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FORMULATION OF 3D EUCLIDEAN DISTANCE FOR NETWORK CLUSTERING IN WIRELESS SENSOR NETWORK

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Abstract: In wireless sensor networks, nodes operating under dynamic topology are often correlated with their behavior. Correlated behavior may pose devastating impact towards network connectivity. A node may change its behaviour from cooperative node to misbehave node which directly affects the network's connectivity. Misbehaviour nodes tend to have correlated effect which creates partitioning within the network. To improve network connectivity in providing an efficient communication in the events of the correlated behaviors, a new formulation of correlated degree to perform network clustering is required. This paper proposes a formulation on correlated degree using 3D Euclidean distance to achieve higher network connectivity under correlated node behavior. The key idea behind the 3D Euclidean distance in network clustering is to identify a set of sensors whose sensed values present some data correlation referring to correlated degree. The correlated degree is formulated based on three-point distance within a correlation region to identify the level of node correlation within neighboring nodes. In addition, the correlated degree also be able to detect the same group of node behavior which is grouped in correlated regions. 3D Euclidean distance is shown in mathematical analysis and how the new formulation calculates correlated degree is also discussed. It is also expected that the new 3D Euclidean distance formulation may help correlation region to change it cluster formation dynamically to achieve the required network connectivity.

Keywords: 3D Euclidean Distance; Network Clustering; Wireless Sensor Network.

I. INTRODUCTION

Wireless Sensor Networks(WSNs) are composed of a large number of sensor nodes that cooperatively monitor physical or environmental conditions and transmit collected data to the sink node, such as self-organizing, multi-hop, low cost and data centric networking[1]. In this network, sensor nodes may observe a physical phenomenon, such as temperature in some areas. Early research has shown that nodes exhibit independent failure, but it is against the recent studies. For example, Than [2] stated that an interruption in network application may cause by only a single node failure. While Yu Xi in [3] also mentioned that a series of failures are instigated by the earlier nearby failure. This scenario is commonly called correlated node event or correlated node failure[4]. A correlated node behaviors in sensors nodes of wireless sensor networks commonly arise from other nodes behavior as well. For example, if a node has more and more neighbors failed, it may need to load more traffic originally forwarded by those failed neighbors, and thus might become failed faster due to excessive energy consumption [5]. The correlated failure, on the other hand, imposed high severity upon network availability and connectivity.

Existing formulations are focused an effective and runtime-efficient iterative improvement heuristic to solve the active sensor node determination problem, and a benefit function that aims to minimize the number of active sensor nodes while maximizing the residual energy levels of the selected active sensor nodes. That cluster should comprise of nodes with highly correlated degree.
The cluster is evaluated on its model for a simple linear distribution of nodes, and formulated the optimal size of the clusters as a function of distance to the sink, and the number of nodes with similar correlated degree. Therefore, 3D Euclidean distance between three-point distances is introduced in this paper to formulate a new correlated degree between nodes in correlated region.

Deriving the Euclidean distance between three different nodes involves computing the square root of the sum of the squares of the differences between corresponding values in the correlated region. The 3D Euclidean distance is applied here to construct clusters which connect neighboring nodes. Euclidean distance is able to reduce the distance and connect each node to the cluster based on correlated degree[6].

Therefore, the distance between the nodes determines the degree of correlation. The organization of the paper is as follows: Section 2 discusses related work of correlated degree and clustering algorithm, then, this paper proposed a new formulation for correlated degree based on 3D Euclidean distance by measuring three-point distance of the node in the correlated region in Section 3. Next, analysis of the proposed formulationevaluated in a mathematical analysis in Section 4 and followed by a conclusion in Section 5.

II. RELATED WORKS

Many clustering algorithms have been proposed in the literature for wireless sensor networks (WSN).The objectives of clustering are to minimize the total transmission energy over the nodes in the selected path, and to balance the load among the nodes for prolonging the network lifetime.The cluster is managed by a special node or leader, called cluster head (CH), which is responsible for coordinating the data transmission activities of all sensors[7]. As clustering is vital for efficient resource utilization and load balancing in large-scale sensor networks.Clustering algorithms have been proposed for wireless sensor networks recently such as LEACH [3], R-HEED, PEGASISand BECA [8-15]to reduce energy consumption of sensors in a wireless network. Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is one of the most famous hierarchical routing algorithms for energy efficiency in WSNs [16]. The reason we need network protocol such as LEACH is due to the fact that a node in the network is no longer useful when its battery dies.This protocol allows us to space out the lifespan of the nodes, allowing it to do only the minimum work it needs to transmit data. Another research done by [17]the context of Euclidean geometry, a metric is established in one dimension by fixing two points on a line and choosing one to be the origin.

