Analyze and Evaluate the Performance of Multimedia Data in Wireless Networks by Adjusting Parameters

Ngo Hai Anh and Nam-Tien Do*

Institute of Information Technology, Viet Nam Academy of Science and Technology, Vietnam
Email: ngohaianh@ioit.ac.vn (N.H.A.)
*Corresponding author

***Abstract*—Nowadays, multimedia data in wireless networks plays an increasingly important role in network services. Wireless standards for multimedia data, such as IEEE 802.11e, have certain effects on network performance. Our paper will propose a solution to evaluate multimedia data performance in wireless networks using a testbed system. Specifically, our research analyzes the performance of multimedia data in wireless networks by simulation to find the optimal set of parameters, then evaluate the proposed set of parameters on a real hardware system (testbed), Experimental results on the testbed system compared to software simulation show that the results close to reality to demonstrate the optimal network performance of the proposed set of parameters.**

***Keywords*—network performance, wireless Ad Hoc network, multimedia, Quality of Service (QoS), IEEE 802.11, IEEE 802.11e**

I. Introduction

Nowadays, wireless networks are becoming more and more popular. The advantages of wireless networks are mobility and freedom from the limitations of wired or fixed connections. It is very simple for two or more computers to connect to each other using radio waves for the purpose of transferring data or sharing resources. However, there are many complex technologies behind wireless networks, of which Quality of Service (QoS) is an important issue that is being researched and improved with the goal is to increase the performance of the wireless network.

Among the components of a wireless network, the IEEE 802.11 [1] standard plays the most important role, it includes the operating principles of both Media Access Control Layer (MAC) and Physical Layer (PHY) in network layers. However, the IEEE 802.11 standard – the unofficial standard for ad hoc wireless networks – does not perform well in terms of delay, throughput, and characteristics, especially the *fairness* factor in ad hoc networks.

A wireless ad hoc network is a mobile distributed network in which stations within the network can move freely. Moving stations causes delays in establishing new network configurations and changes communication conditions that affect network throughput.

Multimedia communications include many effective and efficient methods for exchanging information, which is becoming increasingly necessary in the context of the rapid advancement of network technologies, such as broadband networks, wireless network. Due to technology limitations, communication between computers initially only served for plain text data, but sound, still and moving images, new animation adapted to human senses. Thus, the need for multimedia data communication is inevitable today. Communication can be based on a traditional wired computer network or a wireless network, in which wireless networks have many advantages such as mobility, portability, and support for many types of devices and many different terrains. However, wireless networks with mobile characteristics, highly dependent on factors such as temperature, humidity, interference, always have problems ensuring quality of service (QoS), for multimedia data format, this problem becomes even more difficult.

On the Internet, three popular QoS models exist: IntServ [2], DiffServe [3] and MPLS [4]; however, these QoS models are not suitable for wireless networks and multimedia data. Wireless networks, especially ad hoc wireless networks, exist in situations where there is no specific infrastructure, but QoS must ensure clustering, maintaining virtual channels, and managing mobility as well as power control. With multimedia data, the network must also ensure real-time interactions, multi-directional transport (many-to-many) with many data types (audio, image), requiring high throughput at the same time. And the QoS factors such as delay tolerance, packet variation, loss and corruption of information… must be at the lowest possible level.

Voice applications have major differences compared to traditional data applications. This type of data itself is always real-time, data communication of this type must have minimal delay when transmitting packets as well as

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not accepting packet loss, packet mis-ordered transmission, packet variation [5].

Currently, there are several solutions for multimedia data quality in Ad Hoc Networks. However, there are still some shortcomings that need further research and improvement, specifically as follows:

In the traditional Transmission Control Protocol/Internet Protocol (TCP/IP) network layer architecture, strict boundaries between layers ensure easy network deployment, but data encapsulation at the layers prevents the sharing of some important information between layers. Traditional routing protocols optimize each of the three layers Physical, MAC and *Network* independently, which can contribute to suboptimal network designs pros [6]. Traditional ad hoc routing protocols are designed for point-to-point communication, which does not take advantage of cooperative diversity [7, 8].

From the issues analyzed above, the motivation of the research article to improve bandwidth control mechanisms and fair use in the network has been announced. The goal is to further improve the quality of wireless network services, especially for multimedia data.

