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Clustering Of 2100 Mhz Cellular Network Devices With Som Algorithm Using Device Hardware Capacity And Rssi Parameters

Ogbonna Chima Otumdi [1]
Department of Electrical/Electronic and Computer Engineering
University of Uyo
otumdii@yahoo.com

Ozuomba, Simeon[2]
Department of Electrical/Electronic and Computer Engineering
University of Uyo
simeonoz@yahoomail.com
simeonozuomba@uniuyo.edu.ng

Kalu Constanc[3]
Department of Electrical/Electronic and Computer Engineering
University of Uyo
conskay4@yahoo.com

***Abstract*— In this paper, clustering of 2100 MHz cellular network devices with Self organizing map clustering (SOM) algorithm using hardware capacity of the network nodes and the received signal strength intensity (RSSI) parameter is presented. Particularly, in this paper, a set of 100 cellular network devices which are located randomly over the 1600 m by 1600 m network coverage region are considered. The x and y location coordinates of the 100 devices were randomly obtained using Matlab rand function. Afterwards, the distance of each of the devices from the base station was computed using Pythagoras formula. Next, based on the distances computed for each of the devices, the link budget expression was used along with the free space path loss to determine the RSSI of each of the 100 devices. The hardware capacity value of 4.0 and above were considered suitable for cluster heads while RSSI values in the range of -65 dB ≤ RSSI≤-90 dB were considered adequate for cluster heads. The computations and the SOM clustering were implemented in Matlab software. The result showed that only 4 cellular network devices were selected as cluster heads from the set of 100 devices. Also, the result of the SOM clustering of the remaining 96 slave cellular network devices to the 4 selected cluster heads showed that the second cluster head had the highest RSSI value of -84.4 dB, the second to the highest device hardware capacity value of 4.7842 and the highest number of slave 47 devices clustered around it by the SOM algorithm. On the other hand, the first cluster head had the lowest RSSI value of -89 dB, the lowest device hardware capacity value of 4.59365 and the lowest number of slave 4 devices clustered around it by the SOM algorithm.**

Keywords — Clustering, Cellular Network , Self Organizing Map, Cluster Heads, Received Signal Strength Intensity, Network Coverage

I. INTRODUCTION

In the wireless communication industry, losses in signal strength due to terrain, atmospheric and other environmental factors and the usual free space spreading of signal over distance make the transmission power demand to be significantly high and increase with transmission distance [1,2,3,4,5,6,7,8]. As such, device-to-device (D2D) communication has been adopted as one of the ways of enhancing overall energy efficiency in the wireless communication networks [9,10,11,12,13,14,15,16,17,18]. In D2D communication, clustering of the devices to cluster heads is required. In turn, cluster head selection is also required before the clustering of the slave devices to the cluster heads can be implemented [19,20,21,22,23,24]. Accordingly, a clustering algorithm is needed for both the cluster head selection and the clustering of the devices.

Among other things, clustering algorithms require one or more parameters for the cluster head selection. The distance of the devices from the base station is one of the parameters usually used by clustering algorithms [25,26,27,28,29,30]. However, in some cases, instead of the distance, the received signal strength intensity (RSSI) of the devices is used [31,32,33,34,35,36,37]. In other cases, two or more parameters are used together to select the cluster heads. In this paper, the RSSI and the device hardware capacity are used to determine the eligible devices to be selected as cluster heads. Specifically, in this paper, the RSSI is determined from the free space path loss and link budget equation. Furthermore, the Self organizing map clustering (SOM) algorithm is used to select the cluster heads from the devices that satisfied the threshold values set for the RSSI and the hardware capacity. Also, the SOM algorithm is used for clustering of the slave devices to the cluster heads. The relevant mathematical expressions are presented and Matlab software is used for the computations and the implementation of the clustering using the SOM algorithm.

II. METHODOLOGY

The focus of the paper is to implement cluster head selection in a cellular network using self organizing map (SOM) clustering algorithm. The SOM algorithm utilizes the cellular device hardware capacity and the received signal strength intensity (RSSI) of the cellular network devices to determine the cluster heads. Particularly, in this paper, a set of 100 cellular network devices which are located randomly over the 1600 m by 1600 m network coverage region are considered . The cellular network base

station in located at the 800 m by 800 m (center) of the coverage region.

The x and y location coordinates of the 100 devices are randomly obtained using Matlab rand function. Afterwards, the distance of each of the devices from the base station is computed using Pythagoras formula. Next, based on the distances computed for each of the devices, the link budget expression was used along with the free space path loss to determine the received signal strength at the location of each of the 100 devices. The analytical expressions used for the computations of the free space path loss ($FSPL(\text{dB})$) and received signal strength intensity, RSSI (dB) in dB for the give distance , d in km and frequency , f in MHz are as follows;

$$FSPL(\text{dB}) = 32.44 + 20\log(\text{f}) + 20\log(\text{d}) \quad (1)$$

$$\text{RSSI} = \text{EIRP} - FSPL(\text{dB}) \quad (2)$$

Where EIRP = effective isotropic radiated power given in dB. Meanwhile, the distance d in km is computed from the xcd, ycd coordinates of the cellular network devices and xb,yb coordinates of the base station as follows;

$$d = \sqrt[2]{(xcd - xb)^2 + (ycd - yb)^2} \quad (3)$$

Where d, xcd, ycd, xb and yb are in km.

