Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 3 Issue 4, April - 2019

CLUSTERING OF CELLULAR DEVICES WITH SELF-ORGANIZING MAP (SOM) ALGORITHM BASED ON FREE SPACE PATHLOSS COMPUTED RECEIVED SIGNAL STRENGTH

Kufre M. Udofia

Department of Electrical/Electronic and Computer Engineering, University of Uyo, Nigeria

kmudofia@uniuyo.edu.ng

Abstract— **In this paper, clustering of cellular devices with self-organizing map (SOM) algorithm based on free space pathloss computed received signal strength is presented. First, the x and y coordinates of the devices around the base station are randomly determined and the distances of the devices were computed and then used to compute the pathloss and the received signal strength intensity (RSSI) for each of the devices. Based on the distance and the computed RSSI of each of the devices, the SOM algorithm was used to select the cluster heads and to cluster the other nodes to he heads. The SOM algorithm is implemented using the SOM tools in the Matrix Laboratory (MATLAB) software. Specifically, in this paper, 100 cellular devices were considered to be located in a 1000 m by 1000 m region around the base station, which is located at the centre of the region. The results showed that among the 100 cellular devices considered, only 16 cluster heads were selected by the SOM algorithm. Also, the cluster head with device number 89 had the highest number of 10 slave devices clustered around it while the cluster head with device number 2 has the highest number of 3 slave devices clustered around it.**

Keywords— Clustering, Cellular Devices, Self-organizing Map (SOM) Algorithm, Pathloss, Clustering Algorithm, Received Signal Strength Intensity (RSSI), Free Space Pathloss

1. Introduction

Nowadays, in order to improve on the energy efficiency of wireless network communication system, device-to-deice (D2D) communication mechanism is employed [1-7]. This helps the devices within the network coverage area to rely on their neighbouring device to relay their data to the base station in a way that reduces that overall communication energy demand.

In order to effectively implement the D2D communication, clustering algorithm is used to select cluster heads from the available devices [8-11]. Most studies have shown clustering algorithms that rely on the relative distance of the device from the base station for the selection of the cluster heads [12-17]. However, the ultimate aim is to use the RSSI at the location of the devices for the cluster head selection. In reality, the RSSI depends on distance, but the actual relationship between the distance and RSSI depends on the pathloss model used in the computation of the RSSI [18-24]. Accordingly, this paper presents results of computed RSS from free space pathloss based SOM algorithm [25-28]. The MATLAB based SOM is also used for the implementation.

2. Methodology

This paper considers clustering of cellular devices based on the received signal strength which is computed based on link budget analysis that used the free space pathloss model for the determination of the pathloss. The x and y coordinates of the devices around the base station are randomly determined and the distances of the devices were computed and then used to compute the respective pathloss and RSSI (in dBm) for each of the devices. Based on the distance and the computed RSSI of each of the devices, the SOM algorithm was used to select the cluster heads and to cluster the other nodes to the heads.

2. 1 The Received Signal Strength Based on Free Space Pathloss

In wireless communication, due to pathloss and other losses in the system, only a portion of the transmitted power (P_T) is received by the receiver (as shown in Figure 1). With the free space pathloss model, the received signal strength (P_R) is inversely proportional to the square of the distance between the transmitter and the receiver;

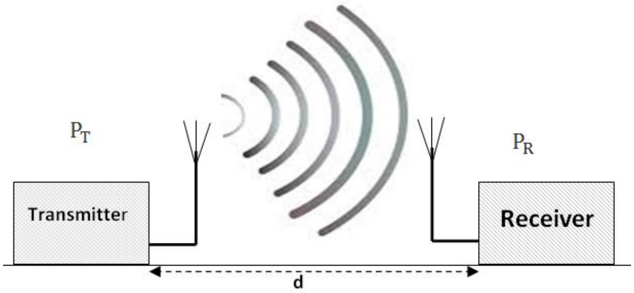

Figure 1: The image of the received power based on free space pathloss

Free space pathloss model expressed pathloss in different forms. The free space pathloss (PL_{FSPL}) in watt expressed with respect to wavelength is given as;

$$PL_{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 \quad (1)$$

The free space pathloss (PL_{FSPL}) in watt expressed with respect to frequency is given as;

$$PL_{FSPL} = \left(\frac{4\pi df}{c}\right)^2 \quad (2)$$

Where PL_{FSPL} is the free space pathloss (unitless); d is the transmitter to receiver distance (in metre); f is the frequency of the signal (in Hz); λ is the wavelength of the signal (in metres) and c is the speed of light (in metre per second).

In terms of frequency, the free space pathloss (PL_{FSPL}) in dB is given as;

$$PL_{FSPL}\,(\mathrm{dB}) = 20\log(\mathrm{d}) + 20\log(\mathrm{f}) + 32.44 \tag{3}$$

Where PL_{FSPL} (dB) is the free space pathloss (in dB); d is the transmitter to receiver distance (in km); f is the frequency of the signal (in MHz).

