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Throughput Optimization on Wireless Networks by Increasing the Maximum Transmission Unit

Edward Guillén, Stephanne Rodríguez, Jhordany Rodríguez

***Abstract*—**Throughput enhancement can be achieved with two main approaches. The first one is by the increase of transmission rate and the second one is reducing the control traffic. This paper focuses on how the throughput can be enhanced by increasing Maximum Transmission Unit -MTU. Transmission of larger packets can cause a throughput improvement by reducing IP overhead. Analysis results are obtained by a mathematical model and simulation tools with a main focus on wireless channels.

***Keywords*—**802.11, Maximum Transfer Unit, throughput enhancement, wireless networks.

I. Introduction

IN last years, evolution of physical channel parameters as well as new modulation and media access techniques have allowed high transmission rates [1], [2]. The main purpose of high transmission rates is throughput enhancement. Throughput is defined as the number of bits, excluding control bits, successfully transmitted in a time slot [3].

However, high transmission rates are not useful for throughput enhancement if the probability of receiving a corrupted bit is high. This probability is known as Bit Error Rate –BER [1] and it depends on several factors including Signal to Noise Ratio –SNR or even modulation scheme. Low BER condition reduces retransmissions; as a consequence, the throughput is increased.

Low BER conditions also allow large packet transmissions without significant corruption risks. Lost risk is measured with the Frame Error Rate - FER. The relationship between BER and FER can be calculated based on the packet length *S* as described in (1) [4]:

$$FER = 1 - (1 - BER)^S \quad (1)$$

Under low FER conditions, it is possible to improve throughput by increasing the Maximum Transmission Unit – MTU. MTU is defined as the maximum number of bytes allowed in a single transmitted frame [5]. Transmitting large packets reduces load in routing and switching devices while at the same time reduces overhead.

Although sending large packets can improve throughput by reducing overhead caused by fragmentation, most of the common implementations still use the traditional 1500 bytes as MTU because of link layer constraints [5], [6]. This paper focuses on the possibility of increasing data size in order to improve wireless throughput.

Packets larger than 64K bytes, known as Jumbograms, are theoretically possible with IPv6 implementations [7]. A theoretical and mathematical analysis for evaluating jumbograms implementation in wireless networks was presented in [4]. The results showed that Jumbograms implementation is only convenient when BER is lower or equal to $1x10^{-7}$. However, packets larger than 1500 bytes can be used for throughput enhancement in wireless networks. The work presented in this paper considers the mathematical model presented in [4] to determine the optimal MTU configurations for different BER conditions. Throughput performance obtained by using optimal MTUs is compared with throughput obtained when traditional MTUs are used. The results are based not only on the mathematical analysis described in [4] but also using a simulation environment.

Although network performance can be enhanced by using large packets; some conditions should be considered when frame size is increased [6], [7]. For instance, the processing time required for Cyclic Redundancy Code –CRC testing becomes longer as the packet length increases. In the same way, current implementations of User Datagram Protocol - UDP and Transmission Control Protocol - TCP require some modifications in order to be implemented with large packets [6], [8]. On the other hand, some applications such VoIP require a continuous transmission of small packets [9], [10]. To wait until a large packet gets ready for transmission would cause a non-continuous transmission and quality of service - QoS would be decreased. The use of large packets depends on the application requirements, application designers must be aware about it.

The analysis performed in this work does not consider delay or jitter requirements. It assumes a non-interrupted transmission where the input criteria are BER, network capacity and MTU. In order to establish a relationship between throughput and MTU, the results obtained by different MTU configurations are analyzed and compared each other to determine the influence caused by different MTU over throughput performance.

This paper is organized as follows: some related work as well as a brief overview of used mathematical model is presented in Section II. In Section III the input parameters required for testing are described. In Section IV, the results obtained by using different MTU configurations as well as different analysis methods -Mathematical and simulations- are compared. Discussion about the results is given in Section IV and finally, conclusions are shown in Section V as well as

E. Guillen, S. Rodriguez, and J. Rodriguez are with the Military University Nueva Granada, research professor at telecommunication engineering department. Bogota, Colombia (e-mail: edward.guillen@unimilitar.edu.co, stephanne.24@ieee.org, jhordany.rodriguez@ieee.org).

some potential issues that can be addressed by future research.