There are many metrics to calculate a distance between 2 points $p(x_1, y_1)$ and $q(x_2, y_2)$ in x, y plane. We can count Euclidean distance, or Chebyshev Distance or Manhattan Distance. Each one is different from the others. The length of the line segment between these points defines the unit of distance and the direction from the origin to the second point is defined as the positive direction. In Chebyshev Distance, for all adjacent cells from the given point can be reached by one unit. AndtheManhattan Distance between two points in a grid based on a strictly horizontal and/or vertical path that is, along the grid lines, as opposed to the diagonal or "as the crow flies" distance. The first one is Euclidean distance. The distance can be defined as a straight line between 2 points [18]. Euclidean Distance is defined as the global process of gathering and routing information through a multi-hop network, processing data at intermediate nodes with the objective of reducing resource consumption in particular energy, thereby increasing network lifetime. The method computes a distance based minimum spanning tree of the weighted graph of the WSN. The best routebetween a node and its cluster-head is searched from all the optimal trees on the criterion of energy consumption. Cluster-heads are elected based on the energy available to the nodes and the Euclidean distance to its neighbor node in the optimal tree[19].

Begins with neighbor discovery phase which is initiated by the sink by sending a Hello packet. Hello packet consists of Sender, Euclidean distance to reach the sink and location of the sender. Euclidean distance is used to measure distance from the sink. Receiving nodes of Hello packet add sender as its neighbor and record information. Each receiving node also forwards the Hello Packet by setting its id as Sender, location parameter distances Euclidean distance, to reach the sink [20] In addition, it distributes the sensor nodes uniformly considering Euclidean distance and coverage redundancy among the sensor nodes. Nodes have to transmit for a longer distance when Euclidean distance is used protocol. On the other hand, Euclidean distance is more flexible as the sensor nodes can be placed conveniently by dissemination and without prior information about the monitoring environment. This kind of distance though easy to implement and feasible in all kinds of environment, cannot always guarantee the complete coverage and connectivity of the correlation region [21]. In this work, we further studied the correlated degree function and showed that the assumptions only fit in certain correlation region.

III. PROPOSED FORMULATION OF CORRELATED DEGREE

In this section, correlated degree is calculated based on similar values of node behavior in its closed proximity which is called correlated region. According to[22], the Euclidean distance between the different nodes detect similar values, depends on both network requirements and event parameters. The Euclidean distance between four nodes in either the plane or *n*-dimensional space measures the length of a segment connecting between four nodes. It is the most obvious way of representing distance between four nodes. The formulation of 3D Euclidean distance for correlated node behavior involves two steps which are to determine correlation region and Euclidean distance to calculate the correlated degree.

IV. CORRELATION REGION

Correlated region, which determine the correlation between sensor nodes are determined predominantly only by their degree distances. The approach defines a weight for each sensors node when send their data which depends on the distance from the cluster head to the target sensor node. Thus, correlation region can be define as an area where the values sensed by the sensor nodes are considered similar for the region. Therefore, a single reading within this region is sufficient to represent it. The size of the correlation region varies according to both application and event type. When a node send data to another node an initial correlation which receives no acknowledgement will increase the correlation range till the minimal amounts of neighbors are discovered. For events whose parameters change significantly at short range, the sink node should decrease the size of the correlated region, this event needs to be notified by closer nodes. For events whose parameters do not change significantly at short range, the sink node can increase the size of the correlated region. Fig.1 shows the correlation region is determine at step 1 and to calculate correlated degree is at step 2 in next sub section.

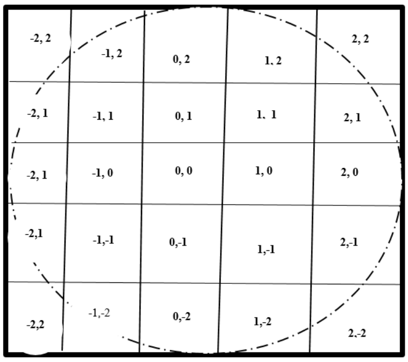

Fig.1 Correlation Region

V. FORMULATION OF CORRELATION DEGREE

Each sensor node within the wireless sensor network runs the following algorithm that proceeds by iterations but does not require node synchronization. Let S_i denote any sensor node and (x_i, y_i, z_i) be its coordinates. Each node sends its position and the node it hears in order to perform the neighborhood discovery within correlation region. Then, each sensor node is able to determine its 1-hop neighbors and 2-hop neighbors, and compute its new position according to the forces exerted on it by its 1-hop and 2-hop neighbors. Let d_{ij} denote the Euclidean distance between sensor nodes s_i and s_j . D_{ij} is given by:

$$\sqrt{(x_j - x_i)^2 + (y_j - y_i)^2 + (z_j - z_i)^2} \qquad (1)$$

The conventional localization algorithm in 3D WSN uses the estimated distances between the unknown node and some known anchor nodes to calculate the positions of the unknown node. Each unknown node needs to communicate with at least four neighboring anchor nodes to obtain the correlated degree values. Using a formula, an unknown node can estimate its distance to each anchor node. If there are four or more anchor nodes, the unknown node can use the estimated distances to estimate its coordinates.