In addition, SOM clustering algorithm was implemented in Matlab for selecting the cluster heads from the 100 cellular network devices based on the RSSI and the device hardware capacity parameters. The hardware capacity value of 4.0 and above are considered suitable for cluster heads while RSSI values in the range of -65 dB ≤ RSSI≤-90 dB are considered adequate for cluster heads. After the cluster heads were selected from the 100 devices, the SOM algorithm was implemented again for clustering of the slave cellular network devices to the cluster heads. The whole SOM implementations and computations were conducted in Matlab software.

III. RESULTS AND DISCUSSION

The computations and the SOM clustering were implemented in Matlab software. The screenshot of the Matlab codes used for the computations and the SOM cluster ring of the cellular network devices is shown in Figure 1. The generated and computer data on cellular network devices hardware capacity, x and y location coordinates, distance from the base station, pathloss and RSSI are shown in Table 1. The plot of the x-coordinates and y-coordinates of the cellular network devices around the sink (base station located at the center) of the network coverage region of 1600 m by 1600 m is shown in Figure 2. The distance of the 100 cellular network devices from the base station is shown in Figure 3 while the pathloss obtained is plotted as shown in Figure 4. The RSSI of the 100 cellular network devices and hardware capacity of the 100 cellular network devices are shown in Figure 5 and Figure 6 respectively. Figure 5 and Figure 6 also shows the cellular network devices that are eligible for selection as cluster heads.