II. Related Work and Mathematical Model Overview

Fast spreading of wireless networks has encouraged some researches and standardizations task in order to improve their characteristics [11]-[13]. Many efforts have been focused on throughput performance [5], [14]-[19]. Throughput improvement can be done by using different methods: some approaches focus on increasing transmission rates by using different modulation and encoding schemes [11], [12]. The development of such techniques requires low BER conditions [4]. If the BER is low, it is possible to increase transmission rate without having significant data corruption [4]. The transmission rate can also be increased by using spatial multiplexing and spatial diversity techniques [1]. Some researchers try to reduce the control traffic caused by ACK generation in order to improve throughput performance. Standard 802.11e proposed a protocol called "block acknowledgement protocol" to reduce ACK control traffic. In summary, throughput enhancement strategies can be classified in two groups according to their purpose: the first group tries to increase transmission rate in order to send more data in the same time slot and the second one tries to reduce additional traffic generated by fragmentation and control features. Both strategies must work together. According to [20], throughput enhancement by only increasing transmission rate has a theoretical limit if the overhead caused by control traffic is not reduced. However, using larger packets is only suitable under low BER conditions.

Most of the methods used for throughput improvement depend on BER. BER condition is affected by external factors including: transmission media, distance, receiver sensitivity level, and usual propagation issues [12], [21]. This paper will assume a BER value and the throughput performance obtained when different MTUs are used is evaluated. In summary, this work tries to reduce additional control traffic generated by small packet transmissions.

Since most of the additional traffic comes from fragmentation, using larger MTU implies control traffic reduction as it is suggested in [4]. The relationship between packet size and throughput has been analyzed in [4]-[21]. In [22] the authors described a video transmission, they concluded that these two variables are correlated, video performance over packet switched networks is drastically degraded due to IP packet overhead.

The mathematical model used in this work establishes a relationship between MTU, BER and throughput as follows: throughput performance is decreased when the probability of receiving a corrupted packet -FER is high. At the same time, FER is increased when the packet length is high, but larger packets reduce overhead caused by fragmentation. The mathematical model can be described according to (2), where Z is the normalized throughput. The normalized throughput is understood as real throughput divided by transmission capacity. The rest of variables considered in (2) are described in Table I. Z was used in [4] and described in [21].

$$Z = \left[\frac{S_d}{S}\right] * \left[\frac{\rho}{1+\beta-\rho*\beta}\right] \quad (2)$$

The variables used in two are described as follows:

TABLE I
Variables for Normalized Throughput Calculation

EQUATION	DEFINITION
$\rho = (1 - FER)$	Error frame probability
$\beta = (\alpha - 1)$; $\alpha = T_t / T_i$	Standardized parameter
T_t	Total time
T_i	Installation time
$S = (S_d + S_c)$	Total length
S_d	Payload length
S_c	Length of the control field

Normalized throughput can be calculated based on transmission parameters such as: transmission capacity, propagation time, installation time, time out and total time, as it is shown in (2).

III. Towards the Definition of Testing Scenarios

This work uses two evaluation perspectives, the first one is a mathematical approach and the second one is a network simulation tool. Experiments were performed using configuration described in Table II. Since the main goal is the evaluation of throughput improvement when different MTUs are used, first evaluation compares throughput performance when the traditional MTU of 1500 bytes is used versus throughput performance obtained by using other MTUs, thus the mathematical model is used for this purpose. Fig 1 shows throughput performance for different MTUs under specific BER conditions. The numbers located in the top of the curves correspond to the optimal MTU for specific BER environments.