In addition to the introduction and related research, the main contents of our paper include: "*Overview research*" to learn and analyze the main problem of the paper and available solutions. "*IEEE 802.11 Wireless Throughput Analysis*" performs calculation of the maximum theoretical throughput of IEEE 802.11 wireless networks. Among the factors affecting QoS, throughput plays an important role. However, with the IEEE 802.11 wireless standard, throughput is a factor with many different values, for example with 802.11b the throughput is 11 Mbps however this is the data rate of the radio waves (radio data rate) rather than the packet transmission rate (the main factor of network throughput). Theoretical maximum throughput is important because it can be used to facilitate optimal network provisioning for data transmission, especially for multimedia data. The 802.11 family of standards includes many technologies such as 802.11a/b/g/n/ac. This section of the paper performs theoretical calculations with two popular standards 802.11b and 802.11g. "*Proposed method for controlling data streams with different priorities*" performs simulation-based evaluation to demonstrate that although IEEE 802.11 can provide bandwidth separation, communication for different types of multimedia data, however this division does not really ensure the service quality requirements of the data streams. For example, voice data always receives the highest rate and background data always receives the lowest. Therefore, in some cases such as real-time data where service differentiation is needed for best effort traffic and real-time variable data traffic, IEEE 802.11 is not suitable for providing QoS for such requirements. And therefore, it is necessary to have a more flexible division mechanism. In our paper, the problem is solved by measuring real data at each receiving node over a period of time, then comparing it with theoretical data to determine whether the CW (Contention Window) value needs to be increased or decreased. The proposed algorithm will control the increase or decrease of this CW value to achieve the split ratio dynamically in accordance with user requirements with various types of data such as voice, video and background. Our solution is evaluated on the NS-2 network simulator tool to demonstrate the effectiveness of the proposed solution. Our research analyzes the advantages of the evaluation method based on experiments, then builds an evaluation system using testbed, propose evaluation steps, then use it to evaluate the impact of changing the value of the multimedia data QoS parameter set on factors such as throughput, latency, rate packet loss in the multi-hop ad hoc model. The results demonstrate that using real hardware devices will have results closer to reality instead of ideal values in other methods, such as modeling, simulation, or theoretical analysis. That result shows the positive significance of the research in this paper.

II. Related Works

In 1997, Institute of Electrical and Electronics Engineers – IEEE created the first wireless local area network (Wireless LAN – WLAN) standard. Since then, the IEEE 802.11 standard has had a long development process as illustrated in Fig. 1. Among the many 802.11x standards, the IEEE 802.11e standard proposed in 2005 [9] is notable for providing focused Quality of Service – QoS into multimedia applications such as voice and video, and the IEEE 802.11e standard was incorporated as a component of the IEEE 802.11 WLAN standard in 2012 [10, 11]. The development process of IEEE 802.11 wireless standards as well as proposed extensions are summarized in Fig. 1 [12].

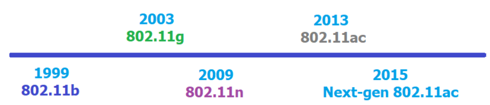


Fig. 1. The evolution of the IEEE-802.11 family of standards.

Wireless communication technology based on the 802.11 [1] standard has become popular in many fields, for example Wi-Fi access points, wide area metropolitan networks, vehicular networks. . . In those fields, multi-hop wireless communication plays an important role. However, the Quality of Service (QoS) provided in these communications remains a challenging research problem. The IEEE 802.11e [9] standard, based on 802.11, was created to provide better standards for ensuring quality of service and has been adopted as an extension to support multimedia (Wi-Fi Multimedia – WMM or Wireless Multimedia Extensions – WME) of IEEE 802.11 [12].

The highlight of IEEE 802.11e is that it has *Hybrid Coordination Function* – HCF, a combination of DCF and PCF functions that have existed since 802.11, with mechanisms to ensure QoS Enhanced to Support Differentiated Services (DiffServ). HCF includes two control mechanisms: Contention-based *Enhanced* Distributed Channel Access (EDCA) and Contention-free HCF Controlled Channel Access (HCCA) is based on a poll-based mechanism. Of these two mechanisms, EDCA technique is used more because it is suitable for the distributed characteristics of nodes in ad hoc wireless networks.

The EDCA method uses a differentiated medium access method, using different priorities for each type of data flow. EDCA defines four priority categories according to Access Categories for different data types and has differentiated services for each of these AC categories. How different data frames are mapped into ACs will depend on the quality-of-service requirements of the upper layer. Each frame from the upper layer to the MAC layer is weighted *UP–User Priority* depending on the application that generated the frame. There are 8 priority weight values described in Table I [9].

TABLE I. PRIORITY AND ACCESS LEVELS

Priority	UP	AC	Data Type
lowest	1	AC_BK	Background
–	2	AC_BK	Background
–	0	AC_BE	Best effort
–	3	AC_BE	Best effort
–	4	AC_VI	Video
–	5	AC_VI	Video
–	6	AC_VO	Voice
highest	7	AC_VO	Voice

The EDCA technique handles channel access contention based on the following parameters.

Arbitrary InterFrame Space Number (AIFSN), is the number of time slots after each SIFS period that a station must wait before entering the rollback phase or transmit phase data. The AIFSN value will affect the Interframe Interval (AIFS), which determines the amount of time (in specific time units rather than timeslots) that a station must wait before transmitting the next packet, or start the backtracking algorithm:

$$AIFS = SIFS + AIFSN \times SlotTime$$

Contention Window – CW, each station calculates the total backoff time value from a random value taken within the limits of the concurrency window:

$$Backoff = AIFS + random\ [1, CW]$$

TXOP limit – is the maximum transmission time for each station after winning a Transmission Opportunity. If this value is zero (0), that is, when the Access Type (AC) has access to the channel, then it is allowed to send only one frame from the corresponding AC queue.

