SELF-ORGANIZING MAP (SOM) CLUSTERING OF 868 MHZ WIRELESS SENSOR NETWORK NODES BASED ON EGLI PATHLOSS MODEL COMPUTED RECEIVED SIGNAL STRENGTH

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***Abstract*— In this paper, Self-Organizing Map (SOM) clustering of 868 MHz wireless sensor network (WSN) nodes based on Egli pathloss model computed Received Signal Strength (RSS) was carried out. The case study WSN consist of 100 sensor nodes that are randomly distributed in a region of 1000 m x 1000 m square region with a base station or LORA gateway device located at the center of the region. Matlab random function was employed in generating the (x_i, y_i) coordinates of the WSN nodes for i = 0,2,3,4,…,100, where (x_0, y_0) is for the LORA gateway or base station. Egli path loss model and link budget equation were then used to determine the RSS for each node. The SOM clustering algorithm was used in selecting the cluster head based on RSS range of -65 dBm ≤ RSS ≤ -75 dBm. The results showed that only 16 WSN nodes were selected as cluster heads. Also, the sensor node with RSS value of -73.445 dB and located at a distance of 768.11m from the LORAWAN gateway had the highest number of (10) slave nodes clustered around it.**

***Keywords*— LORA Technology, Self-Organizing Map (SOM) , LORAWAN, Clustering, Egli Pathloss Model, Received Signal Strength**

1.0 Introduction

LORA (Long Range) technology a growing technology for divers Wireless Sensor Network (WSN) applications [1,2,3,4,5,6,7]. LORA technologies have been tested and deployed in many smart cities applications [8,9,10,11,12]. LORA operates in different frequencies depending on the region where it is employed [13,14,15,16,17]. For the European region, the frequency of 868 MHz applies.

In WSN, energy efficiency is paramount [`8,19,20,21,22]. This is because the sensor nodes which form the greater part of the WSN are mainly battery-powered and energy-limited [23,24,25,26,27,28,29]. As such, approaches for energy efficient WSN is greatly desired in LORAWAN. Among other approaches, clustering [30, 31,32,33,34,35,36,37,38] of sensor nodes to cluster heads has become one of the most popular approach. The cluster head selection can be based on different parameters such as distance of the nodes from the LORAWAN gateway, the Received Signal Strength (RSS) of the sensor nodes, etc. In this paper, the RSS based approach is adopted. Particularly, because pathloss [39,40,41,42,43,44,5,46] is the key loss factor in the determination of received power, in this paper the EGli path loss model is employed in link budget equation [47,48,49,50,51,52] to determine the RSS for each of the sensor nodes. Then, Self-Organizing Map (SOM) clustering algorithm [53,54,55,56] was used in selecting the cluster heads based on the computed RSS values for a set of 100 sensor nodes. The SOM clustering of the slave nodes to the cluster heads was also performed. The whole computations were carried out in Matlab software. Salient mathematical expressions for the computations are presented along with key simulation data , results and discussion of findings.

2. Methodology

LORAWAN operates in the 868 MHz frequency. In this paper, clustering of WSN that operates in the LORA technology frequency band is studied. Self-Organizing Map (SOM) clustering algorithm is used along with received signal strength (RSS) of the WSN nodes to select the cluster heads from a WSN consisting of 100 sensor nodes randomly distributed in a region of 1000 m x 1000 m square region with a base station or LORA gateway device located at the center of the region. Matlab random function is employed in generating the (x_i, y_i) coordinates of the devices for i = 0,2,3,4,…,100, where (x_0, y_0) is for the LORA gateway or base station. Hence, the distance, d_i from the gateway to the node i is given as;

$$d_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2} \quad (1)$$

The plot of the x-coordinates and y-coordinates of the WSN nodes around the gateway device is shown in Figure 1.

