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IDENTIFYING THE OPTIMUM NETWORK ARCHITECTURE AND WLAN TECHNOLOGY FOR VIDEO CONFERENCING APPLICATION

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Abstract - Handling Video Conferencing (VC) services is currently a vast challenge in the communication industry. Wireless networks have been designed to provide provision for real-time applications such as VC. VC QoS metrics should be evaluated for different IEEE 802.11 technologies in order to identify the optimum technology standard across different infrastructure and network architectures.In this paper, an algorithm scheme is proposed to evaluate VCservices of different IEEE 802.11 technologies in order to identify the optimum network architecture among Basic Service Set (BSS), Extended Service Set (ESS), and the Independent Basic Service Set (IBSS).Hence, the algorithm considers and evaluates multi-criteria access network selection such as spatial distribution and number of nodesto facilitate the provision ofthe best overall network performance and high-quality services.

Keywords - Video Conferencing, IEEE technologies, Performance Analysis, QoS.

I. INTRODUCTION

Video conferencing is widely adopted by end-consumers in everyday life. The Internet architecture has been successful in supporting traditional data applications like textual applications, news, and file transfer. In addition, it is able to fulfil the demands of real time applications such as video conferencing [1].Wireless LAN (WLAN)connects people and allow to access information over a distance without cables; it operates in an air interface.WLAN has become more and more popular these days because of the easy and simple deployment process [2]. By providing permanent access to the network resources and implementing of real-time traffic such as video and audio in business, institutional and home networks the WLAN become a dominant service and gained increased popularity.Internet-based services such as web, email and file transfers affect the usage of WLANs in addition to voice over wireless networks. Real-time applications enable users to use the Internet as a transmission medium by sending voice data in packets using Internet Protocol (IP) rather than by traditional circuit-switched Public Switched Telephone Network (PSTN).In WLANs where VCapplications have been deployed, a number of aspects that affect the network performance should be analysed and evaluated such as the wireless network architectures (BSS, ESS and IBSS) and IEEE MAC layer technologies [3].

VC performance over WLAN standards has been analysed in number of studies [4], [5]. Baldi and Ofek [4]analysedthe end-to-end delay VC QoS metric in six system configurations obtained by combining three network architectures with two video encoding schemes in order to provide adequate end-to-end delay below 10ms.Aperformance evaluation study has been proposed of IEEE 80211e compared to the legacy 802.11 in Mangold et al. [5] over BSS network architecture through building different simulation scenarios.

Various efforts have been developed to evaluate VC QoS metric parameters that are configured over IEEE technologies [6]–[8]. QoS parameters such as an end to end delay and throughput were observed by Sharma et al. [6] across two IEEE technologies 802.11, 11g and demonstrated that the IEEE 802.11a technology performed better across BSS network architecture.Mehmood and Alturki [7] introduced an architecture that analysed an IBSS network for a mix of HTTP, voice and video applications over 802.11g technology to scale and provisions QoS. This architecture scales well with an increase in the network size, and outperforms well-known routing protocols.Lakramiet al. [8] 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.

II. PRELIMINARIES

A. IEEE MAC Layer Technologies

The Institute of Electrical and Electronics Engineers (IEEE) developed the 802.11 group as a technology for WLAN technology. IEEE 802.11a operates in the 5 GHz frequency band and 802.11b operates in the frequency band 2.4 GHz, IEEE 802.11b supports transmission speeds of up to 11 Mbps and IEEE 802.11a provides a transmission speed of 54 Mbps [9]. IEEE 802.11g supports transmission speeds of up to 54 Mbps by applying Orthogonal Frequency Division Multiplexing (OFDM) in the 2.4 GHz band. IEEE 802.11 standard does not support time-sensitive voice applications but only best-effort services. After several refinements and with the increasing call for real-time applications, a new amendment named IEEE 802.11e was designed [10].