TABLE II
Parameters Required for Throughput Evaluation under Different BER Environments

PARAMETERS	DESCRIPTION
Capacity	11 Mbps
Distance	80 m
Propagation media	Air
BER	1x10

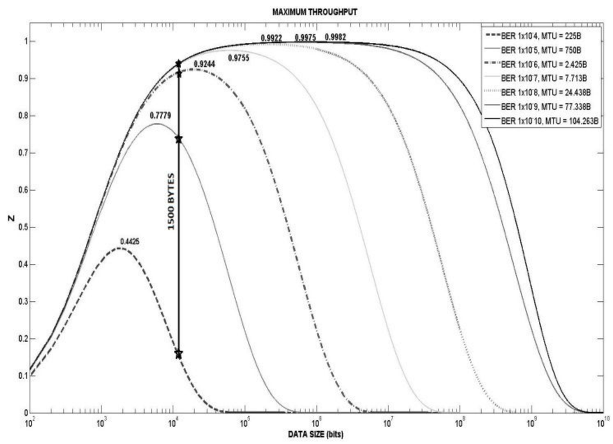

Fig. 1 Maximum Throughput reached for specific BER values, using mathematical approach

As it can be seen from Fig. 1, using packets larger than 1500 bytes is only convenient when BER is lower or equal to $1x10^{-6}$, otherwise, as it was suggest in (1), probability of receiving a frame with error would be high enough to cause a throughput reduction. In the rest of the paper, the numbers located in the tops of the curves will be referred as optimal MTUs. Table III shows optimal MTUs for specific BER conditions and their normalized throughput (*Z*).

TABLE III
SELECTING SETTINGS FOR SIMULATION AND THEIR MATHEMATICAL NORMALIZED THROUGHPUT

BER	IDEAL MTU	Z
$1x10^{-4}$	225	0.4425
$1x10^{-5}$	750	0.7779
$1x10^{-6}$	2425	0.9244
$1x10^{-7}$	7713	0.9755
$1x10^{-8}$	24438	0.9922
$1x10^{-9}$	77338	0.9975
$1x10^{-10}$	104263	0.9982

The optimal MTUs are used as reference points. Some tests are performed based on them and their comparison with traditional MTU configurations. In order to evaluate the accuracy of mathematical model some simulations are also performed according to the parameters described in Table IV.

TABLE IV
GENERAL SETTINGS USED IN THE SIMULATION TOOL

PARAMETER	DESCRIPTION
Data Rate	11 Mbps
Distance	80 m
Transmission profile	Point to point communication where the transmission is being performed without interruptions, similar to a FTP communication.
Simulated time	1 hour

The simulations are performed ten times in order to obtain an average result.

IV. Definition of Testing Scenarios

There are some possible scenarios according to the strategy used to perform the analysis. The two strategies are the mathematical model and the simulation tool. On the other hand, there are two possible MTU configurations: traditional MTUs and optimal MTUs. First test establishes a comparison between simulation results and mathematical expectations when optimal MTU configurations are used.

A. Simulated Results vs. Mathematical Results with Optimal MTU Configurations

In order to evaluate the accuracy of the mathematical model, its results are compared with simulation results. Fig. 2 shows the normalized throughput (Z) for optimal MTU configurations when simulation and theoretical tests are performed.

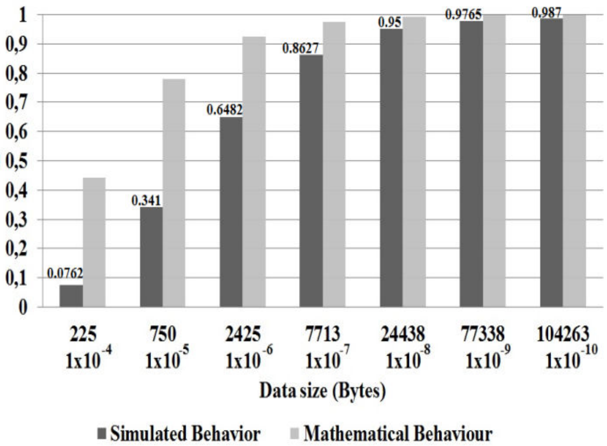

Fig. 2 Simulated behavior VS mathematical expectations when optimal MTUs values are used

As it can be seen, results are not exactly the same, but they keep a visible proportion, difference becomes smaller when more bytes are transmitted in a single packet. It suggests that most of the discrepancies are caused by additional control bytes and installation times when small packets are used.

