Multidisciplinary

Study Wi-Fi as a study sample inspired by wireless networks and consider it as an access point for networks

Israa Falih Muslm
Department of Quality Assurance and Academic Performance, University of Babylon, Iraq
Correspondence Author: Israa Falih Muslm
Received 20 Feb 2025; Accepted 1 Apr 2025; Published 10 Apr 2025

Abstract
Wireless network is one of the means of connecting to the Internet that allows the exchange of data without the need to use wires and connections. The research problem was to propose a method to find the optimal location for the access point in Wi-Fi networks inside buildings using a technology inspired by nature. Including low data transfer rate, signal depletion, and poor roaming coverage, which leads to increased costs by adding additional access points. By observing and analyzing the behavior of living organisms that are less intelligent than humans, we have obtained algorithms inspired by nature that have proven successful in solving many engineering problems.
When the building's structural design requires increasing the wireless network capacity by adding more access points close to each other, this is where the proposed method comes in, in order to choose the optimal location to reduce interference and the possibility of Interference between access points. Taking into account the environmental and climatic conditions around the access points, such as the number of people, humidity, and surrounding trees.

Keywords: Network, Wireless, Wi-Fi networks

Introduction

A wireless network is a flexible data transmission system used as an extension or alternative to a wired network. This network transmits information via radio frequency technology over the air, eliminating the need for wired communications due to its ability to transmit data at a lower cost and with greater ease of access to the user anywhere [1]. The use of wireless networks has increased in many fields and sectors, including military and civilian sectors such as: health, trade, manufacturing, institutes and educational centers. These various sectors have benefited from the gains of increased production by using hand-held devices to transfer and broadcast data immediately to central devices for processing.

The general reliance on networks in commerce and the rapid growth of the Internet and instant services have been strong testimonies to the advantages of shared data and resources. Using wireless networks, customers can access shared data without needing a place to connect to the network. In addition to many advantages related to increased productivity, convenience and cost advantages, which include:

Ease of mobility: Wireless network systems allow their users to have instant access to data anytime and anywhere in the organization they work in. This ease of access helps increase productivity and opportunities for providing services in a way that is not possible with wired networks [2].

Simplicity and speed of installation: The installation of a wireless network system is characterized by speed and ease and eliminates the need to pull and connect cables through walls and ceilings.

Installation flexibility: Wireless networks often reach places that traditional wired networks cannot.

Lower costs: While the initial investment required for wireless network equipment is higher than the cost of wired network equipment, the overall installation and maintenance costs are much lower, which means that the long-term cost advantages are greater in interactive businesses that require frequent changes and movement. If you sit in an airport, a coffee shop, a library, or even if you are staying in a hotel today, you are undoubtedly sitting in the middle of a wireless network. Many people use a wireless network called Wi-Fi or 802.11 according to the standard classified by the International Institute of Electrical and Electronics Engineers (IEEE) [3] to connect their devices at home, and today some cities are trying to use this technology to provide free or low-cost Internet service to citizens.

Wi-Fi technology has many advantages. Wireless networks are easy to set up and inexpensive. Wi-Fi technology is nothing but a wireless network that uses radio waves just like cell phones, televisions and radios do. Below is a summary of what happens in this technology [4]: The wireless connection in the device translates the data into radio signals and transmits them via the antenna. The wireless router receives the signal, decodes it, and then sends the information to the Internet via a wired Ethernet connection.

The process also takes place in the opposite direction, as the router receives information from the Internet and translates it into radio signals and then sends it to the wireless link in the device [5]. The wireless signals used for Wi-Fi communication are exactly like the wireless signals used in Walkie-Talkies, mobile devices and other communication devices, as they can convert zeros and ones (0 - 1) into radio waves and convert the radio waves back into zeros and ones. However, the wireless signals in Wi-Fi technology differ significantly from other signals, as they are [6]:

It transmits on frequencies of 2.4 GHz or 5 GHz, which is much higher than the frequencies used in cell phones, wireless devices and televisions, as the higher frequency allows the signal to transmit more information. It uses the 802.11 network standards, which come in several types.

