Journal of Computer Engineering, Electronics and Information Technology (COELITE)

Journal homepage: https://ejournal.upi.edu/index.php/COELITE

Graph Theory-Based Simulation for Optimal Access Point Selection in Smart Buildings

Devi Aprianti Rimadhani Agustini[1], Deva Naufal[2], Muhammad Zirly Atthaulah[3], Halimah Kiysa Fiddien[4], Alaqso Fattar Djuson [5]*

[12345]Departement of Computer Engineering, Universitas Pendidikan Indonesia, Indonesia
Correspondence E-mail: deviaprianti@upi.edu

ABSTRACT

This study investigates the optimization of Access Point (AP) selection for microcontroller-based devices within smart building infrastructures using a graph theory approach. The primary challenge in multi-story wireless networks is the topological complexity that triggers signal interference, subsequently degrading the connectivity stability of IoT devices. In this research, the network is modelled as a weighted graph, where vertices represent access points and edges represent transmission paths weighted by distance. The Welch-Powell algorithm is implemented to optimize frequency channel allocation, effectively minimizing co-channel interference between adjacent nodes. Furthermore, Dijkstra's algorithm and Traveling Salesman Problem (TSP) logic are applied to determine the most efficient communication routes. The results demonstrate that transmission distance is the most significant parameter in optimal AP selection; a distance variance of 1.2–1.7 m is proven to correlate with improved signal quality. Meanwhile, frequency channel alignment and interference management serve as crucial secondary factors in optimizing connection stability. This approach provides a mathematical framework for strategic AP placement to ensure reliable data communication for microcontroller-based devices in high-rise environments.

© 2026 Universitas Pendidikan Indonesia

ARTICLE INFO

Article History:
Submitted/Received 10 Mar 2026
First Revised 23 Mar 2026
Accepted 31 Mar 2026
First Available online 01 Apr 2026
Publication Date 01 Apr 2026

Keyword:
Graph Coloring,
Access Point Selection,
Welch-Powell Algorithm,
Smart Building, Simulation.

1. INTRODUCTION

The development of Internet of Things (IoT) technology is driving the transformation of conventional building concepts into smart Buildings where building structures, services, and management are digitally integrated to produce environmentally friendly structures and support user productivity [1]. The integration of various IoT devices as sensor and actuator data processing units allows buildings to operate independently in managing energy efficiency, occupant comfort, and security systems. However, the reliability of this system is highly dependent on the stability of the wireless connection because microcontrollers scattered throughout the building require continuous internet network access to send data to the cloud and receive operational commands in real-time.

The main problem that often arises in the implementation of smart buildings is communication failure due to suboptimal placement of Access Points (AP) [2]. The physical structure of the building such as concrete walls, glass partitions, and the presence of other electronic devices often cause signal attenuation and interference. For IoT devices that generally have limitations in antenna sensitivity and transmission power, even the slightest signal interference can cause high latency or complete disconnection. This not only reduces system efficiency but also poses a fatal risk to critical functions such as fire detection or access security.

To overcome problems related to wireless networks, both regarding access point placement, signal interference management or other wireless network optimizati on, many studies have been conducted. In a study conducted by [3], the Simulated Annealing and tri literation methods were applied to determine the optimal access point position in an office building to reduce blank spots. Another study conducted by [4] used a graph theory approach to select Wi-Fi channels aimed at reducing network interference. A graph theory approach was also used in a study [5] to optimize radio frequency allocation in East Java through simulation. By using the graph colouring method, the number of frequencies produced in the simulation was fewer than the number of frequencies used in reality. The graph colouring method was also used in a study [6] to solve interference problems in an uncoordinated IEEE 802.11 network. Another study [7] applied the Kruskal algorithm in designing an access point network in a university building.

Graph theory is a field of mathematics with a very relevant approach in modeling problems regarding wireless network topology [8]. In this study, simulations are carried out by modeling the network center and access points as graph nodes, while the weights on the graph edges represent the distances between nodes. By utilizing graph coloring, access point channels can be allocated efficiently so that interference on adjacent nodes can be minimized. In certain scenarios, such as when there are mobile IoT devices or when the communication path must pass through several nodes, the Dijkstra algorithm is utilized to find the most efficient communication route. Therefore, this study proposes a graph theory-based simulation to determine the optimal Access Point configuration, in order to ensure connectivity stability in smart building infrastructure.

