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Evaluating Multimedia Data Throughput Rates in Wireless Networks using Testbed System

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***Abstract* - Wireless networks play a vital important role in life and are developing rapidly. In related studies, the issue of ensuring Quality of Service (QoS) for multimedia data on wireless networks has received much of research attention. Multimedia data includes main types such as voice, video, background, and best effort, with many different uses and receives other network resource allocations. Among the factors affecting the quality of multimedia data services in wireless networks, the throughput factor plays an essential role because it affects the bit transmission rate of data and, accordingly, the types of data, whether multimedia such as voice and video, can be transmitted smoothly to meet user needs. This paper will analyze how wireless network parameters affect throughput, thereby proposing a set of parameters to ensure proportional throughput division/ratio for multimedia data types such as voice, video, background and verify the proposed set of parameters by evaluating using a network emulator with real devices (testbed).**

***Index Terms* - 802.11e, multimedia, testbed, throughput, QoS, wireless.**

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 to transfer data or share 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 of increasing 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 MAC (Media Access Control layer) and PHY (physical layer) layers in network layers. However, the IEEE 802.11 standard – the unofficial standard for ad hoc wireless networks – could perform better regarding *delay*, *throughput*, and other 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 advanced network technologies, such as broadband networks, wireless networks, etc. Due to technology limitations, communication between computers initially only served for plain text data, but sound, still and moving images, and new animation adapted to human senses. Thus, the need for multimedia data communication is inevitable in today's society. Communication can be based on a traditional wired computer network or a wireless network, in which wireless networks have many advantages 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, and 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, and multi-directional transport (many-to-many) with many data types (audio, image), requiring high throughput simultaneously. At the same time, delay tolerance, packet variation (jitter), loss, and corruption of information… must be at the lowest possible level.

Voice applications have significant 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 and not accepting packet loss, packet no-ordered transmission, and packet variation [5].

Ensuring service quality for multimedia data in wireless networks is a topical and practical topic analyzed and researched by many authors. Some recent studies have proposed some methods as evaluating contention both at the link layer and the MAC layer, to suggest scheduler improvements to achieve an appropriate level of fairness between data flows [6].

There are several solutions for multimedia data quality in ad hoc networks. However, there are still some problems that need further research and improvement. In the next part of the paper, we will explore some related issues and propose solutions.

RELATED WORKS

The always-shared and bandwidth-limited nature of wireless links shifts competition for bandwidth from router queues to channel access times, so the *Contention Window* (CW) does not determine the transmission rate of the wireless node. Therefore, research results already available in wired networks can be directly applied to wireless networks. Research [7] – shows that to extend the Kelly [8] rate control algorithm on a wireless network, neighboring nodes must regularly exchange information.

To avoid large message overhead, some research explores methods that use the *Distributed Contention Window* allocation algorithm to support fair and efficient bandwidth allocation. The challenge with such approaches is that in wireless networks, the sending rate of a node is determined by the concurrency window size of all competing nodes. Since no node completely controls its sending rate, the Kelly [8] rate control algorithm can be directly translated to concurrency window control, and new algorithms can be designed, and designed to achieve arbitrary fairness and efficient channel utilization.

However, most existing approaches focus only on specific fairness definitions rather than arbitrary levels, allocating bandwidth according to a standard distribution (uniform) or a weighted ratio. The mechanisms AOB [9], MFS [10], and Dynamic-802.11 [11][12] only focus on bandwidth allocation according to a normal distribution. IEEE 802.11e [13][14] and P-MAC [15] provide only weighted proportional fairness. Some such algorithms (Dynamic-802.11, MFS, and P-MAC) also create network instability as they try to achieve channel utilization efficiency through dynamic CW adjustment. This is because the solutions require an individual node to run iterative algorithms to estimate both the CWs used by the contending nodes and the number of contending nodes.

However, such estimation requires all nodes, with or without packets to transmit, to simultaneously start both the dynamic contention window adjustment and the iterative estimation algorithm, and run concurrently. step-by-step set of these algorithms. Nodes with expired values for CW size and number of contending nodes, due to asynchronous algorithm execution or transient errors (prone to wireless networks), can cause these algorithms to fail and to lose.