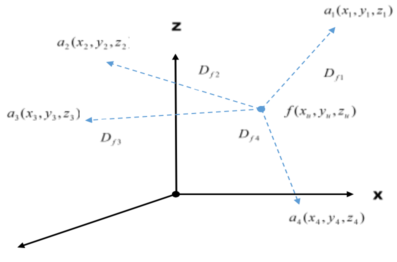

Fig.2the 3D Euclidean Distance

Example of 3D Euclidean distance is illustrated in Fig.2. The known coordinates of the four anchor nodes a_1, a_2, a_3 and a_4 are (x_1, y_1, z_1) , (x_2, y_2, z_2) , (x_3, y_3, z_3) and (x_4, y_4, z_4) , respectively for every sensor node and a representative sensor node is selected in each merged cluster head. As these three variables are measurements in a wireless sensor networks, sensor nodes are classified into three types of representative sensor nodesas distance, packet, and energy. In cluster-based networks, representative sensor nodes are selected by the undirected graph where the sensor node set consist of all sensor nodes in the wireless sensor network and the edge set consist of all links in the wireless sensor network. The antenna of the sensor node is an omnidirectional antenna, with a communication radius be the set of sensor nodes within the circle of the communication radius. The coordinates of the unknown node f is (x_f, y_f, z_f). The distances from the node f to the four anchor nodes a_1, a_2, a_3, a_4 , respectively are D_{u1}, D_{u2}, D_{u3} , and D_{u4} . Since there are estimation errors on these distances, there will also be estimation errors in node f coordinates. There will usually be no solution to Equation (1) if there is any distance estimation error. Instead, the coordinates are estimated as follow:

$$(x_f, y_f, z_f) = \underset{(x_{ff} y_f, z_f)}{\arg\min} \sum_{i=1}^{4} \left|(x_{a_i} - x_f)^2 + (y_{a_i} - y_f)^2 + (z_{a_i} - z_f)^2 - d_{if}^2\right| \qquad (2)$$

Since Equation (1) is nonlinear, an error in distance estimation could result in a much larger error in coordinate estimations, especially when node f is not at or near the center of the region surrounded by the anchor nodes.

The estimated coordinates to measure distance between four variables (a_1, a_2, a_3, a_4) of node f can be calculated by solving the following system of nonlinear equations. For anytwo nodes f and (a_1, a_2, a_3, a_4) , their 3D Euclidean distance can be shown as follows:

$$D_{a_i f} = \sum_{i=1} a_{if} (x_i - x_f)^2 + (y_i - y_f)^2 + (z_i - z_f)^2 \quad (3)$$

The distance can be expressed by the minimum hop between two nodes and also can be expressed by the shortest path distance between two nodes or any other distance, such as the Euclidean distance. From Equation (2) and Equation (3), the estimated position of unknown target nodes can be calculated.

Thus, the mean points (x, y, z) are all on the circle with radius Equation (4).

$$D_{a_i f} = \frac{\sum a_{if} (x_i - x_f)^2 + (y_i - y_f)^2 + (z_i - z_f)^2}{\sum a_i} \quad (4)$$

VI. DISTANCES BETWEEN VARIABLES

Assume that WSN in 3D space is made up of a_1, a_2, a_3, a_4 and f as anchor nodes. Consider distance is represent as (D), packet transfer (β), and energy (ℓ). Thus, $D_{a_i f}$ represents the measuring distance between nodes f and a_1 until a_4 as equation (5). To measure correlated degree the distance (D), packet (β), and energy (ℓ) is needed as $(x_{a_i} - x_f)^2 + (y_{a_i} - y_f)^2 + (z_{a_i} - z_f)^2$ in between one-hop neighbor nodes by the 3D Euclidean distance method x, y, z which represents the coordinates of the nodes in 3D space f and a_1, a_2, a_3 & a_4.

$$D_{a_i f} = \sum_{i=1} a_{if} (x_{a_i} - x_f)^2 + (y_{a_i} - y_f)^2 + (z_{a_i} - z_f)^2 \quad (5)$$