Simply, with respect to the PL_{FSPL} (dB), for a given distance, d (in km) from the transmitter, the received signal strength P_R in dB, is given as;

$$P_R = \mathrm{EIRP} - PL_{FSPL}\,(\mathrm{dB}) \tag{4}$$

Where EIRP is the effective isotropic radiated power in dBW.

This paper considers 100 cellular devices to be located in a 1000 m by 1000 m region around the base station, which is located at the centre of the region. The location of the cellular network base station is denoted as xb, yb while the location of each of the cellular devices is denoted as denoted as xd_j, yd_j, for j = 1,2,3,…,100. Now let;

$$x_j = xd_j - xb \tag{5}$$

$$y_j = yd_j - yb \tag{6}$$

Hence, the distance of device j from the base station is given as:

$$d_j = \sqrt[2]{{x_j}^2 + {y_j}^2} \tag{7}$$

Specifically, the xd_j, yd_j, for j = 1,2,3,…,100 were generated using random function in MATLAB for a 1000 m by 1000 m region, such that, $0 \leq xd_j \leq 100$ and $0 \leq yd_j \leq 100$. The Base station located at the centre of the region has a coordinate, $xb = 500\,m$ and $yb\ 500\,m$. The xd_j, yd_j and xb, yb are used in Eq 5, Eq 6 and Eq 7 to compute the distance, d_j for each of device.

The distance, d_j for j = 1,2,3,…,100 is used to compute the pathloss based on free space pathloss model of Eq 3. Then, the pathloss was used in Eq 4 to the received power or RSSI. In this paper, a value of 53 dB was used for EIRP. Then, the SOM clustering algorithm was used to select the cluster heads from the 100 cellular devices based on their RSSI with a given threshold RSSI value.

3. Results and Discussion

The x and y coordinates, along with their corresponding distance in the metres from the sink (base station), the pathloss and the received signal strength as generated in MATLAB, are given in Table 1. The plot of the x-coordinates and y-coordinates of the cellular devices around the sink (base station at the centre) are shown in Figure 2 while the resultant distance of the devices is shown in Figure 3, the pathloss obtained is plotted and shown in Figure 4 and the plot of the RSSI of each device is shown in Figure 5.

Table 1: The x and y coordinates, along with their corresponding distance in the metres from the sink (base station), the pathloss and the received signal strength as generated in MATLAB

Device number	x-coordinate (m)	y-coordinate (m)	Resultant distance (m)	Pathloss (dB)	RSSI (dBm)
1	631.1887	782.8721	1005.6	157.65	-104.15
2	355.0737	693.7876	779.37	155.44	-101.94
3	997.0033	9.8023	997.05	157.58	-104.08
4	224.1715	843.2133	872.5	156.42	-102.92
5	652.4511	922.3320	1129.8	158.67	-105.17
6	604.9906	770.9542	979.99	157.43	-103.93
7	387.2454	42.6599	389.59	149.42	-95.918
8	142.1872	378.1861	404.03	149.73	-96.234
9	25.1350	704.3396	704.79	154.57	-101.07
10	421.1123	729.5130	842.33	156.12	-102.62
11	184.1003	224.2771	290.16	146.86	-93.358
12	725.7753	269.0547	774.04	155.38	-101.88
13	370.3627	673.0312	768.21	155.31	-101.81
14	841.5601	477.4922	967.59	157.32	-103.82

15	734.2297	623.7164	963.39	157.28	-103.78
16	571.0259	236.4449	618.04	153.43	-99.926
17	176.8551	177.1238	250.3	145.57	-92.075
18	957.3840	829.6434	1266.8	159.66	-106.16
19	265.3220	766.9217	811.52	155.79	-102.29
20	924.5809	934.4783	1314.6	159.98	-106.48
21	223.7704	107.8889	248.42	145.51	-92.009
22	373.5638	182.2275	415.64	149.98	-96.48
23	87.5003	99.0953	132.2	140.03	-86.53
24	640.1165	489.7638	805.99	155.73	-102.23
25	180.6169	193.2453	264.51	146.05	-92.554
26	45.0511	895.8916	897.02	156.66	-103.16
27	723.1735	99.0896	729.93	154.87	-101.37
28	347.4376	44.1656	350.23	148.49	-94.993
29	660.6168	557.2952	864.29	156.34	-102.84
30	383.8686	772.4951	862.61	156.32	-102.82
31	627.3465	311.9401	700.62	154.52	-101.02
32	21.6498	178.9825	180.29	142.72	-89.225
33	910.5700	338.9557	971.61	157.36	-103.86
34	800.5587	210.1456	827.68	155.96	-102.46
35	745.8475	510.1525	903.63	156.73	-103.23
36	813.1128	906.3643	1217.6	159.32	-105.82
37	383.3063	628.9239	736.52	154.95	-101.45
38	617.2792	101.5339	625.57	153.53	-100.03
39	575.4949	390.8548	695.67	154.45	-100.95
40	530.0517	54.6166	532.86	152.14	-98.638
41	275.0698	501.2829	571.79	152.75	-99.25
42	248.6290	431.7212	498.2	151.55	-98.053
43	451.6388	997.5603	1095	158.39	-104.89
44	227.7128	811.6026	842.94	156.12	-102.62
45	804.4496	485.6517	939.68	157.07	-103.57
46	986.1042	894.4478	1331.3	160.09	-106.59
47	29.9920	137.5466	140.78	140.58	-87.076
48	535.6642	390.0049	662.6	154.03	-100.53
49	87.0772	927.3562	931.44	156.99	-103.49
50	802.0914	917.4938	1218.7	159.32	-105.82
51	989.1449	713.5740	1219.7	159.33	-105.83
52	66.9463	618.3374	621.95	153.48	-99.981
53	939.3984	343.2879	1000.2	157.61	-104.11
54	18.1775	936.0273	936.2	157.03	-103.53
55	683.8386	124.7740	695.13	154.45	-100.95