Characteristics of the wireless signal

It is known that the intensity index of the received wireless signal expresses the amount of electromagnetic energy present in the wave propagating in a medium, and received by the antenna of the receiving device. According to studies conducted in both the frequency and time domains, it has been shown that the wireless signals propagating in an environment are only non-periodic signals [7], and have variable values according to the surrounding environmental conditions. In order to understand the characteristics of the signal intensity accurately, the following two issues must be clarified:

How the wireless signal spreads between the transmitter and the receiver

Factors affecting this spread-

In fact, the electromagnetic wave spreads along multiple paths with different gains and lengths, and at different times, and when this wave collides with obstacles in its propagation environment, the intensity of the signal fluctuates, affected by several factors, the most important of which is what is known as fading or dimming [8] (depending on the frequency, speed of movement and paths of the received signals) as well as reflection by obstacles and large objects, and refraction depending on the density and properties of the medium, and other factors affecting the intensity of the signal.

The following figure shows the most important factors affecting the intensity of the signal propagated over multiple paths.

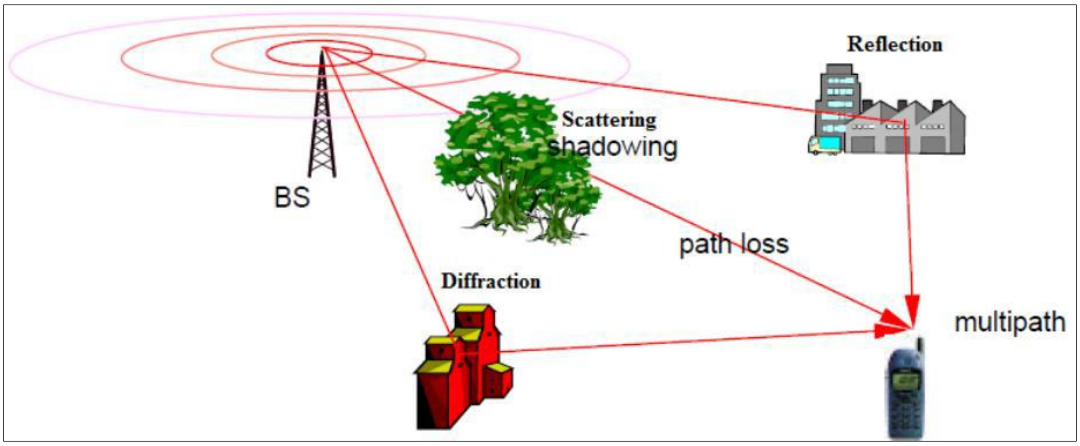

Fig 1: Factors affecting the intensity of the transmitted signal

Mechanism of wireless signal propagation

All signal propagation models [9] describe the relationship between distance on the one hand and the ratio of the transmitting and receiving powers of the wireless signal on the other hand. These models differ according to the environments in which the signal propagates. If the propagation environment is external and there are no obstacles, the model will be the signal propagation is one, while if the environment is internal then the variables of the propagation pattern that the signal follows will change.

Theoretical models

There are several theoretical models that the signal follows, the most important of which are:

1. Free space model

The free space propagation model is used to predict the received signal strength when there is a clear line of sight between the transmitter and the receiver without any obstacles between them. As is the case in most models of broadband radio wave propagation, the free space model predicts that the received power decreases as a function of the distance between the transmitter and the receiver. The equation representing the free space power received by a receiving antenna is given by the following formula (Fris) [10]:

$$P_r(d)=(P_t*G_t*G_r*\lambda^2)/(4\pi)^2*d^2$$

Pt=transmitted energy

Pr(d)= It is the received energy which is a function of the distance between the transmitter and the receiver.

Gt=Represents the gain of the transmitting antenna.

Gr=Represents the receiving antenna gain.

d=The distance between the transmitter and the receiver is represented in meters.

The above equation is not accurate in most cases when used alone, because in the radio channel the direct path between the transmitter and the receiver is not repeated.

