JOURNAL OF INFORMATION SCIENCE AND ENGINEERING 36, 323-335 (2020)
DOI: 10.6688/JISE.202003_36(2).0011

Employing Graph Theory in Enhancing Power Energy of Wireless Sensor Networks

AMEEN SH. AMEEN[1], KHATTAB M. ALI ALHEETI[2] AND SALAH A. ALIESAWI[3]
[1]*Department of Applied Mathematics*
[2]*Department of Computer Networking Systems*
[3]*Department of Computer Science*
University of Anbar
Ramadi, 31001 Iraq
E-mail: [1]*amensh66@yahoo.com;* [2]*co.khattab.alheeti@uoanbar.edu.iq;*
[3]*salah_eng1996@yahoo.com*

Wireless sensor networks are considered one of the most important applications in mobile computing and networking. These networks play an important role in our daily life. However, wireless sensor networks have a lot of vital purposes in modern technology, such as scientific research, rescue operations, and scientific discoveries. The energy power consumption of wireless sensor networks is considered a significant issue because of their relationship with live mode. Therefore, sensor devices are heavily based on modern schemes to save its energy power consumption. In this case, any random response of sensor nodes will have a direct and negative impact on devices' life. In this paper, a novel scheme is proposed to manage consumption energy rate of sensor devices. It is heavily depended on graph theory in control/ management on amount of power consumption per time. This technique will enable mobility sensor nodes stay at waiting in sleep mode to obtain new information/ control data at certain time for response / moving from one location to another under radio coverage area. Thus, the mathematical model is employed in positioned wireless sensor nodes. In addition, graph theory has the ability to identify sensor nodes movement without energy power losses. Our experimental results of the proposed system show that graph theory sensor devices possess outstanding results with a significant reducing in the amount of energy power consumption for sensors.

Keywords: sensor networks, energy power, wireless sensors, ad hoc networks, mobile computing, graph theory

1. INTRODUCTION

Wireless sensors networks (WSNs) compose of tiny devices that have the ability to processing, sensing and interacting with its surround environment [1]. In modern applications, sensors networks are considered an ideal choice in a scientific research area. These networks have the ability to adapt with harsh environments to achieve significant tasks and applications, such as real-time monitoring systems, scientific discoveries and natural disasters [2]. WSNs are classified one of the types of ad hoc networks that work without communication infrastructure [3]. These networks play a vital role in both a scientific field and commercial applications. At the same time, wireless sensor networks expose some of the critical problems which are energy, capacity, direction, and movements [4].

The WSNs are like mobile ad hoc networks in the sense that control data, sensitive

Received September 26, 2019; revised September 28 & 29, 2019; accepted October 14, 2019.
Communicated by Osamah Ibrahim Khalaf.

information can be sent / receive between nodes wirelessly [5]. However, these networks are spatially located to track / monitor conditions whether environmental or/and physical, for instance, sound, pressure, earthquake, humidity, dust, temperature, and oxygen rate. In addition, its effective role in many applications has increased the importance of this type of networking in many modern scientific research areas. However, it plays cooperatively role in pass their important data, warning messages, notification messages, cooperative awareness messages, and control data through the network to the main bus station. Moreover, bi-directional is considered main aspect of the modern wireless network that enabled control activity for more than one sensor at the same time [6]. The basic structure of WSNs is shown in Fig. 1.