B. IEEE Network Infrastructures

IEEE 802.11 defines two basic modes of communication between WLAN nodes: Infrastructure and Independent which are known as Ad Hoc Networks [11]. Infrastructure BSS is a group of stations that connect to the same wireless medium and are controlled by a centralized coordination function or access point (AP). All stations can communicate directly with all other stations in a fixed range of the base station. The IEEE 802.11 infrastructure networks use APs. AP supports wave extension by providing the integration points necessary for network connectivity between multiple BSSs, thus forming an Extended Service Set (ESS). In addition, the IBSS or Ad-hoc network is a specified group of nodes in a single BSS for the purpose of internet working without the aid of a centralized coordination function [12] (i.e. access point).

C. QoS Performance Metrics and Importance Coefficient for Real-time Applications

Performance metrics are defined in terms of QoS metric parameters for real-time applications. For each application, a satisfaction criterion (acceptable threshold) for each QoS metric parameter is identified [13], [14] as shown in Table I, which represents the key QoS requirements and recommendations for each application (bearer traffic).

TABLE I QoS METRIC PARAMETERS IMPORTANCE FOR VC APPLICATIONS

Application	Importance & Threshold	Delay (sec)	Packet Delay Variation (sec)	Throughput (kbps)	Racket Loss Rate (%)
VC	Importance	H	H	H	M
	Threshold	0.15	0.03	250	1

Where: H=High and M=Medium

The VC quality is directly affected by the following QoS metric measurements:

- Packet End-to-End delay (sec): the time taken by data/voice to travel from node A to node B on the network, should be below 150 ms.
- Packet Delay Variation (sec): the variance in delay caused by queuing, should be less than 30 ms.
- Throughput (bit/sec): the total rate at which packets are transferred from the source to the destination at a prescribed time period. The required throughput for a VC in one direction is 250 kbps.
- Traffic Sent (packet/sec) and Traffic Received (packet/sec): used to calculate packet loss rate, which is the percentage of packets that get lost along the communication path after the packet is transmitted by the sender into the network, which should be below 1%.

It is worth noting that an important coefficient is assigned to each VCparameters (VCP) in terms of its impact on the call and image qualityof the service. Table I shows the QoS qualitative importance of each QoS parameter and their related threshold values for VC application. In order to be able to account for these qualitative factors in a simulation they have to be translated into numbers (H=1 and M=0.5).

III. PROPOSED ALGORITHM: PROTOCOL AND NETWORK ARCHITECTURE SELECTION

A. Building Projects (Simulation Environment)

In this paper, an OPNET simulation platform [15] is used to build and analyse all applications scenarios. Using OPNET Modeller, we have considered two main inputs for the user configuration stage, these are: the number of nodes and VC application.

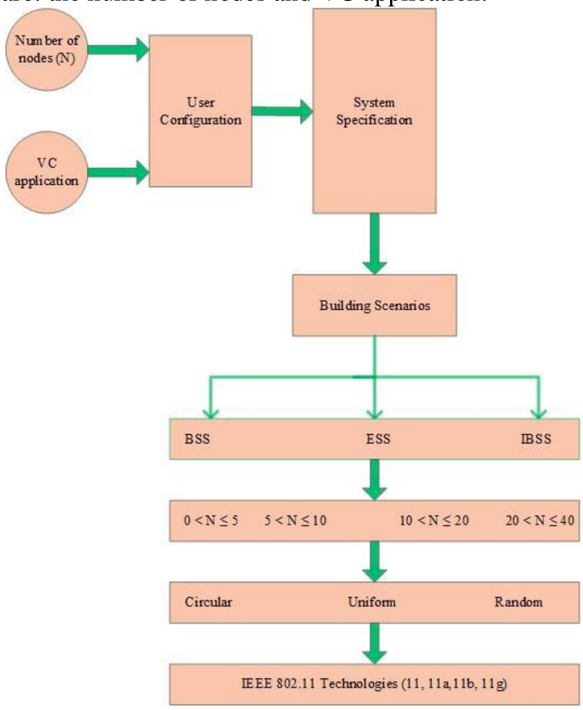

Fig. 1 Flowchart of the proposed algorithm

Fig. 1. illustratesthe main factors of this algorithm. System specification definesthe environmental aspects that will be studied and analysed to build many different scenarios:network architectures, spatial distributions and QoS metrics. Network architectures specify how different wireless components connect together in either of two modes: the presence of access points (BSS and ESS) mode or the absence of access points (IBSS) mode, spatial distribution which specifies the topology in which these nodes will be distributed – in a circular (oval)