56	783.7365	730.5854	1071.4	158.2	-104.7
57	534.1376	646.4774	838.59	156.08	-102.58
58	885.3595	833.1520	1215.7	159.3	-105.8
59	899.0049	398.2822	983.28	157.46	-103.96
60	625.9376	749.8222	976.75	157.4	-103.9
61	137.8690	835.2205	846.52	156.16	-102.66
62	217.8016	322.4604	389.12	149.41	-95.907
63	182.1411	552.2616	581.52	152.9	-99.397
64	41.8199	979.1291	980.02	157.43	-103.93
65	106.9417	549.3085	559.62	152.56	-99.063
66	616.4435	330.4236	699.42	154.5	-101
67	939.6610	619.4716	1125.5	158.63	-105.13
68	354.4557	360.6366	505.67	151.68	-98.183
69	410.6291	756.5095	860.77	156.3	-102.8
70	984.3494	413.9007	1067.8	158.18	-104.68
71	945.5792	492.3451	1066.1	158.16	-104.66
72	676.6447	694.7432	969.8	157.34	-103.84
73	988.3023	972.7339	1386.7	160.45	-106.95
74	766.8314	327.7550	833.94	156.03	-102.53
75	336.6993	837.8032	902.93	156.72	-103.22
76	662.3819	739.0722	992.46	157.54	-104.04
77	244.1653	954.1745	984.92	157.47	-103.97
78	295.5073	31.9226	297.23	147.07	-93.567
79	680.1784	356.8690	768.11	155.31	-101.81
80	527.8468	662.6538	847.19	156.17	-102.67
81	411.5935	281.5016	498.65	151.56	-98.061
82	602.6382	230.3831	645.17	153.8	-100.3
83	750.5201	711.1286	1033.9	157.9	-104.4
84	583.5332	624.5729	854.75	156.24	-102.74
85	551.7925	590.6087	808.27	155.76	-102.26
86	583.5706	660.4380	881.32	156.51	-103.01
87	511.8199	47.5547	514.02	151.83	-98.325
88	82.5927	348.7848	358.43	148.69	-95.194
89	719.5701	451.3406	849.41	156.19	-102.69
90	996.1561	240.9050	1024.9	157.82	-104.32
91	354.5343	715.0450	798.11	155.65	-102.15
92	971.2588	856.1823	1294.8	159.85	-106.35
93	346.4488	281.5077	446.4	150.6	-97.1
94	886.5439	731.0508	1149.1	158.81	-105.31
95	454.6949	137.7629	475.11	151.14	-97.641
96	413.4273	836.7228	933.29	157.01	-103.51

97	217.7321	138.6017	258.1	145.84	-92.341
98	125.6546	588.2094	601.48	153.19	-99.69
99	308.9146	366.1568	479.06	151.21	-97.713
100	726.1044	806.7595	1085.4	158.32	-104.82