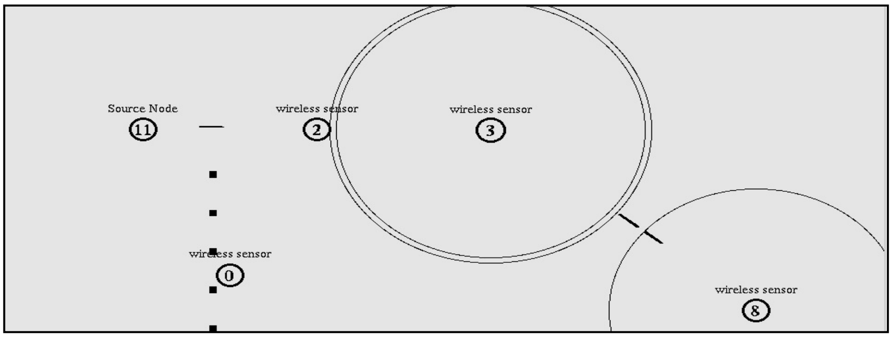

Fig. 1. Basic wireless sensors networks.

According to Fig. 1, we can easily notice that the selection process has a direct impact on performance of WSNs. In more detail, graph theory is integrated with wireless networks in this paper to support us to select the best sensors that do specific tasks. However, the proposed system will response on inquire via calculate all available paths between source and destination as well as it has the ability to select the best and shortest path between them. Thus, it plays a positive and direct impact on network / computerize performance.

The basic idea of graph theory is formed by Leonhard Eluer [7]. Therefore, this mathematical model plays a vital role in many modern applications [8]. Basically, graph theory is designed to calculate and allocate the best path between two random points on maps [9, 10]. However, a lot of studies approve the positive and direct impact role of graph theory on its performance. In addition, it has established as a subpart of mathematics, but it is having been commonly employed in many research fields, such as social applications, chemistry, computer, engineering and biological [11, 12]. The proposed model is heavily based on graph theory to reduce the amount of consumption power of mobility nodes for wireless networks.

In this paper, the originality of this research is considered to be the first time to employ this mathematical model with this type of wireless network. However, a novel model is proposed for WSNs to manage its movement that heavily based on graph theory. In other words, sensor movement will be programmed according to a mathematical system to reduce the amount of consumption of power and energy. However, graph theory plays an important role in determining movement of nodes at WSNs. Our contribution in this research will distinguish us from others by descaling response time, increasing life mode, reducing the amount of consumption energy power and cost of mobility nodes at WSNs. Our contributions in this paper are summarised below:

(1) A novel approach is proposed to manage the consumption rate of sensor devices energy which based on graph theory.
(2) A hybrid integrated between graph theory and the mobility model of sensors had a direct and positive impact on the effective and efficient of wireless sensor networks.

The motivation of the paper is employing graph theory in distributing wireless sensors mathematically. This model plays an important role in reducing the amount of consumption power. In addition, it will provide adequate communication links among nodes in that radio coverage area. This paper organizes as follows; section two presents the recent related studies. The graph theory is presented in section three. Section four presents more details about the applications of wireless sensors. The implementation process of the proposed is explained in section five of this paper as well as experimental results are demonstrated in section six. Whereas, our results are discussed in section seven. In section eight, conclusion and future works are mentioned in detail.

2. RELATED WORKS

Recently, the integrating process of graph theory with wireless networks is considered a significant issue in the scientific research filed. The spotlight on this field is increased after fast growth in the revolution of modern information technology. All these aspects help us to find a new relation between graph theory and wireless sensor networks. However, this process in this research is made to obtain optimal solution to determine the movement of sensors at wireless networks. Some of important related studies are mentioned in this subsection.

Sarioz has presented a new approach that applied combinational schemes and geometric to explain a different obstacle trigger by WSNs [13]. The author can explore all visible problems of wireless sensors. In other words, this system enables in define and determine all problem that exposes any develop or deploy wireless sensor networks. Wang *et al.* have built a new routing protocol that depended on graph theory at an energy centre [14]. This mathematical model plays an important role in declining the amount of consumption energy power for mobility nodes. However, it can achieve the lowest-cost by employing some features nominated from the local network. For instance, these features are load connection condition and power transmission for each node via channels. Moreover, graph theory had a vital role in improving power consumers or nodes.

