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Ali, Ali Mohd, Dhimish, Mahmoud and Mather, Peter (2021) Optimization and Selection of Best Sustainable Services in Various IEEE 802.11 Technologies. Journal of Green Engineering. pp. 420-439. ISSN: 2245-4586

Optimization and Selection of Best Sustainable Services in Various IEEE 802.11 Technologies

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Abstract: The work presented in this paper is demonstrated by the design of the framework/algorithm and the ability to implement a method for analysing network performance in order to achieve the most efficient network set-up based on the technologies currently available; in addition, to identify which IEEE technology and network architecture can be implemented for Best-effort services. Further, the proposed algorithm takes into consideration the selection of networks by various factors such as spatial distribution and number of nodes in order to make it easier to provide high-quality services and best overall network performance. For additional performance improvements and to build a computational algorithm model, we maintain the quality of the service measure for each application, providing accurate numerical results for the classification and identification of the optimum technology overall performance. Our empirical findings support the study and prove the capability of the algorithm proposed.

Keywords: HTTP, FTP, E-mail, QoS, Performance Analysis; IEEE technologies

1.0 Introduction

Managing best-effort services is internet-based, whereby data packets are forwarded at the network layer with no guarantee or preference for reliability or timeliness of delivery, such as HTTP, FTP and E-mail, it is therefore a big obstacle at the moment in the communication industry because it has observed a continued exponential growth. Best effort protocols are used to request/response pattern, and also work in TCP (Transmission Control Protocol) protocols which is an equitably good service for all file transfer applications. File transfer, either explicit (FTP) or implicit such as web page download (HTTP) or E-mail (SMTP), constitutes the enormous majority of Internet traffic. A set of traffic measurements reported in Claffy *et al.* [1] suggests that 95% of IP traffic is TCP, of which HTTP is 70%, FTP 5% and SMTP 5%. It's important to implement the WiFi traffic by rapidly moving business infrastructure and home users to Wireless LAN (WLAN). Wireless Internet is now prominent as it is fast and simple to use [2]. In combination with voice over wireless networks, internet services such as social media, electronic mail and data transmission have an impact on wireless connectivity. The Internet architecture was successfully used to share classic data such as news, texting applications, and file transfers. The delivery of such services, though, puts high demands on the Internet infrastructure in the number of connected users and the ability of their data connections. This significantly influences the quality of service and is especially obvious when WLAN is being used, leading to poor network efficiency [3]. A variety of network performance influencing factors such as, wireless architectures/configuration and IEEE technologies should be discussed and measured in WLANs where multi-applications have been deployed. Nonetheless, the provision of accurate quality of service (QoS) is considered an issue of best-effort services in the presence of real-time multimedia applications [4-7]. In addition, Chen et al. [4] suggested the QoS algorithm to decrease the average delay duration and jitter for VoIP and packet loss for HD video applications. A. Mohd Ali et al. [5] aimed to construct different scenarios to evaluate the characteristics of QoS and to examine the impact of QoS enhancements. The evaluation, carried out using the OPNET simulator, would involve the various parameters of the WirelessLAN802.11e in order to see whether this improvement in the distribution of channel access improves the efficiency of the Wireless LAN 802.11 standard. Wei *et al.* [6] examined HTTP and FTP protocol performances for five users in the same network architecture using two measuring parameters. A. Mohd Ali *et al.* [7] proposes to use an algorithmic and mathematical scheme to allow the user/client to assess the optimum WLAN technology and the performance of the network architecture for a given mix of internet applications such as HTTP, FTP and Email. The QoS metrics were adopted for each application in order to provide accurate numerical results.

Several efforts have been put into evaluating QoS metric parameter applications that have been configured using IEEE technologies [8-12]. Sharma *et al.* [8] observed QoS parameters for end-to- end delays and performance in two IEEE 802.11 and 11g technologies, showing IEEE 802.11a technology improved over BSS architecture. To measure and provision QoS Mehmood and Alturki [9] have implemented the IBSS network analytics framework for a mixture of HTTP, voice and video applications using 802.11g. The architecture well increases the network size and significantly improves popular routing protocols. Circiumarescu *et al*. [10] also performed a comparative analysis to determine which protocol is best adapted for the network between RIP, OSPF, EIGRP and IGRP. This analysis was carried using QoS metric parameters for evaluating VC, E-mail, FTP and the HTTP services with OPNET, such as variation of delay, end-to-end delay and video traffic, showing that the protocol most suitable for VC was EIGRP. In a series of video, voice and best effort nodes, Pérez *et al.* [11] presented a scenario for evaluating IEEE802.11e for the range from 5-45 nodes, with an improvement in average delay for such services. Lakrami *et al.* [12] proposed a new algorithm over infrastructure wireless network to enhance the IEEE 802.11e in order to improve the QoS for voice and video services which gives better results for all performance metrics.

Literature demonstrates a lack of assessment of the best-effort services QoS metrics of various IEEE 802.11 systems with a view to defining the optimal infrastructure and independent network architecture implementation model to be introduced in this article. It is also a huge task to incorporate QoS parameters like delay, jitter, and packet loss on best-effort networks. In addition to various IEEE 802.11 technologies, it is also important to evaluate objectively the technologies to be used and implemented. Furthermore, the availability of different network architectures has led to uncertainty of specifying which network architecture is best used for the assigned wireless network resources to ensure optimum network quality. This is precisely why this research offers an overview study that suggests best possible technology/ technology and network architecture to the user without wasting time and resources.

On the other hand, the "technology", that is the PHY layer is dependent on the hardware used and more capable hardware can automatically downgrade the PHY layer for a lower throughput and better robustness when the signal-to-interference-plus-noise ratio (SINR) is too low. This means that devices can automatically switch from 11g to 11b for instance if the conditions are bad. But still can't upgrade itself automatically from 11g to 11e for instance. As an example, if the devices are valid for a certain bandwidth and it's required to upload 8 Mbps video, at this point the device can’t upgrade itself to match the required bandwidth, so either it is needed to upgrade it physically or downgrade the video quality to optimize the available bandwidth. However, this is exactly where this study is beneficial and provide its main contribution, that it maintains the resources (cost-efficient) and provide network optimization, it is not only considered the usage by its own. The subsequent sections of this article are organized as follows. Section 2 introduces the fundamentals and principles of IEEE physical layer technologies. Section 3 presents the details of the proposed algorithm along with mathematical calculations. In section 4 the results are analysed and evaluated in detail, while section 5 and 6 present a comparative study and the conclusion.