2. Reflected pattern of the earth (Two ray ground model)

This model takes into account that there are two propagation paths between the transmitter and the receiver, a fixed propagation path and a propagation path reflected from the ground. The expected signal intensity in this model is more accurate than the free space model. The received power at distance d in this model is given by the equation [11]:

$$P_r(d)=(P_t*G_t*G_r*(h_th_r)^2)/d^4 \qquad (2-3)$$

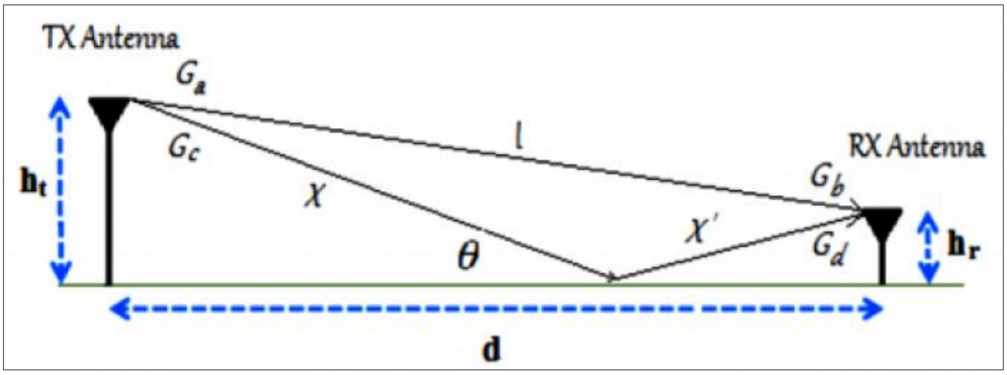

Fig 2: Model of ground-reflected propagation

3. Simplified track loss model

The following formula illustrates the simplified path loss model:

$$P_r = P_t k[d_0/d]^{\beta} \qquad (3-3)$$

This model represents the average value of the signal intensity, and does not take into account the surrounding environmental changes, i.e. it does not take into account the effect of shadowing, in addition to the fact that it is considered a fixed path loss coefficient, [13] which is unrealistic, as the ratio of transmitted energy to received energy (rP/tP) is considered random, i.e. the value of this ratio is a Gaussian random variable with a zero mean and its standard deviation ranges from 4 to 10 decibels, and follows the logarithmic normal distribution represented by the following equation:

$$F_x(x, \mu, \sigma^2) = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left(\frac{-(\log x - \mu)^2}{2\sigma^2}\right) \qquad (4-3)$$

Now, when we combine the simplified path loss model with the shadowing effect, we obtain a workable diffusion model that can take into account the surrounding changes, which is the following model [14].

4. Lost track pattern with shadow fading

This model is considered a general diffusion model, and is suitable for use in both internal and external environments. This model is provided with a number of parameters that can be organized according to the difference in the environment (internal or external) and is given according to the following equation:

$$P_L(d) = P_L(d_0) + 10 * \beta * (\log d/d_0) + X_\sigma$$

β= Path loss coefficient depends on a specific propagation environment, and its value will become larger when there are obstacles in the environment.

d0 = The reference distance close to the ground (its value in the indoor environment becomes one meter) and is determined based on experimental values.

Xσ= A Gaussian random variable with zero mean and variance 2σ that represents the shadowing effect, which is a multi-path attenuation caused by objects obstructing the path of the signal propagation between the transmitter and the receiver. This model is considered the most suitable model for use in wireless sensor networks.

5. Experimental model

This model is given according to the relationship[3-5], as most of the researches used the experimental model to estimate the distance, and all of them assumed that the value of the path loss coefficient is fixed and known or can be measured experimentally, but in reality the value of the path loss coefficient is equal to [2] in the free space model in which the signal propagates according to a direct line of sight (LOS), but for cases in which it does not propagate [15].

Pointing along a direct line of sight will make it difficult to find path loss coefficient measurements, and since most propagation cases in a realistic application environment are indirect, this will lead to a path loss coefficient that is constantly changing, and will not take a fixed value in the equation describing this model, and thus this factor will greatly affect the calculated distances. The following figure shows an explanation of the relationship between signal intensity and distance at different values of the path loss coefficient [16]. In this diagram, we see that all curves have the same starting point, which is the fixed point r1P in equation [3]. Therefore, r1P is another variable that explains the different environments.