A correlated degree is measured based on correlation coefficients which measure the strength between variables and correlation or relationships in Equation (6).

$$\begin{aligned} \beta &= (\beta_{a_i} - \beta_f)^2 + (\beta_{a_i} - \beta_f)^2 + (\beta_{a_i} - \beta_f)^2 \\ D &= (D_{a_i} - D_f)^2 + (D_{a_i} - D_f)^2 + (D_{a_i} - D_f)^2 \\ \ell &= (\ell_{a_i} - \ell_f)^2 + (\ell_{a_i} - \ell_f)^2 + (\ell_{a_i} - \ell_f)^2 \end{aligned} \quad (6)$$

The correlation coefficient often referred to as the 3D Euclidian distance correlation which tested using statistical formula that measures the strength between variables and correlations or relationships.

To determine how strong the correlation or relationship is between three variables, we need to find the coefficient value between nodes.

The three variables are often given the coordinate x, y, and z with variable D_{n_1}. In order to illustrate how the variables are related, the values of x, y and z are represent as below in Fig.3 in the 3D Euclidean distance.The distance is given first, and then the correlation coefficient method of determining Correlated Degree (CD) is presented. In presenting the following examples, relatively small sample is given.

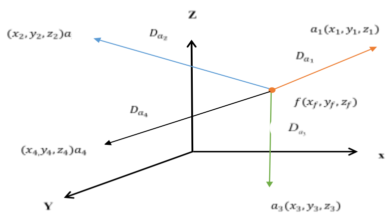

Fig.33D Euclidean Distance

A correlation coefficient measures the strength of that correlation or relationship. The coefficient value can range between -1.00 and 1.00 [23]. If the coefficient value is in the negative range, then that means the relationship between the variables as distance, packet, and energy are negatively correlated, or as one value increases, the other decreases. If the value is in the positive range, then that means the correlation or relationship between the variables above is positively correlated, or both values increase or decrease together.

The correlation coefficient can be defined as follows. Suppose that there are four nodes (a_1, a_2, a_3, a_4) each having values of distance (D) packet (β) energy (ℓ) and measuring distance between f with these variables D, β and ℓ respectively. Let node f to be cluster head of nodes (a_1, a_2, a_3, a_4) which are within the cycle of the communication radius of r .Thus, the correlation coefficient of the nodes within node f can be shown below in Equation (7)

$$CD_{a_{ii} f} = \frac{\sum (D_{a_i} - D_{a_i f})^2 (\beta_{a_i} - \beta_{a_i f})^2 (\ell_{a_i} - \ell_{a_i f})^2}{\sqrt{\sum (D_{a_i} - D_{a_i f})^2 \sum (\beta_{a_i} - \beta_{a_i f})^2 \sum (\ell_{a_i} - \ell_{a_i f})^2}} \quad (7)$$

Where the summation proceeds across all f possible values of (a_1, a_2, a_3, a_4) respectively. A method of computing correlated Degree (CD) is presentedin next section, with an example. Following this, there is some discussion of the meaning and interpretation of the correlation coefficient.

VII. CALCULATING OF CORRELATED DEGREE (CD)

In WSN, node f connected to (a_1, a_2, a_3, a_4) as neighboring nodes and they are roaming within correlated region. These node can represent its neighbors in the domain and they are measured based on correlation coefficient of the correlated degree node in equation (7).

Assume node f has (a_1, a_2, a_3, a_4) as neighboring nodes. The correlation coefficient of f is calculated based on variables (D, β, ℓ) to measure the correlated degree (CD). The CD variable D, β, ℓ must be between this ranges from -100 to +100 to measure relationship of the node in 3D Euclidian distance. If correlation coefficient close to 0, but either positive or negative. This implies little or no relationship between the three variables.

Table.1 of data *f* nodes

nodes	distance D	Packet β	Energy ℓ	D^2	β^2	ℓ^2	Sum variable
a_1	100	16	200	100	256	4000	3200
a_2	70	24	300	490	576	9000	5040
a_3	50	40	400	250	160	1600	8000
a_4	90	33	250	810	108	6250	7420
sum	310	113	1150	255	352	1162	2.366