2. METHODS

In this study, the network is modeled as a weighted graph, which will then implement the Welch-Powell algorithm to group the main access points on each floor and the Dijkstra

DOI: https://doi.org/10.17509/coelite.v5i1.99031
p- ISSN 2829-4157 e- ISSN 2829-4149

algorithm to determine the optimal transmission distance for IoT devices. The stages used in this study can be seen in **Figure 1**.

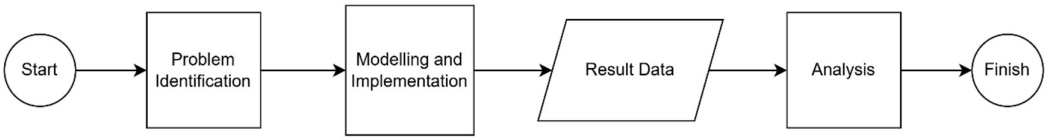


Figure 1 Research Flow

The research phase begins with problem identification, specifically examining the issue of selecting the appropriate Access Point position in buildings, particularly multi-story buildings. Often, installations are carried out without considering the extent to which signals can collide (interference), both on the same floor and between different floors. This results in unstable or slow internet connections in buildings. In this study, a visualization was developed to help map Access Point locations and automatically select the most optimal Access Point (AP).

The second stage is to build a graph model that aims to represent the network structure, so that the relationship between devices can be analyzed systematically and measurably. The graph model to be built is a undirected weighted graph where the nodes represent important elements in the signal network, namely the server as the main controller of the system and the access point, the edge describes the relationship or connection between two nodes in the graph and the weight indicates the transmission distance between the access point to the server or the device to the access point. With this approach, each device involved in the network system is modeled as a node in the graph, so that the interaction and connection between devices can be analyzed comprehensively. Meanwhile, an edge is formed when two nodes are within signal range and allow direct communication.

In this study, edges not only indicate the presence of a connection but also indirectly represent various technical network parameters, such as data transmission path, signal strength, interference level, network traffic load, and distance between devices. Edge weights are determined based on distance, signal quality, or interference level. Therefore, the lower the edge weight, the better the resulting connection quality and the lower the potential for interference between devices.

The next stage of the research is to implement the algorithm used based on the graph model that has been constructed. The Welch-Powell algorithm is used to group nodes based on similar signal characteristics, such as device type, signal strength, and frequency channel used. In theory, in the node coloring process, there is a rule that two neighboring nodes must not have the same color because they have the potential to cause signal interference. Therefore, graph coloring is used to avoid channel interference between access points. This, node coloring helps map network conditions, making it easier to identify areas prone to interference.

Meanwhile, an optimization algorithm is used to determine the most efficient communication path and network configuration. The algorithm used to determine the communication path of the device is the Dijkstra Algorithm [9]. This algorithm is used to find the communication path that minimizes the total distance or path weight between nodes, so that the most efficient network connection path is obtained. In accordance with the research objectives, the implementation of this algorithm aims to minimize the signal transmission

DOI: https://doi.org/10.17509/coelite.v5i1.99031
p- ISSN 2829-4157 e- ISSN 2829-4149

distance so that it can increase network stability for IoT devices. The implementation of the Dijkstra algorithm in determining the communication path follows the flowchart in **Figure 2**.

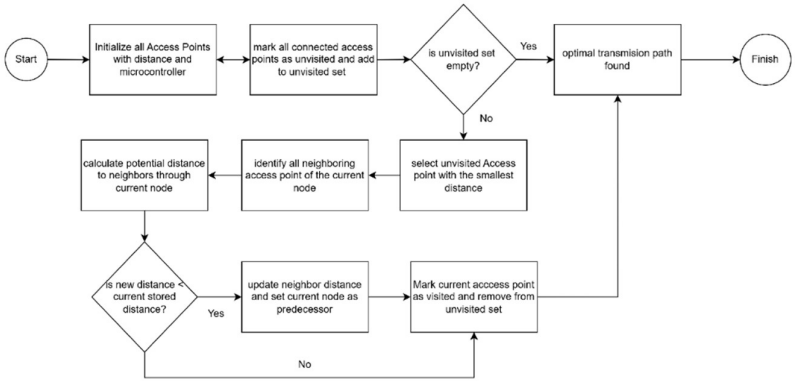


Figure 2. Dijkstra Algorithm for access point selection

The effectiveness of an access point in serving IoT devices is greatly influenced by the distance between the devices. The closer distance between the device and the access point is increase signal quality, smaller the delay, decrease interference level and more efficient the device's power consumption. Conversely, the further device is from the access point, the greater the transmit power required, the lower the signal quality, the greater the potential for interference, and the higher the risk of data loss. By implementing this algorithm, the system will find the optimal path that connects all devices in the network with the minimum total distance, so that the network connection path formed is more efficient, stable, and in accordance with the needs of the smart building system.