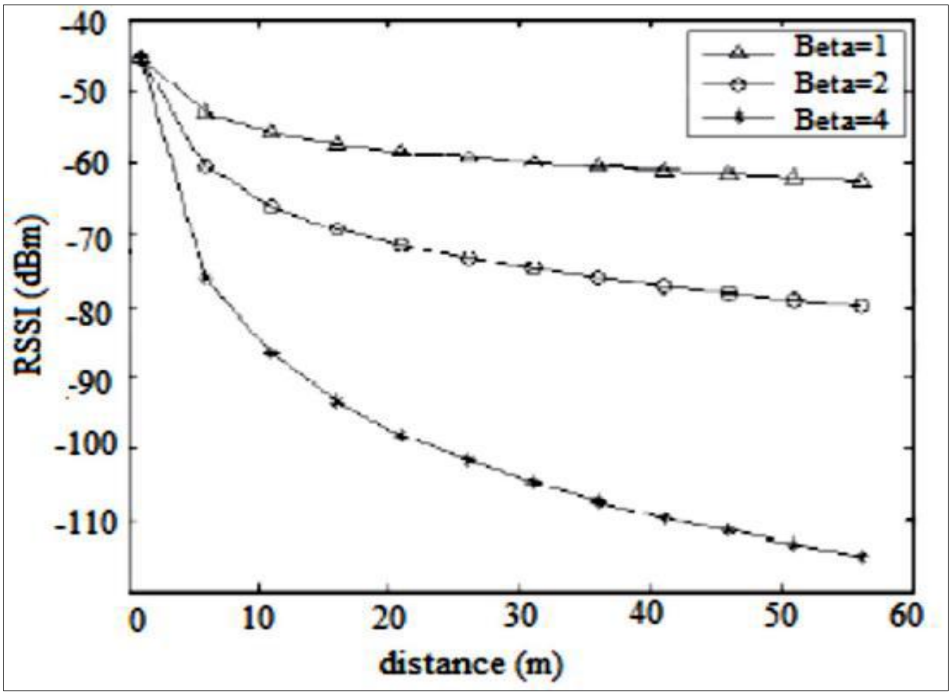

Fig 3: The relationship between signal intensity and distance at different values of path loss coefficient

Factors affecting the spread of the wireless signal

There are many factors [17] that affect the intensity of the signal spread between the transmitter and the receiver. We will explain the most important of these factors below.

a) Path loss

Is the reduction in the energy of an electromagnetic wave as it propagates through space, and is indicated using a path loss factor which has different values depending on the environment. Table (1) and Table (2) present different values of the path loss coefficient and its relationship with the standard deviation in different environments.

Table 1: Different values of path loss coefficient

Environment	Path loss exponent
Free space	2
Urban area cellular radio	2.7−3.5
In−building los	1.6−1.8
Obstructed in –building	4−6
Shadowed urban area cellular	3−5

Table 2: Path loss coefficient in different environments

Environment	Path loss	Standard deviation
Free space	2	−
Retail store	2.2	8.7
Grocery store	1.8	5.7
Office ,hard	3	7
Office ,soft	2.6	14

b) Fading

It refers to the deviation from the decrease that the signal suffers from, and fading changes with the geographical location, and is affected by both radio frequency and time, and is formulated as a random process, meaning that it can have constructive or destructive interferences on the signal energy, and thus amplify or reduce the signal energy at the receiver, and fading has many types, the most important of which are [18]:

Small scale multipath fading: Explains the fleeting changes in the received power due to small wavelength changes at the receiver. Medium Scale Shadowing: Caused by various obstacles.

Large scale path loss mode: Explains the difference between the transmitter and receiver power.