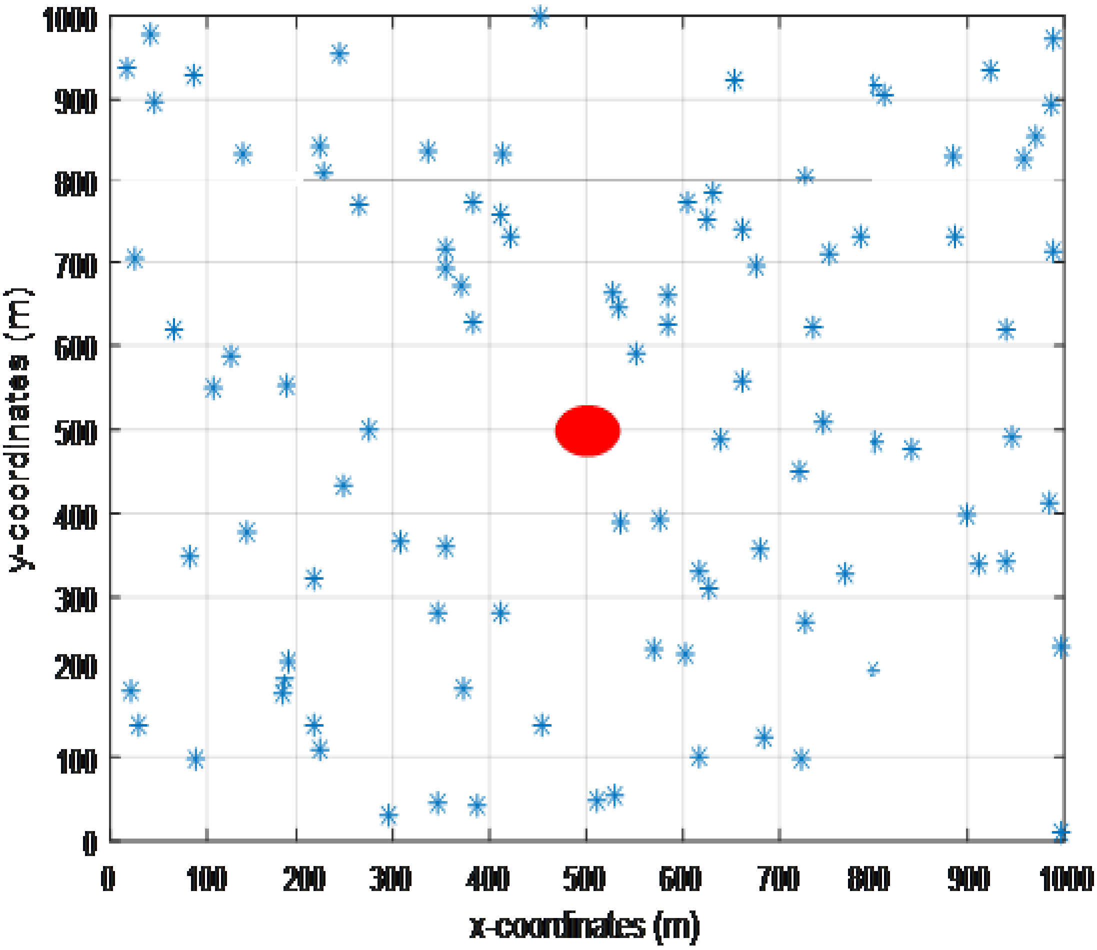

Figure 1; The plot of the x and y coordinate positions of the WSN nodes.

The path loss (in dB) according to the Egli model for the node i is given as follows:

$$LP_{E(i)} = \begin{cases} 20\log_{10}(f_c) + 40\log_{10}(d) - 20\log_{10}(h_b) - 10\log_{10}(h_m) + 76.3 & \text{for } h_m \le 10 \\ 20\log_{10}(f_c) + 40\log_{10}(d) - 20\log_{10}(h_b) - 10\log_{10}(h_m) + 85.9 & \text{for } h_m \ge 10 \end{cases} \quad (2)$$

where

h_b = Height of the base station antenna. Unit: meter (m)

h_m = Height of the mobile station antenna. Unit: meter (m)

d = Distance from base station antenna. Unit: meter (m)

f_c = Frequency of transmission. Unit: megahertz (MHz)

The scatter plot with only marker for the pathloss of the WSN nodes is shown in Figure 2.