2.2 IEEE 802.11 Principles outline

2.1 IEEE 802.11 technologies

The 802.11 group has been developed as a WLAN technology by the Institute of Electrical and Electronics Engineers (IEEE). IEEE 802.11a is in 5 GHz and 802.11b is in 2.4 GHz, and IEEE 802.11b supports up to 11Mbps transmission and IEEE 802.11a delivers a performance speed of 54 Mbps [13]. Through implementing orthogonal frequency multiplexing division (OFDM) in the 2.4 GHz band, IEEE 802.11g allows the transmission speeds of up to 54 Mbps.The standard IEEE 802.11 does not support time-sensitive applications, it supports just the best-effort services. A new amendment named IEEE802.11e was designed following a number of refinements, with increasing demands for real-time multimedia applications [14].

2.2 Infrastructure of IEEE networks

The main component of 802.11 WLAN is BSS [15]. BSS is a wireless network operated by a central coordination or access point (AP) system. All stations may exchange information with any station within a given range of base stations. A set of infrastructure BSSs is called an ESS. Infrastructure networks shall be built using APs that regulate the communication process. Instead, the IBSS network is a small group of BSS-nodes operating without the assistance of centralized coordination [16].

2.3 Performance measurements of QoS and Importance Coefficient for best-effort services

The QoS metrics for multi-service applications are defined by performance metrics. The criteria for fulfilment of each application (acceptable thresholds) is defined for each QoS metric parameter [15, 17], as shown in Table 2, reflecting main QoS specifications and guidelines for each application (bearer traffic). The following QoS metric measurements explicitly impact the efficiency of the best-effort applications:

- Packet End-to-End delay (sec): The transmission rate from node A to node B on the network is being used by data / voice.
- Page response time (sec): The time necessary to download the whole page including all inline objects embedded.
- Throughput (bit/sec): The cumulative rate at which packets are transmitted at a given time from the source to the destination.

- Traffic Sent (packet/sec) and Traffic Received (packet/sec): utilised measure the loss rate of packets, which is the proportion of packets lost further along communication path, once the transmitter sends the packet to the network.

It is noteworthy that every best-effort application parameter has a significant coefficient (ICB), in terms of its impact on service quality. Table 1 demonstrates the consistency importance and the associated threshold values for each application for each QoS parameter. These qualitative considerations (H=1, M=0.5 and L=0.1) to be taken into account in the simulation should be converted into numbers

Table 1 Importance coefficient and threshold values for best-effort services

Application	Importance & Threshold	Delay/Response time (sec)	Throughput (kbps)	Racket Loss Rate (%)
E-mail	Importance	L	L	L
	Threshold	1	30	10
HTTP	Importance	M	L	L
	Threshold	1	30	10
FTP	Importance	L	M	H
	Threshold	1	45	5

3.0 Algorithm proposed: Selection of protocol and architecture for network

3.1 Development schemes (Environment simulation)

This paper uses an OPNET model of simulation [18] to construct and evaluate all scenarios. OPNET Modeler offers the ability to easily explore network communication, facilities, architectures and protocols. We have taken two key sources' inputs for this algorithm into account with the OPNET simulation: user configuration and technical specifications (standards). The size of the network and space distribution is described in user configurations. Technology specifications describe the technology and architectures of the physical layer. These factors are defined in the top part of the Fig. 1. Network architectures indicate how wireless nodes interconnect with each other in one of the two approaches: the existence of AP (BSS and ESS) or lack of AP (IBSS), the size of the network needed (1-5, 6-10, 11-20, 21-40) and spaces allocations, which topological distribution of wireless implemented nodes is defined (circular, random, uniform). IEEE MAC Technologies describes the IEEE 802.11 technologies that are used to build several possible scenarios. Figs. 2(a), (b) and (c) show some of these implemented scenarios. The performances in just about every service / application scenario were analysed using the OPNET Modeler platform. The IEEE standards/technologies used were 802.11, 11a, 11b, 11g and 11e. The protocols used and the multi-service applications' settings for the simulation are listed in Tables 2, 3 and 4.

