Self Organizing Map Algorithm-Based Clustering For 1800 Mhz Cellular Network Located In Vegetation Covered Area

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Abstract— **In this paper, self organizing map algorithm-based clustering for 1800 MHz cellular network located in vegetation covered area is presented. In view of vegetation in the network location, Weissberger foliage path loss model was used along with the popular link budget expression to determine the received signal strength intensity (RSSI) in dB. In addition to the RSSI value, the SOM algorithm also utilized the hardware capacity (HWC) of the nodes in selecting the cluster heads. The computations and cluster heads selection with SOM were implemented in Matlab software. The study considered a network with about 100 devices out of which only 9 devices were selected as cluster heads by the SOM algorithm. The SOM algorithm was also used for clustering the slave devices to the cluster heads. The results show that the number of slave devices clustered around the cluster head is strongly correlated to both the RSSI (with R = 0.726213) and hardware capacity (with R = 0.711569). The results also showed that cluster head 3 with the highest hardware capacity value of 4.852958 and the highest RSSI value of -66.824 dB had the highest number of 15 slave nodes clustered around.**

Keywords— Self Organizing Map, Link Budget , Path Loss, Clustering, Received Signal Strength Intensity, Slave Devices, Cluster Heads, Weissberger Foliage Model

I. INTRODUCTION

Wireless network signals suffer different kinds of losses as they propagate through the atmosphere .Some of the losses are due to the atmospheric conditions, some loses are due to terrain factors while other losses are due to obstructions in the propagation path [1,2,3,4,5,6,7,8,9,10,11,12,13]. Particularly, for wireless networks located in vegetation covered areas, in addition to the free space path loss, the signals also suffer losses due to the foliage and the extent of the foliage losses depends on frequency and the depth of the foliage [14,15,16,17,18,19,20,21]. Apart from the reduction in received signal strength, the losses makes the transmission energy demand to be high especially for sensor networks that use battery-powered energy limited sensor devices [22,23,24,25,26,27,28]. As such, for such wireless networks energy efficient technologies are of utmost importance [29,30,31,32,33,34,35,36]. In such case, clustering of network nodes is one of the approaches used to achieve energy efficiency [37,38,39,40,41]. Accordingly, in this paper, self organizing map (SOM) clustering algorithm [42,43,44,45,46] is employed in the selection of cluster heads and for clustering of the network nodes for a 1800 MHz cellular network located in vegetation covered area. Matlab software is used for the implementation of the SOM clustering and other requisite computations in the study.

II. METHODOLOGY

The study considers cluster head selection for cellular network located in vegetation covered area. In this wise, Weissberger foliage path loss model [47,48,49,50] is used along with the popular link budget expression to determine the received signal strength intensity (RSSI) in dB as follows;

$$\text{RSSI} = \text{EIRP} - P_{twb}(dB) \quad (1)$$

$$P_{twb}(dB) = 32.5 + 20 * \log(\text{f}) + 20 * \log(\text{d}) + \begin{cases} 0.45 f^{0.284}(d_f) & for \ \ 0 \le d_f \le 14\text{m} \\ 1.33 F^{0.284}(d_f)^{0.588} & for \ \ 14 \le d_f \le 400\text{m} \end{cases} \quad (2)$$

Where $P_{twb}(dB)$ is the total pathloss which is a combination of free space path loss and the Weissberger foliage path loss, d is the distance in km of the nodes from the base station, d_f is the foliage depth (or depth of vegetation covered area) in meters, f is the frequency in GHz and EIRP is the effective isotropic radiated power.

The distance, d is computed for each network node (device) using the x and y coordinates of the nodes (denoted as xn,yn) and those of the base station (denoted as xb,yb) as follows;

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

In the study 100 nodes are considered and they are randomly distributed within an area of 2000 m by 2000 m , where xb =1000 m and yb =1000 m. The x and y coordinates of the 100 nodes are generated randomly in Matlab using the random number function.

Apart from RSSI value, hardware capacity (HWC) of the nodes is also considered in selecting the cluster heads. The range of values for the HWC is $0.0 \leq HWC \leq 5.0$. Again, the hardware capacity of the 100 nodes is generated randomly in Matlab using the random number function.