Accordingly, an AC with a lower *AIFSN* value will have a small AIFS and thus receive a higher priority. An AC with a lower value of *CW* will have a higher probability of receiving a smaller random number, thus having a higher priority. An AC with a higher value of *TXOPlimit* will have higher priority.

In general, an AC with a higher priority will have a smaller AIFSN, *CWmin*, *CWmax* and a larger *TXOPlimit* than an AC with a lower priority. These EDCA parameters are different for each AC type, and are detailed in Table II [9]. Corresponding to the parameter sets for these priorities, network performance parameters such as *packet transmission delay*, *packet loss rate*, and *throughput,* also has differences between data types.

TABLE II. DEFAULT EDCA PARAMETERS

Parameters	BK	BE	VI	VO
AIFS	7	3	2	2
CWmin	15	15	7	3
CWmax	1023	1023	15	7
TXOPLimit (ms)	0	0	1504	3008

A. IEEE 802.11e EDCA Throughput Analysis

IEEE 802.11 EDCA uses different parameters that result in different priorities for data streams [13]. Therefore, although there is no contention over channel access, there will be contention between flows over channel usage. That leads to different throughput of each flow. However, multimedia data does not always have a fixed priority. In many cases, it is necessary to change the priority level dynamically, so assigning fixed EDCA parameters to each data type will not solve the problem of such priority flexibility. To clarify this issue, the paper will focus on analyzing the influence of *Contention Window* size value (CW) on throughput in EDCA 802.11 [14].

This paper evaluates the performance of 802.11 EDCA using a simulation tool. There is a lot of software used to simulate wireless networks, but they are limited to the original 802.11 standard – which does not yet have multimedia data support like 802.11e. NS2 [15] is very popular tool for network simulation but it does not support 802.11e. Therefore, we have applied the extension of NS2 tool [16] to simulate and evaluate the related problems in our paper.

The paper considers a single-hop model consisting of two network nodes with streams of three types of data (voice, video, best-effort) as shown in Fig. 2 to Considering that the 802.11e parameters are set only for contention between data flows with different priorities, there is no contention for channel access. This model will be used to evaluate the influence of CW values on the throughput of different data types.

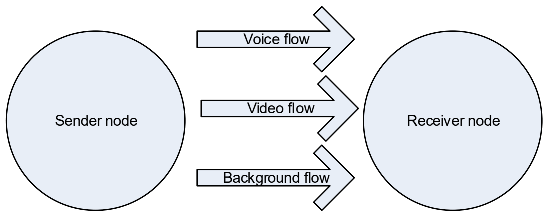


Fig. 2. Two-node scenario with three data flows.

The simulation parameters are given in Table III.

TABLE III. SIMULATION PARAMETERS

Parameter	Value
Channel data rate	11 Mbps
Antenna type	Omni direction
Radio Propagation	Two-ray ground
Transmission range	250 m
Carrier Sensing range	550 m
MAC protocol	IEEE 802.11e (EDCA)
Connection type	UDP/CBR
Packet size	1024 bytes
Send rate	increasing from 1 to 1000 (packets/s)
Simulation time	400 seconds

Multimedia data can use TCP or UDP, but within the scope of research, the paper only performs simulations with UDP data as shown in Table III because of many video and multimedia applications, like VoIP using UDP. These applications can tolerate data loss with little or no noticeable impact on performance. TCP's reliable transmission mechanisms (e.g., retransmission, flow control, congestion control…) are not suitable for real-time applications because they can lead to high latency and cause latency. delay jitter, which significantly reduces QoS.

Fig. 3 shows the throughput of each traffic class under recommended load, with default QoS parameters, recommended load increased with high priority.

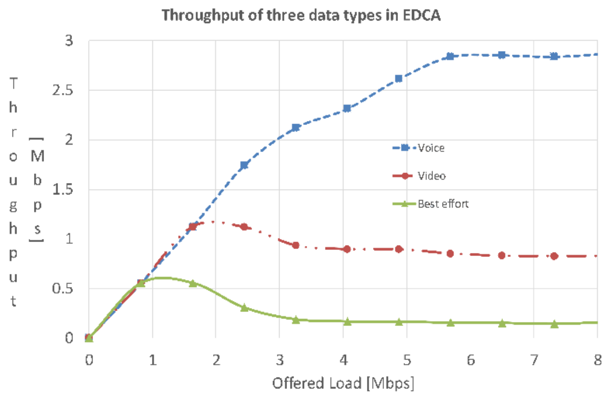


Fig. 3. Simulation results for single-hop scenario with three data flows.