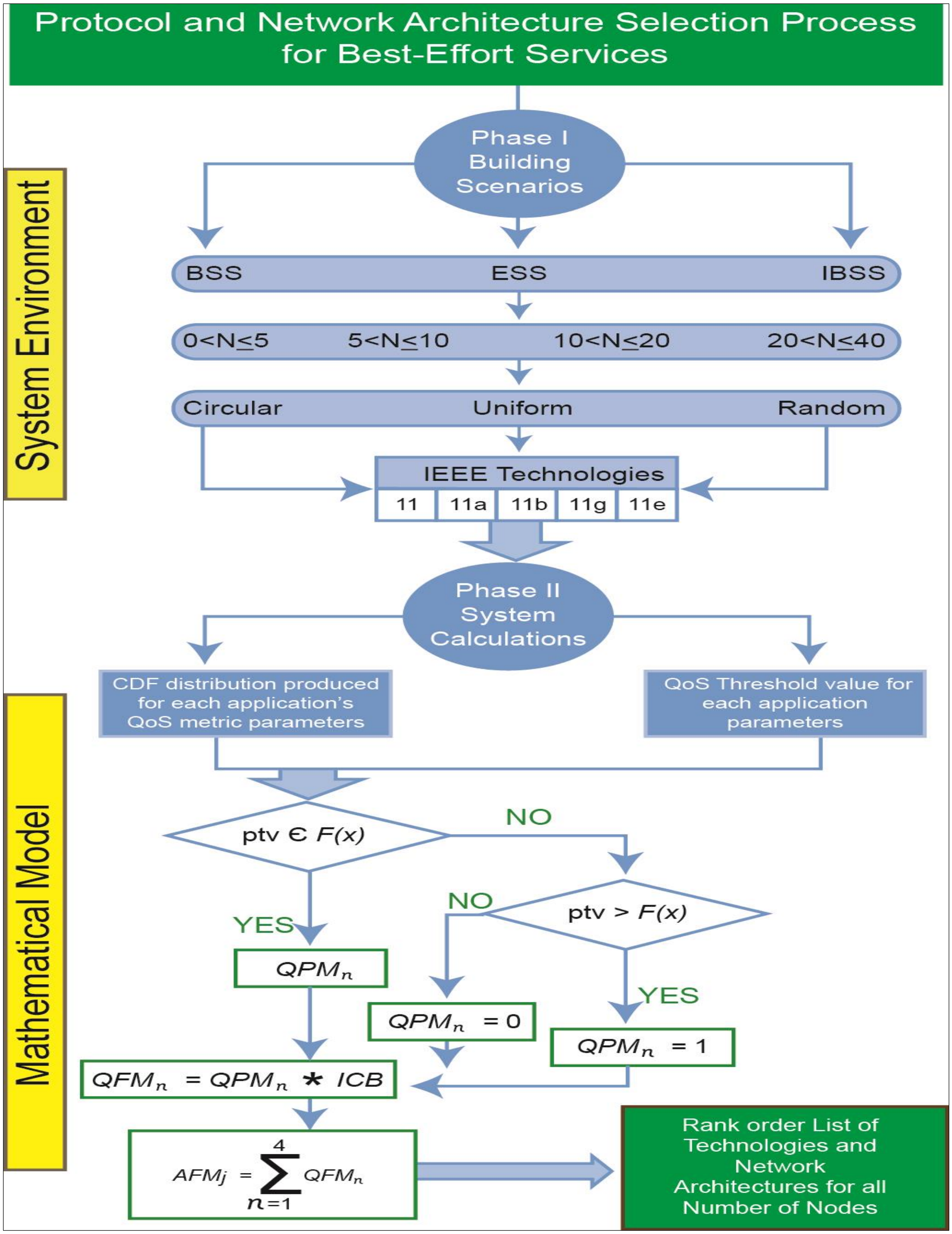


Figure 1: Proposed algorithm flowchart

The literature [6, 9 and 11] is consistent with a number of nodes known to be up to 40. At the other hand, the findings obtained using these four groups of nodes were considered suited to preserve the consistency of network efficiency, that is more nodes within the network, which means that relatively few traffic volumes cause service quality deterioration due to bandwidth ability of fixed network

Table 2: E-mail Simulated traffic parameters

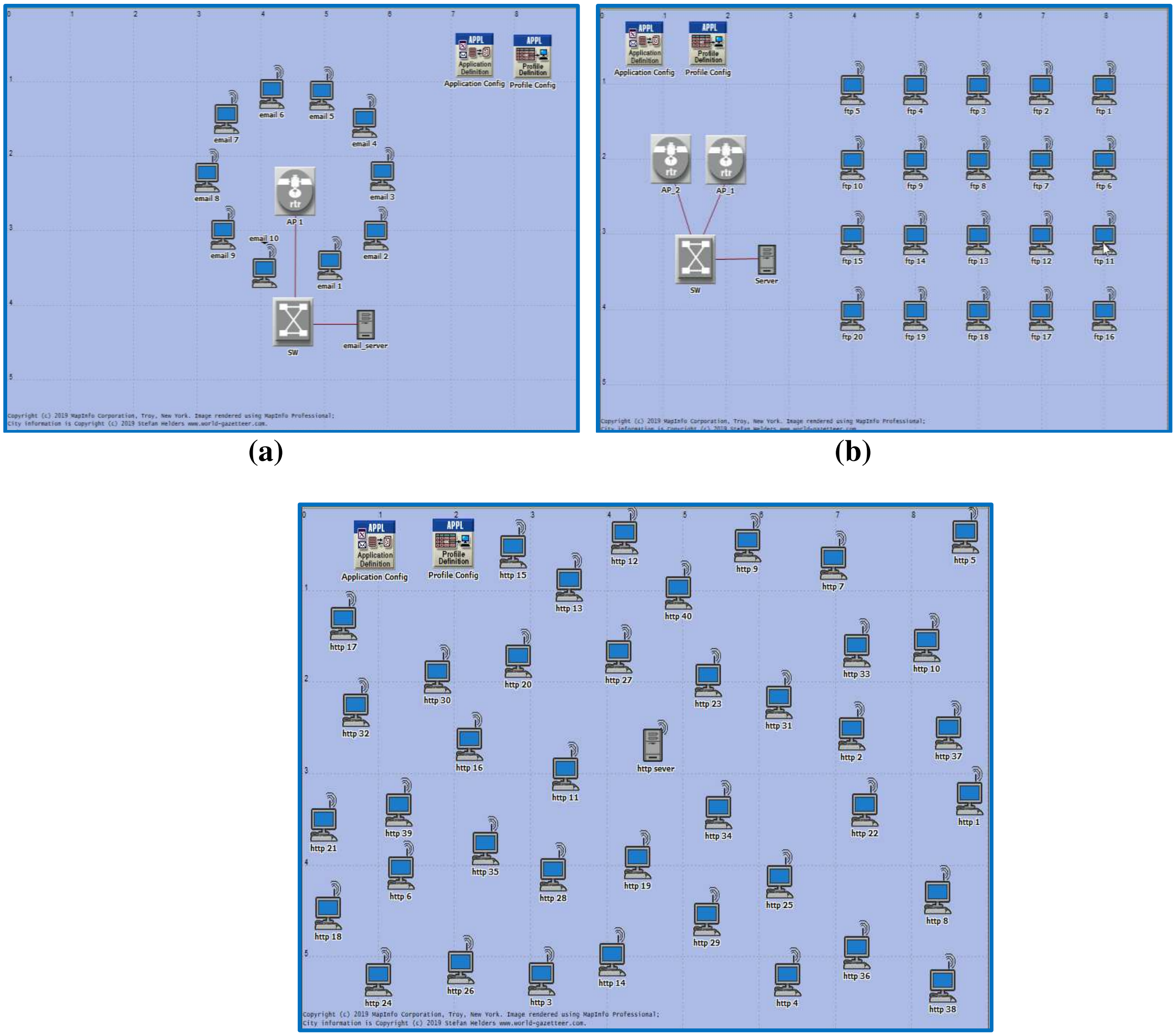
Parameters	Values
Send Inter-arrival Time (sec)	exponential (360)
Receive Inter-arrival Time (sec)	exponential (360)
E-Mail Size (bytes)	20000
Symbolic Server Name	Email Server
Types of service (TOS)	Best Effort

Table 3: HTTP Simulated traffic parameters

Parameters	Values
HTTP Specification	HTTP 1.1
Page Interval Time (sec)	Exponential (60)
Types of service (TOS)	Best Effort

Table 4: FTP Simulated traffic parameters

Parameters	Values
Command Mix (Get/Total)	50%
Inter-Request Time (sec)	Exponential (360)
File Size (bytes)	50000
Types of service (TOS)	Best Effort



(a) (b)

(c)

Figure 2: Network Architectures for E-mail, FTP and HTTP across three Spatial Distributions **(a)** BSS, **(b)** ESS, **(c)** IBSS

3.2 Structure for the Computation System

In the lower part of Fig. 1, Phase II displays the system calculations and the mathematical model. QoS Threshold values for each application and cumulative distribution function (CDF) were used to input the mathematical calculations of the algorithm. There will be mathematical calculations to see how many performance metrics have been achieved for each scenario. In order to illustrate the calculations and the results for each of the projects above, the following criteria must be met.