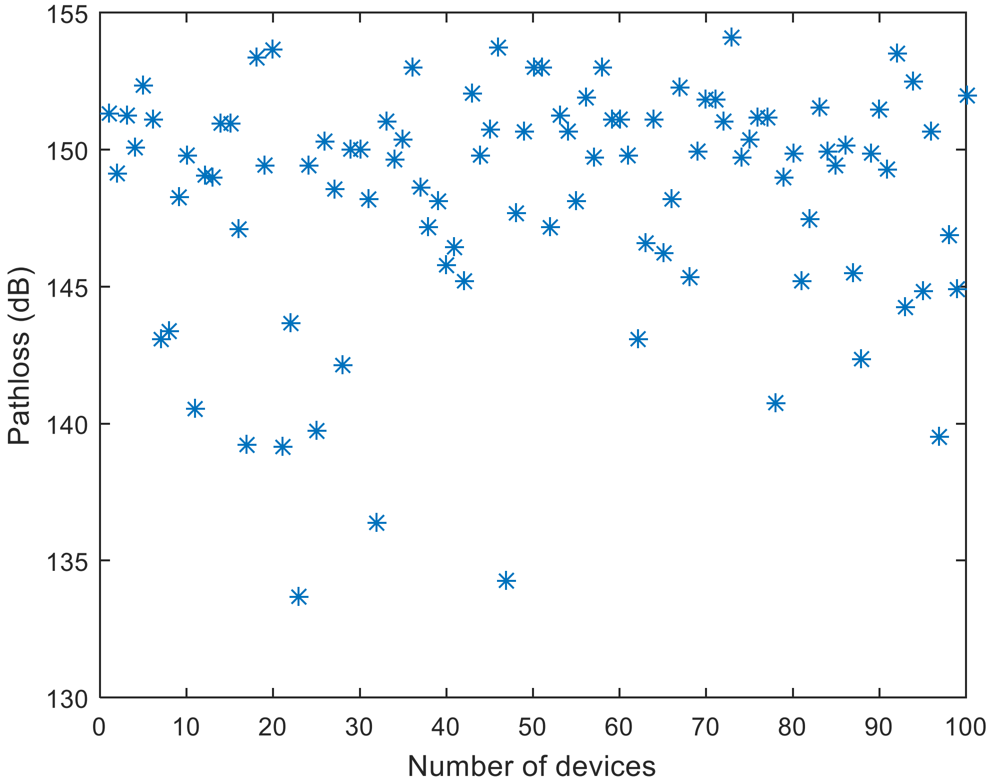

Figure 2; Pathloss of each of the WSN nodes.

The RSS (in dB) for the node i according to the Egli model and link budget is given as follows:

$$RSS_i = EIRP - LP_{E(i)} \text{ (dB)} \quad (3)$$

Where EIRP = effective isotropic radiated power given in dB.

The scatter plot with smooth lines and marker for the distance and pathloss of the WSN nodes is shown in Figure 3. Also, the scatter plot with smooth lines and marker for the distance and RSS of the WSN nodes is shown in Figure 4. In order to select the cluster heads, a range of -65 dBm ≤ RSS ≤ -75 dBm is used as shown in Figure 5.

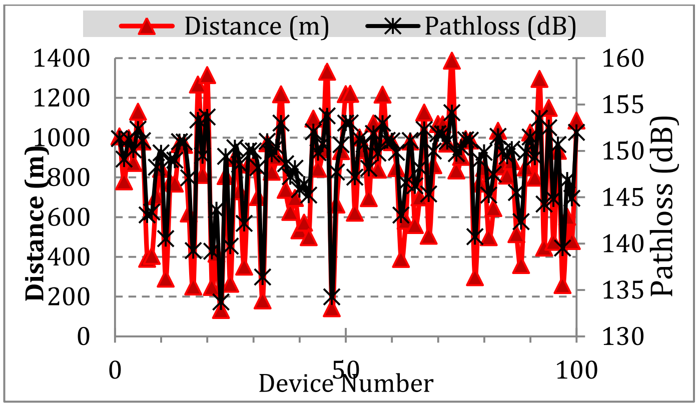

Figure 3 The scatter plot with smooth lines and marker for the distance and pathloss of the WSN nodes