From the issues analyzed above, our paper aims to improve bandwidth control mechanisms and fair use in the published network. The goal is to further enhance the quality of wireless network services, especially for multimedia data.

In this paper, we study the throughput analysis of multimedia data in ad hoc wireless networks. We propose a set of parameter values *Contention Window* (CW) to achieve a high distribution rate, and divide the throughput appropriately for different multimedia data types. The value of the proposed parameter set will be evaluated effectively using an experimental evaluation system (testbed).

ANALYZE THROUGHPUT AND PROPOSE PARAMETER SETS FOR MULTIMEDIA DATA IN AD HOC WIRELESS NETWORKS

Traffic classification problem in wireless networks

To provide Quality of Service for multimedia data, IEEE-802.11e was introduced in 2005 [13] and has been adopted as an official standard in 2012 [14]. This standard generally meets the goal of enhancing QoS for multimedia data. However, this standard does not accommodate adapting the throughput of data streams according to different needs; for example, the ratio between different data types such as *voice*, *video*, and *best effort* in 802.11e are always kept highest for voice and lowest for best-effort. Such a fixed ratio does not meet the need for a flexible ratio in reality, and in the *saturation state*, traffic-classed flows that have higher priority will often take up the entire bandwidth, as lower priority traffic-classed flows will have difficulty accessing the channel.

Several studies have shown that although 802.11e has focused on improving QoS, many issues still need to be resolved [16][17]. The study [16] evaluated EDCA performance with integrated voice and data traffic, and observed increased inefficiencies if channel access classification was performed solely based on traffic type classification. In [17], the authors evaluate using the EDCF mechanism in 802.11e to address transport layer inequality in wireless LANs.

In this paper section, we will present a simulation-based evaluation exercise to demonstrate that although 802.11e can provide bandwidth separation for different multimedia data types, this division ratio is fixed. For example, voice data always receives the highest rate and background data always gets 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, more than 802.11e is needed, and can provide QoS commensurate with such requirements [18]. And therefore, it is necessary to have a more flexible division mechanism. Through simulation results with NS2 [19] software, we will propose a set of *Contention Window* (CW) values corresponding to the three types of data Voice, Video, and Background to achieve a flexible split ratio to suit user requirements–for example, typically the bandwidth ratio for Voice data will be higher than the other two types of data.

IEEE 802.11e EDCA Throughput Analysis

IEEE 802.11e introduced several enhancements to IEEE 802.11's existing DCF and PCF with *Hybrid Collaboration Function* (HCF) [13][14]. HCF includes two mechanisms: *Enhanced Distributed Channel Access* (EDCA), corresponding to enhanced DCF, and *HCF Controlled Channel Access* (HCCA), corresponding to enhanced PCF. Both EDCA and HCCA can operate separately or together, where DCF is mandatory, and PCF is optional. Although the fundamentals of the original functions are not changed, enhanced information allows HCF to provide QoS to specific flows and/or stations. In EDCA, the MAC layer parameters priorize to each *Traffic Class* (TC) in a contention access manner similar to DCF. The parameters that can be manipulated are *Arbitration Inter-Frame Space* (AIFS), *Transmission Opportunity* (TXOP), *CWmin* and *CWmax*. These parameters are given default values at each station for each TC, or they can be overridden by the Access Point using special coordination frames.

EDCA uses differential, distributed, and contention-based media access mechanisms to enhance the initial DCF by providing priority QoS for each data flow type. The EDCA mechanism defines four *Access Categories* (ACs) to provide support for traffic distribution with *User Priority* (UP) at stations. There are four types of traffic corresponding to four ACs: AC_BK, AC_BE, AC_VI and AC_VO, which are respectively denoted by the types: background, best-effort, video and voice. For example, voice data should be sent with the highest priority, so AC_VO is chosen for this data type. The default value of AC is described in Table I. Note that although in this Table 1, EDCA 802.11e has defined eight default priority levels for different data types [14]. However, these eight levels do not fix, and EDCA 802.11e may allow less or more.

TABLE I
USER PRIORITY VÀ ACCESS CATEGORY [14]

Priority	UP	AC	Designation
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

EDCA parameters for each AC are shown in Table II.