way, uniform way, or randomly scattered way, number of nodes needed in this network which breaks down to four groups (0-5, 6-10, 11-20 and 21-40). IEEE MAC Technologies defines the physical layer technologies that will be used to build many different scenarios. All network architectures (BSS, ESS, IBSS) have been configured and implemented across all three spatial distributions (circular, uniform, random) for the four groups of nodes. Figs. 2(a), (b) and (c) show some of these implemented scenarios. VCapplications' settings for the simulation run which lasted for 20 minutes, the VC traffic has been configured with the following parameters: the VC traffic parameters configuration are (High resolutions): the frame interarrival time is 15 frame/sec and frame size information of 128x240 pixels (bytes).

B. System Model's Calculation

The system calculations and the mathematical model are shown in Fig. 3. The inputs for the algorithm's mathematical calculations are QoS Threshold values for VC application and Cumulative Distribution Function (CDF). VC QoS Threshold values (satisfaction criterion) are taken from literature as shown in Table I [13], [14]. CDF distribution is produced for these QoS metric parameters from OPNET after running the simulation scenarios. Mathematical calculations will be done to determine how a particular scenario has satisfied certain performance metrics for each application. The following steps are used to explain the calculations of this algorithm results:

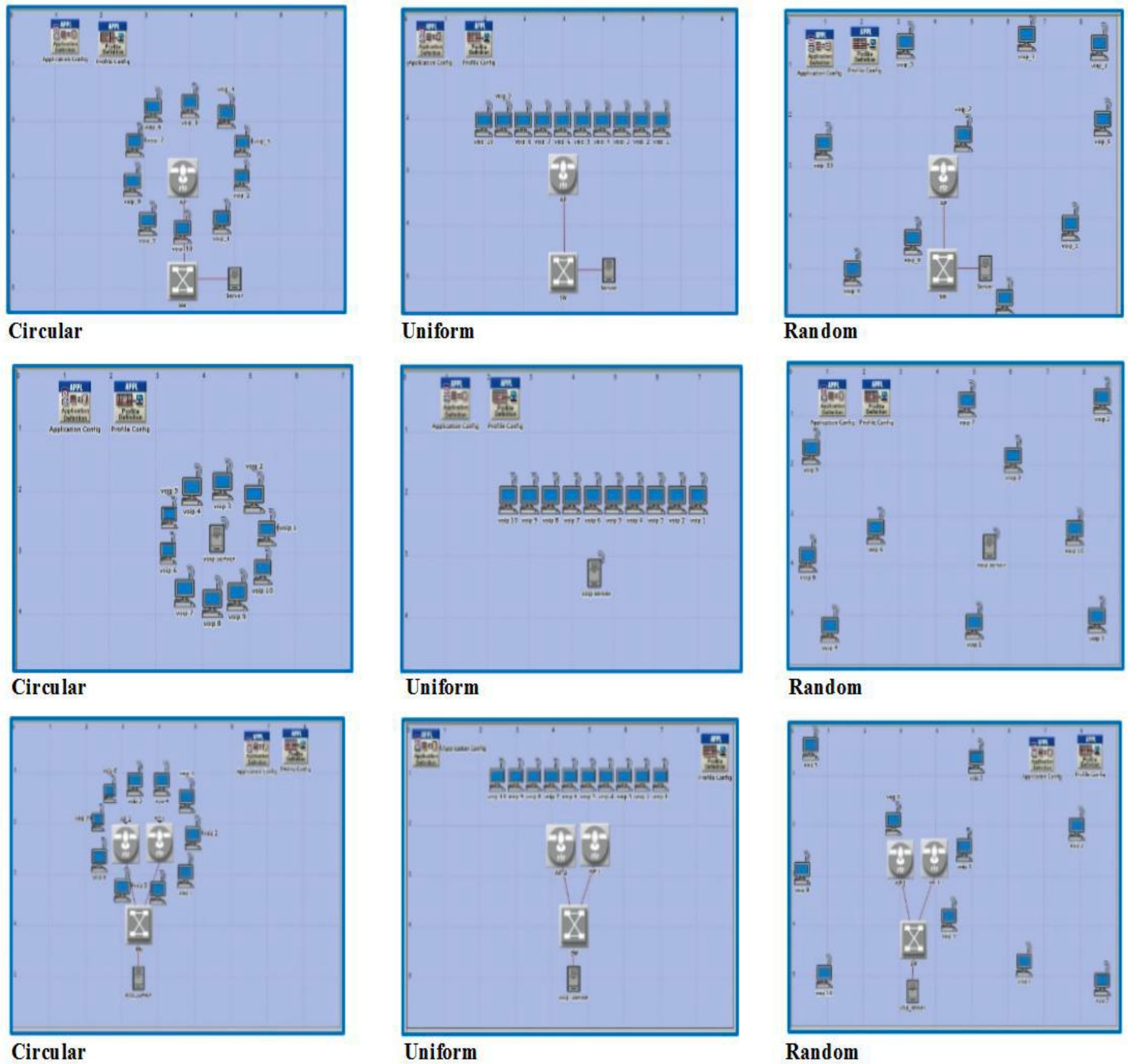

Fig. 2. Design of the three Network Architectures across three Spatial Distributions for VC.
(a) Basic Service Set (BSS), (b)Independent Basic Service Set (IBSS), (c) Extended Service Set (ESS)

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

QoS Performance Metric (QPM): as Fig. 4 illustrates, the value that is produced by applying the VC QoS metric Parameter Threshold Value (PTV) for each

QoS performance criterion n once is represented in CDF distribution F(n), which is given by (1).

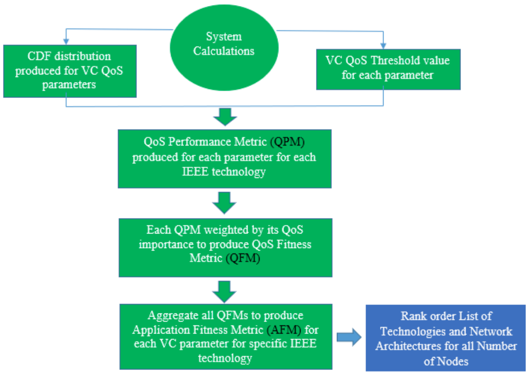

Fig. 3Algorithm"s calculations flowchart

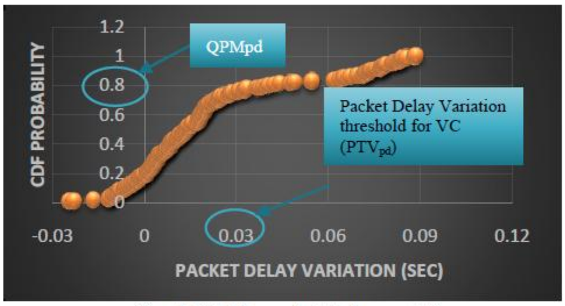

Fig. 4 QPM for packet delay variation

- QoS Fitness Metric (QFM): the value that is produced by applying a weighting to the QPM (assigned by importance) for each QoS metric parameter (H=1 and M=0.5) is expressed by (2).

$$QFM_n = QPM_n \times VCP \qquad (2)$$

- The final step will be calculating the Application Fitness Metric (AFM) which is to aggregate all QFMs for n VC QoS metric parameters (delay, delay variation, throughput and packet loss), for each IEEE 802.11 technology j, as demonstrated by (3).This is to show that each VC QoS metric has its importance and impact on the VC service and should not be ignored through the process of identifying the optimum IEEE technology performancefor certain VC parameters.