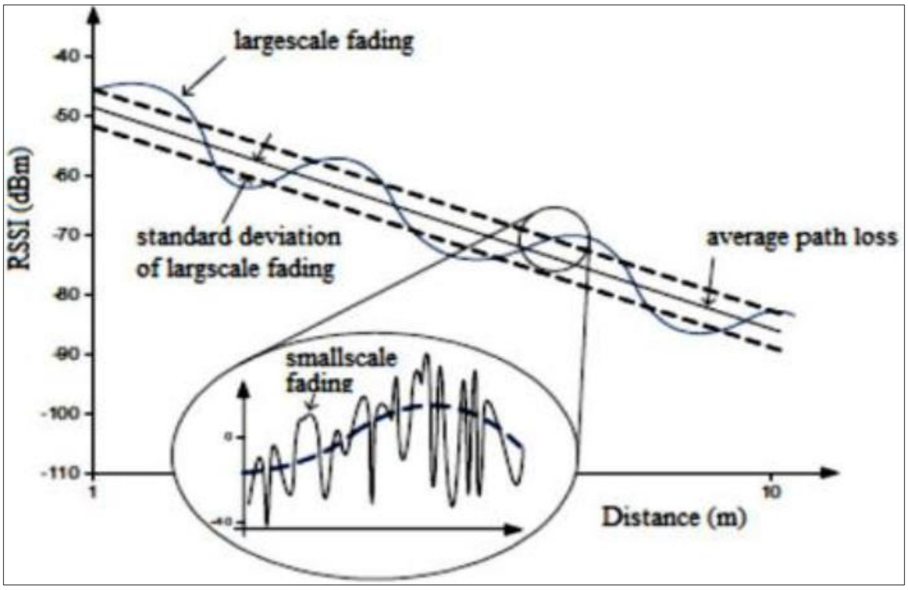

Fig 4: Fading in its various types

Shadowing effect

In which there is a loss in the signal between the sender and the receiver due to various obstacles such as walls, trees, buildings and the movement of people, which are considered the most important causes of this effect.

Wireless local area networks (WLAN)

With the tremendous development in the field of technology and communications, and the need for the possibility of exchanging information and accessing the Internet anywhere and at any time, which prompted researchers to develop networks and move to the field of wireless networks, which the IEEE 802.11 standard represents [19].

wireless LAN 802.11

They operate in the frequency bands (2.4, 3.6 and 5 GHz) and include a number of different protocols. These networks use radio waves to transmit data over the air, and are capable of penetrating walls and non-metallic barriers. Data transfer speeds range from 11 to 54 megabits per second. Since these networks transmit information via electromagnetic waves, they eliminate the need for wired networks.

The IEEE 802.11 wireless communication standard is known as the wireless Ethernet network standard. This standard has a group of sub-standards, including: IEEE 802.11a, IEEE 802.11b, IEEE 802.11c, and other standards [20].

Table 3: The most important specifications of the standards within the IEEE 802.11 family

The standard	Description
IEEE 802.11	The original or basic standard for wireless networks, operating at a data transfer rate of 1 to 2 megabits per second on the 2.4 GHz frequency and was launched in the year 200
E802.11a	A standard that operates on the 5 GHz frequency and supports a data transfer rate of 54 Mbps and uses the orthogonal frequency division multiplexing (OFDM) technology.
IEEE 802.11b	An adaptation of the original 802.11 standard, operating at 2.4 GHz with speeds of 5.5 and 11 Mbps, it was launched in 1999.
IEEE 802.11c	Description of Bridging technologies that have been integrated into the 802.11d standard, which is concerned with wireless bridging standards
IEEE 802.11d	A protocol for characterizing cellular roaming operations and was launched in 2001.
IEEE 802.11e	A standard for describing Quality of Service (QOS) services, which includes the Wi-Fi Multimedia WMM technology.
IEEE 802.11f	A standard that is no longer in use, it was for the Inter Access Point Protocol (IAPP) technology, which describes the method of transferring data between the point of entry and was launched in 2003 and ended in 2006.
IEEE 802.11g	It operates on the 2.4 GHz frequency like the 802.11b standard and transmits data at a speed of 54 megabits per second like the 802.11a standard. It was launched in 2003.
IEEE 802.11h	A standard for improving data transmission over the 5 GHz frequency to prevent interference and interference and was launched in 20

The previous table shows some of the sub-standards within the IEEE 802.11 family. There are many other standards as well.