The paper demonstrates the relationship between Contention Window (CW) size of three types of data (Voice, Video and Background). To do that, we keep the CW of the two priority levels: highest (voice data) and lowest (background data) fixed, and change the *CW* of the video data. The range of *CW* values varies in many cases, for example {3 – 15} in the default EDCA parameter as shown in Table II or {7 – 31} with AP/(BSS) QoS Access [17] or {17 – 1023} for maximum fair throughput allocation [18]. To show that the proposed method can adapt to changing CW values, the paper will apply a range of CW value changes between 17 and 33 to make observations about the ratio, and how the throughput rates of the three data types change relative to changes in CW.

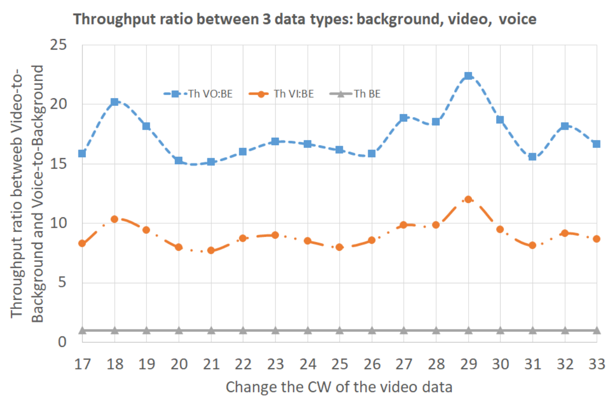


Fig. 4. Throughput estimated by priority (*CWmin*) between Voice and Video data compared to Background data.

Look at the simulation results in Fig. 4. Here, the best-effort data throughput is considered as the baseline (*Th BE*), the ratio of Voice and Video to Best-effort throughput (*Th VO:BE* and *Th VI:BE*) is used to observe the effect of varying the CW value on the throughput of three data types. When CW increases, throughput decreases, and conversely when CW decreases, throughput increases. As we see, the throughput ratio between the three data types *3:2:1* corresponding to the CW set is (*17*, *20*, *32*). We can see the variation of throughput across different CW values, so to have the data rate change dynamically according to user needs, we will need multiple sets of CW values. It proves that when assigning fixed CW values to data types, changing the throughput ratio in the network is very difficult to achieve. In the next section, the paper will propose a method to achieve this ratio with dynamically changing CW size.

III. Proposing a Method to Evaluate Throughput Control Solutions Using Testbed

In this part of the paper, we will analyze the advantages of the experimental-based evaluation method (also known as testbed), then build an evaluation system using testbed, and then propose evaluation steps. Then evaluate how changing the value of multimedia data QoS parameters will affect factors such as throughput, delay, and packet loss rate. Evaluation results have proven that evaluation using hardware devices will have results closer to reality instead of ideal results in other methods such as modeling, simulation or theoretical analysis.

A. Set up Testbed System

Based on the OMF [19] software tool kit developed to control and manage the testbed; the paper also builds a testbed to evaluate some basic tests of network performance. Our testbed system used in the paper is built using the main hardware component including wireless nodes as shown in Fig. 5.

Fig. 5. Wireless node in the testbed system: frond-side and back-side.

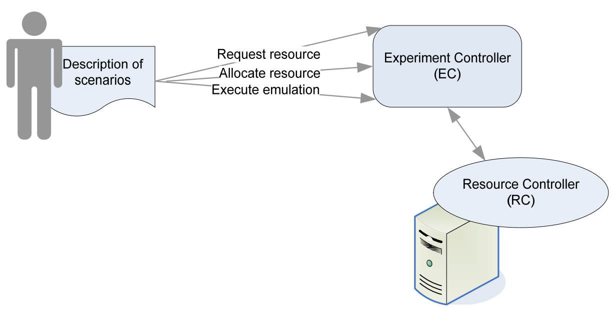


Fig. 6. Overview diagram of the built testbed system.

The network nodes in the diagram above are specifically designed based on *Orbit style wireless network node* [19].

Fig. 5 is an actual image of these network nodes, with the following basic hardware configuration: CPU Pentium G3240 3.1GHz, 3MB cache, 4GB RAM, 500GB HDD; Wi-Fi card support IEEE 802.11 a/b/g/n/ac; Antenna: Dual Band Wi-Fi Antenna 9dBi, u.FL/IPX to RP-SMA (F) Extension Cable.

The goal of our testbed system is to evaluate wireless network performance based on real hardware as well as provide wireless network evaluation and testing services for external users.

Figs. 6–7 show the overview diagram and logic diagram of the system, respectively.