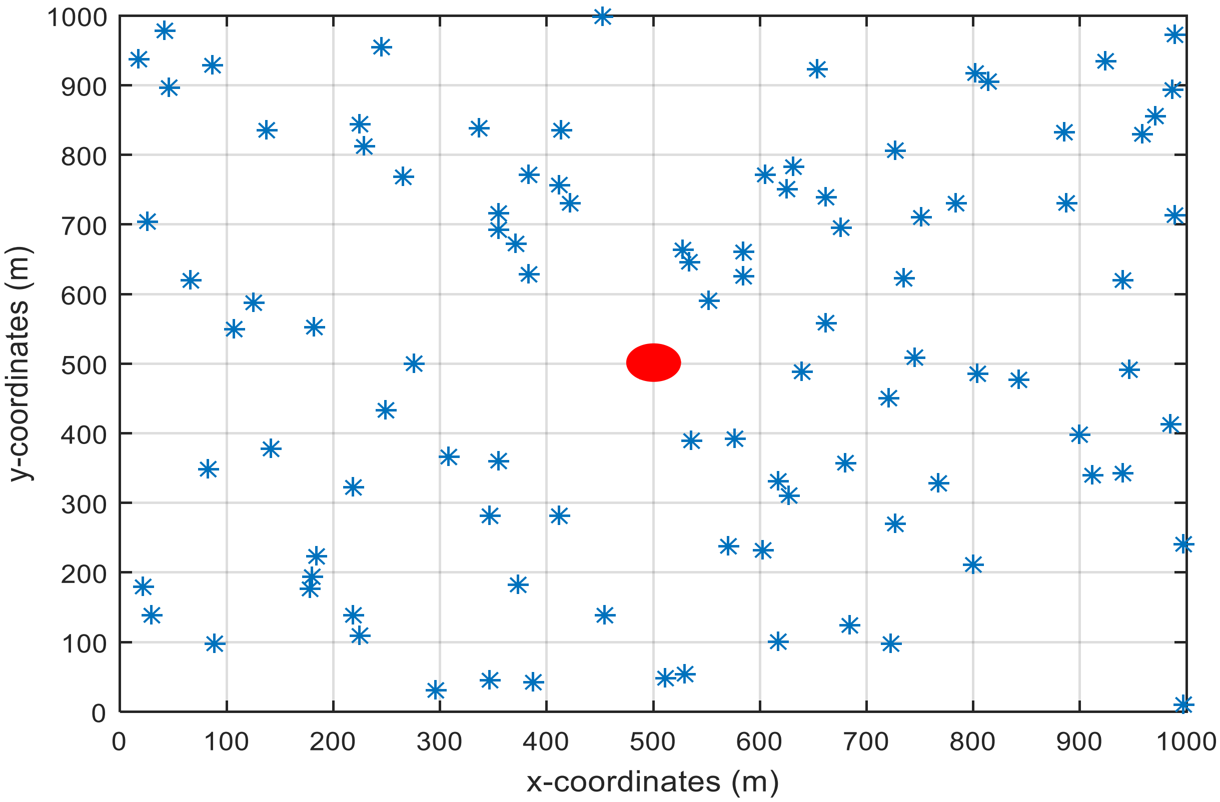

Figure 2: The x and y coordinate position of the cellular devices.

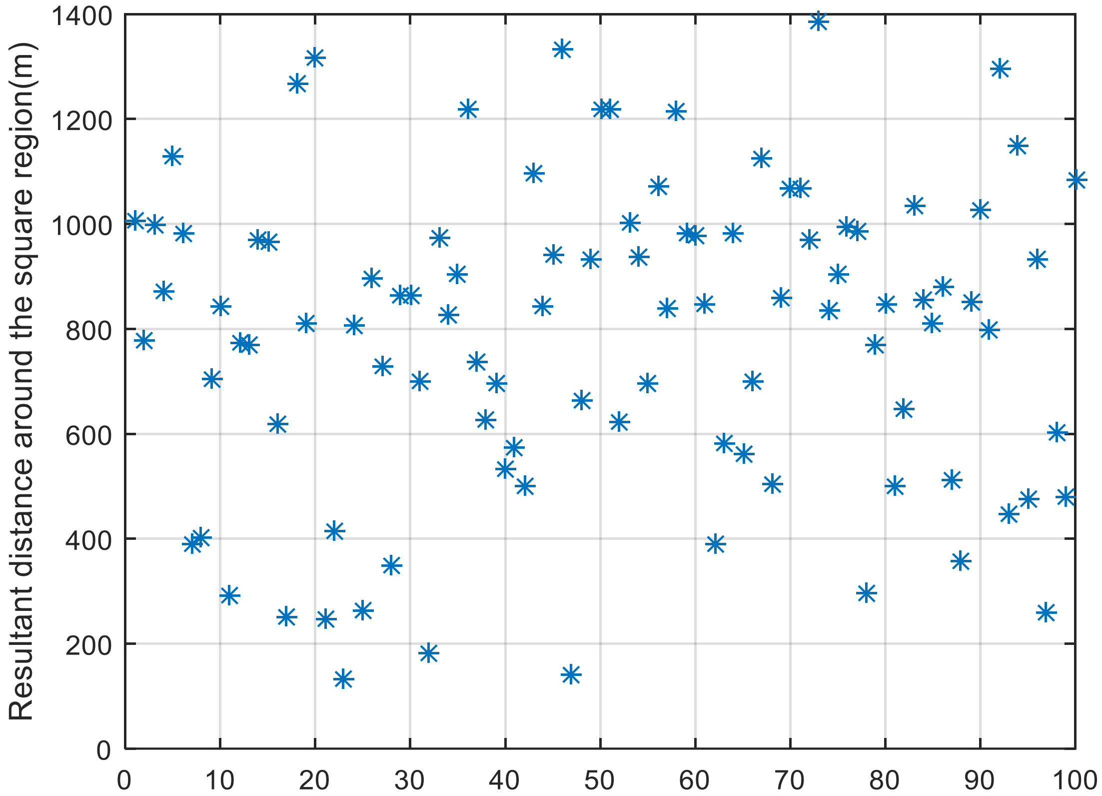

Figure 3: Resultant distance of the devices.