III RESULTS AND DISCUSSION

The detail values of the generated data and the Matlab computation results for the cluster head selection and clustering of the slave nodes are presented in Table 1. The plot of the x-coordinates and y-coordinates of the 100 nodes around the sink (base station at the center) is shown in Figure 1.The plot of the distance of the 100 nodes from the sink (base station at the center) is shown in Figure 2. The plot of the RSSI of the 100 nodes is shown in Figure 3 and the plot of the hardware capacity of the devices is shown in Figure 4.

Table 1 The detail values of the generated data for the cluster head selection and clustering of the slave nodes

Device Number	Hardware Capacity	x-coordinate (m)	y-coordinate (m)	Distance (m) from the Base Station	Pathloss (dBm)	RSSI (dBm)
1	3.759278	1697	1945	2581.2	124.1356	-99.1871
2	2.678054	140	103	173.8	100.7026	-76.8023
3	3.908394	681	513	852.6	114.515	-90.5556
4	4.864673	1781	1855	2571.6	124.1032	-99.1592
5	4.741147	1992	1921	2767.4	124.7405	-99.7072
6	4.600664	98	93	135.1	98.51489	-74.4522
7	4.866635	241	128	272.9	104.6212	-80.8871
8	4.064211	770	409	871.9	114.7095	-90.7371
9	4.489477	730	1283	1476.1	119.282	-94.9194
10	4.796264	35	51	61.9	91.73629	-66.8242
11	4.716582	81	84	116.7	97.24333	-73.0622
12	4.506676	123	263	290.3	105.158	-81.4347
13	3.498119	649	500	819.3	114.169	-90.2318
14	4.744065	1764	1422	2265.8	123.0037	-98.2069
15	4.400679	1838	1942	2673.9	124.442	-99.4509
16	3.674045	57	92	108.2	96.58652	-72.337
17	4.327354	121	229	259	104.1672	-80.4217
18	2.513527	791	637	1015.6	116.0344	-91.9659
19	4.651981	952	1706	1953.6	121.7161	-97.081
20	4.097446	1856	1684	2506.1	123.8792	-98.9658
21	2.042137	33	68	75.6	93.47273	-68.8307
22	4.550988	1782	1799	2532.2	123.9691	-99.0435
23	3.550211	723	454	853.7	114.5262	-90.566
24	4.450141	1610	1031	1911.8	121.5283	-96.9157
25	4.852961	138	205	247.1	103.7587	-80.0013
26	4.572951	164	121	203.8	102.0855	-78.2617
27	3.792721	80	2	80	93.96405	-69.3916
28	2.613339	717	623	949.9	115.4536	-91.429
29	4.738745	1330	840	1573.1	119.8347	-95.4141

30	4.174815	1994	1990	2817.1	124.8951	-99.8398
31	4.857772	70	3	70.1	92.81672	-68.0771
32	3.271799	216	229	314.8	105.8617	-82.1483
33	4.535682	545	740	919	115.1664	-91.1624
34	4.079162	1885	1583	2461.5	123.7232	-98.831
35	4.685623	83	41	92.6	95.23434	-70.8284
36	3.854169	1535	1667	2266.1	123.0049	-98.2079
37	3.432878	248	170	300.7	105.4637	-81.7453
38	3.880983	494	771	915.7	115.1351	-91.1334
39	4.655252	853	1284	1541.5	119.6585	-95.2567
40	3.49854	1857	1652	2485.5	123.8075	-98.9039
41	4.035516	25	0	25	83.86208	-57.2216
42	3.967626	261	257	366.3	107.1776	-83.4702
43	3.895402	609	428	744.4	113.3364	-89.4486
44	3.799768	1332	1605	2085.7	122.2844	-97.5794
45	2.458884	1551	1564	2202.7	122.7584	-97.9934
46	4.650883	17	100	101.4	96.0228	-71.7107
47	4.701499	229	147	272.1	104.5957	-80.861
48	4.173927	540	447	701	112.8147	-88.9549
49	3.578017	972	1350	1663.5	120.32	-95.8466
50	2.721458	1824	1529	2380.1	123.4311	-98.5781
51	4.568692	32	76	82.5	94.2313	-69.6955
52	4.787222	187	103	213.5	102.4893	-78.6842
53	4.00912	721	502	878.5	114.775	-90.7981
54	4.837141	884	1711	1925.9	121.5921	-96.9719
55	3.88849	1900	1806	2621.4	124.2698	-99.3027
56	3.9114	47	83	95.4	95.49306	-71.1187
57	4.119226	270	139	303.7	105.55	-81.8327
58	4.605612	490	601	775.4	113.6907	-89.7826
59	4.788318	1317	1617	2085.5	122.2836	-97.5787
60	3.372328	1506	1894	2419.8	123.5748	-98.7026
61	4.482854	76	95	121.7	97.60769	-73.4623
62	4.363619	249	107	271	104.5605	-80.825
63	4.27746	737	737	1042.3	116.2598	-92.1735
64	4.397817	92	14	93.1	95.28111	-70.881
65	3.368069	1919	1775	2614	124.2453	-99.2816
66	3.368069	1919	1775	2614	124.2453	-99.2816
67	4.569236	261	149	300.5	105.458	-81.7394
68	3.836852	544	783	953.4	115.4855	-91.4586
69	2.266369	1283	794	1508.8	119.4723	-95.09
70	4.626351	1606	1957	2531.6	123.9671	-99.0417