```
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 1: The screenshot of the Matlab codes used for the computations and the SOM cluster ring of the cellular devices.

Table 1 The generated and computer data on cellular network devices hardware capacity, x and y location coordinates, distance from the base station, pathloss and RSSI

Device Number	Cellular network devices Hardware Capacity	x-coordinate of the cellular network devices	y-coordinate of the cellular network devices	Distance of the cellular network devices from the base station	Pathloss (dBm) of the cellular network devices	RSSI (dBm) of the cellular network devices
1	4.039791	12	81	81.8841	66.5	-84.8
2	3.2888	54	141	150.987	77.7	-86.2
3	4.748972	533	417	676.741	104.6	-94.8
4	3.517156	445	1462	1528.22	133.5	-102.7
5	2.577354	1398	766	1594.1	123.1	-99.9

6	4.720578	302	91	315.412	88.0	-89.7
7	4.784195	2	236	236.008	85.9	-89.0
8	4.76914	751	532	920.34	111.1	-96.7
9	4.103329	246	973	1003.62	119.4	-99.0
10	4.756502	860	1090	1388.42	126.1	-100.8
11	3.55281	282	74	291.548	86.5	-89.2
12	4.923507	73	331	338.954	92.9	-91.3
13	4.293753	435	656	787.122	110.7	-96.6
14	3.696911	1313	942	1615.96	126.1	-100.7
15	3.783761	810	1449	1660.03	134.5	-102.9
16	4.676859	36	106	111.946	72.6	-84.4
17	3.981551	78	388	395.763	96.1	-92.3