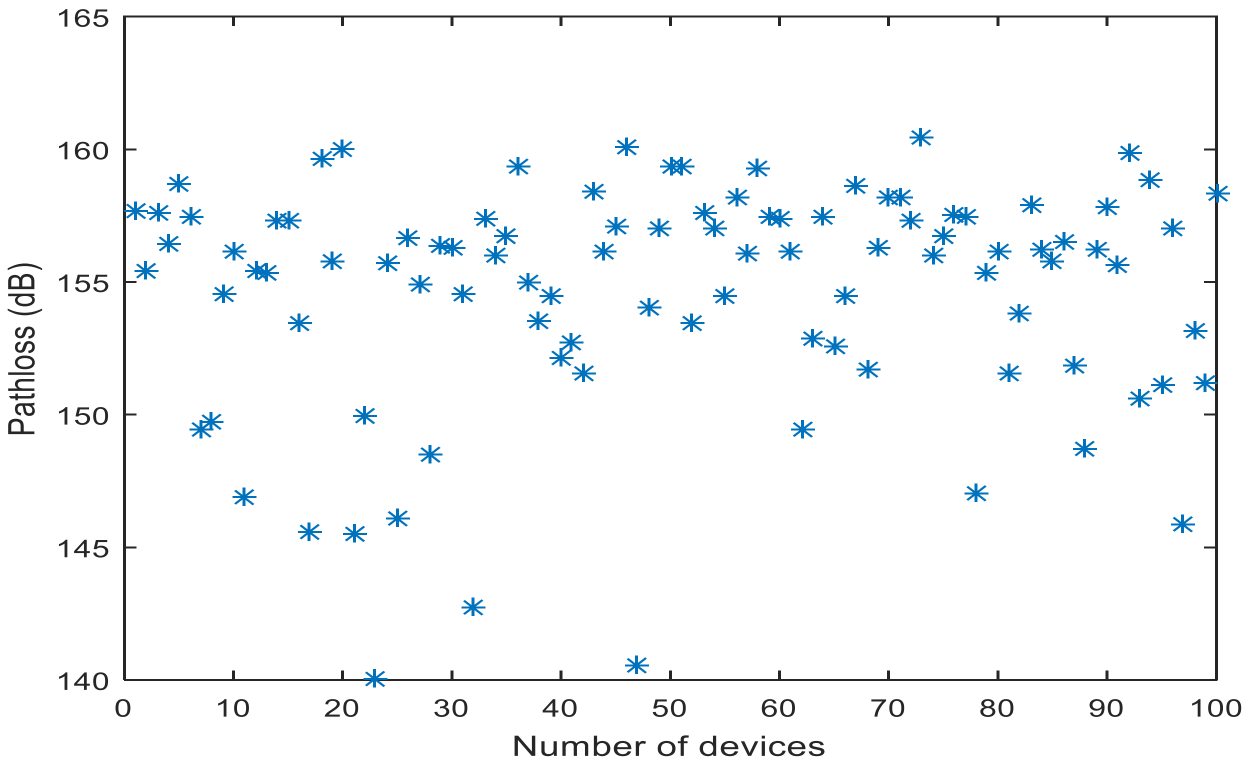

Figure 4: Pathloss of each device based on free space pathloss model.