- QoS Performance Metric (QPM): As shown in Fig. 3, the value produced by the use of the QoS metric Parameter Threshold value (PTV) application in CDF distribution F(n), for each performance criterion n, that is expressed by (1).

$$QPM_n = F(ptv) \qquad (1)$$

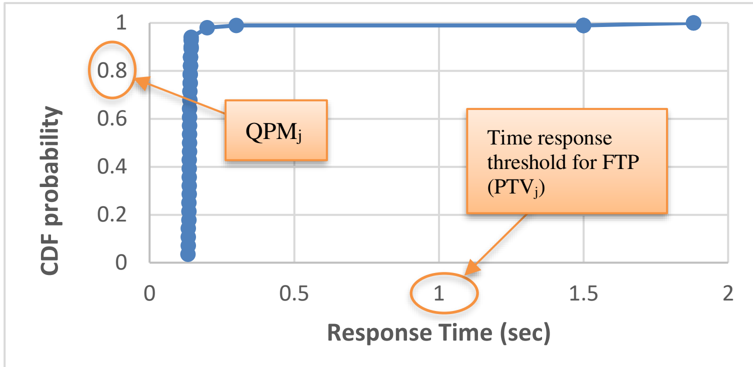


Figure 3: QPM for Response time

QoS Fitness Metric (QFM): The weighting value for QPM for each QoS metric parameter generated by the use of (H=1 and M=0.5 and L=0.1), is expressed by (2).

$$QFM_n = QPM_n * ICB \qquad (2)$$

Finally, the Application Fitness Metric (AFM) is measured, and all QFMs are aggregated with n application QoS metric parameters (delay, jitter, throughput and losses), for j IEEE 802.11 technology, as express by (3).

$$AFM_j = \sum_{n=1}^{4} QFM_n \qquad (3)$$

The rank order of the five IEEE technologies will be generated for every network architecture based on AFMs. As stated earlier, CDF distribution F(n) [19] will be generated from the OPNET modeler simulation and then analysed for PTV in all applications by QoS metric parameters:

1. If $ptv \in F(n)$: For this metric parameter, it means *PTV*'s CDF distribution has a particular value equal to QPM. In order to produce QFM, QPM is weighted by ICB. Then all QFMs are added to AFM that is used to categorize IEEE 802.11 technologies.
2. If $ptv > F(n)$: It implies that the value of QPM is equal to 1 and QFM has been generated.
3. If $ptv < F(n)$: QPM equals null and QFM is initialized.

The resulting value for QoS applications will lead for filling out Table 5, which ultimately can lead to a rank of IEEE technologies for each architecture in the network. All QoS metric applications are computed, except for the packet loss parameter, as outlined in the previous sections. OPNET Modeler is programmed to generate a Boolean value (0.0 or 1.0) resulting from a packet loss parameter that corresponds to packet acceptance or rejection. But for the packet loss this work needs a numerical value. A code for a method for calculating the packet loss percentage for each application was developed using MATLAB software. This is directly related for each application to the OPNET Modeler to generate a particular percentage of packet loss. Application packet loss rate ω_i for a node i is the proportion of the packet lost ki to the overall packet ρ_i times 100%, as expressed by (4).

$$\omega_i = (ki/\rho_i) * 100\% \qquad (4)$$

To generate the total number of received and sent packets, the traffic received/sent rate of OPNET Modeler should be integrated and offered as a CDF illustration.

Table 5: Calculation of IEEE technologies and order lists for a specific project

Technology	**Application**			**AFM**	**Technology Rank order**
	Delay/Response Time	**Throughput**	**Packet Loss**		
802.11	QFM_D	QFM_{TH}	QFM_{PL}	$\boldsymbol{AFM_{11}}$	Technology1
802.11a	QFM_D	QFM_{TH}	QFM_{PL}	$\boldsymbol{AFM_{11a}}$	Technology2
802.11b	QFM_D	QFM_{TH}	QFM_{PL}	$\boldsymbol{AFM_{11b}}$	Technology3
802.11g	QFM_D	QFM_{TH}	QFM_{PL}	$\boldsymbol{AFM_{11g}}$	Technology4
802.11e	QFM_D	QFM_{TH}	QFM_{PL}	$\boldsymbol{AFM_{11e}}$	Technology5

4.0 Findings and assessment of Results

In this paper, the algorithm output describes the client (user) options available based on the results table generated. Preferences suggest the optimum technological performance in all three network architectures. The findings are divided into three main divisions (HTTP, FTP and E-mail) relating to the best-efforts services. All modelled/simulated scenarios are for laboratory (room) dimensions from 2x3 m to 10x14 m. The result format is displayed based on the existence of an AP; thus, the results tables are converted into two flowcharts of results: the generic flowchart and the IBSS flowcharts.

- If the network has at least one AP, the proposed algorithm will be implemented in Fig. 1 and the result will be in Figs. 4, 6 and 9. This case applies to both layers of infrastructure (ESS and BSS). In every IEEE 802.11 technology and three spatial distributions, all scenarios function: circular, uniform and random.
- The proposed flowchart in Fig. 1 and the result in IBSS defined in Figs. 5, 7 and 9, will be used if the network is configured without APs. The five IEEE 802.11 technologies and three spatial distributions are all covered.

The findings of both results are based on the number of nodes used to configure the required network and to work for 1 to 40 nodes environment.

4.1 Results of HTTP

The algorithms for both the results indicate four key node groups presented as follows, depending on the user configuration to create the specified network.

1. The first, second and fourth categories, (1-5), (6-10), (21-40), respectively, in the generic flowchart as shown in Fig. 4, both BSS and ESS architectures have the optimal output for all five technologies throughout all spatial distributions. However, in the case of the IBSS flowchart for the first and second categories, the 802.11 technology provides the best performance, while all technologies performing well in the fourth category, for all three spatial distributions as shown in Fig. 5.
2. The BSS and ESS offer a number of options in the third category (11-20), is present in the generic flowchart. For BSS architecture, all three space distributions are well equipped with the five technologies. The preferred ESS solutions are recognized as IEEE 802.11, 11b and 11g. However, according to the IBSS flowchart, all IEEE technologies are performing well as can be seen in Figure 5.