6G networks (Wi-Fi 6)

Wi-Fi 6, or 802.11ax, is the latest version of the 802.11 standard for wireless networks, also called Wi-Fi. Wi-Fi 6 is not a new way to connect to the Internet like fiber optics, but rather an improved standard that compatible devices, especially routers, can take advantage of to transmit Wi-Fi signals more efficiently.

The most obvious improvement that Wi-Fi 6 will offer over previous generations is speed. When used with a single connected device, the potential maximum speed will increase by 40% compared to Wi-Fi 5, an increase of 6.1 Gbps [28]. Theoretically, the maximum speed of Wi-Fi 6 is 9.6 Gbps, compared to 3.5 Gbps in Wi-Fi 5, but more importantly, this speed can be split across an entire network of devices instead of a single device, resulting in a speed increase for each device on the network.

The most important features of Wi-Fi 6 networks are as follows:

i) Better performance in crowded places

Unlike previous Wi-Fi standards, this new version doesn't just focus on improving core speeds. Instead, Wi-Fi 6's priority is to enable much better performance in crowded environments where there are a lot of connected wireless devices, including crowded public places like airports and stadiums. In addition to managing the connection pressure resulting from the ever-increasing number of IoT devices connected to the network, Wi-Fi 6 devices use different technologies to achieve all of this, including OFDM, which allows the wireless communication channel to be divided into a large number of sub-channels, with each channel carrying data dedicated to a different device. This allows more people to use the same wireless channel at the same time in order to more efficient operation, as well as better productivity and much lower latency.

ii) High data transfer rate

In Wi-Fi 6, this technology has been upgraded to double the number of streams that can be transmitted from the previous maximum of four, to approximately eight devices. It also allows devices to respond to a wireless access point that includes multiple antennas at the same time, allowing the access point to connect to multiple devices at once. In addition, the use of QAM-1024 means more capacity to provide super-fast speeds across the coverage area, unlike QAM-256 in Wi-Fi 5. For smart home devices and IoT devices in general, these improvements will be very important going forward to improve the efficiency of wireless Internet connection.

iii) Improved battery life for devices

The new standard supports a technology called Target Wake Time, abbreviated as TWT, which allows the router and connected devices to communicate to determine when the connected devices need to work to send or receive data. As a result, the connected devices will not have to stay in constant contact with the router via wireless signals, which in turn means less battery usage, thus extending its lifespan. This will be particularly useful for IoT devices that communicate over the Internet infrequently, as well as wearable devices, smartphones, tablets, and laptops. Ultimately when you factor in the key features of faster Wi-Fi speeds, greatly improved connectivity in crowded wireless environments, and some improved battery efficiency, there's a lot to look forward to from Wi-Fi 6.

Theory of operation

Figure (3-5) shows the main components of the IEEE 802.11 local area network architecture. The basic unit that makes up this network is called the "Basic Service Set (BSS)), which consists of a central base station (Base Station) known as an access point (AP) and one or more wireless stations (Wireless). In Figure (3-1), there are two access points that connect to the wired network (for example, the Internet) from an interconnection device (such as a switch or router). In a typical home network, there is one access point and one router (usually combined into one unit) to connect the BSS to the Internet.

As in the case of Ethernet devices, each wireless station has a six-byte MAC address stored in the network adapter card in the station. Each AP also has a MAC address for its wireless interface. As in the case of Ethernet, the The IEEE allocates these addresses so that they are different globally. As in the case of Ethernet, the IEEE manages the allocation of these addresses so that they are different globally.

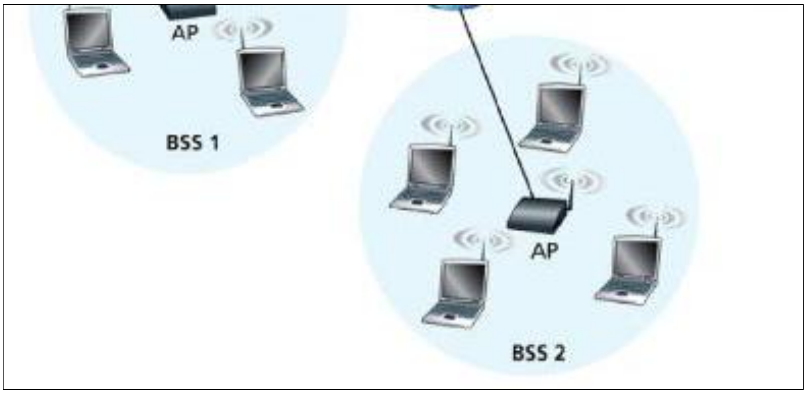

Fig 3-5: IEEE 802.11 Local Area Network Structure

An access point (AP) is a wireless hub. It connects the transmitter/receiver (wireless points) together and connects different wireless devices to form what is called a wireless local area network.