TABLE II
CONTENTION WINDOW MAX AND MIN VALUES

AC	CWmin	CWmax	AIFS	TXOP limit (ms)
AC_BK	15	1023	7	0
AC_BE	15	1023	3	0
AC_VI	7	15	2	3.008
AC_VO	3	7	2	1.504

With the correct adjustment of the EDCA parameters set, traffic performance from different traffic types can be optimized, and traffic prioritization can be achieved. These parameters are only intended to define a fixed priority for each type of data: voice always has the highest priority, then lower for video and background.

IEEE 802.11 EDCA uses different parameters that result in different priorities for data flows [14]. 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 only sometimes has a fixed priority. In many cases, changing the priority level dynamically is necessary, so assigning fixed EDCA parameters to each data type will not solve the problem of such priority flexibility. To clarify this issue, our paper will focus on analyzing the impact of *contention window size* value (*CW*) on throughput in EDCA 802.11.

This paper evaluates the performance of 802.11 EDCA using a simulation tool. A lot of software is 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[19] is very popular for network simulation, but does not support 802.11e. Therefore, our paper has applied the extension from [20] integrated with NS2 to simulate and evaluate the related problems in the 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 Figure 1; 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.

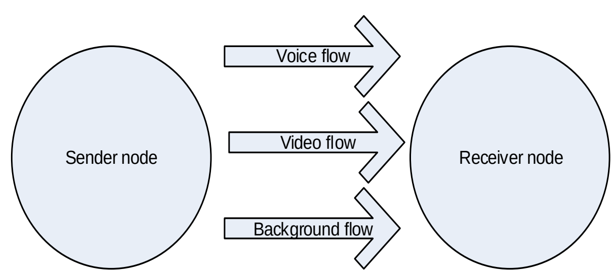


FIGURE 1 TWO NODES WITH THREE DATA FLOWS SCENARIO.

The simulation parameters are shown in Table III.

TABLE III
NS2 SIMULATION PARAMETERS

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

Multimedia data can use TCP or UDP, but within the scope of research, our paper only performs simulations with UDP data, as shown in Table III because of many video and multimedia applications, for example VoIP applications are 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 delay and jitter, which significantly reduces QoS.

Figure 2 shows the throughput of each traffic class under recommended load, with default QoS parameters, recommended load increased with high priority.

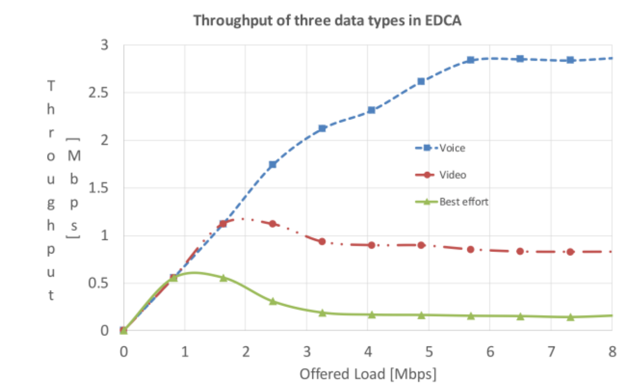


FIGURE 2 TWO NODES WITH THREE DATA FLOWS SCENARIO.

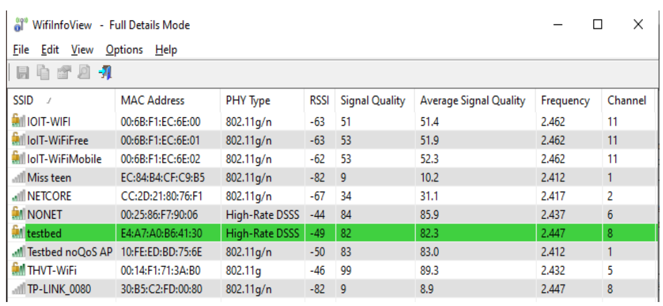
The paper demonstrates the relationship between contention window size *CW* of three data types (Voice, Video and Background). To do that, we keep the *CW* of the two priority levels; highest (voice data) and lowest (background data) fixed, and change the *CW* of the video data. The range of *CW* values 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 [21] or {17–1023} for maximum fair throughput allocation [22].

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 of how the throughput rates of the three data types vary relative to changes in *CW*.