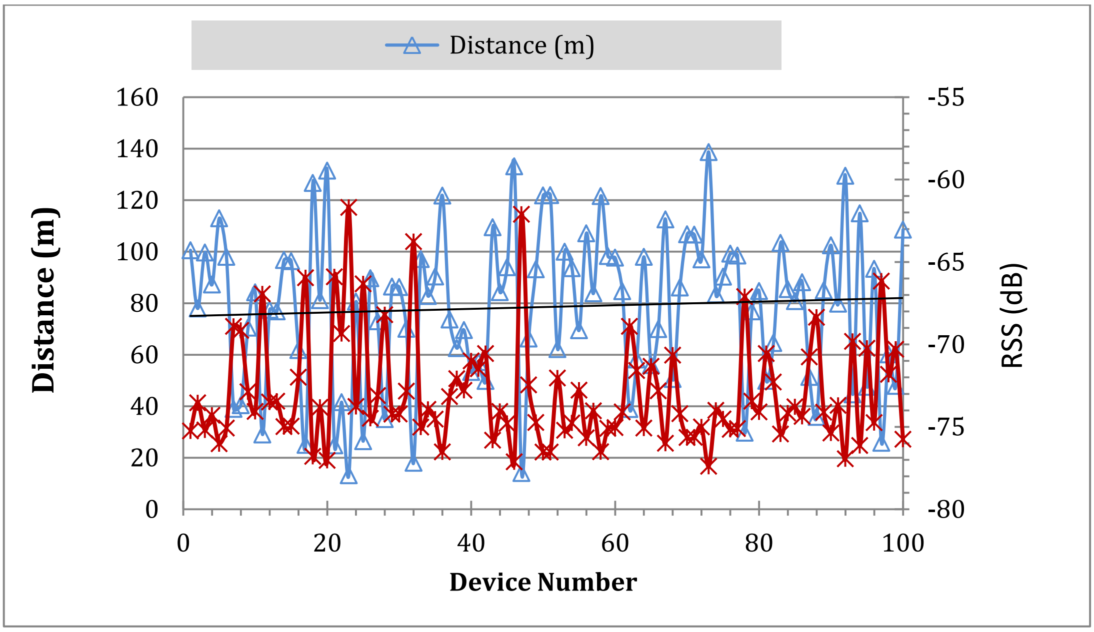

Figure 4 The scatter plot with smooth lines and marker for the distance and pathloss of the WSN nodes