18	4.90879	634	596	870.156	111.3	-96.7
19	3.980134	1238	999	1590.8	126.7	-100.9
20	4.486084	848	576	1025.12	113.4	-97.3
21	3.767678	385	94	396.309	91.5	-90.8
22	4.05799	348	77	356.417	89.6	-90.2
23	4.081484	739	440	860.07	108.6	-96.0
24	4.109389	353	1345	1390.55	130.2	-101.8
25	3.816578	1136	155	1146.53	108.4	-95.9
26	4.35071	210	77	223.672	82.6	-87.9
27	3.905658	60	392	396.565	96.2	-92.3
28	4.870439	41	144	149.723	77.6	-86.2
29	3.392827	1381	808	1600.01	123.8	-100.1
30	4.035307	819	1227	1475.23	129.2	-101.6
31	4.875913	262	2	262	83.7	-88.3
32	2.133282	656	568	867.733	110.8	-96.6
33	4.62589	523	522	738.927	107.6	-95.7
34	3.747785	701	1364	1533.59	132.0	-102.3
35	4.028747	1286	381	1341.25	114.4	-97.6
36	4.606285	360	86	370.13	90.3	-90.4
37	2.803828	31	263	264.821	88.1	-89.7
38	4.235068	742	776	1073.66	117.3	-98.4
39	4.942079	617	1096	1257.74	124.7	-100.4
40	4.002431	810	1394	1612.25	133.2	-102.6
41	4.414363	210	93	229.672	83.2	-88.1
42	4.936618	19	264	264.683	88.1	-89.7
43	3.053856	619	647	895.416	112.5	-97.1
44	4.619946	684	852	1092.59	118.7	-98.8
45	4.993525	1392	693	1554.96	121.5	-99.5
46	4.395431	229	22	230.054	82.1	-87.8

47	4.477401	54	108	120.748	73.8	-84.8
48	4.870435	657	568	868.489	110.8	-96.6
49	4.672617	1004	1152	1528.11	128.5	-101.4
50	4.455156	1166	925	1488.35	124.5	-100.3
51	3.690761	356	72	363.208	89.8	-90.3
52	4.533798	5	309	309.04	91.1	-90.7
53	4.553897	763	704	1038.16	115.6	-97.9
54	2.317016	749	1073	1308.56	125.0	-100.5
55	3.727924	884	746	1156.71	117.9	-98.6