In [15], the researchers were able to use one of the well-known techniques of mathematics with information technology that is graph theory. A vital role of graph theory ideas is presented in various research areas of computer sciences applications. They have been found a relationship between significant information of the graph theory and its positive impact on information technology. Summary and *et al.* have presented the significant role of graph theory in the analysis network of protein-protein interaction [16]. However, Markov Clustering algorithm (MCL) is utilised to find clustering relation between protein to others. In other words, the important role of graph theory is distinguished with huge number of relations between nodes for protein-protein networks.

In [11], the authors have been employed graph theory to decline the rank of graph construction and obtain optimal solutions for problems. In other words, this mathematical model plays a vital role to find the critical / maximal path of graph calculation. Moreover, each level of the graph corresponds to a definite subsystem of the security system. Whereas, each subsystem located in the claimed that has the ability to overcome security by the intruder. Alheeti and *et al.* have proposed a novel security system for protecting university of Anbar [8]. It has the ability to design per-define movement for robotics on e-maps to increase efficiency of the security system. Graph theory plays important role in reduce response time, decline the amount of delay and Ideal exploitation of the carrier medium.

Leila *et al.*, have designed a system of wireless nodes variant graph filters that can achieve a trade-off between variance and expected error [17]. However, it plays important role in optimising the graph filter and increasing the accuracy rate. Moreover, the proposed system has the ability to adapt to various wireless sensor networks topology. In [18], two reliability schemes are proposed to enhance the performance of wireless sensors networks. However, graph theory is employed to assess the reliability rate of wireless networks. The previous studies mentioned above show that most of the wireless sensor network is based on direct techniques in its work. In this paper, we are trying to find the optimal solution via applying graph theory in movement sensors mathematically. In this case, a lot of common obstacles are avoided that exposed wireless sensors networks. The intelligent integration system is proposed between wireless sensors networks and graph theory is distinguished from others. However, the algorithm is proposed in this paper will identify us from other works by reducing the amount of energy consumption rate increasing efficiency, optimal exploitation of bandwidth and reducing cost.

3. GRAPH THEORY

Graph theory is one of a well-known field in discrete mathematics, it deals with the study of graphs, which are a mathematical representation of a network used to model pairwise relations between objects. A graph consists of a set of “vertices” or “nodes”, with certain pairs of these nodes connected by “edges” (undirected, meaning that there is no distinction between the two vertices associated with each edge) or “arcs” (directed, meaning that its arcs may be directed from one vertex to another). In 1736, the problem of the Seven Königsberg Bridge was an effective role in the origination of graph theory as a branch of modern mathematics. The importance of graph theory is rapidly increasing in mathematics and in other areas of sciences and technology because of its applications in various fields which include, electrical engineering (coding theory and communications network), biochemistry, operations research (scheduling) and computer science (computations and algorithms) … *etc.* The wide scope of these and other applications has been well-documented in [1, 2]. However, in our daily life graph theory is become a significant field in one of the most important applications in mobile computing and networking especially wireless sensor networks.

Since the matrices are an alternative way to represent and summarize network data. Therefore, a graph can be represented in many distinct matrices because a matrix contains exactly the same information as a graph but is more useful for computation and computer analysis. In below some type of these matrices that important in our work:

- Adjacency Matrix: Sometimes more convenient to represent a graph by its adjacency matrix or connection matrix. The adjacency matrix of a graph *G* with *n* vertices and no parallel edges is *n* by *n* symmetric binary matrix *A*(*G*)= [*a_ij*] defined over the ring of integers Fig. 2 such that:

$$a_{ij} = \begin{cases} 1; & \text{if there is an edge between } i^{\text{th}} \text{ and } j^{\text{th}} \text{ vertices, and} \\ 0; & \text{if there is no edge between them.} \end{cases}$$

$$A(G) = \begin{bmatrix} 0 & 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 0 & 1 \\ 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$

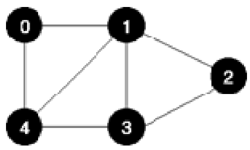

Fig. 2. Graph *G* and its adjacency matrix.