71	4.638785	45	57	72.6	93.12107	-68.4273
72	4.097901	230	291	370.9	107.286	-83.5783
73	4.315423	466	565	732.4	113.1952	-89.3152
74	4.253947	1426	1426	2016.7	121.9922	-97.3234
75	3.624937	1650	1690	2361.9	123.3645	-98.5203
76	4.46499	89	75	116.4	97.22097	-73.0376
77	3.100804	286	203	350.7	106.7996	-83.0921
78	3.992136	719	616	946.8	115.4252	-91.4026
79	3.828402	1607	1611	2275.5	123.0408	-98.2392
80	3.935848	1756	1723	2460.1	123.7183	-98.8267
81	2.538642	64	6	64.3	92.06666	-67.2089
82	2.663868	239	255	349.5	106.7699	-83.0623
83	4.532961	497	667	831.8	114.3005	-90.355
84	3.8033	1794	943	2026.7	122.0352	-97.3611
85	2.818184	1679	1526	2268.9	123.0156	-98.2173
86	4.746854	57	94	109.9	96.72192	-72.4869
87	3.687202	156	277	317.9	105.9468	-82.2343
88	4.746854	57	94	109.9	96.72192	-72.4869
89	4.468895	55	59	80.7	94.03971	-69.4777
90	4.029463	1660	1555	2274.6	123.0374	-98.2362
91	3.877472	1289	1339	1858.6	121.2832	-96.6997
92	3.18295	259	151	299.8	105.4377	-81.7189
93	3.450346	720	534	896.4	114.9501	-90.9613
94	3.483047	1831	1592	2426.3	123.5981	-98.7228
95	4.621675	170	179	246.9	103.7517	-79.994
96	4.402663	19	60	62.9	91.87547	-66.9865
97	2.368922	1801	1793	2541.3	124.0003	-99.0704
98	4.110072	621	591	857.3	114.5628	-90.6002
99	4.487533	1849	1824	2597.3	124.1896	-99.2336
100	3.028734	1594	1826	2423.9	123.5895	-98.7153

