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Throughput Analysis On WiFi Channels For Using IPV6 Jumbograms

Edward Guillen, *Member, IAENG*, Stephanne Rodríguez, *Member, IAENG* and Paola Estupiñan, *Member, IAENG*

***Abstract*—When a data transmission is made by a communication network, the maximum frame size is limited according to physical parameters such as signal to noise ratio, bit error rate or even the channel distance. However, the maximum size is programmed manually in the network equipment with preconfigured small values, although IPV6 allows jumbograms transmission of packets larger than 64KB. This paper explores the possibility of using jumbograms over WiFi channels by analyzing the throughput with involved parameters in order to establish advantages of such uses.**

***Index Terms*—Bit Error Rate, Jumbograms IPV6, MTU, Normalized Throughput, WIFI 802.11n.**

I. Introduction

IN data networks, the speed of data transmission is significantly affected by applications that needs real time transmissions. These applications include Music on Demand (MOD), Video on Demand (VOD), Voice over IP (VoIP) and Videoconference, among others [1], [2]. The speed loss in transmission is caused by the fragmentation due to wide variety of information that is managed in these types of applications. In Local Area Networks the fragmentation produced by routers generates packets that reach a maximum of 1500 bytes, defined as the Maximum Transfer Unit (MTU). An overload of packets may result in a decrease in the pay load per unit time.

The MTU is maintained in low ranges; 1007 bytes and 2046 bytes [3], 1500 bytes [4], 4500 bytes [5]. However, the maximum theoretical length of an IP datagram is 65535 bytes including header. If the MTU value is incrementing it would allow a better performance of a data network and a reduction in the data processing of the devices comprised in the network. This increase in the MTU value contributes to use jumbograms, which are IPV6 datagrams larger than 64K bytes [6]. It is possible that the use of jumbograms will enhance the QoS parameters found in real time applications.

This research employed a mathematical model to study the effect of incrementing the MTU value to a value greater than 65535 bytes, in 802.11n wireless data networks. The model assesses three physical parameters in order to create jumbograms: transmission capacity, coverage distance, and Bit Error Rate (BER). It was found that the only physical parameter that contributes to the use of jumbograms is the BER. It is important to point out that this study made modifications at a hardware level, while the software remained unchanged.

The remainder of this paper is organized as follows. In Section II we present related work about the performance analysis over 802.11n. Section III presents the most representative physical layer parameter. In Section IV the mathematical model is formulated. Section V describes 802.11n MAC header and frame details. In Section VI mathematical analysis and results are presented. Jumbograms application is discussed in Section VII. Finally, in Section VIII conclusions and address topics for further research are presented.

II. Performance Analysis over 802.11n

Performance Analysis over a data network is necessary for understanding current data network behavior [7]. To evaluate the performance network at a physical layer, there are several parameters, such us [8]: Throughput, Delay, Jitter, Convergence Time, Bandwidth, Frame Loss, BER, coded Frame Error Rates (FER) and Signal to Noise Ratio (SNR) [9], [10].

Over the last decade, a significant number of research and development efforts have been dedicated to performance measurement analysis. In [11], it is developed an analytical model to compute the normalized throughput of the IEEE 802.11 Distributed Coordination Function (DCF) scheme with hidden nodes in a multi-hop ad hoc network. Comparisons with the physical parameters lets them know that the carrier sense range is equal to the transmission range, with a different throughput interval. On the other hand in [12], it is shown a performance analysis on delay, throughput and packet loss rate in error-prone channels. A mathematical analysis through a performance analysis is consider in [13] based on the frame aggregation mechanism of 802.11n MAC. A theoretical minimum mean square error is derived, in order to propose a novel channel estimation algorithm; also BER and the precision of Channel Estimator were evaluated. Other similar analysis can be seen in [14], [15].

As it is defined in 802.11n, the maximum performance increases when frames are transmitted continuously one after another, instead of sending individual acknowledge (ACK) frame [16]; owing to these control frames that are not to robust as those frames that have to deal with errors. IEEE 802.11n introduced a mechanism to acknowledge a

E. Guillen Author is with Military University Nueva Granada, Research Professor of Telecommunications Engineering Department. Bogotá, Colombia. e-mail: (edward.guillen@unimilitar.edu.co).
S. Rodríguez Author is with Military University Nueva Granada, Student of Telecommunication Engineering. Bogotá, Colombia. e-mail:(stephanne.24@ieee.org)
P. Estupiñan Author is with Military University Nueva Granada, Research Assistant of Telecommunications Engineering Department. Bogotá, Colombia. e-mail: (edith.estupinan@unimilitar.edu.co).