Look at the simulation results in Figure 3. 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* value is (*17, 20, 32*). We can see the variation of throughput across different *CW* values, so we need multiple sets of *CW* values to have the data rate change dynamically according to user needs. 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, we will evaluate the proposed parameter sets on a real system (testbed) to prove that the proposed sets still achieves the desired throughput rate.

PROPOSING A METHOD TO EVALUATE THROUGHPUT CONTROL SOLUTIONS USING TESTBED

In recently research, the wireless environment has many devices that can influence experimental results, such as devices adjacent to the laboratory, personal mobile devices… To eliminate those factors, our paper first scans wireless parameters to "observe" the devices around the experimental location, as shown in Figure 3 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

FIGURE 3 WIFI INFORMATION IN SIMULATION ENVIRONMENT.

Next, our paper proposes a flow chart shown in Figure 4, showing the entire experimental process.

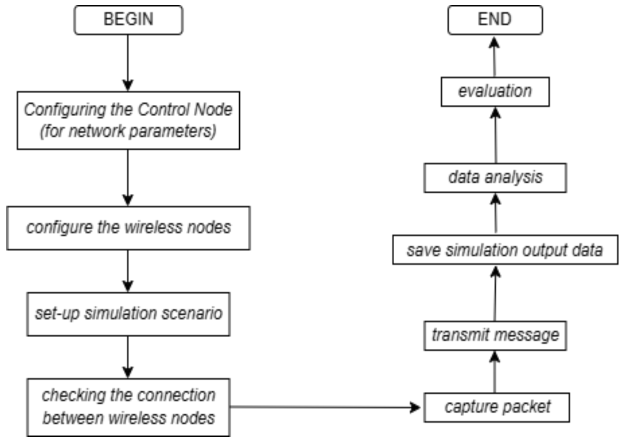

FIGURE 4 SIMULATION DATA PROCESSING FLOWCHART.

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 step *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* 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.

Evaluate proposed throughput rates using testbed

In the previous section, we analyzed details to propose a set of concurrency window values of data types (Voice, Video, Best effort) of (17, 20, 32) that will give the corresponding throughput rate 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 Figure 5.

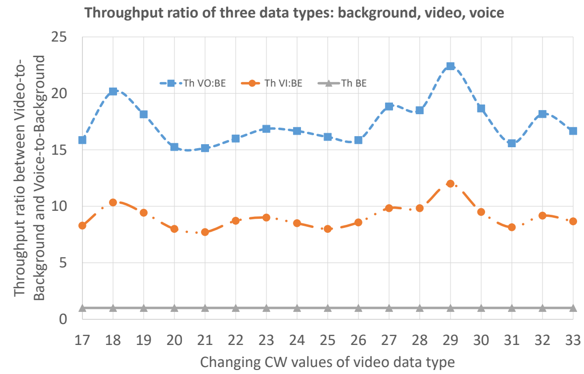

FIGURE 5 THROUGHPUT RATIO OF VOICE AND VIDEO DATA COMPARED TO BEST EFFORT DATA.

To see more clearly that the proposed *CW* values are also correct when running on the testbed system, our research uses *Ratio Index* improved from the formula [23] as follows:

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

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
EVALUATION RATIO INDEX (THE LARGER IT IS, THE MORE ACCURATE IT IS TO THE DESIRED RATIO).

Change in values of CW			Fairness Index
Voice	Video	Best effort	(ratio 3:2:1)
17	17	32	0.782
17	18	32	0.757
17	19	32	0.773
17	**20**	**32**	**0.797**
17	21	32	0.789
17	22	32	0.784
17	23	32	0.781
17	24	32	0.778
17	25	32	0.784
17	26	32	0.787
17	27	32	0.768
17	28	32	0.771
17	29	32	0.753
17	30	32	0.765
17	31	32	0.784
17	32	32	0.767
17	33	32	0.781

Table IV shows that *Ratio Index* of 0.7911 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.

CONCLUSION

Wireless networks are increasingly becoming an important infrastructure of home, business, and even industrial areas. However, the technologies used in wireless networks need to be tested, analyzed, 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… However, the disadvantages of these solutions are they 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, our paper focuses on building a network testbed with an effort to approach existing testbeds in the world. Initially, the construction of a testbed was successfully implemented 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.

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