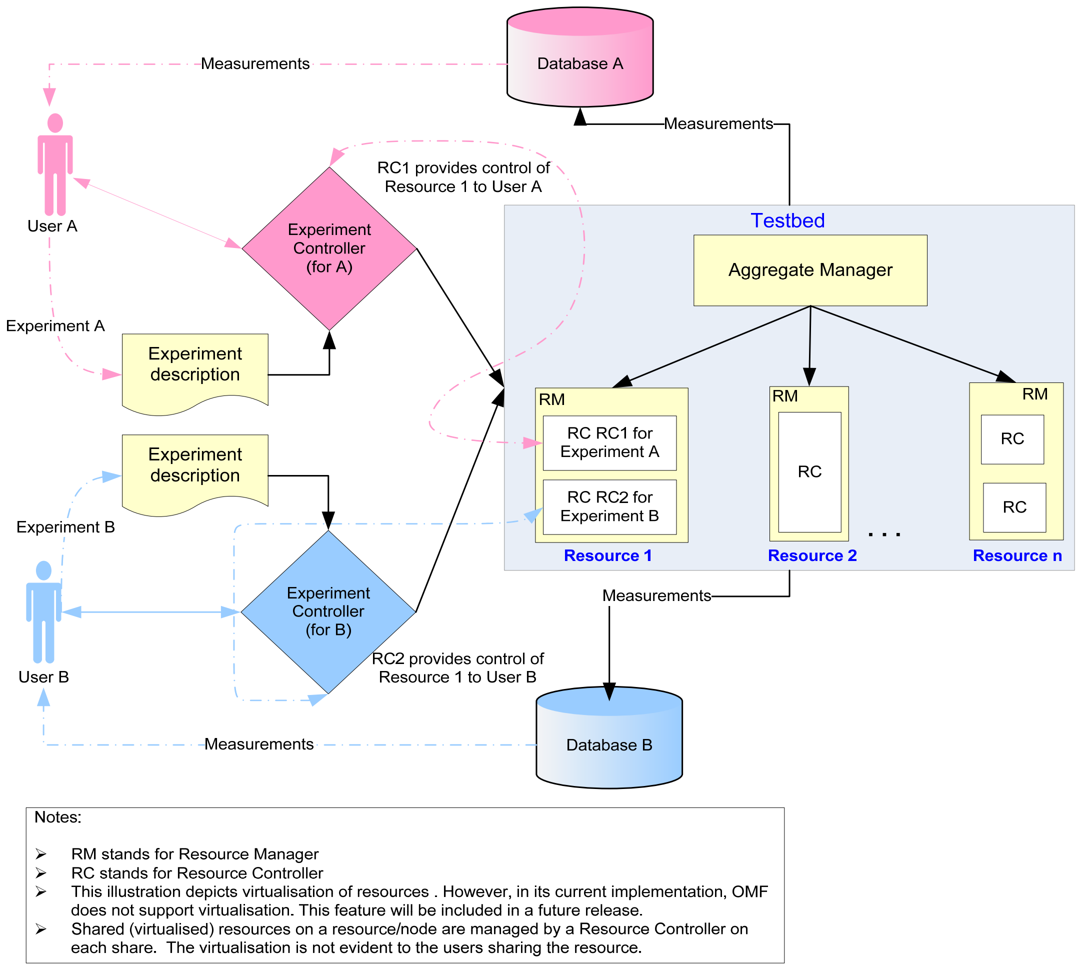


Fig. 7. Logic diagram of the built testbed system.

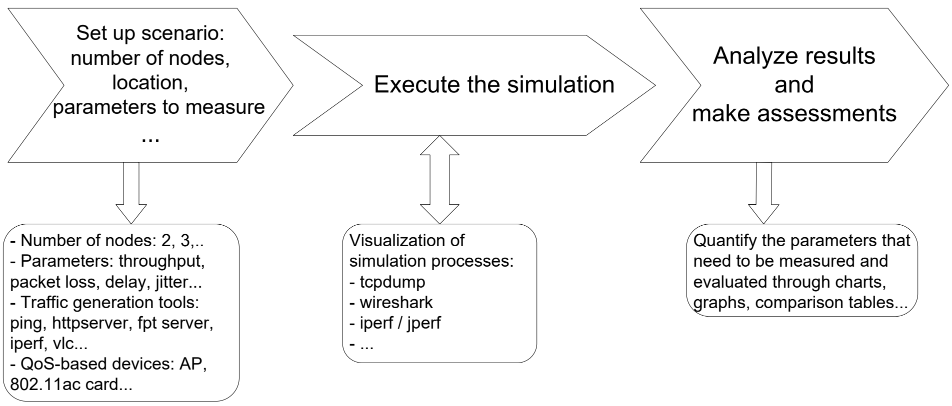


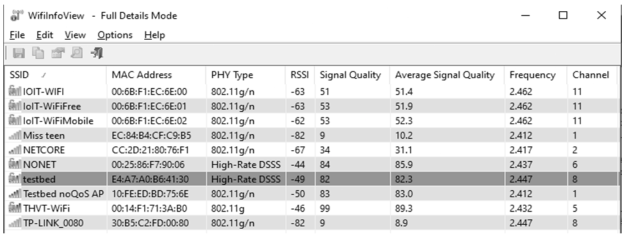
Fig. 8. Installation diagram of the testbed system.