56	2.478634	173	84	192.315	80.4	-87.2
57	4.645171	43	263	266.492	88.2	-89.8
58	4.383771	432	671	798.038	111.1	-96.7
59	4.472039	1296	1162	1740.65	130.7	-101.9
60	4.890083	831	258	870.129	105.9	-95.2
61	4.794443	244	100	263.697	85.4	-88.9
62	4.793316	14	143	143.684	77.0	-86.0
63	4.112942	681	755	1016.75	116.1	-98.1
64	4.555777	1483	1110	1852.4	130.8	-102.0
65	4.993821	1446	501	1530.33	118.2	-98.6
66	4.815316	117	19	118.533	72.1	-84.2
67	4.379192	23	316	316.836	91.6	-90.9
68	3.023746	647	452	789.248	107.5	-95.6
69	4.900817	1156	868	1445.6	123.2	-100.0
70	3.376901	1106	238	1131.32	109.5	-96.2
71	4.950503	368	63	373.354	90.1	-90.4
72	4.496565	13	105	105.802	71.8	-84.1
73	4.103648	707	691	988.6	114.7	-97.7
74	4.092691	570	899	1064.47	119.1	-98.9
75	4.232589	979	983	1387.35	124.4	-100.3
76	3.235369	331	42	333.654	88.1	-89.7
77	2.343891	95	275	290.947	89.7	-90.2
78	4.341435	541	462	711.425	106.1	-95.2
79	4.012082	1008	1431	1750.38	135.0	-103.1
80	4.593654	180	14	180.544	78.4	-86.5
81	3.93797	1482	138	1488.41	112.1	-96.9
82	4.259613	36	291	293.218	90.1	-90.4
83	4.283729	657	762	1006.13	116.1	-98.1
84	4.621711	817	1244	1488.3	129.6	-101.7
85	4.959662	1239	667	1407.13	119.6	-99.0
86	4.25334	377	52	380.569	90.2	-90.4
87	4.577499	10	172	172.29	80.2	-87.1

88	4.115782	681	708	982.357	114.9	-97.7
89	4.420109	1225	1357	1828.13	134.5	-102.9
90	4.871393	1352	1397	1944.1	136.1	-103.3
91	4.869411	281	49	285.24	85.8	-89.0
92	4.544135	78	154	172.627	79.9	-87.0
93	2.5341	638	790	1015.45	116.7	-98.2