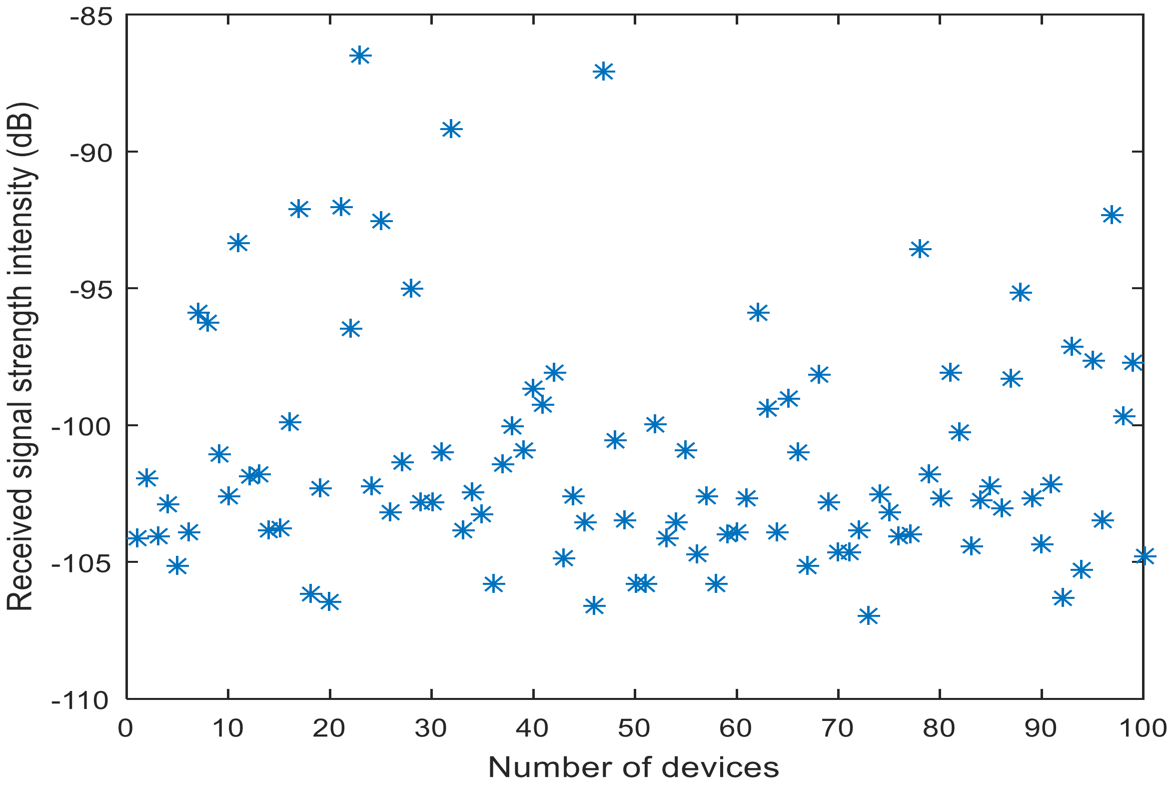

Figure 5: The received signal strength intensity for each device.

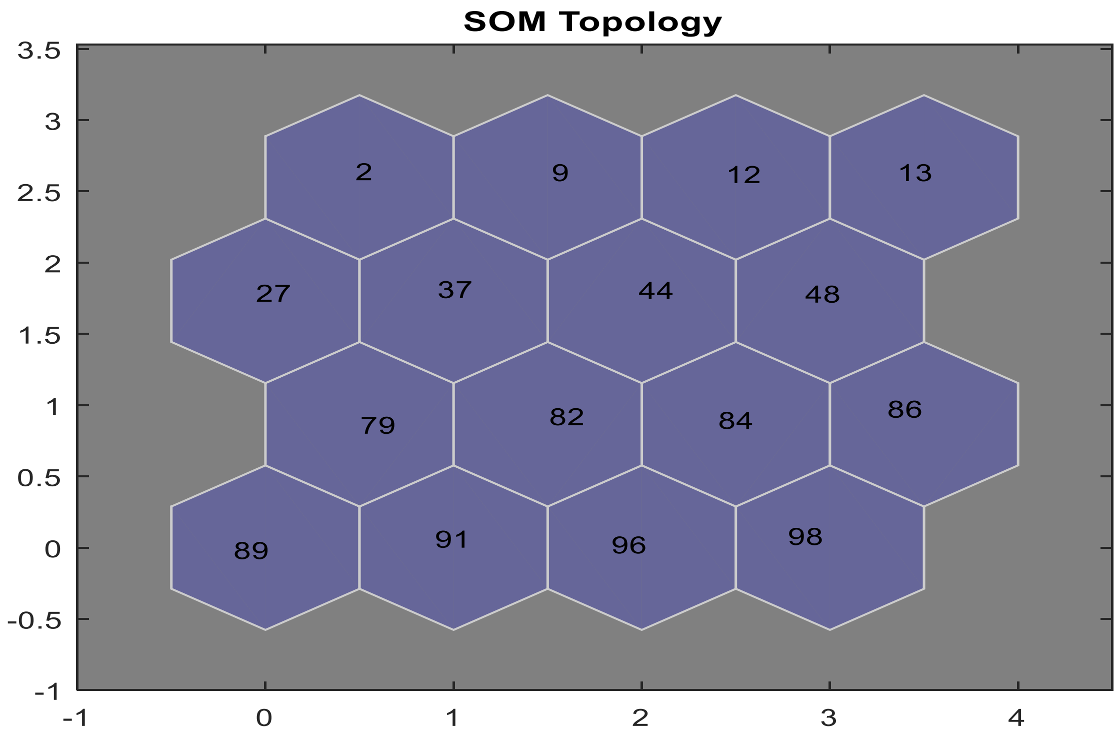

Figure 6: The outcome of the cluster head selection performed using the SOM algorithm showing the SOM topology with 16 cluster heads selected.

The outcome of the clustering performed using the SOM algorithm is shown in Figure 6. According to Figure 6, exactly 16 cluster heads were selected by the SOM algorithm and the device numbers of the cluster heads is indicated on them, as can be seen in Figure 6. The results of clustering of the cluster heads to the cluster slaves performed by the SOM clustering algorithm are shown in Figure 7.

Based on the results in Figure 6 and Figure 7, cluster head with device number 89 has the highest number of 10 slave devices clustered around it while the cluster head with device number 2 has the highest number of 3 slave devices clustered around it.