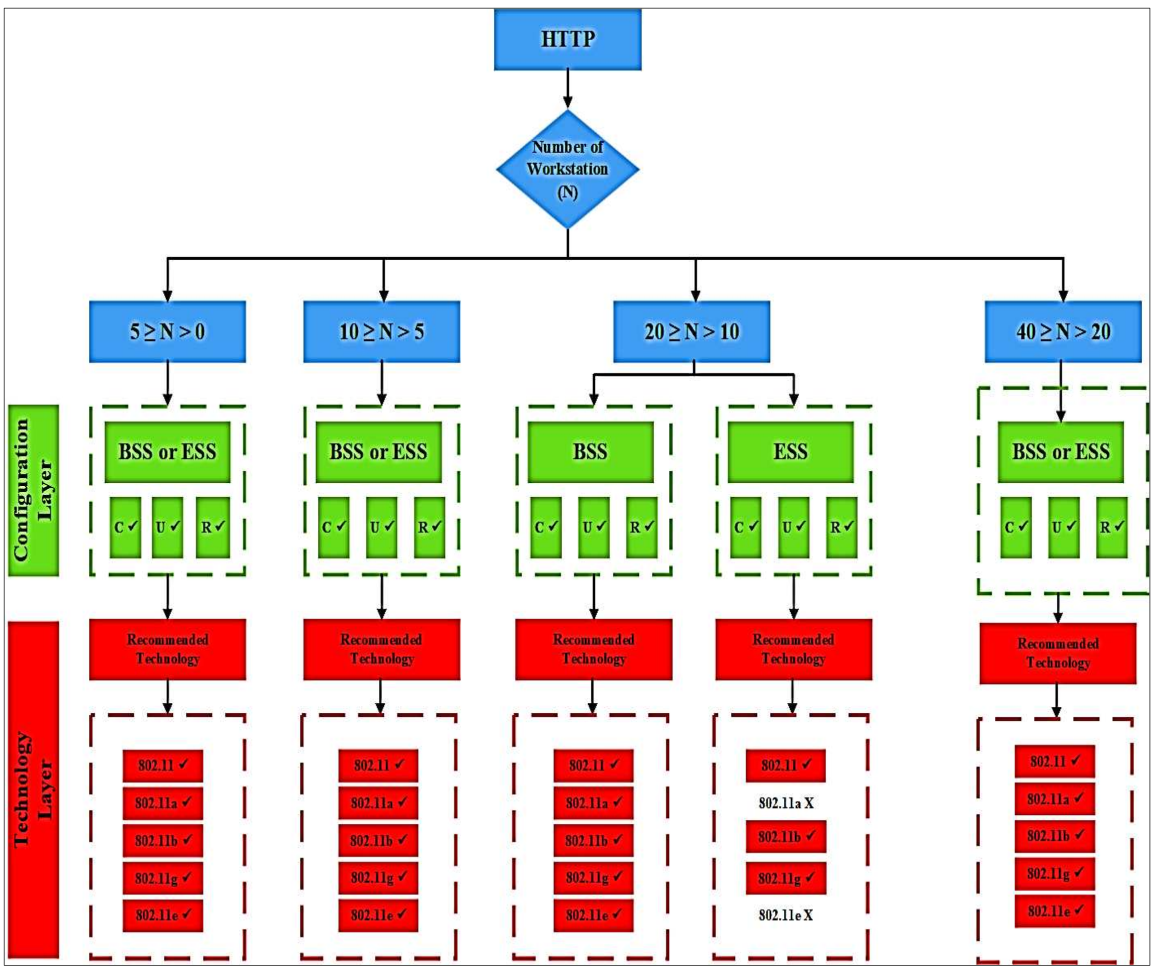


Figure 4: Generic proposed algorithm for HTTP

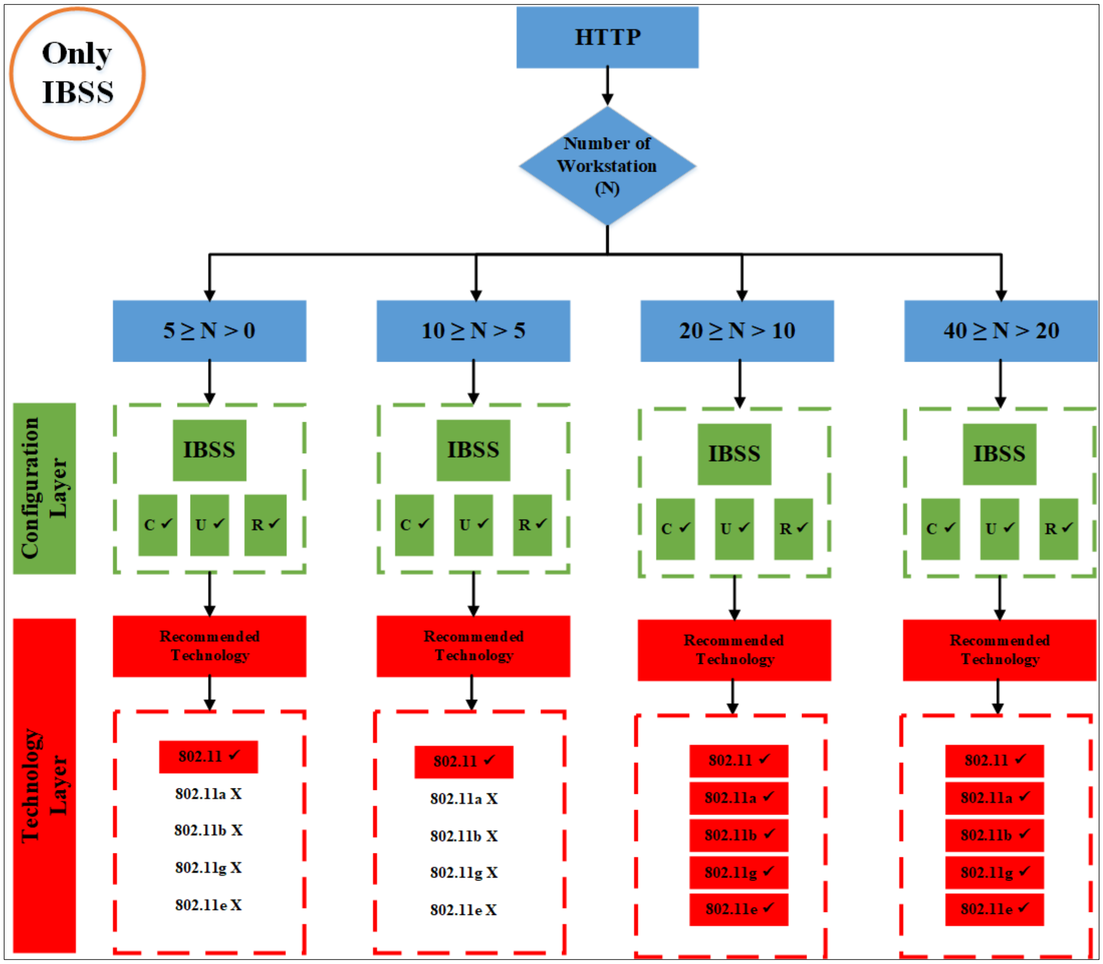


Figure 5: IBSS's results for HTTP

4.2 Results of FTP

1. BSS is the optimal architecture network in the first category (1-5), in the generic flow chart, as shown in Fig, 6. The five technologies perform well across uniform and random distributions. However, according to the IBSS flowchart, IEEE 802.11b technology is considered the preferable solution as demonstrated in Fig. 7
2. BSS and ESS have many choices in the second category (11-20), across all three spatial distributions for the five IEEE standards. All technologies, however, work well in all distribution patterns according to the IBSS process flow
3. As demonstrated in Fig. 6, both generic algorithms have optimum output for all five technologies that users can choose from in the third category (11-20). For the fourth group (21-40), ESS for all of the spatial distribution is the appropriate network architecture for that wide network. However, according to the IBSS flowchart, all technologies perform well across all spatial distributions for both categories, third and fourth, as shown in Fig. 7.