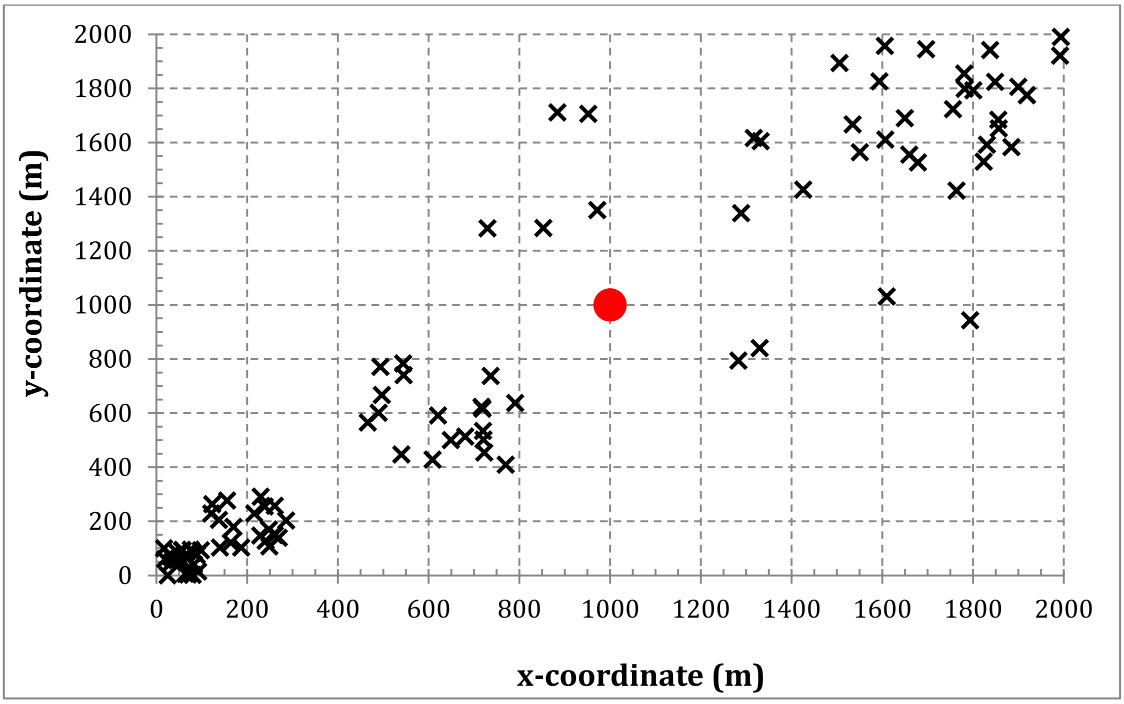

Figure 1; The plot of the x-coordinates and y-coordinates of the 100 nodes around the sink (base station at the center)