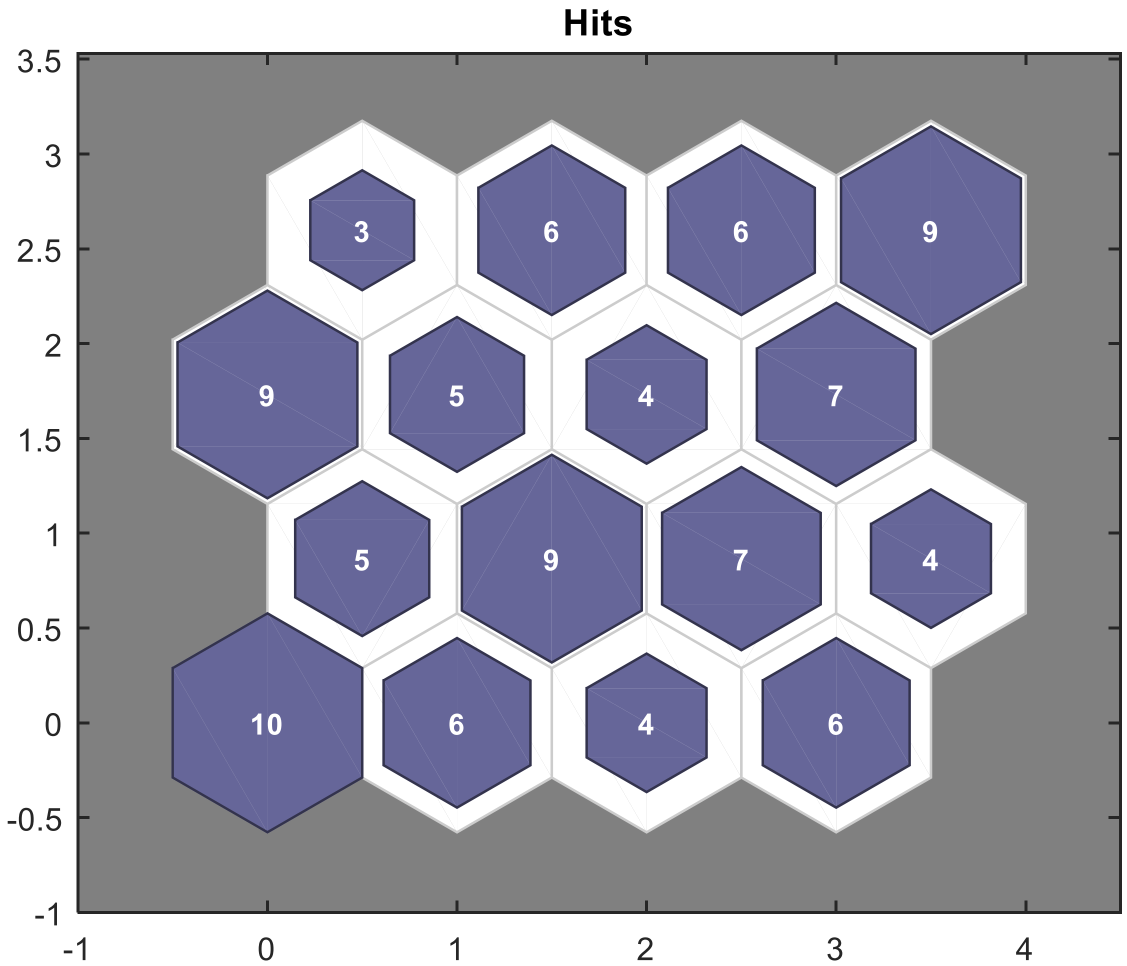

Figure 7: The outcome of the clustering performed using the SOM algorithm showing the clustering of the slave devices to the SOM selected cluster heads.

4. Conclusion

The selection of cluster heads from a set of cellular devices using self-organizing map (SOM) clustering algorithm was presented. The SOM algorithm used the RSSI of the cellular devices as the key parameter for selecting the cluster heads. Also, the SOM algorithm was used to cluster the slave cellular devices to the cluster heads. The SOM algorithm was implemented using the MATLAB software.

References

1. Islam, Mohaiminul, and Shangzhu Jin. "An Overview Research on Wireless Communication Network." *Networks* 5.1 (2019): 19-28.
2. Zappone, Alessio, and Eduard Jorswieck. "Energy efficiency in wireless networks via fractional programming theory." *Foundations and Trends in Communications and Information Theory* 11.3-4 (2015): 185-396.
3. Gočal, Pavol, and Dominik Macko. "EEMIP: Energy-efficient communication using timing channels and prioritization in ZigBee." *Sensors* 19.10 (2019): 2246
4. Huang, Chongwen, et al. "Reconfigurable intelligent surfaces for energy efficiency in wireless communication." *IEEE Transactions on Wireless Communications* 18.8 (2019): 4157-4170.
5. Akyol, Bora A., et al. *A survey of wireless communications for the electric power system*. No. PNNL-19084. Pacific Northwest National Lab.(PNNL), Richland, WA (United States), 2010.
6. Rault, Tifenn, Abdelmadjid Bouabdallah, and Yacine Challal. "Energy efficiency in wireless sensor networks: A top-down survey." *Computer Networks* 67 (2014): 104-122.
7. Abbas, Zeeshan, and Wonyong Yoon. "A survey on energy conserving mechanisms for the internet of things: Wireless networking aspects." *Sensors* 15.10 (2015): 24818-24847.
8. Paramonov, Alexander, et al. "Clustering optimization for out-of-band D2D communications." *Wireless Communications and Mobile Computing* 2017 (2017): 1-12.
9. Gyawali, Sohan, et al. "A D2D based clustering scheme for public safety communications." *2018*

IEEE 87th Vehicular Technology Conference (VTC Spring). IEEE, 2018.