- Incidence Matrix: Let *G* be a graph with *n* vertices, *m* edges and without self-loops. The incidence matrix *T G* is an *n***m* matrix defined by *T*(*G*) = [*t_ij*]; $1 \le i \le n$; $1 \le j \le m$, Fig. 3 where:

$$t_{ij} = \begin{cases} 1; & \text{if } j^{\text{th}} \text{ edge incidents on } i^{\text{th}} \text{ vertex,} \\ 0; & \text{otherwise.} \end{cases}$$

$$T(G) = \begin{bmatrix} 1 & 1 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix}$$

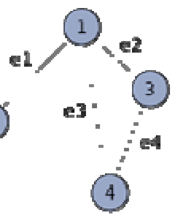

Fig. 3. Graph *G* and its incidence matrix.

• Path Matrix: Let G be a graph with m edges, and u v be any two vertices in G. Also, let k be the number of different paths between u and v in G. The path matrix for vertices u and v, denoted by $P(u, v)$, is the matrix defined as $P(u, v) = [p\_ij]$; $1 \le i \le k$; $1 \le j \le m$, Fig. 4 such that:

$$p_{ij} = \begin{cases} 1; & \text{if } i^{\text{th}} \text{ path contains the } j^{\text{th}} \text{ edge of } G, \\ 0; & \text{otherwise.} \end{cases}$$

$p_1 = \{e_1, e_2\}$
$p_2 = \{e_5, e_7\}$
$p_3 = \{e_2, e_7, e_8\}$
$p_4 = \{e_1, e_5, e_8\}$

$$P(1,3) = \begin{bmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \end{bmatrix}$$

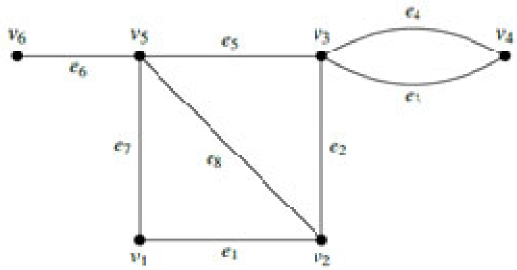

Fig. 4. Graph G and path matrix $P(1, 3)$.

The problem of energy power consumption of wireless sensor networks is considered a significant issue because of their relationship to its life mode. Therefore, sensor devices are heavily based on modern schemes to save their energy power consumption because any random response of sensor nodes will have a direct and negative impact on devices' life. Therefore, we depended on graph theory to obtain modern schemes that solve this problem because it has the ability to identify sensor nodes movement without energy power losses and control the amount of power consumption.

4. THE PROPOSED SYSTEM

Sensors are tiny devices that employed to monitor conditions of environment and sensing tasks. On one side, these devices have the ability to communicate, computation and sensing in a harsh environment. In addition, smart sensors are embedded central processing units with low power radios. On the other side, these devices are suffered from critical issues, such as capacity, security, and energy. In this paper, a novel hybrid mobility algorithm is proposed to overcome some inherent problem which is powerful energy. In other words, the methodical model (graph theory) is integrated with wireless sensor networks to select the best path between source and destination, a located closest sensor from inquiring area. Therefore, it is capable to introduce de-active sensors at safe mode/ sleep mode to save energy as well as reducing the amount of consumption rate.

The proposed system in this paper is utilised in identifying the suitable location of these sensors based on the critical features. These features were extracted from wireless sensor network topology. Moreover, the topology of sensors plays a vital role in distributing these devices mathematically. However, this system will acquisition any sensor that had the ability to choose the appropriate node for the enquire. Thus, this model will decline consumption time, introduce life human at safety side, growing response time, save capacity and optimal occupation of carrier medium. A novelty mode proposed in this research is heavily based on graph theory for wireless sensor networks to finding a suitable location of mobile sensors from inquire zoon without any delay.