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block of packets effectively [12]. This Mechanism is applied to the Aggregated Mac Protocol Data Unit (AMPDU). In order to improve efficiency, the transmitter can send an Add Block Acknowledgment (ADDBA) frame, to the receiver [17]. A more specific analysis about the operation of 802.11n MAC in [18].

In a wireless environment, *Normalized Throughput* is a traffic metric [19]. As a measure of traffic, *Normalized Throughput* is used in different ways including: Coherent time-spreading [20], access and collision probabilities parameter letting know how efficiently the resources are being used by users across two channels [21]. Another application shows *Normalized Throughput* as a measure of comparison and evaluation between more variables, in [22], [23]. This paper is based on [16], where the expression *Normalized Throughput* shows the effect on the speed about, data transmission packet length, field length control and the bit error probability.

III. Physical Parameters

A. Bit Error Rate, BER

A direct measure of data link layer performance for a digital system is the BER, which expresses the probability that a bit will be received wrong. M. Jeruchim refers to probability of one bit being corrupted in some time interval, $BER = 1x10^{-n}$, 1 in 10^n bits is corrupt [24]. BER is a function of SNR. For a physical (PHY) layer implementation, BER increases with transmission range and PHY rate [25], [26]

According to the Optimal Frame Aggregation (OFA) which is a technique for calculating the Aggregated Mac Service Data Unit (AMSDU) frame under different BERs in 802.11n WLANs proposed in [17], the algorithm suggests that the optimal AMSDU frame size must have the following values 1000bytes, 1500bytes, 2500bytes, 4500bytes, and 8000bytes with a BER value of $1x10^{-4}$, $5x10^{-5}$, $2x10^{-5}$, $1x10^{-5}$, and $1x10^{-6}$ respectively [27].

As it was shown in [9], [12] the network throughput increases as the channel condition improves, and under higher BER conditions a single optimal fragment size exists in order to achieve maximal throughput in the network. Other type of variables in the study of physical paramaters are involved, including capacity and distance, as is evident in [28] and [29].

IV. Error Probability at 802.11n Frame

BER refers to the probability of having at least one bit error in the frame. Then taking BER variable, as the bit error probability, the probability without error would be $(1 - BER)$. The error frame probability is P as in (1):

$$P = 1 - (1 - BER)^S \tag{1}$$

Where, the total size of the frame is $S = (S_d + S_c)$, the data field size in the frame is S_d and the control field size in the frame is S_c.

Based on [16], the probability of receiving a frame with error at the receiver is P, so the probability of receiving it correctly is $(1 - P) = \rho$. As seen in Fig. 1, the size of the control data S_c is 320 bits, which is a fixed size, while the data size can change. In order to simulate the efficiency of channel, it is important to consider other variables such as: transmission capacity TC, propagation time T_p which depends on the propagation velocity V_p, equal to $V_p = c/\sqrt{E_r}$, speed of light (c) and air relative permittivity E_r also T_p depends on distance X, so $T_p = X/V_p$, time required to transmit a frame $T_i = S/TC$, time out T_{out}, total time T_t equal to $T_t = T_i + T_{out}$, and α standardized parameter, so time-out interval is represents by $\alpha = T_t/T_i$ and $(\alpha - 1) = \beta$. In order to show the relation between normalized throughput and capacity versus the data size measured in bits, which refers to the length of the frame that can be transmitted, we apply equation (3):

$$z = \left[\frac{S_d}{S}\right] * \left[\frac{\rho}{1 + \beta - \rho * \beta}\right] * TC \tag{2}$$

If $Z = \frac{z}{TC}$, then:

$$Z = \left[\frac{S_d}{S}\right] * \left[\frac{\rho}{1 + \beta - \rho * \beta}\right] \tag{3}$$

V. 802.11n MAC Specification

A. 802.11n Mac Frame Format

Wireless devices that share the same protocol at the MAC layer follow the IEEE 802.11 standard "Wireless Local Area Network (WLAN)"[30]. Wireless devices follow different standards for the physical layer such as 802.11a, 802.11b, 802.11g, 802.11n, etc. [31]. To improve the wireless network performance exist two main external factors, first the ever-growing QoS-sensitive multimedia applications, and second the inherent internal deficiencies of wireless communications, such as low bandwidth resources and time-varying channel conditions [32]. Components and performance of the MAC frame format will be analyzed, based on the 802.11n standard [33].