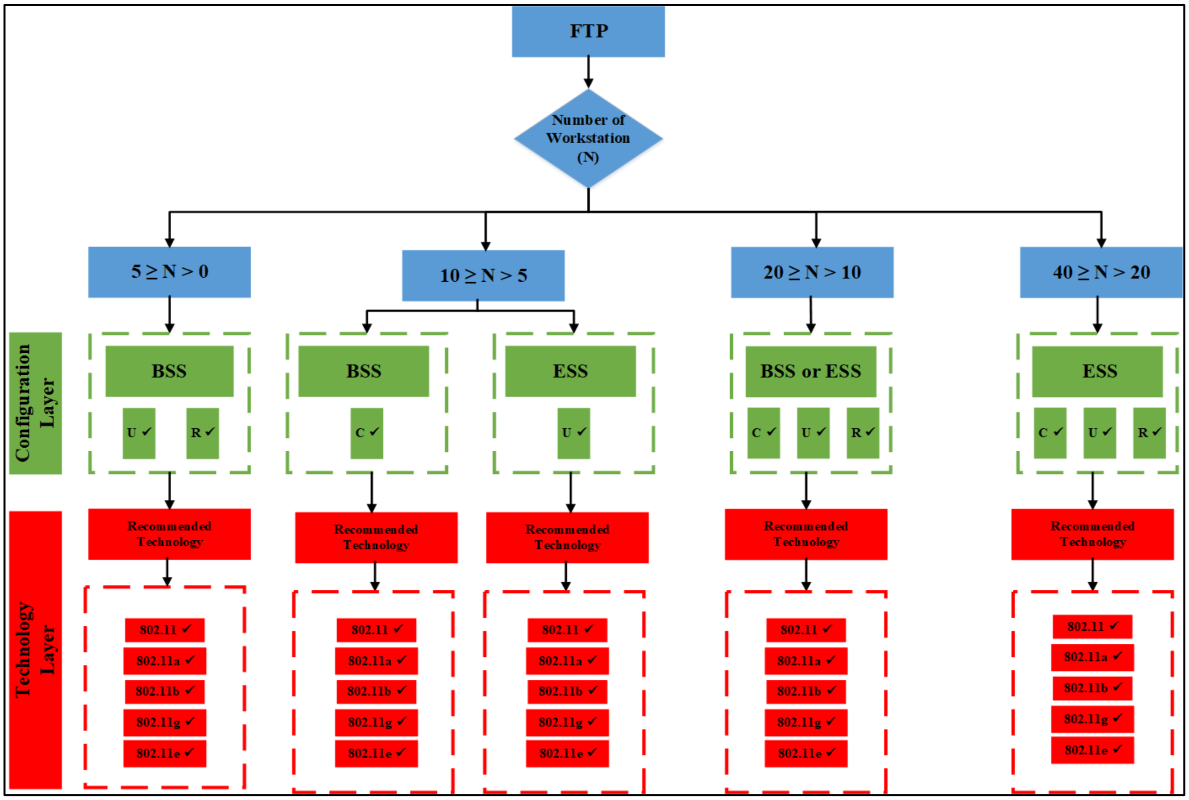


Figure 6: Generic proposed algorithm for FTP

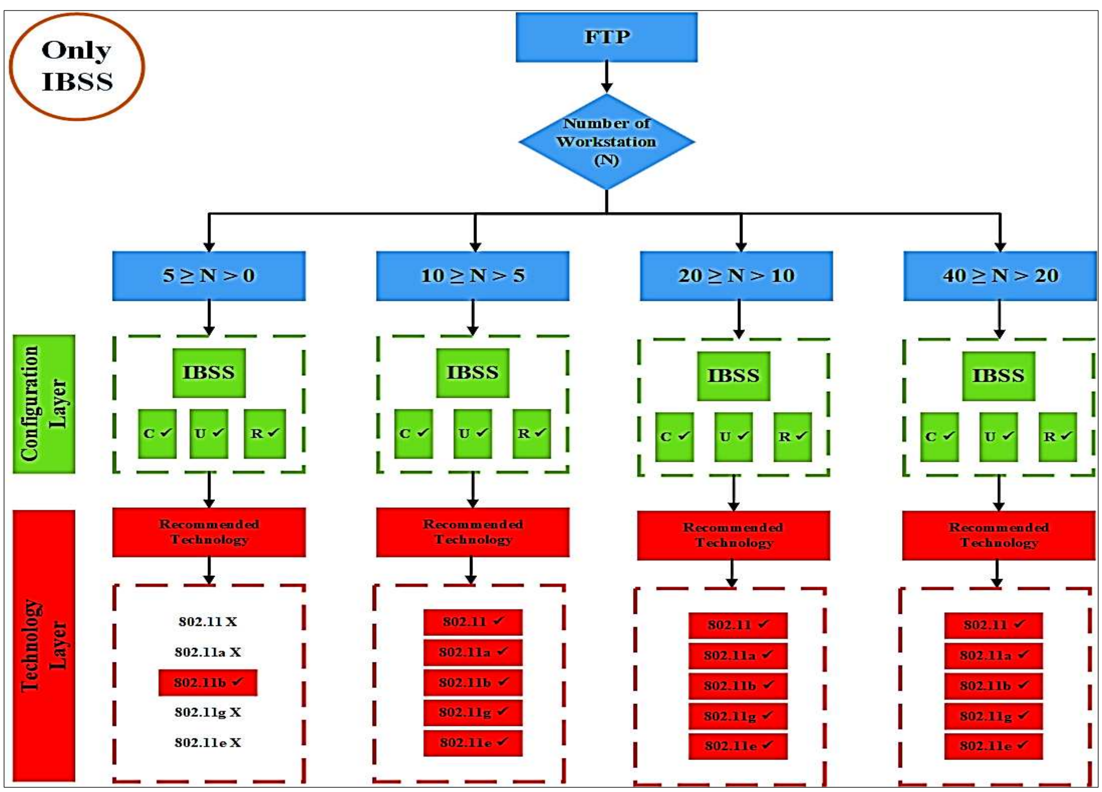


Figure 7: IBSS's results for FTP

4.3 Results of E-mail

1.0 As seen in Fig. 8, where the client generates very less network of $5 \geq N > 0$, both the ESS and the BSS provide optimal efficiency in all three space distributions, when configured only with three technologies including 802.11a, 11g, and 11e. For the IBSS case, 802.11a continues to be the optimal technology throughout all spatial distributions, as Fig. 9 shows.

2.0 The second and third ranges (6-10) and (11-21), respectively, are the best output in the generic flow diagram, as shown in Fig. 8 in all distribution pattern, in which only three technologies are proposed, namely 802.11a, 11 g, and 11e. The technology 802.11a stays the optimal for both categories for the IBSS flow chart in all spatial distributions as seen in the Fig. 9.

3.0 The fourth group, which includes 20 to 40 nodes, for this large network the ESS is the best architecture. Then, according to the details given in Fig. 8, the client can choose two options (802.11a and 802.11g). The 802.11a and 11g systems are suitable for use in all spaces. While, in the IBSS flowchart, 802.11a provides the finest quality in all space distributions