Table 1 shows the calculation table of the correlation coefficient. From table 1Correlated Degree CD is calculated from the variables distance (D) packet (β) and energy (ℓ), where the sum of these values needed obtain $\sum D \sum \beta$, and $\sum \ell$. Then, the squares of each of the (D) values, and the squares of each of the (β) values, and the squares of each of the (ℓ) values are calculated. Then calculate the sums of each of these $\sum D^2, \sum \beta^2$ and $\sum \ell^2$. Further, compute the products of each pair of the $D, \beta,$ and ℓ values, and the sum of these $\sum D\beta\ell$. Below are the summary value of each square variable:

$$\sum D = 310$$
$$\sum \beta = 113$$
$$\sum \ell = 1150$$
$$\sum D^2 = 25500$$
$$\sum \beta^2 = 3521$$
$$\sum \ell^2 = 1162500$$

These values can now be used to determine $(D_{a_1a_2a_3a_4})$, $(\beta_{a_1a_2a_3a_4})$, $(\ell_{a_1a_2a_3a_4})$ and $(D_{a_1a_2a_3a_4})(\beta_{a_1a_2a_3a_4})(\ell_{a_1a_2a_3a_4})$.N represent the number of node in the correlated region.

$$D_{a_1a_2a_3a_4} = \sum D^2 - \frac{(\sum D)^2}{N}$$
$$= 25500 - \frac{(310)^2}{4}$$
$$= 25500 - \frac{96,100}{4}$$
$$= 25,500 - 24,025$$
$$= 1,475$$

$$\beta_{a_1a_2a_3a_4} = \sum \beta^2 - \frac{(\sum \beta)^2}{N}$$
$$= 3521 - \frac{(113)^2}{4}$$
$$= 3521 - \frac{12,769}{4}$$
$$= 3521 - 3,192.25$$
$$= 315,704$$

$$\ell_{a_1a_2a_3a_4} = \sum \ell^2 - \frac{(\sum \ell)^2}{N}$$
$$= 1162500 - \frac{(1150)^2}{4}$$
$$= 1162500 - \frac{1,322,500}{4}$$
$$= 1162500 - 330,625$$
$$= 831,875$$

$$D_{a_1a_2a_3a_4}\beta_{a_1a_2a_3a_4}\ell_{a_1a_2a_3a_4} = \sum D_{a_1a_2a_3a_4}\beta_{a_1a_2a_3a_4}\ell_{a_1a_2a_3a_4} - \frac{(D_{a_1a_2a_3a_4}\beta_{a_1a_2a_3a_4}\ell_{a_1a_2a_3a_4})}{N}$$
$$= 2366500 - \frac{(310)(113)(1150)}{4}$$
$$= 2366500 - \frac{4028450}{4}$$
$$= 2366500 - 1,007,112$$
$$= 1,359,388$$

Once these expressions is calculated, it can be used to obtain both the correlation coefficient and the regression line of correlated degree.

$$CD = \frac{D_{a_1a_2a_3a_4}\beta_{a_1a_2a_3a_4}\ell_{a_1a_2a_3a_4}}{\sqrt{D_{a_1a_2a_3a_4}\beta_{a_1a_2a_3a_4}\ell_{a_1a_2a_3a_4}}}$$
$$= \frac{1,359,388}{\sqrt{1475 \times 315,704 \times 831875}}$$
$$= \frac{1,359,388}{1,968,181}$$
$$= 0.6906$$

Based on these values, the correlation coefficient between three variables of formal correlated degree force is CD = 0.6906. This indicates a relatively large positive relationship between the three variables. A perfect positive relationship would yield a correlation of 1 and no relationship at all between energy$_{(\ell)}$, packet$_{(\beta)}$and distance$_{(D)}$would give a correlation coefficient of 0. The relationship here is then a relatively large one, above 0.5, but considerably less than a perfect association between the three variables.

VIII. CONCLUSION

In this paper, a new formulation is introduced to calculate correlated degree between sensor nodes based on 3D Euclidean distance. From the calculation in Section 4, correlated degree determines accurate correlation measure between sensor nodes based on sensing nodes. In order to achieve complete network connectivityin WSN, applications require correlation dense deployment of sensor nodes that lead to a single event being recorded by several nodes.This leads sensor node to have the correlation degree. This kind of dataredundancy, due to the correlation degree between the sensor nodes in the cluster, enriches the research of in wireless network. So that can figure out the correlation degree mechanism is highly adaptive and scalable regarding events of different intensities. A correlation degree are possible techniques for local decision-making. Such, the strategies help to maximize energy conservation in an application-specific sensor network.Correlation degree is a phenomenon that the packet receptions across multiple receivers have certain correlation and are not independent. In this work, correlation degree mechanism in which nodes that detected the same node are grouped in correlated regions and a misbehavior node is selected at each correlation region for observing the phenomenon. The correlation region can be changed dynamically to achieve the required accuracy of the sensed information. The entire region of sensors per event is effectively a set of misbehavior nodes performing the task of data collection.

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