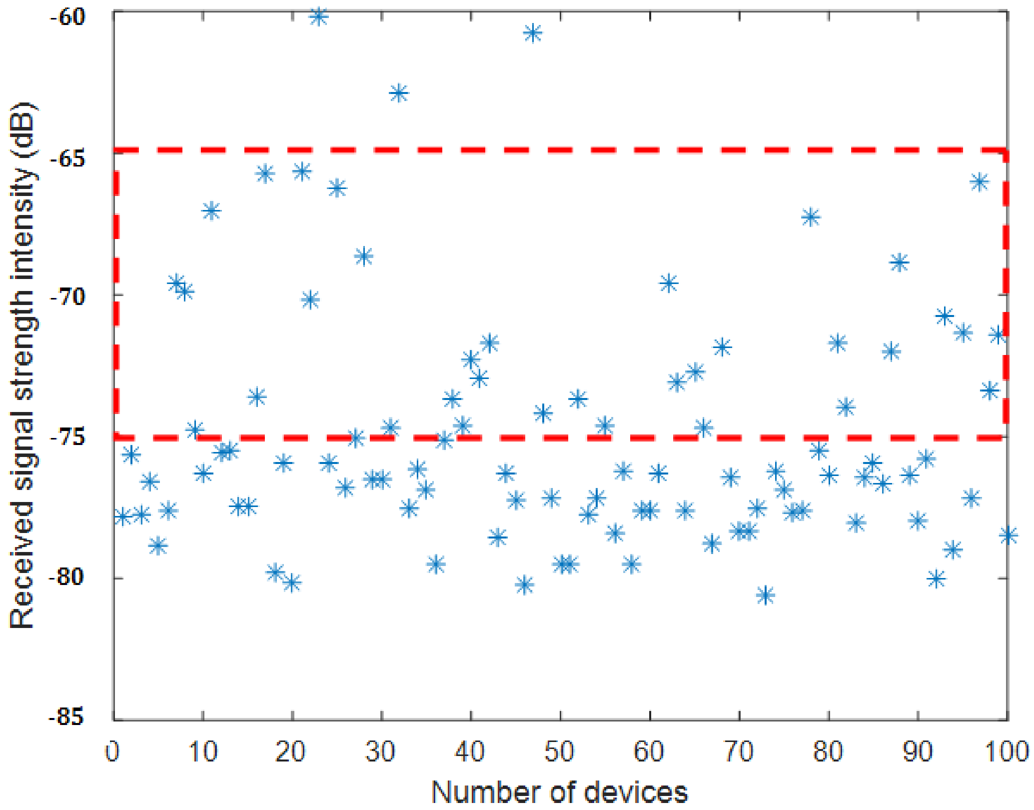

Figure 5; The RSSI range of -65 dBm ≤ RSS ≤ -75 dBm for cluster head selection

The SOM algorithm was implemented in Matlab for the selection of cluster heads from the 100 WSN nodes based on the RSSI range of -65 dBm ≤ RSS ≤ -75 dBm . The SOM environment in Matlab is shown in Figure 6 and the snapshot of the MATLAB program simulated in obtaining the results is shown in Figure 7.