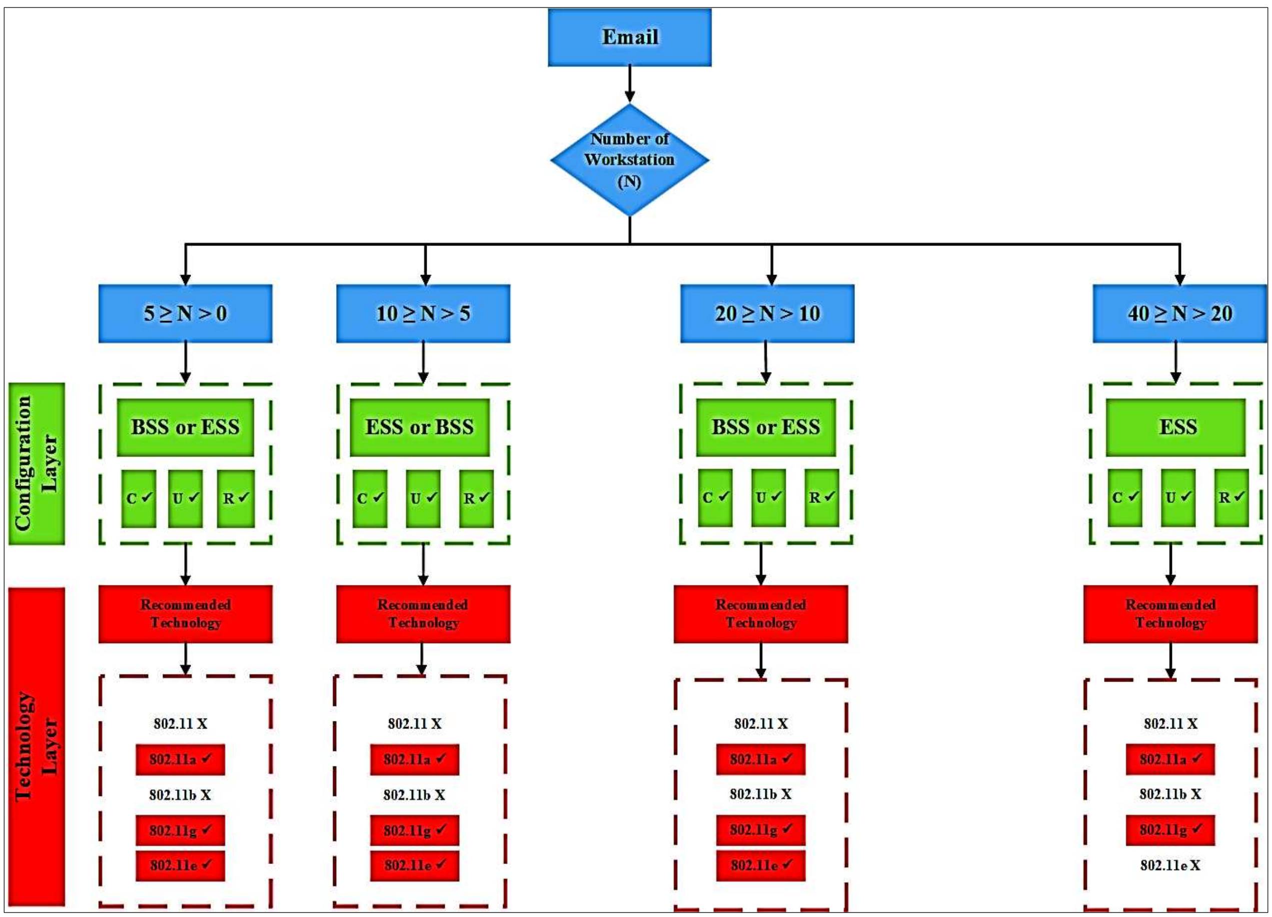


Figure 8: Generic proposed algorithm for E-mail

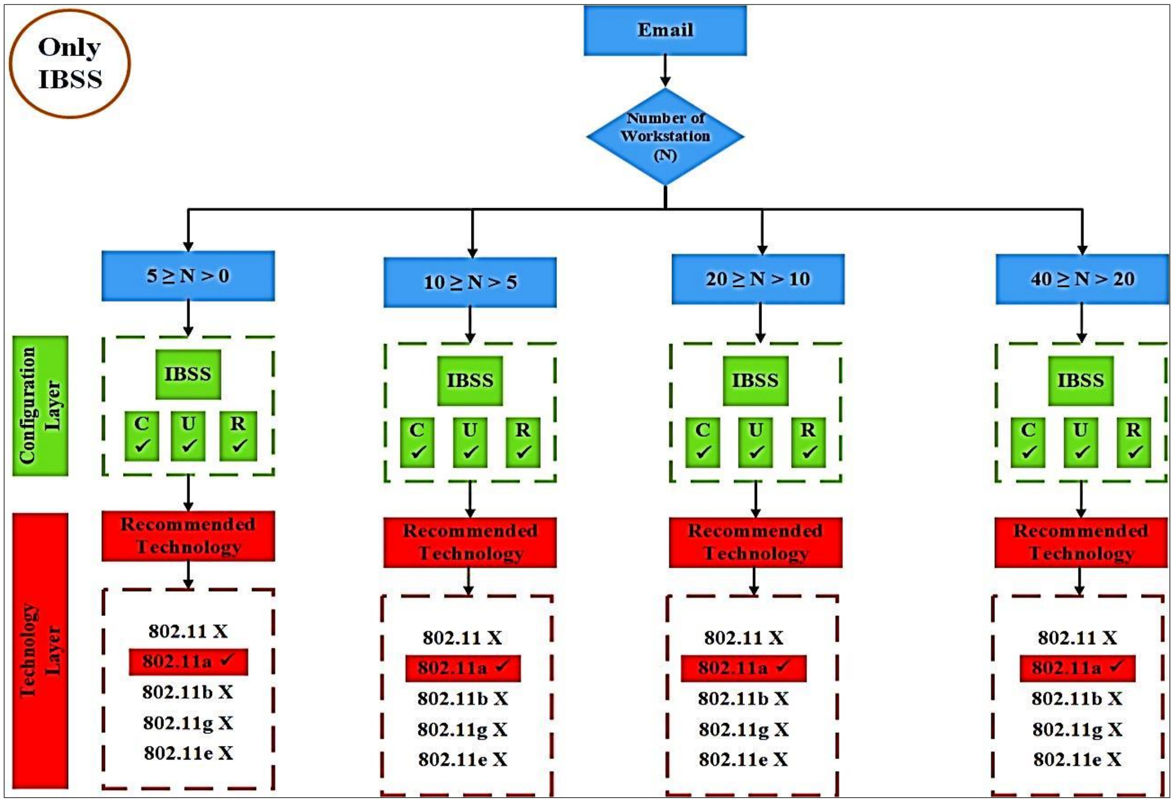


Figure 9: Only IBSS's results for E-mail

5.0 Comparative Study

In this section, a brief comparison between our proposed method with multiple algorithms presented in Wei *et al*., Mehmood and Alturki, Pérez *et al.*, Pal and Vanijja, and AlAlawi and Al-Aqrabi [6, 9, 11, 20 and 21] will be presented. The following features have been compared and summarised in Table 6, features including QoS metric parameters, number of nodes, network architecture, IEEE technology, and the simulation model. As noticed, methods such as Mehmood and Alturki [9] and AlAlawi and Al-Aqrabi [21] incorporated their model with different nodes 9, 25 and 49 and 3-15, respectively, in which the optimum network configuration calculation is dominated by metric parameters such as the end-to-end delay and throughput. Moreover, only IBSS and ESS architectures were being used to validate their proposed approaches. A further downside associated with the Mehmood and Alturki [9] and AlAlawi and Al-Aqrabi [21] approaches is that the evaluation of the algorithm only takes into account one IEEE standard, in particular IEEE 802.11 g and 802.11e. Likewise, Wei *et al.* [6] and Pérez et al. [11] evaluate different IEEE technologies using various nodes and considering only one architecture, such as IBSS and BSS. Methods such as Pal and Vanijja [20], on the other hand, test the network based on the fixed number of nodes (15). Their strategies were only verified with the aid of IBSS network architecture and 802.11b as the only IEEE technology to be configured.

Table 6: Comparative results between the proposed approach and several methods available in the literature

Reference	Approach	QoS metric parameters	Number of nodes	Network Architecture	IEEE Technology	Simulation model
[6]	During the same network environment, different clients examined the efficiency of HTTP and FTP protocols.	Average queuing delay TCP delay	5-30	IBSS	NA	OPNET
[9]	Present an ad hoc network supplier and routing architecture that analyzes over 802.11 g networks with a combination of HTTP, voice and video streaming applications.	End-to-end delay Throughput Delay variation	9, 25 and 49	IBSS	802.11g	OPNET