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

- Based on AFMs of the IEEE 802.11 technologies, the rank order of these five technologies will be produced for each of the three built network architectures. Hence, the best network architecture performance will be identified for all groups of nodes.

As explained previously, CDF distribution F(n) [16] is going to be produced for all applications QoS metric parameters from the OPNET Modeler simulation, then analysed against PTV as follows:

1. If ptv∈F(n): it means that the PTV has a specific value on its CDF distribution equal to QPM for this metric parameter. QPM is weighted by VCP to produce QFM. Then the aggregation of all QFMs yields AFM which is used to classify IEEE technologies.
2. If ptv > F(n): it means that the QPM value equals 1 and QFM has arisen.
3. If ptv<F(n): it means that the QPM value equals 0 and QFM will be initialized.

The value generated for the VC QoS metric parameters will contribute rank order of IEEE technologies for each network architecture.

All QoS metric parameters will be calculated as explained in the previous sections except for a packet loss parameter. OPNET Modeler is designed to produce the result of the packet loss parameter as a Boolean value (0.0 or 1.0) that corresponds to the acceptance or rejection of a packet, respectively. However, this work requires a numerical value for the packet loss.

A code has been programmed using MATLAB software to develop a method to calculate the packet loss percentage for each application. This method is linked directly with the OPNET Modeler to produce a specific packet loss percentage for each application. Application packet loss rate ω_i of a node iis the ratio of dropped voice packetk_i to total voice packets$\rho_i$multiplied by 100%, as demonstrated by (4).

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

This requires the traffic received/send rate values from OPNET Modeler to be integrated to produce the total number of packets received and sent. Then, the exact packet loss ratio is produced and should be presented as a CDF diagram to enable identification of the values of QPM, QFM and AFM using the previously explained flowchart. Identical calculation steps were applied for the other three groups of nodes (0-5, 11-20 and 21-40), to ascertain the best performing IEEE technology/technologies and to produce all values of QPMs, QFMs, and AFMs for all QoS metric parameters regarding VC application in all network architectures across the three spatial distributions.

IV. RESULTS AND PERFORMANCE EVALUATION

In this article, the output of the proposed algorithm identifies the options available for a client (user) based on the tables of the results that have been produced for all scenarios across three network architectures. All simulated scenarios are applicable to the lab (room) sizes from 2x3m to 10x12m. The format of the results, as will be demonstrated in Table

II and III, respectively, is demonstrated based on the presence of an access point; therefore, the tables of the results are interpreted (translated) as: generic results and IBSS only.

TABLE IIBSS AND ESS GENERIC ALGORITHM RESULTS FOR VC

User Configuration	Real-time Application **VC**				
	Number of Nodes	$5 \geq N > 0$	$10 \geq N > 5$	$20 \geq N > 10$	$40 \geq N > 20$
System Specification	Network Architecture	BSS	BSS	BSS	BSSESS
	Spatial Distribution	U R	UCU R C	U C U	R
IEEE Technology	802.11 802.11b 802.11g 802.11a 802.11g802.11a 802.11a 802.11a 802.11a 802.11g802.11e802.11g 802.11b 802.11b 802.11g 802.11e802.11e 802.11g 802.11e 802.11e				

TABLE IIIIBSS ALGORITHM RESULTS FOR VC

User Configuration	Real-time Application **VC**				
	Number of Nodes	$5 \geq N > 0$	$10 \geq N > 5$	$20 \geq N > 10$	$40 \geq N > 20$
System Specification	Network Architecture	IBSS	IBSS	IBSS	IBSS
	Spatial Distribution	R	C U R	C U R	C U R
IEEE Technology	802.11g 802.11 802.11 802.11 802.11b 802.11b 802.11b				

- In case there is at least one access point in the network, then the proposed algorithm in Fig. 1 and the result in Table II will be applied. This case is applicable to both infrastructure architecture layers (ESS and BSS). All scenarios are running in all five IEEE 802.11 technologies and three spatial distributions: circular, uniform, and random.
- If the network is configured without any access points, then the proposed algorithm in Fig. 1 and the IBSS result's described in Table III will be used. All scenarios are running in all five IEEE 802.11 technologies and three spatial distributions: circular, uniform and random. Both results' tables start by identifying the number of nodes that will be used to configure the required network and work for the environment composed of 1 to 40 nodes.