MAC frame format involve a set of fields that happen in a fixed order in all frames. Fig. 1 shows the general MAC frame format. The fields, Frame Control, Duration/ID, Address 1 and the last field Frame Check Sequence (FCS) constitute the minimal frame format and are present in all frames. These Fields include reserved types and subtypes. The field FCS refers to the extra checksum characters added to a frame in a communication protocol for error detection [34], [35]. At the receiver side, if there is no error in frames after checking the FCS field, the receiver sends back an ACK frame to the transmitter. On the other hand the fields Address 2, Address 3, Sequence Control, Address 4, QoS Control, HT control and Frame Body are presented only in certain frame types and subtypes. The Frame Body field has a variable size. The maximum frame body size is determined by the Mac Service Data Unit (MSDU) which size is 2304 octets plus any overhead from security encapsulation. For more specific analysis see [27].

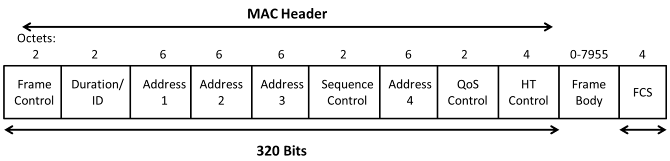

Fig. 1. IEEE 802.11n Mac Frame Format

B. *Frame Control Field of the 802.11n MAC Header*

The first field at the MAC header is the Frame Control. This field consist of the subfields: Protocol Version, Type, Subtype, to Distribution System (DS), From DS, More Fragments, Retry, Power Management, More Data, Protected Frame, and Order. Fig. 2 shows these subfields.

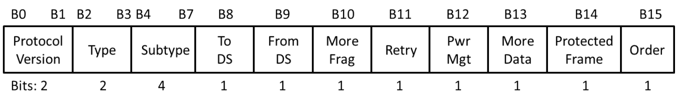

Fig. 2. Frame Control Field, First Field From 802.11n MAC Frame Format

The frame control function is identified by the type and subtype fields. The type field is 2 bits in length and the Subtype field is 4 bits in length. There are three frame types: control frame, data frame, and management frame. We just based on control and data frames. Each of the frame types has several defined subtypes. In data frames, bit 7 is the Most Significant Bit (MSB) of the subtype field, defined as the QoS subfield. This is the most relevant topic in this paper, because of this subfield the description of QoS let us know the status of the data frame. Table I described approximately how it works this field:

TABLE I
VALID TYPE AND SUBTYPE COMBINATIONS,FROM FRAME CONTROL FIELD

Type value b3 b2	*Type description*	*Subtype value b7 b6 b5 b4*	*Subtype description*
01	Control	1101	ACK
00	Management	1110	action no ack

The bits for type value would change depending on what is needed, whether receiving acknowledgment (ACK) or not acknowledgment (NACK), at the same time the subtype value would make the same. The QoS Control field is present in all data frames in which the QoS subfield of the Subtype field is set to 1 (bit 7), this information shows the description of the field.

VI. MATHEMATICAL ANALYSIS AND RESULTS

After analyzing the field of QoS, the main parameter was found to be the ACK policy delivery at the receiver. It was found that WIFI technology gets acknowledgments at the receiver, and due to the type of technology the trasmission is duplex, and frames transmission remains constant. Data frames are transmitted continuously, without waiting for an ACK, in order to use all available bandwidth into the channel. When a NACK is received or time out expires, the frame is relayed. It is an advantage to have a continuous transmission, as it improves the performance especially if the delay is not important compared to the time of frame transmission.

In order to find Z, which is the *Normalized Throughput*, the parameters involved must be evaluated. Thus, it is crucial to determine the parameters that show changes and those that do not. According to 802.11n standard, transmission capacity is supported from 54Mbps to 600Mbps, which is also seen in [12], [36]. In general the maximum distance used on WIFI 802.11 is 100 Km [37]. On the other hand, the typical values for BER used on WIFI are around $1x10^{-4}, 1x10^{-5}, 1x10^{-6}, 1x10^{-7}$, [27], [17]. Based on the above, we relate distance, capacity and BER, as follows:

A. Distance value remains fixed while capacity and BER value change.
B. Capacity value remains fixed while distance and BER value change.
C. BER value remains fixed while distance value change.

A. *Fixed Distance Analysis*

Four scenarios were proposed to accomplish the test. In order to assess possible variation that can happen when the parameters that affect Z change. Table II shows how the capacity varies, and distance is constant in 1 Km. The scenarios are defined in Table II.