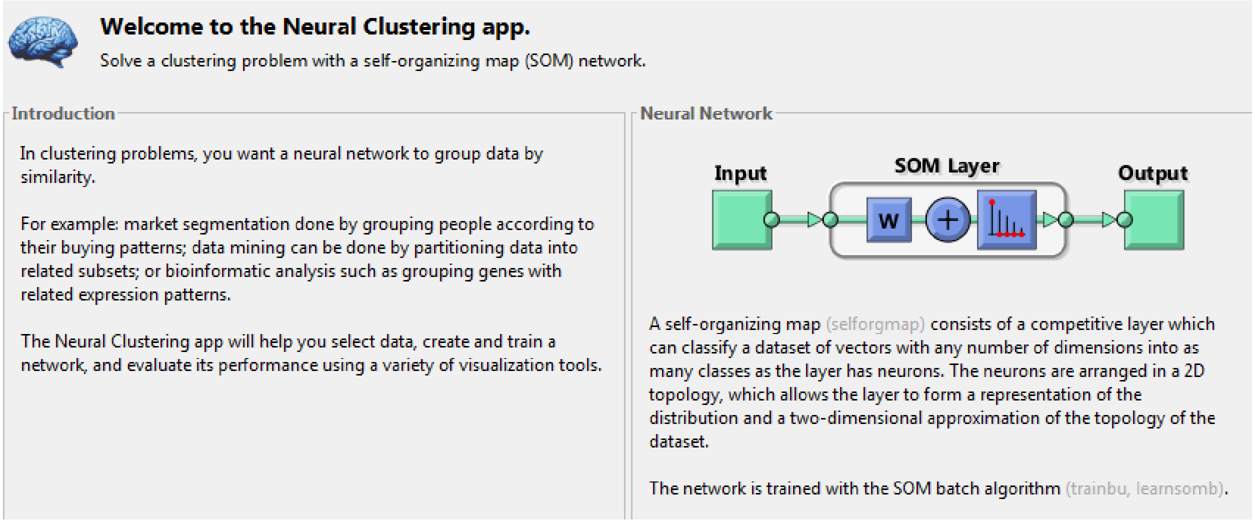

Figure 6; The SOM environment in Matlab.

```
x1 = 0+1000*rand(100,1); %x-coordinate
y1 = 0+1000*rand(100,1); % y-coordinates
x = [1:100]';
d = sqrt(x1.^2+y1.^2);% resultant distance
figure(1)
plot(x1,y1,'*'),ylabel('y-coordinates (m)'),xlabel('x-coordinates (m)'),grid
figure(2)
plot(x,d,'*'),ylabel ('Resultant distance around the square region(m)'),grid
x2 = abs(500-x1);
y2 = abs(500-y1);
d2 = sqrt(x2.^2+y2.^2);
figure(3)
plot(x,d2,'*'),ylabel ('Resultant distance from base station(m)'),grid

% for pathloss
f = 1800;
Pl = 32.5+20*log10(f)+20*log10(d);
RSSI = 53.5-Pl;
figure(4)
plot(x,Pl,'*'),ylabel('Pathloss (dB)'),xlabel('Number of devices')
figure(5)
plot(x,RSSI,'*'),ylabel('Received signal strength intensity (dB)'),xlabel('Number of devices')
```

Figure 7: The snapshot of the MATLAB program simulated in obtaining the results.

3. Results and Discussion

The outcome of the clustering performed with the SOM algorithm is shown in Figure 8 and Table 1. Specifically, Figure 8 shows the SOM topology with 16 cluster heads selected by the SOM cluster algorithm along with the node number of the cluster heads . The results of the clustering of the cluster slaves to the cluster heads performed by the SOM clustering algorithm are shown in Figure 9. Specifically, Figure 9 and Table 1 show the 16 cluster heads selected by the SOM cluster algorithm along with the number of slave nodes clustered around each of the cluster heads.

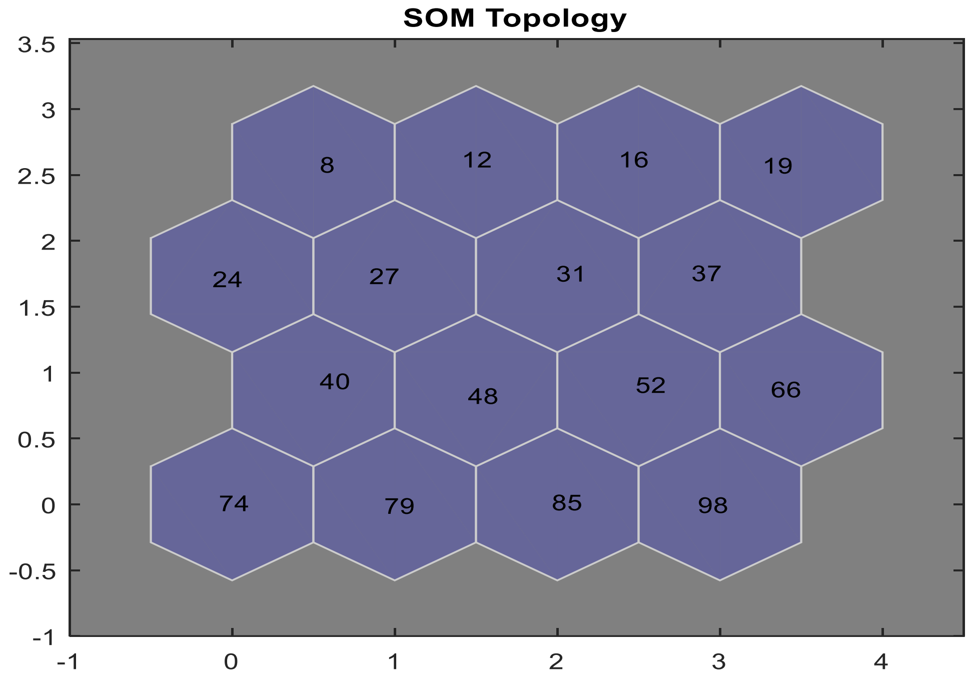

Figure 8; The SOM topology with 16 cluster heads selected by the SOM cluster algorithm along with the node or device number of the cluster heads .