94	4.105697	892	1263	1546.23	130.5	-101.9
95	4.041955	1500	225	1516.78	113.7	-97.4
96	4.987135	196	98	219.135	82.6	-87.9
97	4.010717	13	334	334.253	92.7	-91.2
98	2.672952	587	680	898.315	113.1	-97.2
99	4.311555	291	837	886.143	115.4	-97.9
100	4.16201	1213	1357	1820.11	134.4	-102.9

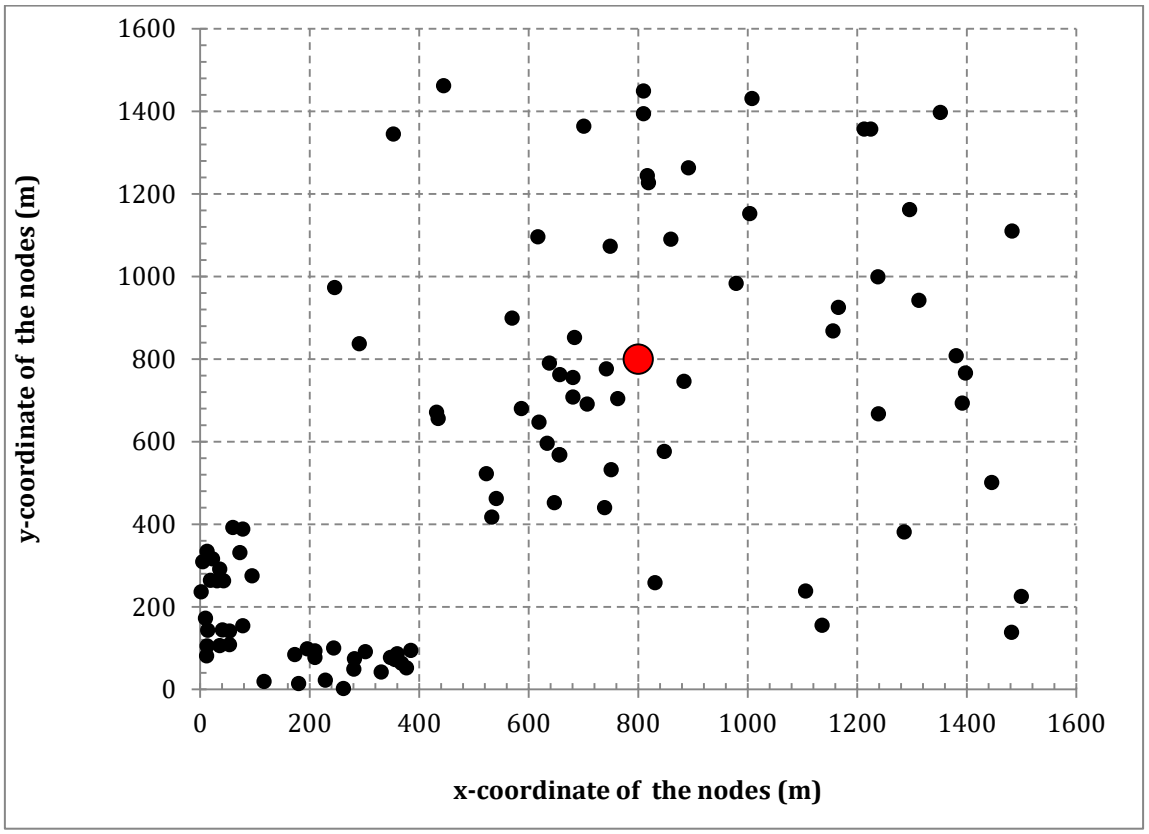

Figure 2; The 100 cellular network devices x and y coordinate positions within the network coverage region of 1600 m by 1600 m

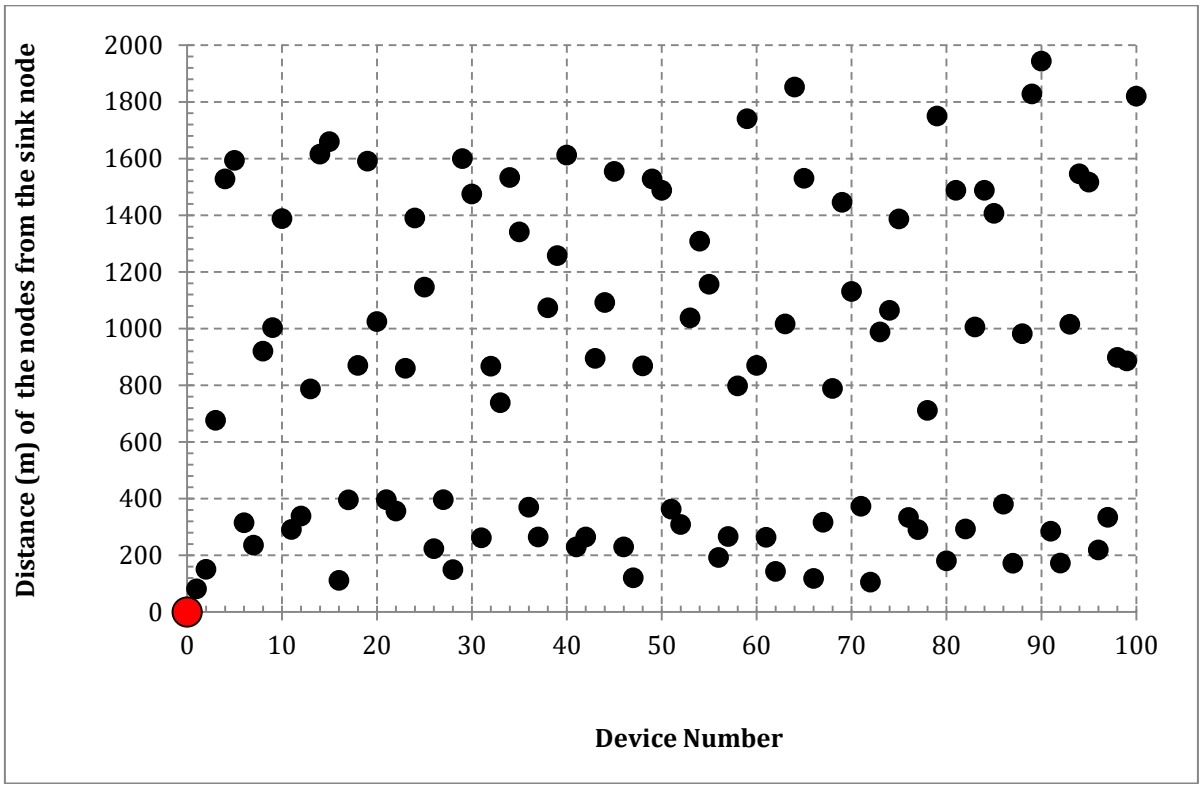

Figure 3; The distance of the 100 cellular network devices from the base station

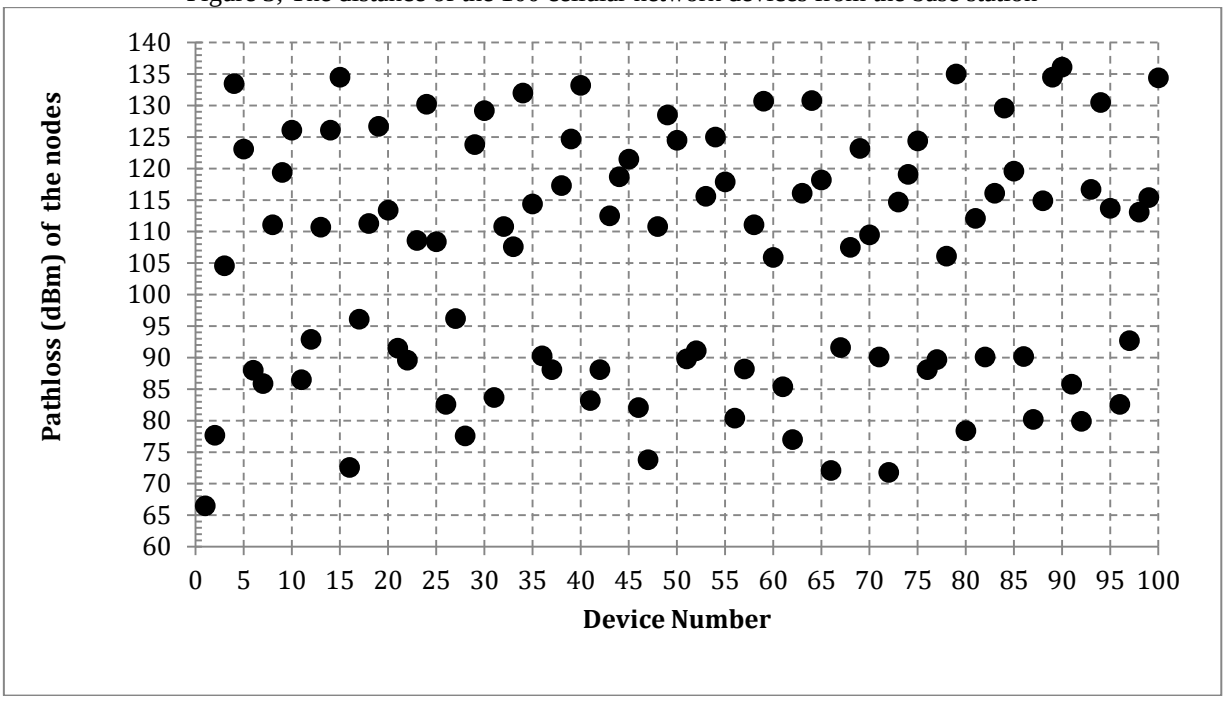

Figure 4; The Pathloss of the 100 cellular network devices .

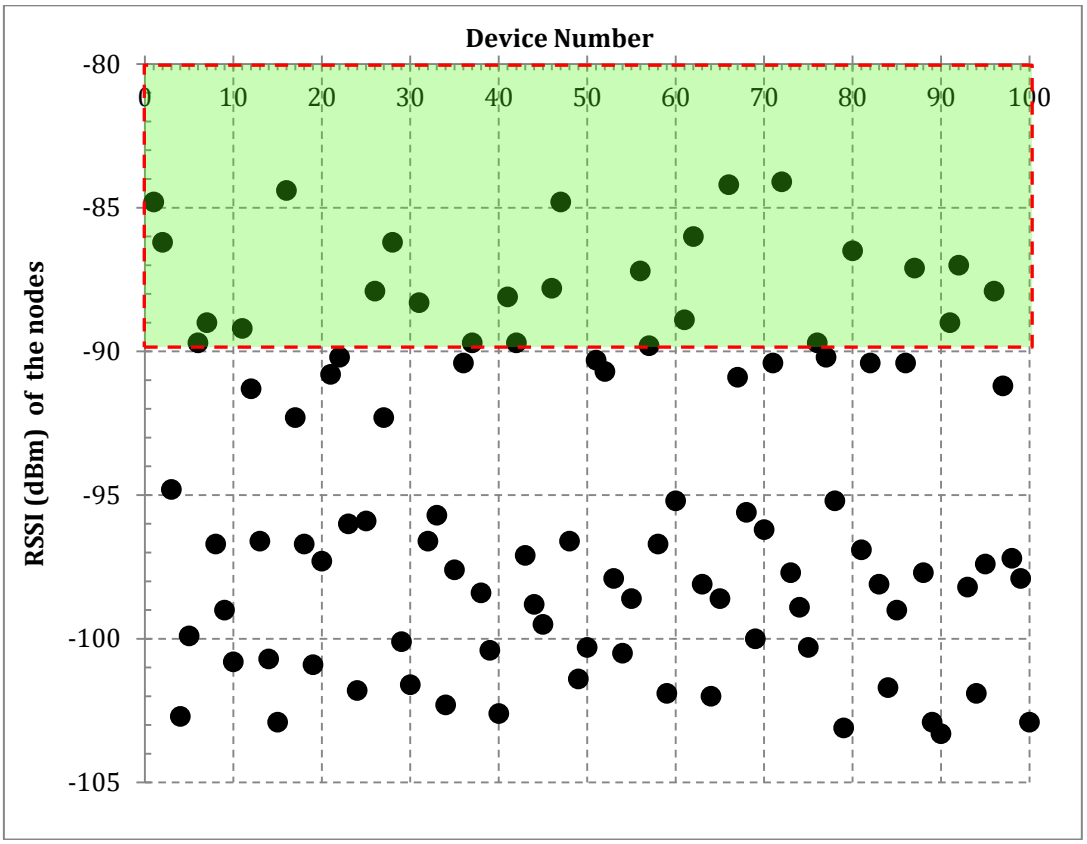

Figure 5; The RSSI of the 100 cellular network devices showing the devices that are eligible for selection as cluster heads

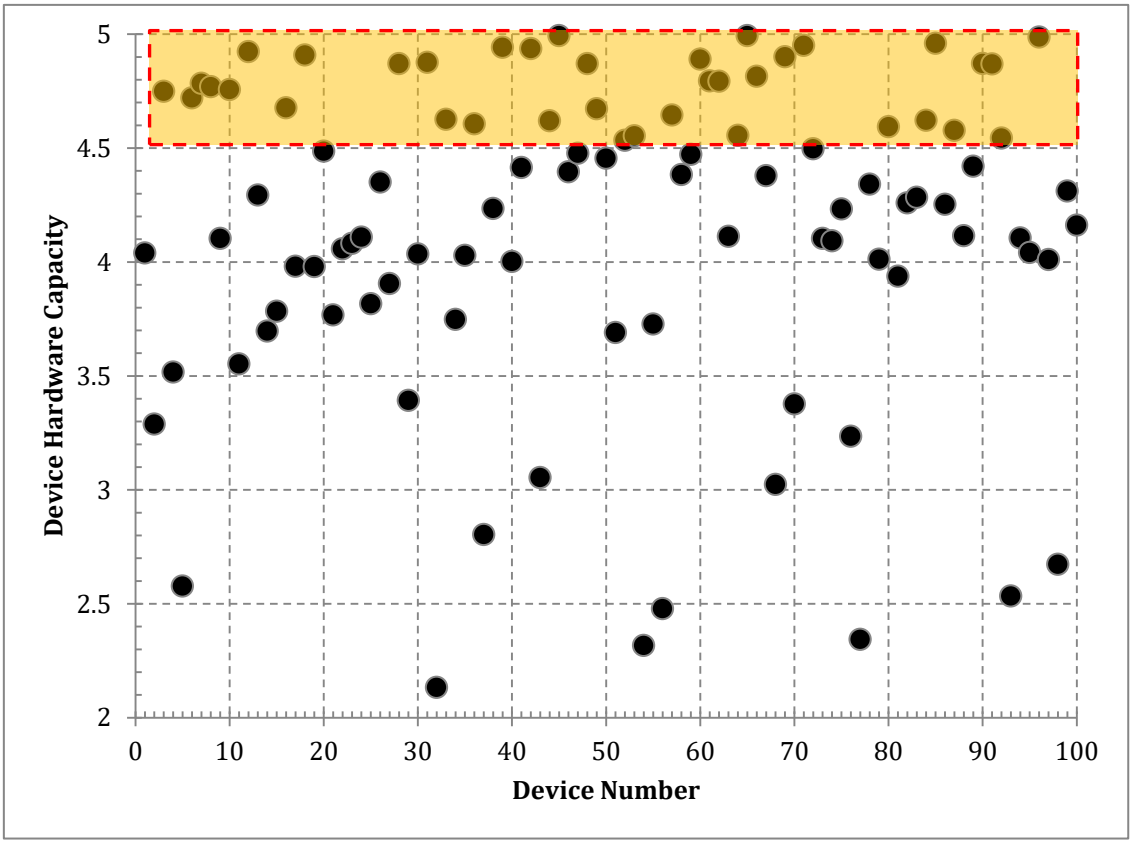

Figure 6; The hardware capacity of the 100 cellular network devices showing the devices that are eligible for selection as cluster heads

The result of the cluster head selection using SOM algorithm based on device hardware capacity and RSSI values is shown in Figure 1 which indicates that only 4 cellular network devices are selected as cluster heads from the set of 100 devices. Also, the result of the SOM clustering of the remaining 96 slave cellular network