TABLE II
SCENARIOS WHEN DISTANCE IS FIXED AND CAPACITY VARIES

SCENARIO	CAPACITY	BER
1	150 Mbps	$1x10^{-4}$ $1x10^{-5}$ $1x10^{-6}$ $1x10^{-7}$
2	300 Mbps	$1x10^{-4}$ $1x10^{-5}$ $1x10^{-6}$ $1x10^{-7}$
3	450 Mbps	$1x10^{-4}$ $1x10^{-5}$ $1x10^{-6}$ $1x10^{-7}$
4	600 Mbps	$1x10^{-4}$ $1x10^{-5}$ $1x10^{-6}$ $1x10^{-7}$

Fig. 3 shows Scenario 1 using equation (3), where each line defines a value of BER.

Table III list the results of the four scenarios that have been evaluated. It shows same values for (x) axis corresponding to data size (Bits). Thus, we are now able to compare values in bytes which are used in today's wireless transmissions. See section III A.

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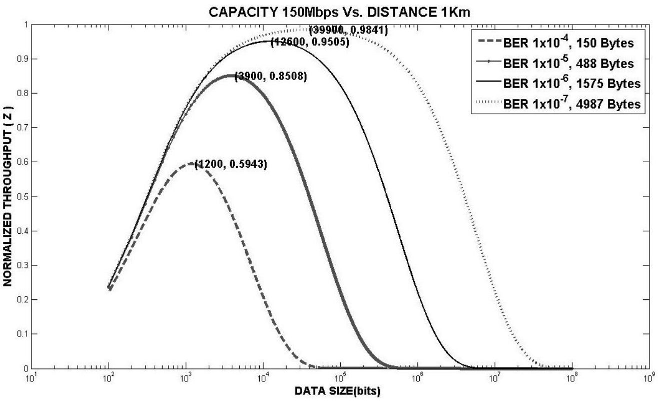

Fig. 3. Normalized Throughput Vs Data Size. Scenario 1, different BER values for capacity of 150 Mbps and distance of 1 Km

TABLE III
VALUE OF BER, Z, DATA SIZE AND BYTES. WHEN DISTANCE IS FIXED AND CAPACITY VARIES

CAPACITY VS DISTANCE	BER	Z (y)	DATA SIZE (x)	BYTES
150 Mbps vs 1 km	$1x10^{-4}$	0.5943	1200	510
300 Mbps vs 1 km	$1x10^{-5}$	0.8508	3900	488
450 Mbps vs 1 km	$1x10^{-6}$	0.9505	12600	1575
600 Mbps vs 1 km	$1x10^{-7}$	0.9841	39900	4987

B. Fixed Capacity Analysis

Another parameter to be evaluated is the capacity, as it was shown in section A, relating a fixed value at distance with different values for capacity, showed no change. In addition we performed simulations of WIFI link with different values for distance at constant capacity in 300Mbps. The scenarios are defined in Table IV.

TABLE IV
SCENARIOS WHEN CAPACITY IS FIXED AND DISTANCE VARIES

SCENARIO	DISTANCE	BER
1	5 Km	$1x10^{-4}$
		$1x10^{-5}$
		$1x10^{-6}$
		$1x10^{-7}$
2	25 Km	$1x10^{-4}$
		$1x10^{-5}$
		$1x10^{-6}$
		$1x10^{-7}$
3	50 Km	$1x10^{-4}$
		$1x10^{-5}$
		$1x10^{-6}$
		$1x10^{-7}$
4	100 Km	$1x10^{-4}$
		$1x10^{-5}$
		$1x10^{-6}$
		$1x10^{-7}$

Fig. 4 shows Scenario 2, where each line represents a value of BER at a distance of 25 Km. Fig. 5 shows scenario 3, where each line represents a value of BER at a distance of 50 Km.

Table V shows the results after performing the corresponding calculations in Fig. 4 and 5. The maximum values reached in Fig. 4 and 5 represent the MTU value.