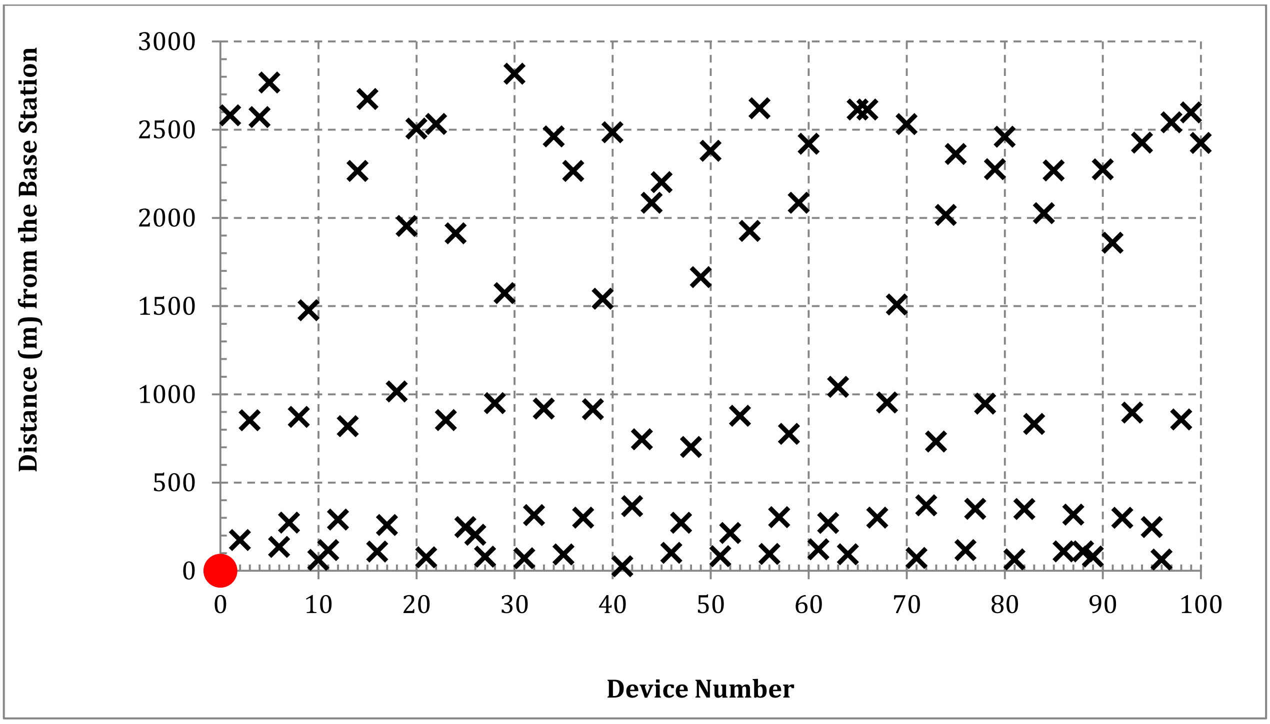

Figure 2; The plot of the distance of the 100 nodes from the sink (base station at the center)