devices to the 4 selected cluster heads is shown in Table 2 and Figure 8. The graph of the number of slave cellular network devices clustered around each cluster head and device hardware capacity versus cluster head number is shown in Figure 9 while the graph of the number of slave cellular network devices clustered around each cluster head and RSSI versus cluster head number is shown in Figure 10. According to the results in Table 2, Figure 9 and 10, the second cluster head had the highest RSSI value of -84.4 dB, the second to the highest device hardware capacity value of 4.7842 and the highest number of slave 47 devices clustered around it by the SOM algorithm. On the other hand, the first cluster head had the lowest RSSI value of -89 dB, the lowest device hardware capacity value of 4.59365 and the lowest number of slave 4 devices clustered around it by the SOM algorithm.

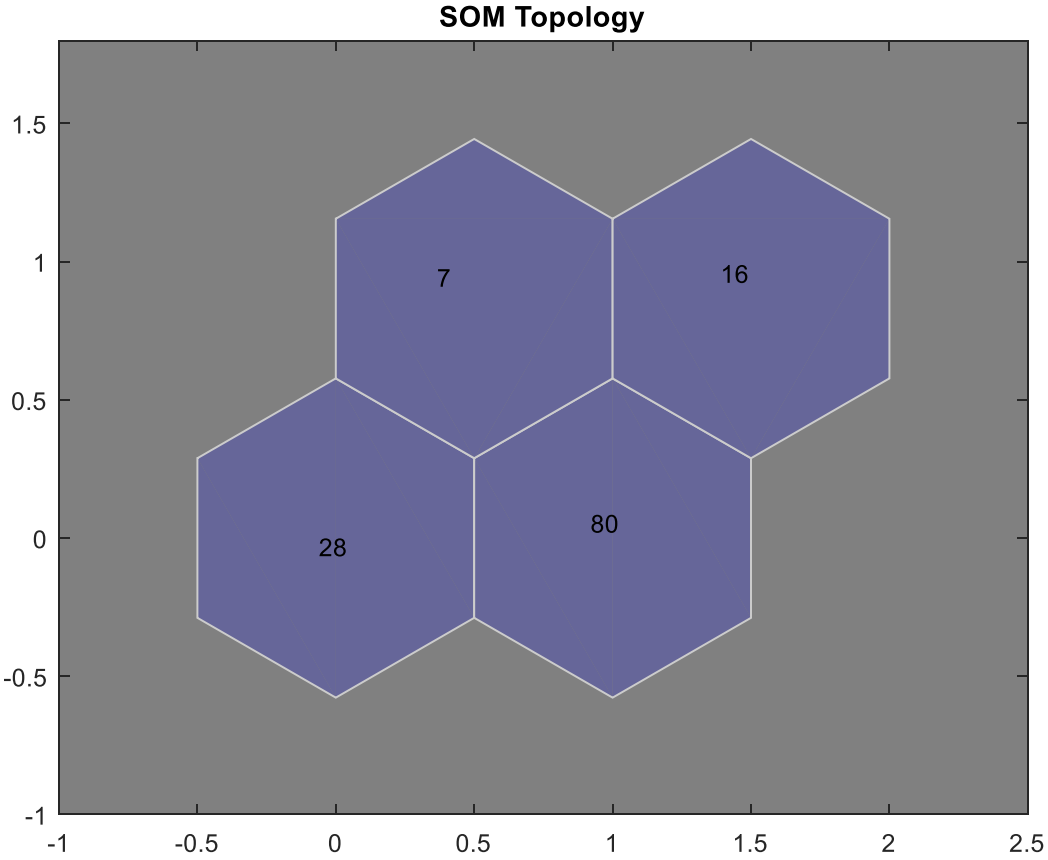

Figure 7; The SOM topology showing that 4 cluster heads are selected.

Table ; The result of the SOM clustering of the remaining 96 slave cellular network devices to the 4 selected cluster heads

Cluster Head Number	Device Number	Cluster Head Hardware Capacity	x-coordinate	y-coordinate	Cluster Head Distance	Cluster Head Pathloss (dBm)	Cluster Head RSSI (dBm)	Number Of Slave Devices To the Cluster Head
1	7	4.59365	2	236	236.008	85.9	-89	4
2	16	4.7842	36	106	111.946	72.6	-84.4	47
3	28	4.87044	41	144	149.723	77.6	-86.2	30
4	80	4.67686	180	14	180.544	78.4	-86.5	19

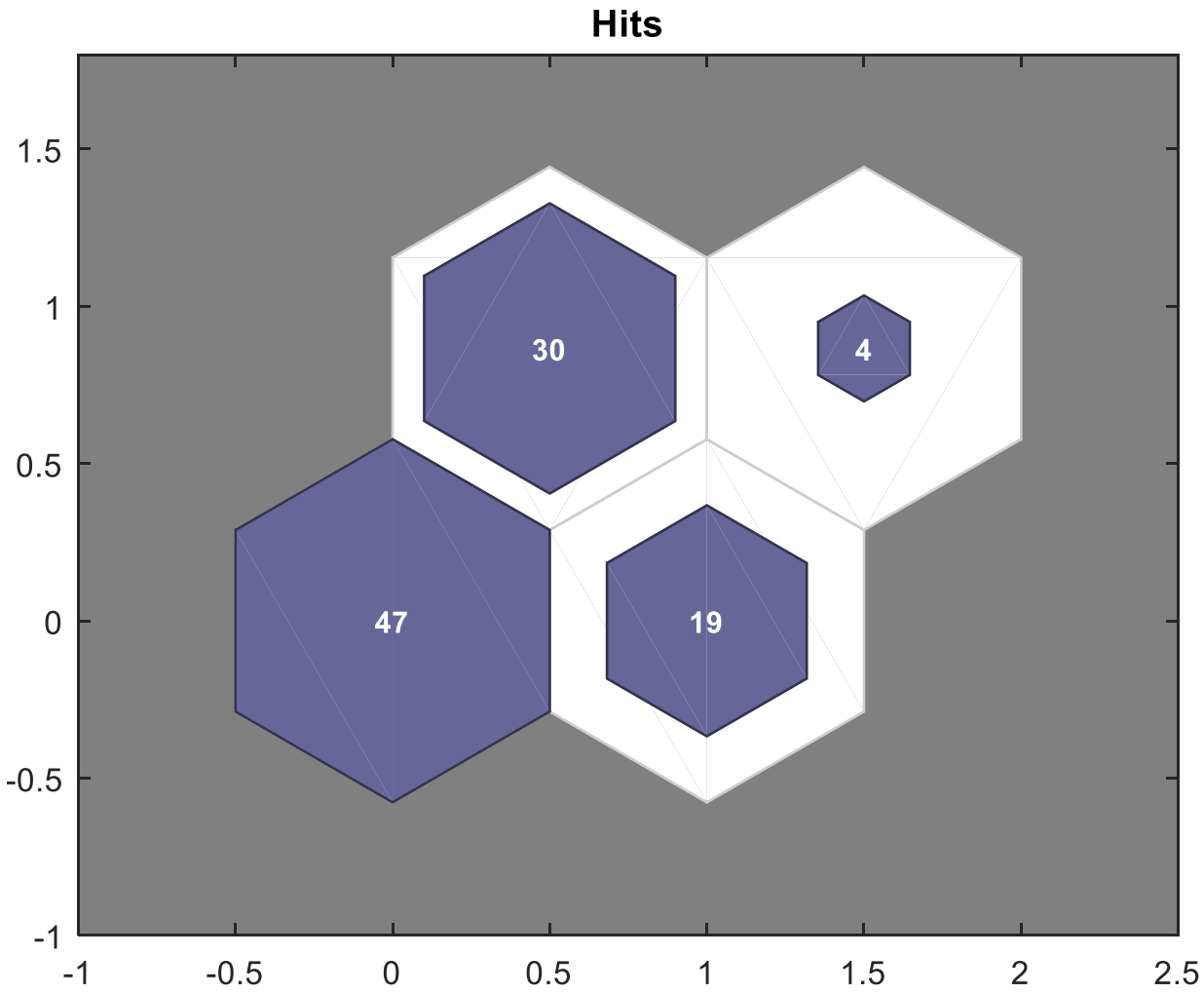

Figure 8; The SOM topology showing the 4 cluster heads and the number of slave cellular network devices clustered around each of them.