We can easily describe the primary scenario of the rescue area that six sensors reply to help messages to the inquiry area. In this case, sensors' energy will be drained because of they are randomly moving. Practically, all sensors at the radio coverage area will directly a response to the inquiry notification. However, the hybrid moving system is employed to select the optimal sensor for moving to the inquiry area proposed in this paper. In addition, the optimal choice of the sensor is based on critical issues, such as distance, energy rate, weigh of a queue waiting and radio coverage zoon.

5. SIMULATION RESULTS

In this paper, the proposed system has the ability to give each sensor a priority value based on some critical issues mentioned above. In other words, it will assign each mobility sensor with preference value based on the distance between a source and inquiry area in that radio coverage zone. However, these priority values will regularly and simultaneously update at each inquiry. The proposed approach plays a vital role in canalizing sensors to the inquiry zone at a suitable time without delay. Therefore, these sensors will be distributed randomly on the e-map of the University of Anbar. In other words, the e-map of Anbar University is employed in determine sensors' locations that required to identify its location at only one time by technician. Moreover, bus topology is utilised to distribute these sensors on the e-map of our study area as shown in Fig. 5.

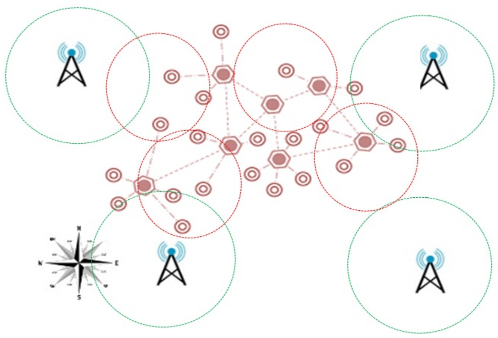

Fig. 5. Sensors at the university of Anbar.

Each sensor has a specific position with known dimensions after applying bus-topology on the e-map of Anbar University. A new mobility system is proposed in this paper that heavily based on graph theory to enhance the performance of wireless sensor networks. In addition, lightweight of the mathematical model that integrated with standard mobility algorithm of sensors plays important role in increasing the efficiency and overall performance of wireless sensors. To find the shortest path, the proposed scheme will measure the distance between sensors and the recuse zone to assign the optimal sensor that moving to the inquiry area. In other words, it is heavily based on mathematical schemes to measure the distance between wireless sensors "edges" in terms of graph theory. However, the shortest distance will have the highest priority in moving to the rescue area. Moreover, the proposed system is drawn the moving path for each sensor on the e-map of the university of Anabr according to the priority value awarded to each wireless sensor. Generally, all wireless sensors will be ready to be moving to the inquiry area at anytime and anywhere. For this, it requires to determine/ identify distance between sensors on e-map after each positioning loop algorithm. In this paper, the principle work of the proposed system is based on matrices and features of graph theory. An inquiry message is generated in this paper to evaluate the performance of the proposed system. However, the proposed system will be tested with normal and abnormal messages to measure its responsibility under certain conditions. An abnormal message generated from inquiry area is required to test the proposed system as shown in Fig. 6.

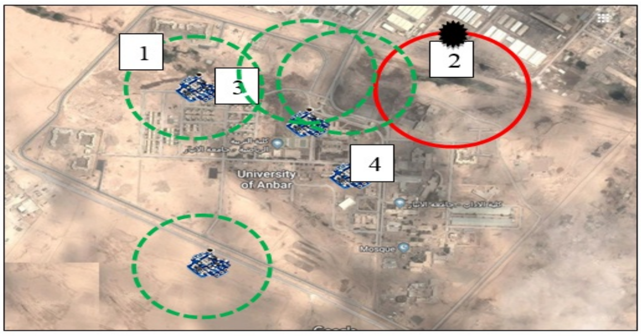

Fig. 6. Sensors' location on the e-map of the university and inquiry area.