With our system as shown in Figs. 6 and 7, users use Experiment Description (ED) to describe the components participating in the experiment, the resources needed to run the experiment, the run time, the related parameters. This specification script will then be sent to Experiment Controller (EC) to execute the script, the EC will contact Resource Controller (RC) to request the necessary resources to run the experiment described in the script. RC will allocate resources to run the experiment, returning results to EC so that users can analyze, evaluate, and process the output of the experiment. For each user *A*, *B*... in general the description of the experiment, resource requirements, running and getting the results of the experiment are repeated similarly.

Fig. 8 shows the testbed system installation diagram, as well as the running steps of this system. First, we need to set up the simulation scenario to run, including information such as: number of network nodes and their locations; parameters that need to be evaluated such as throughput, packet loss, delay, jitter; tools used to generate traffic to simulate real networks; QoS assessment devices such as Access Points, wireless cards that support multimedia Wi-Fi standards such as 802.11ac... The next step is to execute the simulation script and collect generated data by some popular tools such as tcpdump, Wireshark... And the final step is to analyze results and make assessments, thereby proving the effectiveness of the proposed solutions.

B. Network Performance Evaluation Using Testbed

In today’s reality, the wireless environment has many devices that can influence experimental results, such as devices adjacent to the laboratory, personal mobile devices. To eliminate the exception for those factors, the article first scans wireless parameters to “see” the devices around the experimental location, Fig. 9 shows that the frequencies 1MHz, 5MHz, 11MHz are being used by many Access Point devices, so the testbed system uses 8MHz frequency.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SSID	MAC Address	PHY Type	RSSI	Signal Quality	Average Signal Quality	Frequency	Channel
IOIT-WIFI	00:6B:F1:EC:6E:00	802.11g/n	-63	51	51.4	2.462	11
IoIT-WiFiFree	00:6B:F1:EC:6E:01	802.11g/n	-63	53	51.9	2.462	11
IoIT-WiFiMobile	00:6B:F1:EC:6E:02	802.11g/n	-62	53	52.3	2.462	11
Miss teen	EC:84:B4:CF:C9:B5	802.11g/n	-82	9	10.2	2.412	1
NETCORE	CC:2D:21:80:76:F1	802.11g/n	-67	34	31.1	2.417	2
NONET	00:25:86:F7:90:06	High-Rate DSSS	-44	84	85.9	2.437	6
testbed	E4:A7:A0:B6:41:30	High-Rate DSSS	-49	82	82.3	2.447	8
Testbed noQoS AP	10:FE:ED:BD:75:6E	802.11g/n	-50	83	83.0	2.412	1
THVT-WiFi	00:14:F1:71:3A:B0	802.11g	-46	99	89.3	2.432	5
TP-LINK_0080	30:B5:C2:FD:00:80	802.11g/n	-82	9	8.9	2.447	8

Fig. 9. Wi-Fi information at simulated setup environment.

Next, our paper proposes a flow chart as shown in Fig. 10 showing the entire experimental process.

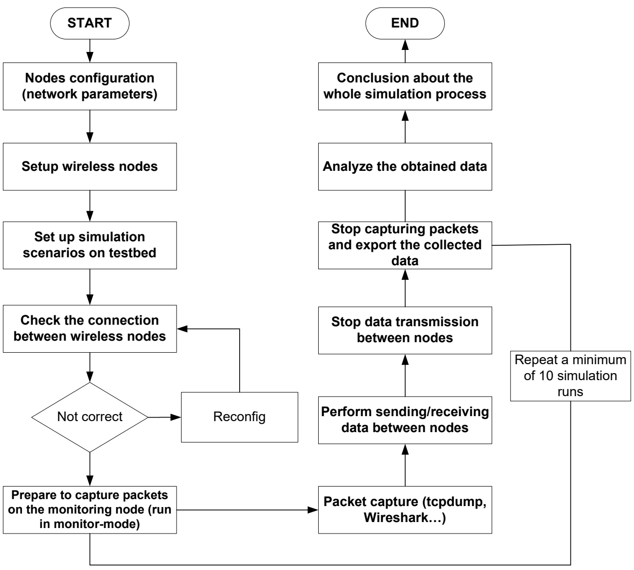

Fig. 10. Research methodology for our testbed system.

Starting the experimental process is “*configuring the control node*,” depending on the need to set up the network topology as well as evaluate the network parameters. Next is the “*configure the wireless nodes*” participating in the simulation scenario, for example, between the nodes will send and receive normal or multimedia data, the wireless standard used is IEEE 802.11 b or g. The “*set-up simulation scenario*” step on the testbed will systematize the previous steps in script form so that they can be easily edited and changed. In network simulation, the “*checking the connection between wireless nodes*” step is essential because if the connection is not correct, running the simulation will be wrong from the beginning. To observe the entire process of sending and receiving data between nodes in the simulation, the testbed needs to set up a “*monitor node*” (monitor) to observe the sending and receiving information of all nodes, to do this. Thus, the wireless card of the monitoring node needs to be configured to run in monitor mode to capture all packets at the Data-Link layer, otherwise monitoring send/receive must be performed on all destination nodes (node receiving data) and that is not feasible with many nodes participating in the simulation. The next steps “*capture packet*”, “*transmit message*”, “*save simulation output data*”, need to be repeated at least ten (10) times to ensure the collected data is large enough to be averaged to resolve data discrepancies (which are very common in real evaluation environments). The final step is “*data analysis and evaluation*” of network performance information.