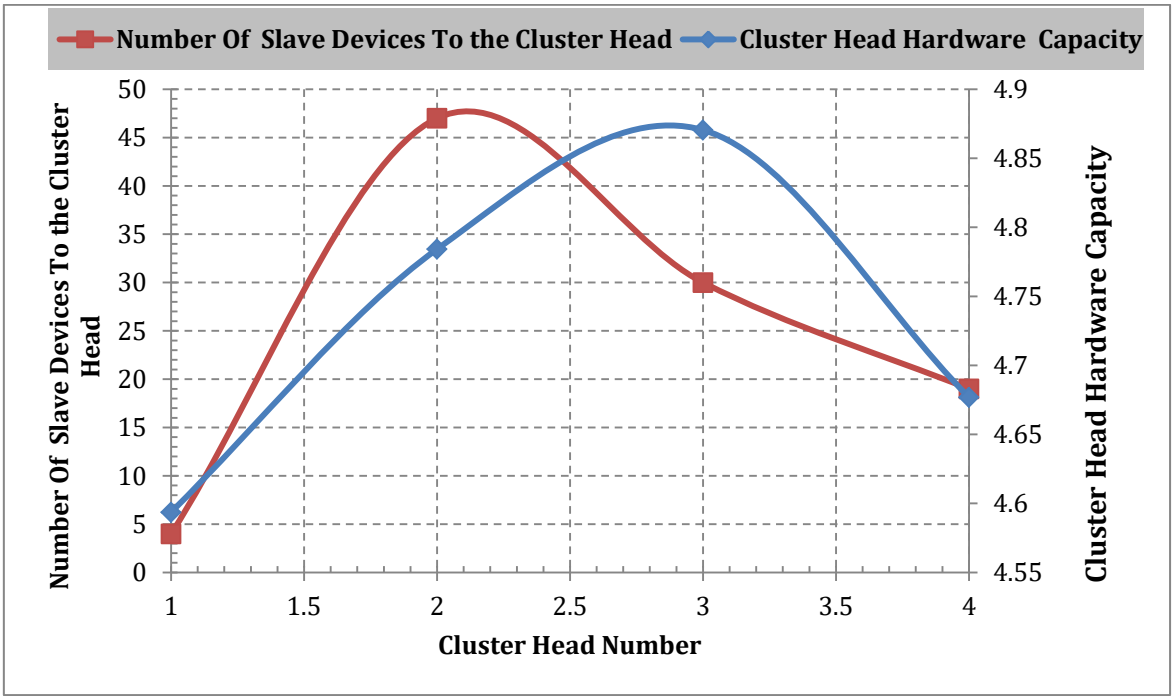

Figure 9; The graph of the number of slave cellular network devices clustered around each cluster head and device hardware capacity versus cluster head number

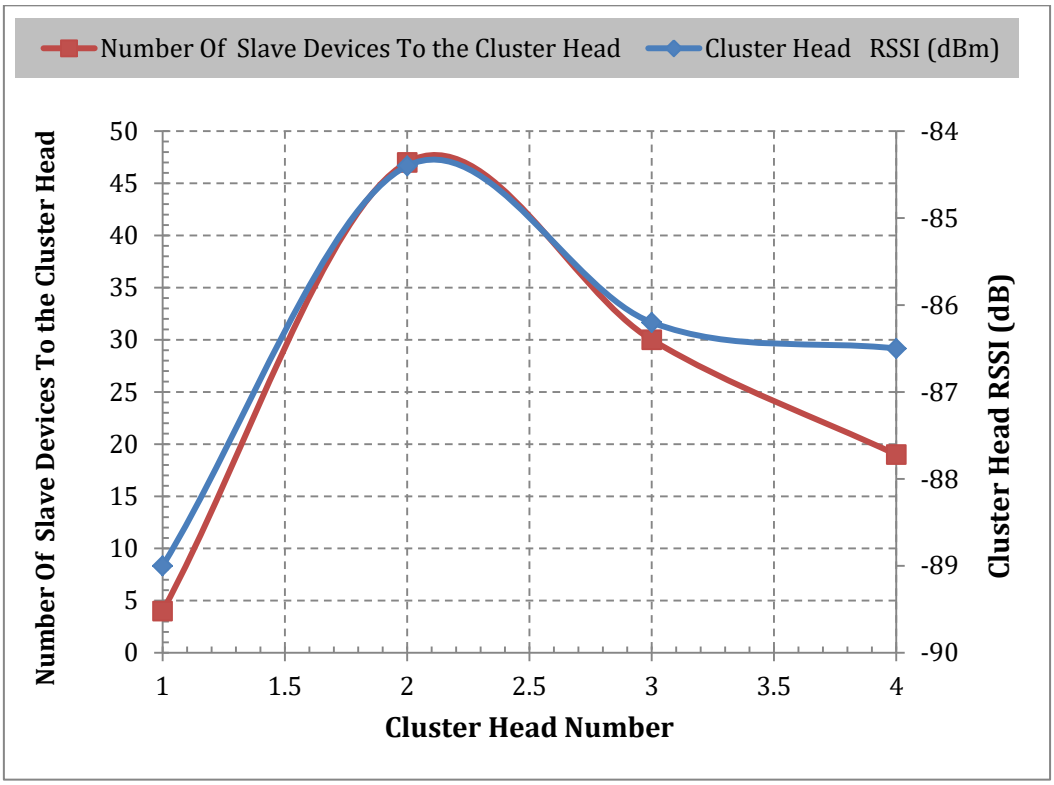

Figure 10; The graph of the number of slave cellular network devices clustered around each cluster head and RSSI versus cluster head number

IV. CONCLUSION

In this paper, Self organizing map clustering (SOM) algorithm is employed in cluster head selection and clustering of lave nodes to the cluster heads in a 2100 MHz cellular network. Specifically, device hardware capacity and received signal strength intensity (RSSI) are used as the main parameters for the cluster head selection. The RSSI computation was done using free space path loss and the link budget expression for wireless networks. The case study network has about 100 nodes spread over an area where the location coordinates of the nodes were generated using Matlab software. A specific threshold value was selected for the hardware capacity and a range of values were selected for the RSSI and the two parameters range of values were combined in the selection of candidate cluster heads from which the SOM algorithm selected the cluster heads. In all, the results show that only 4 cluster heads were selected from among a set of 100 network n9des considered in the study.

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