[11]	Assess the conditions for QoS support protocol for EDCA 802.11e in 802.11a scenario at 36 Mbps.	Average delay Queue size	5-45	BSS	802.11e	Möbius™

[20]	VoIP QoS performance metrics were studied using different routing protocols.	Jitter LAN delay Packets size	15	IBSS	802.11b	OPNET
[21]	Assess VoIP performance in wireless 802.11 networks.	End-to-end delay Jitter Throughput	3-15	ESS	802.11e	OPNET
Present study	To determine the optimum network architecture, evaluate Email, HTTP and FTP metrics from different IEEE 802.11 technologies.	Delay Jitter Throughput Packet loss	1-40	BSS ESS IBSS	802.11 802.11a 802.11b 802.11g 802.11e	OPNET

In opposition to the above restrictions, we present in this article a new parametric evaluation approach which identifies the perfect network configuration with three different network architectures: BSS, ESS and IBSS. The methodology has tested three applications with best-effort in various node sizes (1 to 40) in terms of five different IEEE 802.11standards.

6.0 Conclusion

In order to identify an optimal network architecture between BSS, ESS and IBSS, this study has established a new Algorithm for evaluated best-effort applications from different IEEE 802.11 technologies in different space distributions. The findings of FTP applications show the preference for the use of an ESS network with a large number of workstations / nodes within the network due to the substantial loss of packets and the delay caused by that workstations in that network. Moreover, nearly all IEEE technologies are available for all spatial patterns. IBSS is also efficient to operate in nearly all network sizes using any technology. In comparison, the ESS architecture works similarly for all spatial patterns independent of the network size for both E-mail and HTTP services. In spite of the deterioration of the efficiency of the BSS when the number of nodes for E-mail reaches 20, it works well for all nodes for HTTP. In addition, the results of HTTP indicate that IBSS works well in small network sizes with 802.11 technologies and in large technologies but the results of the E-mail reveal the IBSS technology of 802.11a that is appropriate for the OFDM modulation technique at 5 GHz.

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