C. Evaluate Proposed throughput Rates Using Testbed

In previous section, the paper analyzed in detail to propose a set of concurrency window values of data types (Voice, Video, Best effort) as (17, 20, 32) will give the corresponding throughput ratio of those three data types as (3:2:1). In this part of the paper, we will conduct an evaluation based on the built testbed system. The simulation run parameters with the testbed remain the same as Table II. The evaluation results on the testbed testing system are achieved as Fig. 11.

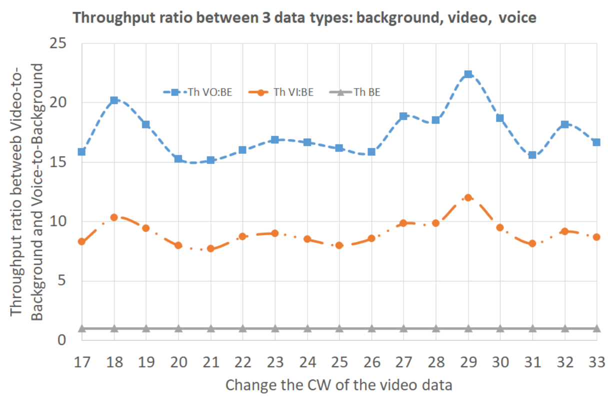

Fig. 11. Throughput ratio of Voice and Video data compared to best-effort data.

To see more clearly that the proposed *CW* values are also correct when running on the testbed system, our paper uses *Ratio Index* as the following:

$$Ratio\ Index = \frac{(\sum_{i=1}^{3}\frac{x_i}{k_i})^2}{3 \times \sum_{i=1}^{n}(\frac{x_i}{k_i})^2}$$

Here, x_i is the throughput of Voice, Video, and Best Effort data streams, respectively; k_i is the weight corresponding to those data streams. This ratio index value will be used to evaluate the ratio between different data types, i.e. the closer it is to one (1), the closer the ratio (3:2:1) will be achieved.

TABLE IV. RATIO EVALUATION INDEX (THE LARGER, THE MORE ACCURATE THE DESIRED RATIO)

The change in the value of CW video data			Fairness Index (ratio 3:2:1)
Voice	Video	Best effort	
17	17	32	0.776
17	18	32	0.761
17	19	32	0.773
17	20	32	0.792
17	21	32	0.791
17	22	32	0.787
17	23	32	0.781
17	24	32	0.780
17	25	32	0.782
17	26	32	0.784
17	27	32	0.767
17	28	32	0.771
17	29	32	0.753
17	30	32	0.768
17	31	32	0.780
17	32	32	0.772
17	33	32	0.780

Table IV shows that *ratio index* of 0.792 is the largest, corresponding to the set of CW values (17, 20, 32) as suggested. So, when running on a real test system, the proposed rate is still guaranteed.

D. Evaluation the Affection of QoS Parameter in Wireless ad Hoc Network by Using Testbed

This part of the paper presents some evaluation results on wireless network performance for multimedia data. With this type of data, modeling [20] and simulation [21] methods can be used because they are based on model analysis as well as simulation source code that complies with standards IEEE 802.11e, which is a standard for multimedia data. However, due to the current reality, the parameters for this type of data have been included in the family of IEEE 802.11a, b, g, n standards, so the paper will establish a testbed model using the above standards immediately to proceed evaluation.

Fig. 12 describes a testbed consisting of two wireless network nodes connected to each other via a forwarding node (forwarding node) that supports QoS for multicast data (Wi-Fi Multimedia function – WMM) with IEEE 802.11g network. This AP is set up using hostapd [21] with the WMM function enabled. IEEE 802.11g default QoS parameters, which classify four data types with increasing priority: AC BK (background), AC BE (best effort), AC VI (video), and AC VO (voice) with the value given in Table II.

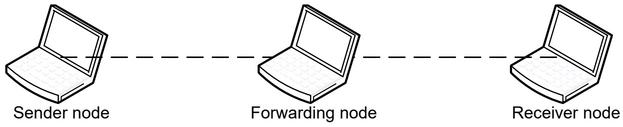

Fig. 12. Multi-hops wireless ad hoc scenario.

To evaluate the process of sending and receiving data between send/receive nodes (Sender/Receiver) in Figure 13, the article uses iPerf [14], this is a popular network performance assessment software that can generate TCP and UDP data, as well as allow changing parameters such as bandwidth, TCP/UPD packet size, number of packets sent /receive, two-way connection, Window Size (with TCP data), etc.