The lifecycle of the proposed scheme is composed of two phases which are re-distribute and select the optimal choice of the existing sensors. However, it uses graph theory that integrated with the mobility system to find a more suitable sensor of wireless sensor as shown in Fig. 7. Thus, the system needs to calculate all distance between sensors and inquiry area as shown in Table 1.

Table 1. Distance value of wireless sensors.

Wireless Sensors ID	Distance / m
Sensor_1	2614
Sensor _2	3215
Sensor _3	1125
Sensor_4	974

The proposed system has the ability to allocate one of the wireless sensors and resign priority numbers for each sensor on the e-map of the university as shown in Table 2.

Table 2. Priority number of wireless sensors.

Wireless Sensors ID	Priority Number
Sensor_1	1
Sensor _2	0
Sensor _3	2
Sensor _4	3

According to Table 2, the proposed scheme will notify the sensor that obtained the highest value of priority to moving to the inquiry area which is sensor number four. The performance metrics of the proposed scheme compare it with others. These metrics are waiting time, response time and end-to-end delay shown in Table 3.

Table 3. Performance metrics of the proposed system.

Metrics	The Proposed System	Ordinary System without Graph Theory
Waiting Time	1.23s	14.62s
Delay	7.23s	32.29s
Response Time	3.76s	24.85s

We can easily notice that the performance of the proposed system is more efficiency and effectiveness of the traditional system without a mathematical model.

6. DISCUSSION

The lightweight of the mathematical model that integrated with the ordinary mobility system for wireless sensors plays an important role in enhancing the whole performance of sensors. In other words, this system has direct and positive impact on real-time applications. The graph theory is employed in measure distance between sensors in terms of edges between wireless nodes. These sensors share sensitive information, control data, warning messages, cooperative awareness messages, and notification messages. More than that, these sensors try to exchange position information between them periodically. The distance information, communication data, and control information of wireless sensors are obtained from adjacency matrix. In addition, it demonstrates information on distance between sensors that established the communication link with each other. According to the graph theory, wireless sensors in this paper are trying to obtain occupy location of vertices. However, the lightweight of mathematical model enables mobility sensors to select the best path of neighbour nodes. These vertices and edges of the graph theory are formed in the adjacency matrix. Therefore, it can measure the eigenvalues that play direct and positive role in support mathematical scheme [19].

The principle value of eigenvector has the ability in supplying some critical information for sensors, such as connection information and the number of neighbours [20]. However, the Topal algorithm is utilised in generated these values od matrix. Moreover, the index values are created from edges of graph theory. Furthermore, the principal values of eigenvector are extracted from the number of neighbour sensors that connected to a recuse sensor. These graph theory values are distinguished sensors have the same information distance. On one side, the proposed doesn't depend on sensors outside the radio coverage area. On the other side, these pre-knowledge making sensors connection could be measured according to another sensor in the same zone [21, 22]. In this paper, the values of eigenvector are employed in measured critical values that utilised in creating the decision of which sensor to be canalising to the inquiry zone. The proposed system in this paper will identify the recuse zone in the northeast direction of the university map. Thus, it will send the closest sensor to the nearest area. Therefore, the model supports mission to the sensors to solve this inquiry. The system waits for any other recuse alarm that generated from any place on map. To evaluate the performance of the proposed system, the proposed system will compare with traditional system that without mathematical model as shown in Fig. 7.

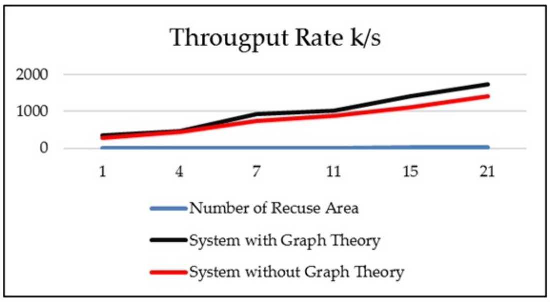

Fig. 7. Throughput of the proposed system.