B. Simulation Results: Ideal MTU vs MTU of 1500 Bytes

This scenario shows how throughput can be improved by using optimal MTU values. Current networks usually send packets according to the traditional MTU of 1500 bytes. Fig. 3 compares the simulation results when traditional and optimal MTU configurations are used.

Fig. 3 shows that a traditional MTU configuration of 1500 bytes prevents networks to improve their throughput. Even under the best BER conditions, they only achieve around 55%. Bars labeled as “MTU: obtained values”, represent throughput achieved when optimal MTUs were used.

Best throughput improvements by using optimal MTUs, were achieved when better BER conditions were present. According to the standard 802.11n, the highest possible BER for WIFI networks is $1x10^{-7}$. According to simulation results, using a MTU of 7.713 bytes[1] would allow an improvement around 57% in applications which use a continuous transmission similar to the one simulated in this work.

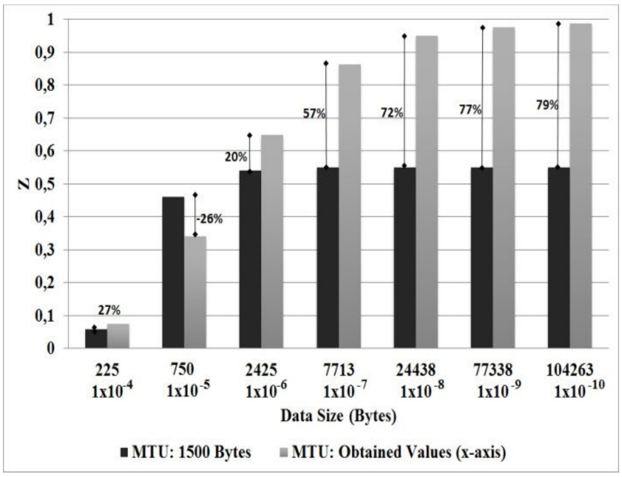

Fig. 3 Throughput improvement, comparison between the current MTU values 1500 bytes and the MTU obtained values, simulated perspective

It suggests that control traffic is one of the main limitations for throughput enhancement. For that reason, reducing protocol headers and number of individual transmissions would improve network performance.

C. Mathematical Results vs. Simulation Results Using a MTU of 1500 Bytes

In order to evaluate the accuracy of the mathematical model, mathematical results are compared with simulation results when MTU is 1500 bytes. Fig. 4 shows the comparison between these two perspectives.

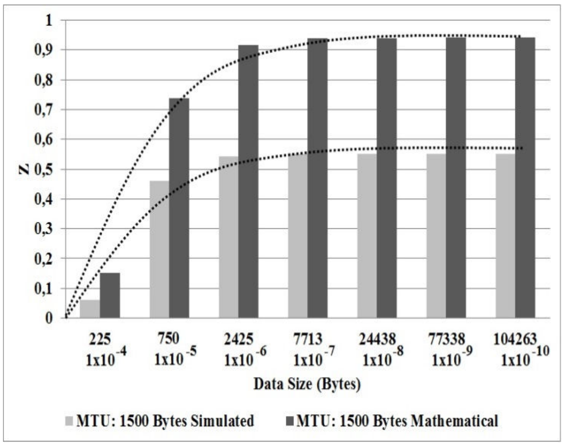

Fig. 4 Throughput comparison between simulated and mathematical analysis with an MTU of 1500 bytes

As it can be seen, simulation results do not exactly match mathematical expectations. However, they keep a proportional relation as plotted lines suggest.