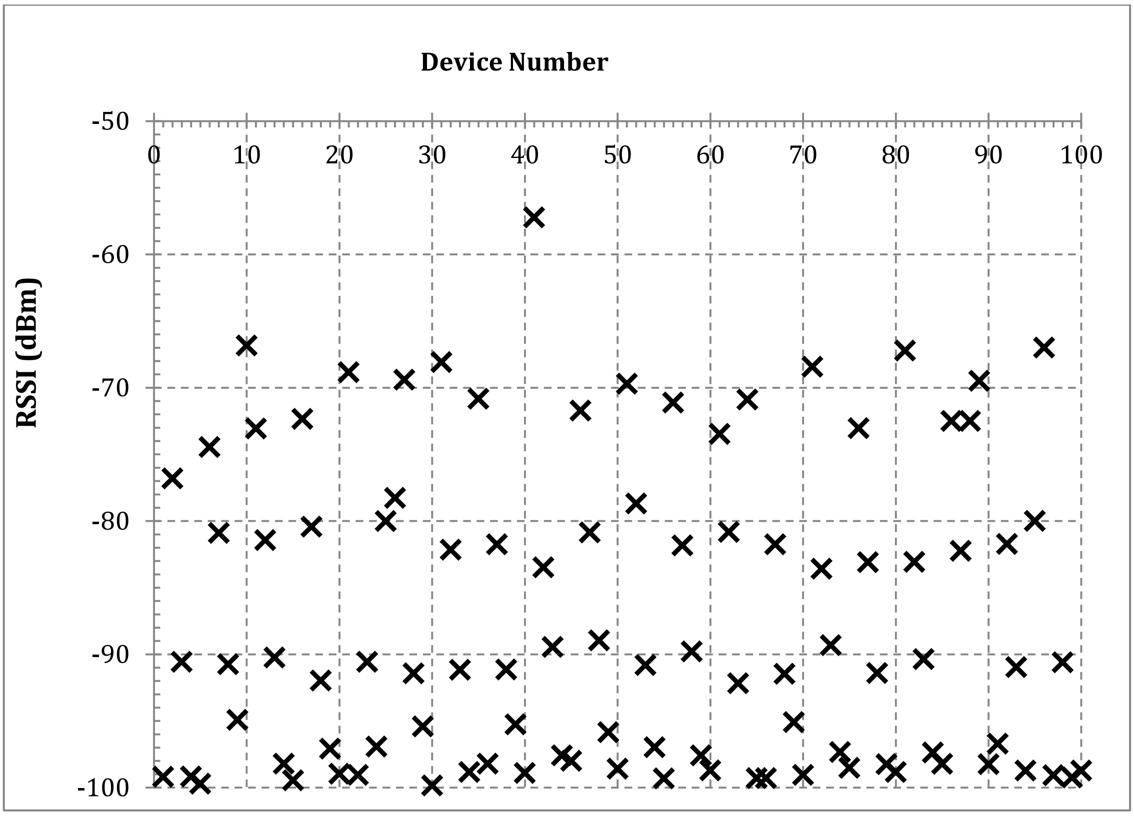

Figure 3; The plot of the RSSI of the 100 nodes

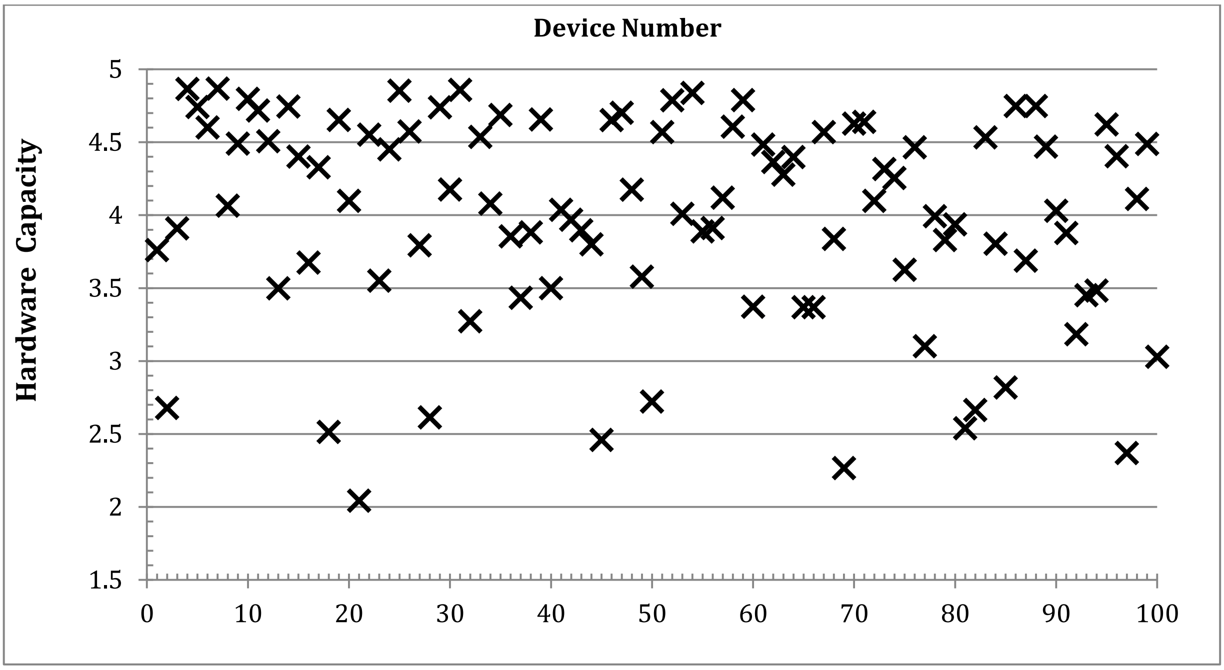

Figure 4; The plot of the hardware capacity of the devices

The results of the SOM cluster head selection is shown in Table 2, Figure 5 and Figure 6. The cluster heads and the number of slave nodes clustered around each of them by the SOM algorithm is shown in Figure 6 and Table 2. The result of the correlation of RSSI, hardware capacity and number of slave devices clustered around the cluster head is shown in Table 3. The results show that the number of slave devices clustered around the cluster head is strongly correlated to both the RSSI (with R =0.726213) and hardware capacity (with R =0.711569). The results in Table 2 show that cluster head 3 with the highest hardware capacity value of 4.852958 and the highest RSSI value of -66.824 dB had the highest number of 15 slave nodes clustered around.

Table 2; The result of the cluster heads and the number of slave nodes clustered around each of them by the SOM algorithm

Cluster Head Number	Device Number	x-coordinate (m)	y-coordinate (m)	Distance of the nodes from the sink (m)	Pathloss (dBm)	RSSI (dBm)	Hardware Capacity	Number of slave devices clustered around the cluster head
1	26	164	121	203.8	102.085	-78.262	4.572953	8
2	25	138	205	247.1	103.759	-80.001	4.685624	12
3	10	35	51	61.9	91.7363	-66.824	4.852958	15
4	35	83	41	92.6	95.2343	-70.828	4.796267	14
5	61	76	95	121.7	97.6077	-73.462	4.482858	9
6	65	92	14	93.1	95.2811	-70.881	4.397822	12
7	88	57	94	109.9	96.7219	-72.487	4.746858	14
8	89	55	59	80.7	94.0397	-69.478	4.621672	12
9	95	170	179	246.9	103.752	-79.994	4.468892	4