A wireless access point is usually connected to a wired network, to enable communication between wired and wireless devices. Several wireless access points can also be connected to each other to form a larger network, allowing wireless devices to stay connected over a wider area. Modern access points can serve more than 255 clients. From the perspective of the wireless user or client (such as a laptop or mobile station), the access point provides a virtual ground cable that connects the user stations. This "wireless cable" connects the user stations to each other and to the wired network. Clients connect to the access points after knowing the "names" of these points. This identification method is called a Service Set Identifier (SSID) which must be shared by all members.

References

1. Li X, *et al*. A review of industrial wireless networks in the context of industry 4.0. Wireless Netw. 2017;23:23–41.
2. Cisco. Cisco Visual Networking Index: Forecast and Trends, 2017–2022 [Internet]. 2017 [cited 2020 Jan 10]. Available from: https://www.cisco.com/
3. Rouse M. Internet of Things (IoT), 2018.
4. Gubbi J, *et al*. Internet of Things (IoT): A vision, architectural elements, and future directions. Future Gener Comput Syst. 2013;29:1645–60.
5. Whitley D. A genetic algorithm tutorial. Stat Comput. 1994;4(2):65–85.
6. Eberhart R, Kennedy J. Particle swarm optimization. In: Proc IEEE Int Conf Neural Netw, 1995.
7. Zedadra O, *et al*. Swarm intelligence and IoT-based smart cities: A review. In: The Internet of Things for Smart Urban Ecosystems. Springer, 2019, p177–200.
8. Yang XS. Nature-inspired metaheuristic algorithms. Frome, UK: Luniver Press, 2010.
9. Abdulshahed AM, *et al*. The application of ANFIS prediction models for thermal error compensation on CNC machine tools. Appl Soft Comput. 2015;27:158–68.
10. Abdulshahed A, *et al*. A particle swarm optimisation-based Grey prediction model for thermal error compensation on CNC machine tools. In: Laser Metrology and Machine Performance XI, LAMDAMAP 2015; Huddersfield, 2015, p369–78.
11. Kaur M, *et al*. Binary cuckoo search metaheuristic-based supercomputing framework for human behavior analysis in smart home. J Supercomput, 2019, 1–24.
12. Yang N, Xiong M, *et al*. A three dimensional indoor positioning algorithm based on the optimization model. In: Proc 13th Int Conf Nat Comput, Fuzzy Syst Knowl Discov (ICNC-FSKD). IEEE, 2017.
13. Kouhbor S, Ugon J, *et al*. Optimal placement of access point in WLAN based on a new algorithm. In: Int Conf Mobile Business (ICMB'05). IEEE, 2005.
14. Vilović I, Burum N. Location optimization of WLAN access points based on a neural network model and evolutionary algorithms. Automatika. 2014;55(3):317–29.
15. Yigit T, Ersoy M. Testing and design of indoor WLAN using artificial intelligence techniques. Elektron Elektrotech. 2014;20(6):154–7.
16. Sadowski S, Spachos P. RSSI-based indoor localization with the Internet of Things. IEEE Access. 2018;6:30149–61.
17. Pahlavan K, Krishnamurthy P. Principles of wireless networks. Upper Saddle River, NJ: Prentice Hall PTR, 2001.
18. Iskander MF, Yun Z. Propagation prediction models for wireless communication systems. IEEE Trans Microw Theory Tech. 2002;50(3):662–73.
19. Iskander MF, Yun Z. Propagation prediction models for wireless communication systems. IEEE Trans Microw Theory Tech. 2002;50(3):662–73.