D. Mathematical Results with a MTU of 1500 Bytes and Other Ideal Values

In the same way, mathematical results using traditional and optimal MTU configurations are compared in Fig. 5.

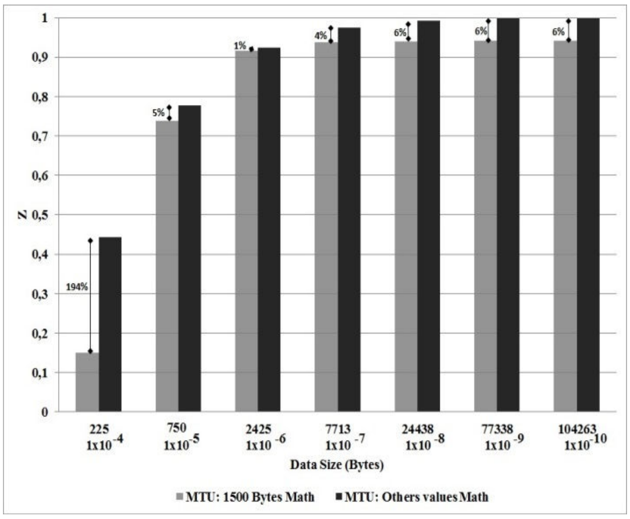

Fig. 5 Mathematical throughput comparison between results using a MTU of 1500 bytes and ideal MTU values

Larger frames take longer time to be transmitted. For that reason, the number of frames transmitted in a time slot becomes small when high MTU configurations are used. As a consequence, the control traffic is reduced. Since the advantage of using large packets consist in avoiding fragmentation and over heading, difference between the performances of two close high MTU becomes smaller. It indicates that using very high MTUs cannot achieve significant throughput improvement after a limit is reached. Fig. 1 also supports this fact by representing the throughput behavior as curve which tries to converge to one, but the improvements after a specific point are very small.

V. DISCUSSION

Based on the results obtained from Figs. 3 and 5, it is possible to determine percentage improvement when optimal MTU configurations are used. Table V registers these improvements beside the probability of receiving a packet with errors.

[1] The optimal MTU configuration when BER is $1x10^{-7}$

TABLE V
THROUGHPUT ENHANCEMENTS: IDEAL MTUS VS COMMON MTU OF 1500 BYTES

BER	Ideal MTU	Improvements		*P*
		Mathematical results	Simulation results	
$1x10^{-4}$	225	194 %	27 %	16.47
$1x10^{-5}$	750	5 %	-26 %	5.82
$1x10^{-6}$	2425	1 %	20 %	1.92
$1x10^{-7}$	7713	4 %	57 %	0.62
$1x10^{-8}$	24438	6 %	72 %	0.20
$1x10^{-9}$	77338	6 %	77 %	0.06
$1x10^{-10}$	104263	6 %	79 %	0.01

VI. CONCLUSIONS

Using larger packets can improve the throughput performance in low BER environments -lower than $1x10^{-6}$. Traditional MTU of 1500 bytes does not take advantage of BER reduction. Even with the best BER conditions it is not possible to achieve high throughput performances. Simulation results show that maximum throughput obtained with current MTU configuration is around 55%.

The throughput improvement can be approximately modeled using a mathematical approach. From Fig. 2, it can be concluded that the quality of the mathematical model prediction decreases with small MTU configurations. It suggests that most of the discrepancies of the mathematical model are caused by control traffic and installations times required for small packet transmissions.

This work assumes a continuous transmission. However, many real time applications have different QoS requirements. For that reason, packet transmission distribution, routing algorithms, and application requirements should be considered by future research. In the same way, time required for large packets transmission can affect other real time applications. A future research can be addressed to design a dynamic model where MTU configurations change according to QoS requirements. In this way, large packets will only be transmitted when QoS requirements allow it. However, the link layer constraints must be removed.

Benefits of large packets transmission are more significant under low BER conditions. For that reason, best transmission media could take advantage of new MTU configurations in a best way. Future research can address the evaluation of jumbograms implementation in other network technologies.

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