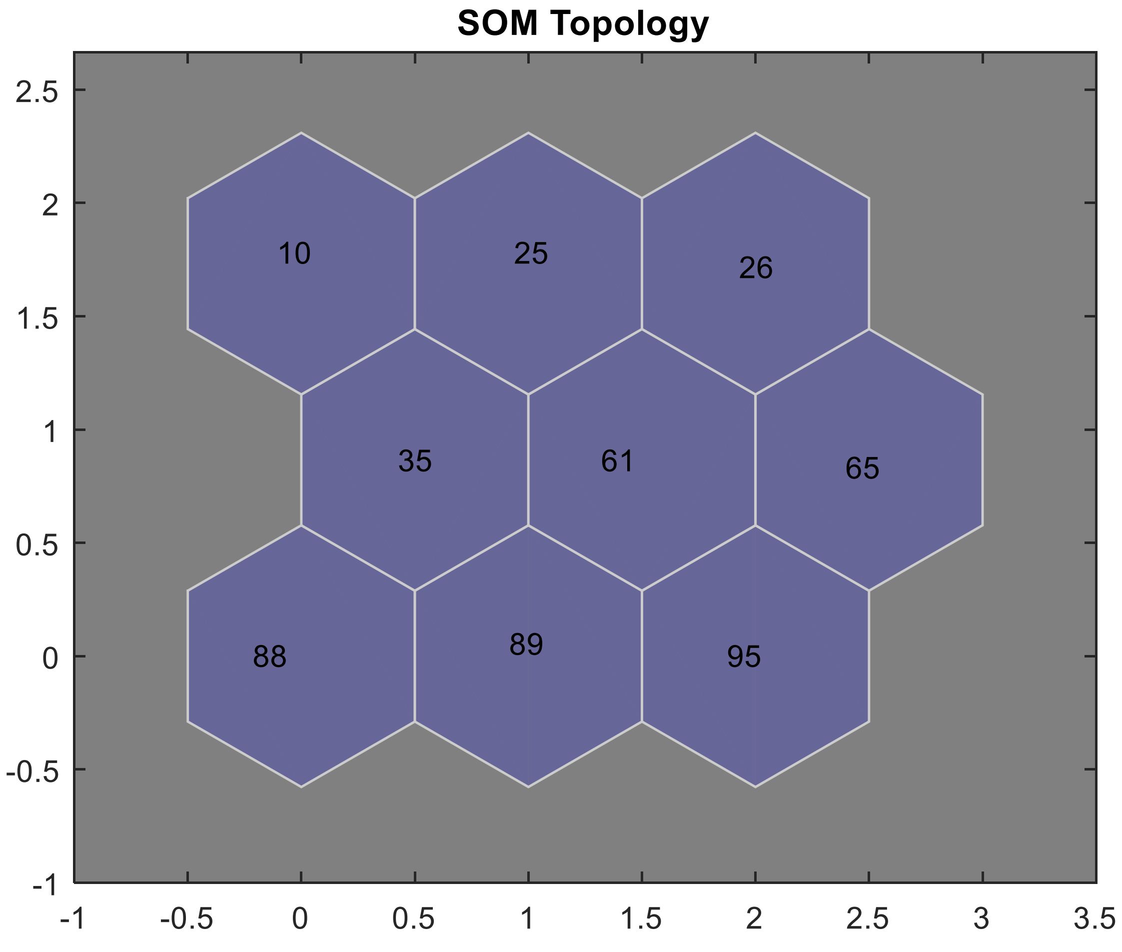

Figure 5; SOM topology showing that only 9 cluster heads are selected.