The algorithms are implemented in a program using the Python programming language, supported by libraries such as *math* library to perform advanced mathematical operations and the *tkinter* library to build user interface (GUI) applications used to visualize the simulations. Data from the simulations will be analyzed to provide an overview of the application of graph theory approaches to network optimization in smart buildings.

3. RESULTS AND DISCUSSION

The simulation applied several scenarios, including the number of floors in the building and the ideal transmission distance, taking into account the conditions of obstacles in the building. In this study, the simulation was conducted using two main scenarios: a single-story building and a multi-story building. The difference in the number of floors in the simulation was intended to observe the effect of the number of floors on the resulting optimal position. The interference distance, as a safe distance to minimize potential interference between two access point nodes, was a parameter set in this simulation. In multi-story buildings, the effect of placing access points on different floors will also be analyzed.

Figure 3 shows the simulation results for access point placement in a one-story building. Using an interference distance of 100 meters, assuming the building is proportional to the interference distance, with minimal obstructions, and a frequency with long range, the number of access points that can be placed indoors, based on the simulation, is 5. The distance between the access points and the server is calculated using the program, with detailed values shown in **Table 1**.

DOI: https://doi.org/10.17509/coelite.v5i1.99031
p- ISSN 2829-4157 e- ISSN 2829-4149

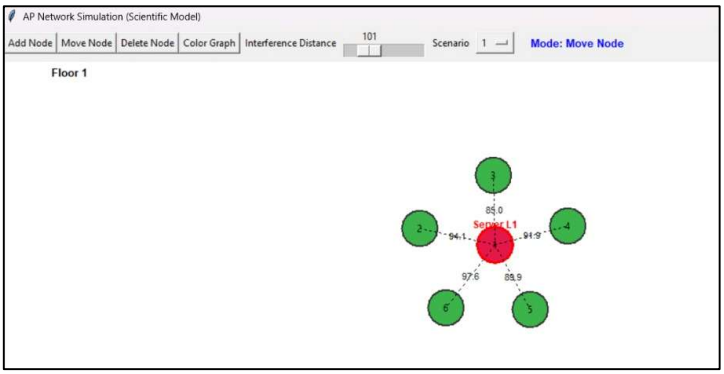


Figure 3. Simulation result of access point placement in a one-story building

For a single-story building, access point placement in this simulation is only affected by the interference distance parameter. The smaller the interference distance parameter, the fewer access points connected to the same channel. The green color shown in Figure 3 indicates that each access point is not adjacent.

Table 1. Access point distance to Server for o ne-story building simulation

Server Number	Access Point Number	Distance (meter)
1	2	94.1
1	3	85
1	4	91.9
1	5	89.9
1	6	97.6

The simulation continues with the next scenario, namely a multi-story building. In this simulation, three floors were selected as an additional simulation parameter, in addition to the interference distance. By using the same interference distance parameter value as the previous scenario, the results of the simulation of access point placement in a three-story building can be seen in **Figure 4.** To visualize the difference in floors in 2D, a horizontal line is used to separate the first floor and the next. The difference in floors is also marked by the difference in connection to the server. The use of 2D takes into account the influence of interference from access points on different floors. Because in reality, access points can transmit signals vertically so the potential for interference is very high [10].

The simulation results show significant differences between single-story and multi-story buildings. One difference is that fewer access points are required per floor in single-story buildings to minimize potential interference.

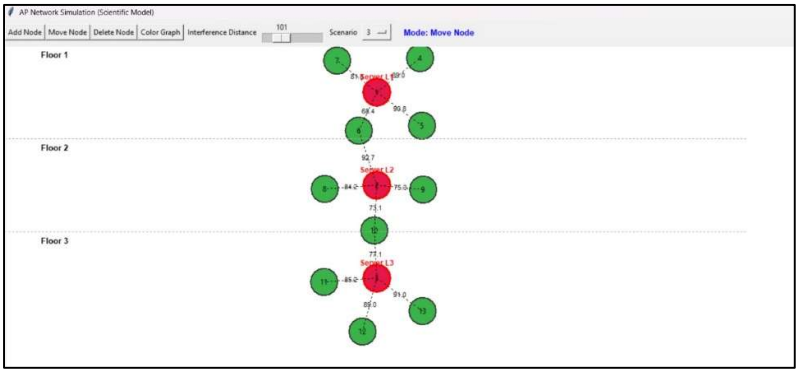


Figure 4. Simulation result of access point placement in a multi-story building

DOI: https://doi.org/10.17509/coelite.v5i1.99031
p- ISSN 2829-4157 e- ISSN 2829-4149

The transmission distance data between the access point and the server on each floor can be seen in **Table 2**. The similarity in color usage shown in the simulation indicates that the generated access points do not cause interference with each other. This is the result of the implementation of graph coloring using the Welch-Powell algorithm. Node coloring helps map network conditions, making it easier to identify interference-prone areas based on the distance parameters implemented in the simulation.