10. Ateya, Abdelhamied A., et al. "Multi-level cluster based device-to-device (D2D) communication protocol for the base station failure situation." *Internet of Things, Smart Spaces, and Next Generation Networks and Systems*. Springer, Cham, 2017. 755-765.
11. Ali, Kamran, et al. "Disaster management using D2D communication with power transfer and clustering techniques." *IEEE Access* 6 (2018): 14643-14654.
12. Yuste-Delgado, Antonio-Jesus, Juan-Carlos Cuevas-Martinez, and Alicia Triviño-Cabrera. "A Distributed Clustering Algorithm Guided by the Base Station to Extend the Lifetime of Wireless Sensor Networks." *Sensors* 20.8 (2020): 2312.
13. Jan, Bilal, et al. "Energy efficient hierarchical clustering approaches in wireless sensor networks: A survey." *Wireless Communications and Mobile Computing* 2017 (2017).
14. Behera, Trupti Mayee, et al. "Residual energy-based cluster-head selection in WSNs for IoT application." *IEEE Internet of Things Journal* 6.3 (2019): 5132-5139.
15. Dayananda, Karanam Ravichandran, and Jeremy Straub. "Zone based hybrid approach for clustering and data collection in wireless sensor networks." *2017 International Conference on Electronics, Communications and Computers (CONIELECOMP)*. IEEE, 2017.
16. Lata, Sonam, et al. "Fuzzy Clustering Algorithm for Enhancing Reliability and Network Lifetime of Wireless Sensor Networks." *IEEE Access* 8 (2020): 66013-66024.
17. Long, Hua. *Research routing and MAC based on LEACH and S-MAC for energy efficiency and QoS in wireless sensor network*. Dissertation, University of Huddersfield, 2013.
18. Ozuomba, Simeon, Johnson Enyenihi, and Ngwu Chinyere Rosemary. "Characterisation of Propagation Loss for a 3G Cellular Network in a Crowded Market Area Using CCIR Model." *Review of Computer Engineering Research* 5.2 (2018): 49-56.
19. Xu, Jiuqiang, et al. "Distance measurement model based on RSSI in WSN." *Wireless Sensor Network* 2.8 (2010): 606.
20. Akaninyene B. Obot , Ozuomba Simeon and Kingsley M. Udofia "Determination Of Mobile Radio Link Parameters Using The Pathloss Models" *NSE Technical Transactions , A Technical Journal of The Nigerian Society of Engineers*, 46.2 (2011): 56-66.
21. Obot, A., O. Simeon, and J. Afolayan. "Comparative analysis of path loss prediction models for urban macrocellular environments." *Nigerian journal of technology* 30.3 (2011): 50-59.
22. Adewumi, Omotayo G., Karim Djouani, and Anish M. Kurien. "RSSI based indoor and outdoor distance estimation for localization in WSN." *2013 IEEE international conference on Industrial technology (ICIT)*. IEEE, 2013.
23. Benkic, Karl, et al. "Using RSSI value for distance estimation in wireless sensor networks based on ZigBee." *2008 15th International Conference on Systems, Signals and Image Processing*. IEEE, 2008.
24. Aloziem, Njoku Chukwudi, Ozuomba Simeon, and Afolayan J. Jimoh. "Tuning and Cross Validation of Blomquist-Ladell Model for Pathloss Prediction in the GSM 900 Mhz Frequency Band." *International Journal of Theoretical and Applied Mathematics* 3.2 (2017): 94.
25. Yamamoto, Brennan, et al. "Received signal strength indication (RSSI) of 2.4 GHz and 5 GHz wireless local area network systems projected over land and sea for near-shore maritime robot operations." *Journal of Marine Science and Engineering* 7.9 (2019): 290.
26. Kalu, Constance. "Development and Performance Analysis of Bisection Method-Based Optimal Path Length Algorithm for Terrestrial Microwave Link." *Review of Computer Engineering Research* 6.1 (2019): 1-11.
27. Johnson, Enyenihi Henry, Simeon Ozuomba, and Ifiok Okon Asuquo. "Determination of Wireless Communication Links Optimal Transmission Range Using Improved Bisection Algorithm." (2019).
28. Valadares, Dalton Cézane Gomes, et al. "802.11 g signal strength evaluation in an industrial environment." *Internet of Things* 9 (2020): 100163.