According to Fig. 9, we can easily notice that the proposed system is more efficient and effective from others. In other words, graph theory plays a significant role in enhancing the performance of the proposed system. However, it can reduce the waiting time, improve response time, increase throughput and reducing end-to-end delay. The natural disaster department of the university has the ability to determine any place of sensor and any time on e-map. Moreover, it can calculate the closest suitable sensor and send a new mobile node to recuse area without any delay.

7. CONCLUSIONS

In this paper, a novel mobility scheme is designed for wireless sensor networks that mathematically distributed depend on graph theory. However, it is employed to build a virtual topology of sensors and determine the closest sensor to the inquire area. According to the experimental results, we can easily observe that our suggested model more effective from others. In this proposal, graph theory plays a vital role in improving the mobility of sensors with a significant declining at consumption energy power rate. The hybrid integrated between graph theory and the mobility model of sensors had a direct and positive impact on the effective and efficient of wireless sensor networks. As a result, the proposed system can increase the life of battery, declining power consumption, reducing rate of breaking down of sensors and increasing efficiency of bandwidth. Moreover, the hybrid system proposed in this paper does not require more calculating time for associating closest sensor to inquire zoon. As future work, we are trying to find a relation between machine learning with graph theory. Thus, it plays an important role to identify and re-located sensors outside of the coverage area. Therefore, this mathematical approach has the ability to improve performance of wireless sensor networks as well as it helps these sensors to avoid any losses cases of connection of sensors. The unique limitation of the proposed system is not easy adapts with various kinds of routing protocols of sensors.

REFERENCES

1. G. Li, S. Peng, C. Wang, J. Niu, and Y. Yuan, “An energy-efficient data collection scheme using denoising autoencoder in wireless sensor networks,” *Tsinghua Science and Technology*, Vol. 24, 2019, pp. 86-96.
2. X. Tang, Y. Cai, Y. Deng, Y. Huang, W. Yang, and W. Yang, “Energy-constrained SWIPT networks: Enhancing physical layer security with FD self-jamming,” *IEEE Transactions on Information Forensics and Security*, Vol. 14, 2019, pp. 212-222.
3. M. W. Maduranga, P. Saengudomlert, and H. M. D. Bandara, “Redundant node management in wireless sensor networks with multiple sensor types,” in *Proceedings of National Information Technology Conference*, 2018, pp. 1-6.
4. “Protocols of the wireless internet of things,” in *The Wireless Internet of Things*, John Wiley & Sons, Inc., NJ, 2018, pp. 21-45.
5. G. M. Dias, C. B. Margi, F. C. P. de Oliveira, and B. Bellalta, “Cloud-empowered, self-managing wireless sensor networks: Interconnecting management operations at the application layer,” *IEEE Consumer Electronics Magazine*, Vol. 8, 2019, pp. 55-60.
6. G. Li, S. Peng, C. Wang, J. Niu, and Y. Yuan, “An energy-efficient data collection scheme using denoising autoencoder in wireless sensor networks,” *Tsinghua Science and Technology*, Vol. 24, 2019, pp. 86-96.
7. W. T. Trotter, “5 – Graph theory basics,” Math Department, Georgia Institute of Technology, 2017.
8. K. M. A. Alheeti and A. S. Ameen, “A novel approach of mobile security robotics moved based on graph theory,” *Journal of Theoretical and Applied Information Technology*, Vol. 31, 2018, pp. 4471-4480.
9. A. Ibeas and M. de la Sen, “Artificial intelligent and graph theory tools for describing switched liner control systems,” *Applied Artificial Intelligence*, Vol. 20, 2006, pp. 703-741.
10. H. Tamura, K. Nakano, M. Sengoku, and S. Shinoda, “On applications of graph/network theory to problems in communication systems,” *Transactions on Computer and Information Technology*, Vol. 5, 2011, pp. 15-21.
11. V. N. Kustov, V. V. Yakovlev, and T. L. Stankevich, “The information security system synthesis using the graphs theory,” in *Proceedings of IEEE International Conference on Soft Computing and Measurements*, 2017, pp. 148-151.
12. J. Susymary and R. Lawrance, “Graph theory analysis of protein-protein interaction network and graph-based clustering of proteins linked with zika virus using MCL