Table 2. Access point distance to Server for multi-story building simulation

Floor	Server Number	Access Point Number	Distance (meter)
1st	1	4	89
	1	5	90.8
	1	6	68.4
	1	7	81
2nd	2	6	92.7
	2	8	84.2
	2	9	75.3
	2	10	73.1
3rd	3	10	77.1
	3	11	85.2
	3	12	89
	3	13	91

In addition to the graph coloring implementation, the Dijkstra algorithm is used to determine the optimal communication path for devices that will connect to the access point to the server. In accordance with the scenario used to determine the placement of the access point, to determine the communication path for the device will be used two scenarios: in a single story building and a multi-story building. The configuration or placement of the access point used in this Dijkstra implementation uses the results obtained in the previous section (the generated access point configuration).

The implementation of searching for a communication path between a device and a server in a single story building with an access point placement configuration as shown in Figure 3 can be seen in **Figure 5**. In this simulation, there is a device whose communication path to the server will be analyzed using the Dijkstra algorithm. Device placement can be done randomly, so the selection of the closest path will depend heavily on the position of the nearest access point.

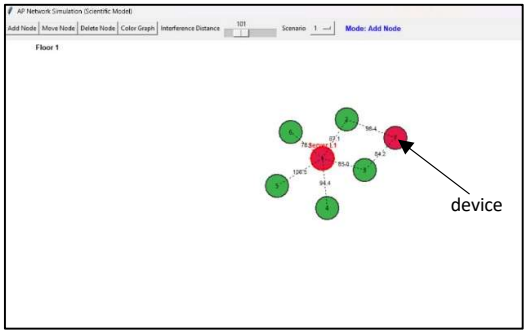


Figure 5. Simulation of communication path in a single-story building

DOI: https://doi.org/10.17509/coelite.v5i1.99031
p- ISSN 2829-4157 e- ISSN 2829-4149

In this simulation, there is one device modeled by node 7. The implementation of Dijkstra's algorithm for this scenario begins with this node (Node 7). Node 7 is connected to the access point modeled by node 3 and node 2. The shortest distance selected is from node 7 to node 3.

The calculation starts from the point with the shortest value in step 1, namely node 3. Node 3 is directly connected to node 1, which is the destination node. The resulting weight of this path is 167.2 m. After that, the calculation will be repeated until all nodes are visited to determine the resulting shortest distance. The resulting path weight will be compared with the existing path. **Table 3** shows the Dijkstra implementation for this scenario.

Table 3. Djikstra Algorithm Implementation for single story building simulation

Step	Node	1	2	3	4	5	6	7	Shortest distance to the next node	
1	7	∞	96.4	84.2	∞	∞	∞	0	96.4	2
2	2	∞	96.4	84.2	∞	∞	∞	0	84.2	3
3	3	167.2	96.4	84.2	∞	∞	∞	0	167.2	1
4	1	167.2	96.4	84.2	261.6	267.7	245.2	0	167.2	6
5	6	167.2	96.4	84.2	261.6	267.7	245.2	0	167.2	4
6	4	167.2	96.4	84.2	261.6	267.7	245.2	0	167.2	5
7	5	167.2	96.4	84.2	261.6	267.7	245.2	0	167.2	

Based on **table 3**, the path that will be selected by the device is through the access point modeled by node 3 with a total distance of 167.2 meters and the selected path is node 7 – node 3 – node 1. The simulation continues with the multi-story building scenario. The simulation results can be seen in **figure 6**.