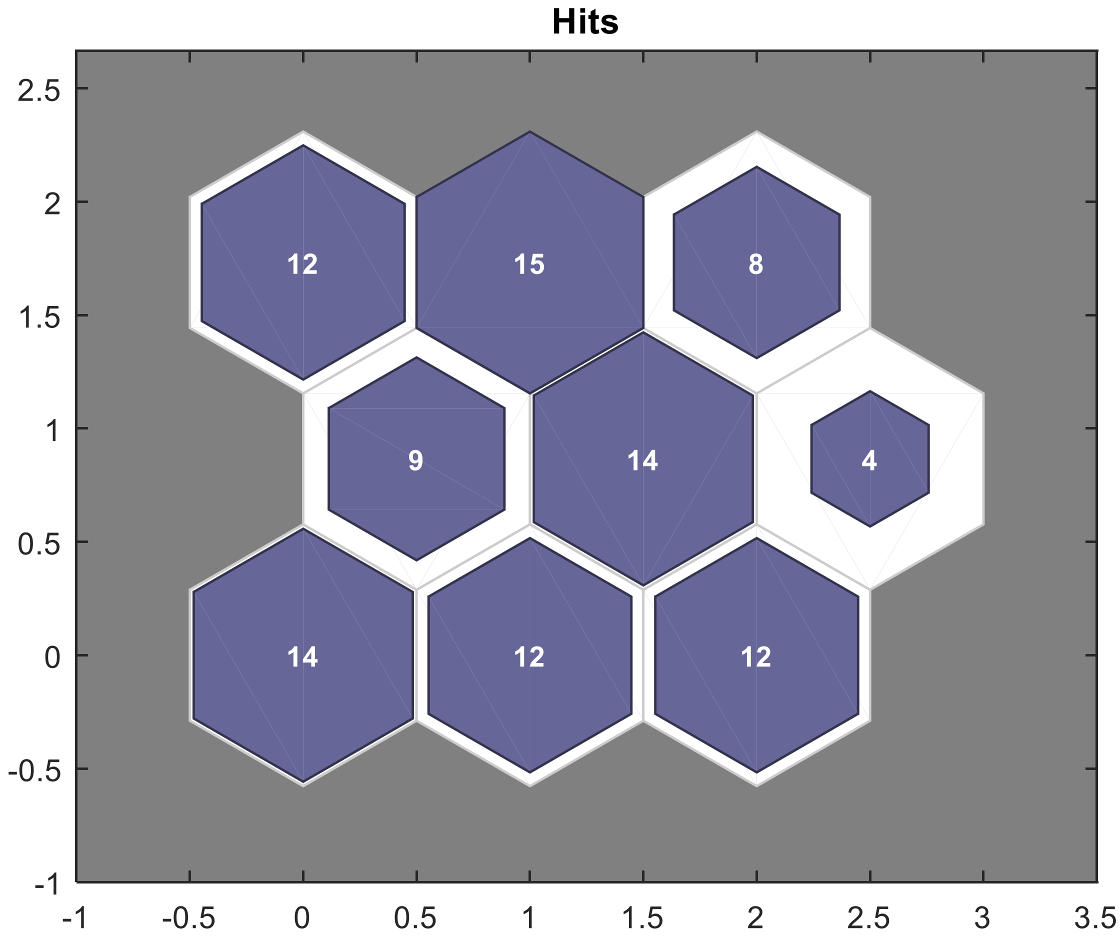

Figure 6; The Cluster Heads and the number of slave nodes clustered around each of them by the SOM algorithm.

Table 3 The result of the correlation of RSSI , hardware capacity and number of slave devices clustered around the cluster head

	RSSI (dBm)	*Hardware capacity*	*Number of slave devices clustered around the cluster head*
RSSI (dBm)	1		
Hardware capacity	0.390986	1	
Number of slave devices clustered around the cluster head	0.726213	0.711569	1

IV. CONCLUSION

Selection of cluster heads for 1800 MHz cellular network located in vegetation covered area is presented. The clustering algorithm used is the self organizing map (SOM) and it used the received signal strength intensity (RSSI) along with the hardware capacity of the communicating devices in the selection of the cluster heads. The Weissberger foliage path loss model was used to determine the pathloss which was then employed in link budget expression to compute the RSSI for the network located in vegetation covered area. The study considered a network with about 100 devices out of which only 9 devices were selected as cluster heads by the SOM algorithm. A correlation among the number of slave nodes clustered to the cluster heads , the hardware capacity and the RSSI showed that there exist strong positive correlation of over 0.71 among those parameters. Essentially, cluster head with higher RSSI and higher hardware capacity results in higher number of slave devices that are clustered around the given cluster head.

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