Table 1; The 16 cluster heads selected by the SOM cluster algorithm along with the node or device number of the cluster heads and the number of slave nodes clustered around each of the cluster heads

Cluster heads number	Device number	x-coordinates	y-coordinates	Resultant distance	pathloss	RSSI	Number of cluster slaves
1	8	142.19	378.19	404.03	143.4	-69.153	4
2	12	725.78	269.05	774.04	149.05	-73.497	6
3	16	571.03	236.44	618.04	147.09	-71.993	7
4	19	265.32	766.92	811.52	149.46	-73.813	8
5	24	640.12	489.76	805.99	149.4	-73.767	5
6	27	723.17	99.09	729.93	148.54	-73.105	4
7	31	627.35	311.94	700.62	148.18	-72.831	5
8	37	383.31	628.92	736.52	148.61	-73.165	7
9	40	530.05	54.617	532.86	145.8	-71.002	8
10	48	535.66	390	662.6	147.7	-72.458	5
11	52	66.946	618.34	621.95	147.15	-72.035	2
12	66	616.44	330.42	699.42	148.17	-72.819	4
13	74	766.83	327.76	833.94	149.69	-73.995	9
14	79	680.18	356.87	768.11	148.98	-73.445	10
15	85	551.79	590.61	808.27	149.42	-73.786	8
16	98	125.65	588.21	601.48	146.85	-71.811	8

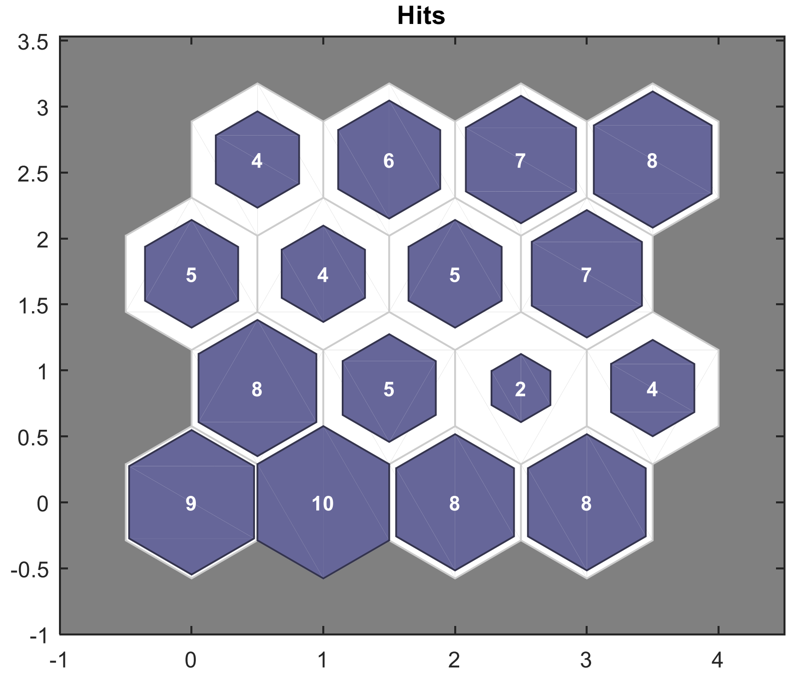

Figure 9; The 16 cluster heads selected by the SOM cluster algorithm along with the number of slave nodes clustered around each of the cluster heads

4. Conclusion

Cluster head selection for LORAWAN network is studied. The network operates at 868 MHz (for European region). The Cluster head selection is implemented using self organizing map (SOM) clustering algorithm tool in Matlab software. Specifically, Egli path loss model and link budget equation were used to determine the received signal strength which was then used to select the cluster heads from a set of 100 sensors nodes. The results showed that only 16 cluster heads were selected by the SOM algorithm based on the RSS range of -65 dBm $\leq$ RSS $\leq$ -75 dBm.

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