To evaluate the priority between Voice, Video and Background data with IEEE 802.11g, our paper simulates the simultaneous transmission of three (3) data streams at a saturation rate of 60 seconds, and such simulation is repeated ten (10) times to obtain an average throughput for 60 seconds, to ensure the stability of the obtained data.

First, we perform simulations to compare the differences between two mechanisms: DCF (default in 802.11) and *EDCA* (QoS support for multimedia data in 802.11). The results are given in Tables V and VI.

TABLE V. SIMULATION RESULTS IN DCF MODE

Data type	Throughput (Mbps)	Jitter (ms)	Loss ratio (%)
Voice	3.16	41.21	0
Video	3.15	32.39	0
Background	3.15	32.62	0

TABLE VI. SIMULATION RESULTS IN EDCA MODE

Data type	Throughput (Mbps)	Jitter (ms)	Loss ratio (%)
Voice	8.47	13.59	0.03
Video	2.07	26.74	9.99
Background	0.11	1667.40	92.4

Look at the performance results of DCF and EDCA when the network is in a saturated state. We see that because DCF does not differentiate between data types priorities, the performance of the three data types is quite similar at all three values: *throughput*, *delay* (jitter) and *packet loss rate* (packet loss). Jitter is a measure of the fluctuation in the time it takes a packet to reach its destination. Under ideal conditions, packets arrive at the destination at the same time, for example packets arrive every millisecond (1 ms). High jitter can lead to packet loss and network congestion. In voice and video applications, a lot of jitters can affect the quality of data transmission. Here, the average jitter for all three data types is the same which can lead to QoS issues for multimedia streams.

With EDCA, priority level has a clear impact on network performance. Obviously, the throughput of background data, which has the lowest priority, is almost zero – corresponding to a very high packet loss rate (considering that packets are completely lost without reaching the destination), as well as large jitter values leading to instability in data transmission. Meanwhile, data with higher priority takes up most of the bandwidth, as well as having quite small jitter and packet loss rate, showing that data transmission is stable, suitable for multimedia data.

E. Comparison with Theoretical Throughput

The 802.11 standard family [10] includes many technologies such as 802.11a/b/ g/n/ac. Theoretical maximum throughput is important because it can be used to facilitate optimal network provisioning for data transmission, especially for multimedia data. As the result of research in [13], theoretical throughput of IEEE 802.11g is calculated as shown in Table VII.

TABLE VII. AVERAGE THEORETICAL THROUGHPUTS FOR 802.11G

Layer	Payload	Speed (Mb/s)			
		6	12	36	54
Application	1470 byte	5.09	9.26	20.38	25.48
UPD	1478 byte	5.12	9.31	20.49	25.62
IP	1498 byte	5.19	9.44	20.77	25.97
LLC	1506 byte	5.22	9.49	20.88	20.88

With the throughput values obtained above in Section IV.E, comparing with the theoretical results in Table VII we see a big difference. Applying the formula to calculate the effectiveness of real throughput (testbed) with theoretical throughput, we have:

$$Different\ (\%) = \left(1 - \frac{11\ Mbps}{25\ Mbps}\right) \times 100 = 56\%$$

Thus, the results from the test system can show that the actual throughput is much smaller than the theoretical throughput. We find that the CW value has a great influence on the throughput of multimedia data. Obviously, even a small change in CW will cause the throughput to increase or decrease very quickly. In contrast to the CW value, the TXOP and AIFS values also produce a change in throughput, but the change is much smaller than in the CW case. With multimedia data, throughput is an important factor affecting network performance. Thus, we can see that if we want to adjust the throughput ratio between multimedia data types, we can control it through the CW value.

IV. CONCLUSION

Wireless networks are increasingly becoming an important infrastructure of home, business, and even industrial ranges. However, the technologies used in wireless networks need to be tested, inspected, and evaluated before they are released for official use. Previously, research on wireless network technologies was mainly tested and evaluated based on either mathematical models or simulation tools. These solutions have the advantage of not requiring hardware costs because they are mainly mathematical proofs or using software toolkits to write test scripts, analyze results, etc. However, the disadvantages of these solutions are: They are only limited by ideal conditions and assumptions that can be evaluated, because neither modeling nor simulation can reflect all the physical factors in the network. The trend of using testbeds to evaluate network parameters increasingly shows superiority compared to modeling and simulation methods. Therefore, this part of the article focuses on building a network testbed with an effort to approach existing testbeds in the world. Initially, we successfully implemented the construction of a testbed and based on that evaluated the influence of some network parameters on the quality of multimedia data services in wireless networks. Experimental results show a large difference between the theoretical parameters and the actual running system.

V. FUTURE WORK

In the future, the research results of the paper will be expanded with more complex network topologies such as multi-hop networks, relay networks, or networks with randomly moving nodes to demonstrate that the proposed method is effective for real-life situations.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Ngo Hai Anh conducted the research; Nam-Tien Do analyzed the data; Ngo Hai Anh wrote the paper; all authors had approved the final version.

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