algorithm," in *Proceedings of International Conference on Circuit*, *Power and Computing Technologies*, 2017, pp. 1-7.
13. D. Sarioz, "Geometric graph theory and wireless sensor networks," Ph.D. Thesis, Department of Computer Science, City University of New York, 2012.
14. R. Wang, J. Wu, Z. Qian, Z. Lin, and X. He, "A graph theory based energy routing algorithm in energy local area network," *IEEE Transactions on Industrial Informatics*, Vol. 13, 2017, pp. 3275-3285.
15. S. G. Shirinivas, S. Vetrivel, and N. M. Elango, "Applications of graph theory in computer science an overview," *International Journal of Engineering*, *Science and Technology*, Vol. 2, 2010, pp. 4610-4621.
16. J. Susymary and R. Lawrance, "Graph theory analysis of protein-protein interaction network and graph based clustering of proteins linked with zika virus using MCL algorithm," in *Proceedings of International Conference on Circuit*, *Power and Computing Technologies*, 2017, pp. 1-7.
17. L. B. Saad and B. Beferull-Lozano, "Graph filtering of time-varying signals over asymmetric wireless sensor networks," in *Proceedings of IEEE 20th International Workshop on Signal Processing Advances in Wireless Communications*, 2019, pp. 1-5.
18. S. Xiang and J. Yang, "Reliability evaluation and reliability-based optimal design for wireless sensor networks," *IEEE Systems Journal*, 2019, pp. 1-12.
19. K. Thangaramya, R. Logambigai, L. SaiRamesh, K. Kulothungan, and A. K. S. Ganapathy, "An energy efficient clustering approach using spectral graph theory in wireless sensor networks," in *Proceedings of the 2nd International Conference on Recent Trends and Challenges in Computational Models*, 2017, pp. 126-129.
20. J. Cadena, F. Chen, and A. Vullikanti, "Graph anomaly detection based on Steiner connectivity and density," *Proceedings of IEEE*, Vol. 106, 2018, pp. 829-845.
21. A. Ortega, P. Frossard, J. Kovacevic, J. M. F. Moura, and P. Vandergheynst, "Graph signal processing: Overview, challenges, and applications," *Proceedings of IEEE*, Vol. 106, 2018, pp. 808-828.
22. A. Nedic, A. Olshevsky, and M. G. Rabbat, "Network topology and communication-computation tradeoffs in decentralized optimization," *Proceedings of IEEE*, Vol. 106, 2018, pp. 953-976.

Ameen Sh. Ameen received the B.Sc. Mathematical Science degree in 1988 from Baghdad University, Iraq, and the M.Sc. Module Algebra in 2002 from the University of Baghdad, Iraq, respectively. He received the Ph.D. degree in Applied Graph Theory from USM, Malaysia in 2012. He is working at University of Anbar.

Khattab M. Ali Alheeti received the B.Sc. Computer Science degree in 2000 from Baghdad, Iraq, M.Sc. (Hons.) Computer Networking and Information in 2009 from the University of Al al-Bayt, Jordan, and Ph.D. from Essex University in 2017, respectively. Currently, he is working at University of Anbar.

Salah A. Aliesawi received the B.Sc. and M.Sc. degrees in Computer Engineering from University of Technology, Baghdad, Iraq, in 1996 and 2002, respectively. He obtained the Ph.D. degree from the University of Newcastle, UK in 2012. His research interests include wireless networks, IoT, digital signal processing and multiuser detection.