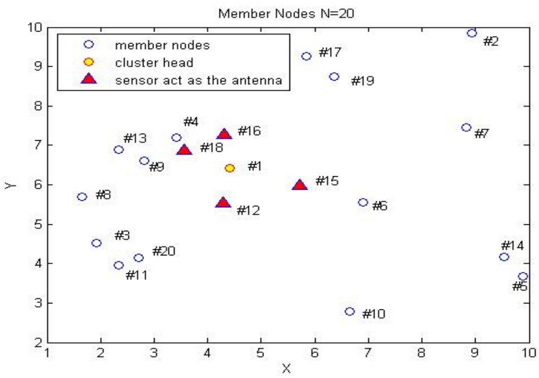

Figure d.1 Member node #= 20 (Unit: meter)

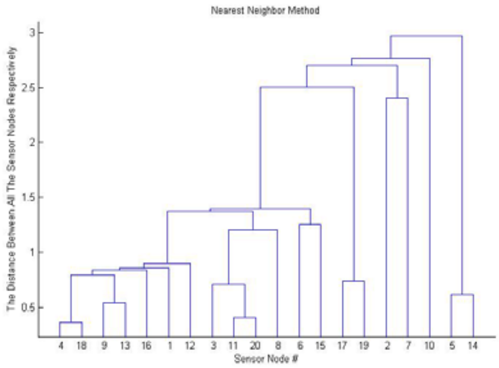

Figure d.2 The distance between all the sensor nodes.

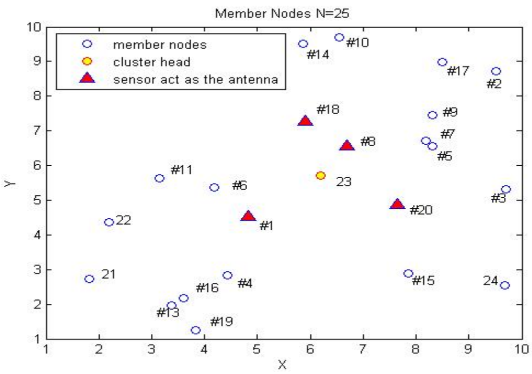

Figure e.1 Member node #= 25 (Unit: meter)

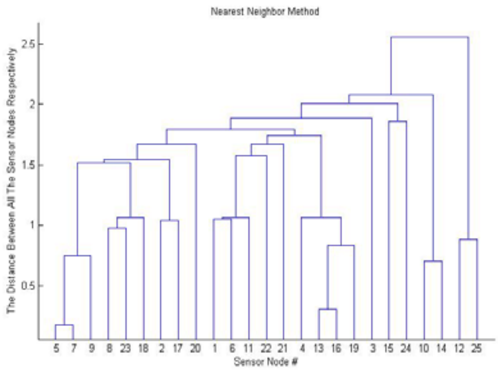

Figure e.2 The distance between all the sensor nodes.

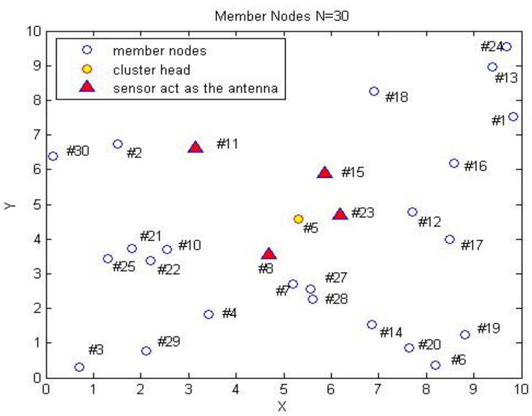

Figure f.1 Member node #= 30 (Unit: meter)

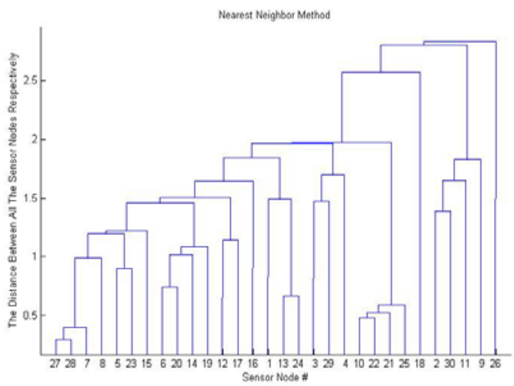

Figure f.2 The distance between all the sensor nodes.