Based on the user's configuration and the number of nodes required to set up the designated network, both results' tables classify four key groups of nodes, presented as follows:

1. The first category, where $5 \geq N > 0$, as can be seen in Table II, if the client is going to build a small network, then BSS is the best architecture network. Additionally, the client has a number of options to select according to the information providedin Table II. First, 802.11 is the optimal technology to use if it is only configured in uniform distribution. The second-best option is to use 802.11b technology which is configured randomly. However, in the case of the IBSS, the 802.11g technology provides the best performance which is configured randomly as shown in Table III.
2. As shown in Table II, when $10 \geq N > 5$, if the client is going to configure a network using a number of nodes between 5 and 10, then BSS provides optimum performance that is configured uniformly and 802.11g has been implemented. But, in the case of the IBSS, both technologies 802.11 and 11b provide the client with the best performance across all spatial distributions as shown in Table III.
3. The third category, where $20 \geq N > 10$, if the client is going to build a medium-size network with the number of nodes from 10 to 20, then BSSprovidesthe best option. Moreover, the client has a number of options to select according to the information providedin Table II. IEEE 802.11a, 11g and 11e are acknowledged as the preferable solutions across three spatial distributions. On the other hand, in the IBSS, both IEEE 802.11 and 11b perform well across all spatial distributions.
4. In the fourth category, where $40 \geqslant N > 20$, both BSS and ESS provide a number of options. For BSS architecture, IEEE 802.11g and 11e technologies perform well only if the network configured uniformly and randomly. Further, IEEE 802.11a technology performs well if it is configured uniformly. However, IEEE 802.11a, 11g and 11e technologies are acknowledged as the preferable solutions for ESS only if the network configured in uniform and random distributions. In addition, bothIEEE 802.11a and 11b technologies provide the optimum performance if they are configured circularly or uniformly as shown in Table II.While, in the IBSS results, both technologies 802.11 and 11bprovide the user with the best performance to use for all spatial distributions.

V. CONCLUSION

Producing VC services and applicationsthat guarantees suitable QoS is considered a main challenge in the communication industry. Particularly, according to the traffic parameters such as delay and packet loss need to acknowledge in order implementing most suitable network configuration. On the other hand, the existence of different IEEE 802.11 technologies needs a logical analysis to decide which technology is preferable to use in real-world practice. Therefore, in this study, the development of an algorithmic approach that gives the option to identify the optimum network topology that gives the best overall performance according to a specific network arrangement. Hence, the algorithm has two input parameters, namely, the number of nodes and the application (VC), whereas the output scenarios including:

- The number of selected workstations/nodes categorized into four main groups: 0 to 5, 6 to 10, 11 to 20, and last, 21 to 40 workstations/nodes.
- The algorithm will decide based upon the selected number of nodes the optimum configuration. Practically speaking, user can visualize all network architectures output including ESS, BSS, and IBSS. In addition, three spatial distribution are included in the analysis process, such as the circular, uniform, and random.
- Finally, the technology layer outlines the optimum IEEE 802.11 technology that would perfectly suit the selected network configuration.

After the implementation of all above case scenarios, it is observed that for BSS network architecture, it is preferable to be used with the first three groups of nodes. However, it is only preferable to use the ESS network with a high number of workstations/nodes in a network; this is due to the high packet loss and delay that might appear in the network due to the increase in the number of workstations. Additionally, 802.11a technology is an option for almost all ESS network architectures. Finally, if the network configured without any access points, then the IBSS algorithm would take place. In this algorithm, it was evident that for all selected number of nodes both IEEE 802.11 and 802.11b are the optimum technologies to use, in fact, both technologies implement the Direct Sequence Spread Spectrum (DSSS) modulation and operate at 2.4 GHz, with a channel width of 20 MHz.

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