Summarizing the results shown in Fig. 3, 4 and 5, and

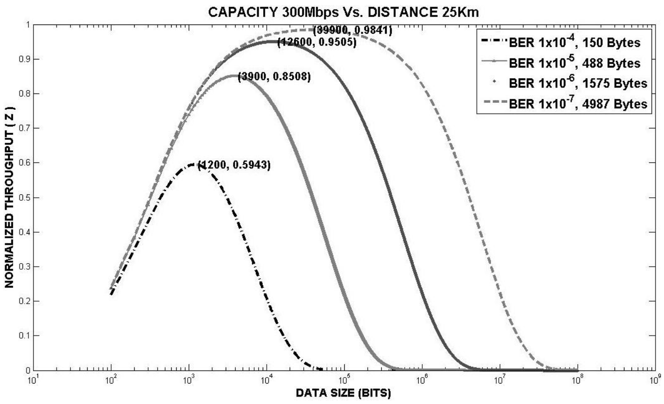

Fig. 4. Normalized Throughput Vs Data Size. Scenario 2, Different BER Values for Capacity of 300 Mbps and Distance of 25 Km

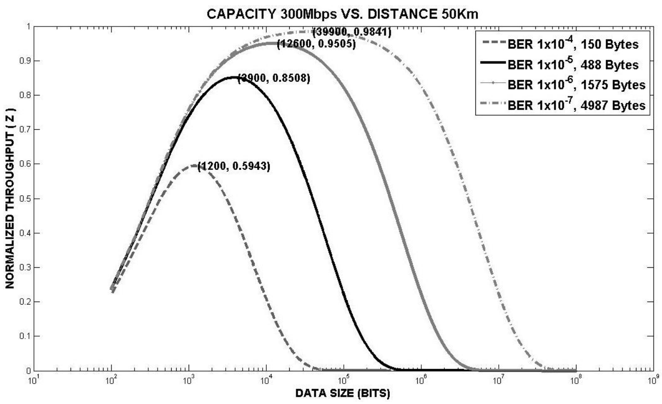

Fig. 5. Normalized Throughput Vs Data Size. Scenario 3, Different BER Values for Capacity of 300 Mbps and Distance of 50 Km

TABLE V
BER, Z, DATA SIZE AND BYTES VALUES. WHEN CAPACITY IS FIXED AND DISTANCE VARIES

CAPACITY VS DISTANCE	BER	Z (y)	DATA SIZE (x)	BYTES
300 Mbps vs 25 km	$1x10^{-4}$	0.5943	1200	510
	$1x10^{-5}$	0.8508	3900	488
	$1x10^{-6}$	0.9505	12600	1575
	$1x10^{-7}$	0.9841	39900	4987
300 Mbps vs 50 km	$1x10^{-4}$	0.5943	1200	150
	$1x10^{-5}$	0.8508	3900	488
	$1x10^{-6}$	0.9505	12600	1575
	$1x10^{-7}$	0.9841	39900	4987

after considering capacity and distance as parameters from Z. At constant capacity and various transmission distance the values in the relation Normalized Throughput Z are unchanged and the propagation time is distance depending.

C. Fixed BER Analysis

From the previous sections the results are independent from the capacity and distance changes. See Table III and Table V. Therefore we conduct our simulations under one BER value, and different distance values. We proceed to evaluate the following scenario, show in Table VI.

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TABLE VI
SCENARIOS WHEN BER AND CAPACITY VALUES ARE FIXED AND DISTANCE VARIES

SCENARIO	CAPACITY	DISTANCE	BER
1	300 Mbps	5 Km, 25Km, 50Km, 100Km	$1x10^{-6}$

Scenario number 1 is plotted in Fig. 6.

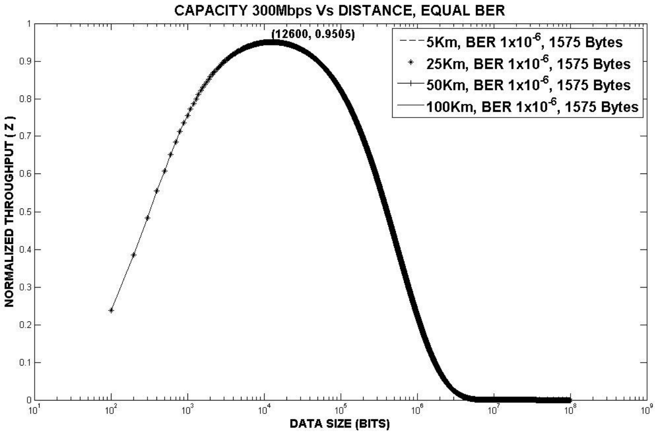

Fig. 6. Normalized Throughput Vs Data Size. Fixed BER value for Capacity of 300 Mbps and Distance of 5 Km, 25 Km, 50 Km and 100 Km

The maximum value reached in Fig. 6, is 12600 bits, which is 1575 Bytes. Table VII listed the results found after performing the corresponding calculations in Fig. 6.