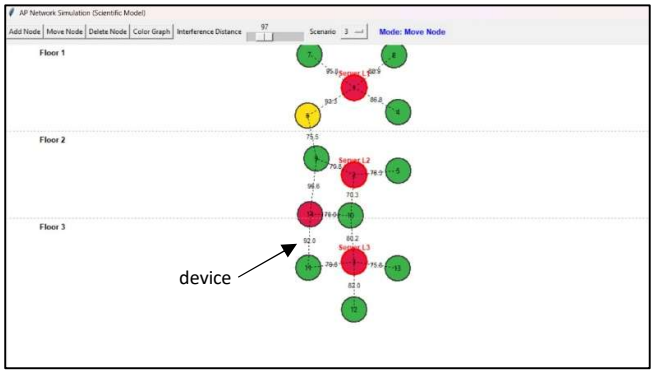


Figure 6. Simulation of communication path in a multi-story building

In this simulation, there is one device modeled by node 14, located on the 2nd floor. The device will connect to the nearest access point to go to the main server on the 1st floor. The shortest path calculation using the Dijkstra algorithm in this scenario produces the shortest path node 14 - node 9 - node 6 - node 1, with a total weight (distance) of 265.4 m.

4. CONCLUSION

The Dijkstra algorithm used to determine the best transmission path from a device connected to an access point to the network hub for each scenario shows that optimal access point selection can be done by considering the transmission distance generated by the program. In this study, the simulation was conducted in 2 dimensions, so the physical representation of wireless signals in 3-dimensional space was only done through a vertical

DOI: https://doi.org/10.17509/coelite.v5i1.99031
p- ISSN 2829-4157 e- ISSN 2829-4149

interference parameter approach. In addition, the coloring algorithm used did not consider other factors, such as external interference or room conditions.

5. ACKNOWLEDGMENT

We would like to thank our colleagues at Computer Engineering Study Program for their helpful discussions and suggestions regarding this research and also to the anonymous reviewers for their constructive comments that helped improve the quality of this manuscript.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

[1] Mangaroska, V., Mangaroski, K. & Mangaroska, L. (2024). *Smart buildings as architectural international technological concept* [Članak]. Zbornik radova sa Nacionalne konferencije sa međunarodnim učešćem – Zelena Gradnja 2024, Niš, Srbija. https://doi.org/10.5937/greenb24023M

[2] Das, S.R., Saha, D., Sinha, B.P. *et al.* (2024). Strategic placement of access points for message communication in a smart building environment. *Innovations Syst Softw Eng* **20**, 425–433. https://doi.org/10.1007/s11334-022-00466-2

[3] Arif, Muhammad. and Utomo, Siswo Mardi. (2022). *Penggunaan Metode Simulated Annealing Dan Trilateration Untuk Optimasi Penempatan Posisi Titik Akses Studi Kasus: Kantor Kesyahbandaran Dan Otoritas Pelabuhan (Ksop) Kelas 1 Tanjung Emas*, Jurnal Komputer Grafis, 15(2):245-253

[4] Orden, David., Guzman, Jose Manuel Gimenez., Mestre, Ivan Marsa-Maestre., and La Hoz, Enrique. (2018). Spectrum Graph Coloring and Applications to Wi-Fi Channel Assignment. *Symmetry*, 10, 65

[5] Putra, Fadhlan Septianto Eka., Darmaji, and Soetrisno. (2017). Implementasi Metode Pewarnaan Graf Menggunakan Algoritma *Welch Powell* untuk Simulasi Penerapan Frekuensi Radio di Jawa Timur, *Jurnal Sains dan Seni ITS*, 6(2), 2337-3520

[6] Gimenez-Guzman, J.M.; Marsa-Maestre, I.; de la Hoz, E.; Orden, D.; Herranz-Oliveros, D. (2023). *Channel Selection in Uncoordinated IEEE 802.11 Networks Using Graph Coloring. Sensors*, 23, 5932. https://doi.org/10.3390/s23135932

[7] Putra, E. Yohanes dan Riti, Yosefina F.(2025). Rancang Jaringan Access Point Menggunakan Algotima Kruskal, *Indexia*, 7(1)

[8] Rusek,K., Suárez-Varela,J., Almasan,P., P. Barlet-Ros and A. Cabellos-Aparicio.(2020) "RouteNet: Leveraging Graph Neural Networks for Network Modeling and Optimization in SDN," in *IEEE Journal on Selected Areas in Communications*, vol. 38, no. 10, pp. 2260-2270, doi: 10.1109/JSAC.2020.3000405

[9] Hadi, H. M., & Ibrahim, I. M. (2025). A Comprehensive Review of Shortest Path Algorithms for Network Routing. *Asian Journal of Research in Computer Science*, *18*(3), 152–175. https://doi.org/10.9734/ajrcos/2025/v18i3584

[10] Hou, B., & Wang, Y. (2023). Positioning by floors based on WiFi fingerprint. *Measurement Science and Technology, 35*. https://doi.org/10.1088/1361-6501/ad179e