TABLE VII
BER, Z, DATA SIZE AND BYTES VALUES. WHEN BER AND CAPACITY ARE FIXED AND DISTANCE VARIES

CAPACITY VS DISTANCE	BER	Z (y)	DATA SIZE (x)	BYTES
300 Mbps vs 5 km	$1x10^{-6}$	0.9505	12600	1575
300 Mbps vs 25 km	$1x10^{-6}$	0.9505	12600	1575
300 Mbps vs 50 km	$1x10^{-6}$	0.9505	12600	1575
300 Mbps vs 100 km	$1x10^{-6}$	0.9505	12600	1575

VII. JUMBOGRAMS APPLICATION

The maximum length of IPV4 packet is set on $2^{16} - 1$ bytes. In order to transmit larger packet than 2^{16}, IPV6 jumbograms should be required, [38], [39], [40], for specific analysis of IPV6 migration and Jumbograms application see [6]. BER value allowed for jumbograms uso it would know when 65535 Bytes is exceeded. For this reason the tests are performed to validate the value of BER that allows jumbograms use with the scale of variation $0,1$. Table VIII shows bytes value of each BER value. Likewise Fig. 7 shows the minimum BER value necessary to use jumbograms.

According to Fig. 7, it is allowed to use jumbograms when a BER value is less than $1x10^{-10}$ as 158100 Bytes, meaning the length of 65535 Bytes it exceeded. After testing, a BER value of $1x10^{-14}$, makes the results of the MTU become constant as is shown in Table VIII.

TABLE VIII
DIFFERENT BER VALUE WITH MAXIMUM VALUE REACHED IN BYTES, MTU. SCALE OF VARIATION 0.1

BER	MTU (Bytes)
$1x10^{-8}$	15800
$1x10^{-9}$	49988
$1x10^{-10}$	158100
$1x10^{-11}$	499975
$1x10^{-12}$	1581100
$1x10^{-13}$	4999000
$1x10^{-14}$	12500000
. . .	. . .
$1x10^{-22}$	12500000

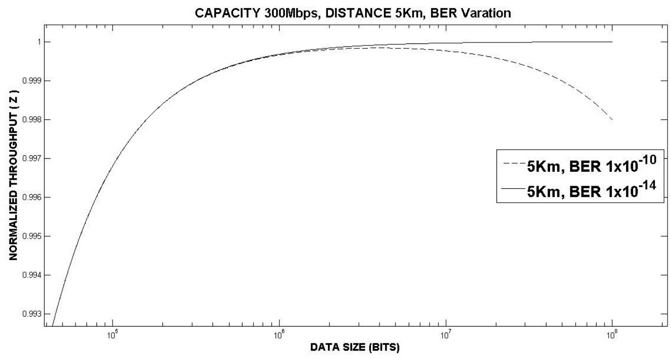

Fig. 7. Normalized Throughput Vs Data Size. Capacity of 300 Mbps and Distance of 5 Km, Minimum Value to use Jumbograms

VIII. CONCLUSION

Based on the mathematical analysis the channel capacity was evaluated, it was found that it is not a variable that defines the maximum value of bits in the transmission. This happens because T_i, time of placing the frame into the channel, $T_i = S/TC$, depends on the size of the header S, and the transmission capacity TC. The TC value will always be much larger than the size of the frame S, which shows that the value of T_i tends to zero. Likewise, the T_i value affects the α value. By maintaining a similar value for all capacities, it can be asserted that the relation throughtput capacity Z value is unchanged.

The same value for BER and capacity, despite of varying the distance values of the ratio Z, are the same values for every parameter. The parameters of capacity and distance do not significantly affect the ratio Z and it is evident that the BER is the most important parameter in Z. Because BER parameter does allow jumbograms use.

Increasing the MTU for data networks may create the opportunity to use IPV6 Jumbograms. Jumbograms fragmentation has been greatly reduced, due to its new MTU value and the decreased production of new headers that allow the transmission of more data and extend the capabilities of a data network regarding the supported applications. The characteristics of the channel in terms of capacity and distance are not relevant in the use of jumbograms unless it is the BER. The size of the packets to transmit is raised, when BER value decreases. With a BER of $1x10^{-10}$ it can be used jumbograms. It is not

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necessary to decrease the BER more than $1x10^{-14}$, because the length of the data remains constant below this BER value.

Our future research would focus on applying models that evaluate other physical parameters at both the hardware and software level. Furthermore, the models should be applied to other types of technologies.

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