Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**A Contribution to 802.16a: MAC Frame Sizes**
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Source(s)	Lei Wang Shane Rogers Brian Gieschen Gordon Antonello Shawn Taylor Wi-LAN Inc. 2891 Sunridge Way, NE Calgary, AB, Canada, T1Y 7K7 Voice: (403)273-9133 Fax: (403)273-5100 Email: LeiW@wi-lan.com
Re:	This is a contribution to IEEE 802.16a.
Abstract	This contribution provides an analysis on the MAC frame sizes vs. system performance.
Purpose	To support the comment of changing the maximum MAC frame size from 10ms to 20ms, for OFDM PHY systems.
Notice	
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Patent Policy and Procedures	

MAC Frame Sizes versus System Performance

Lei Wang

Wi-LAN Inc.

1. Introduction

This document provides an analysis of system performance versus MAC frame sizes in support the comment of increasing the maximum allowable MAC frame size from 10ms to 20ms for the OFDM PHY based systems.

2. References

IEEE P802.16a/D2–2002

3. MAC Frame Size vs. Uplink Throughput

The analysis will use the parameter values given in Table 197, page 135, of P802.16a/D2 document, for the OFDM PHY with 3.5 MHz channel size, 256-FFT, and 16QAM, FIGURE 1 shows the interaction between the MAC frame size, uplink throughput and the number of supported Subscriber Stations (SS's), within a given max tolerable delay in an 802.16a OFDM TDD system. The max tolerable delay at an 802.16a system is assumed to be 40ms in FIGURE 1.

Note that a larger MAC frame size results in a higher uplink throughput, for any given number of supported subscriber stations. The reason for this result is that a larger MAC frame size allows a larger uplink transmission and more OFDM data symbols with the same PHY and control overhead.

4. MAC Frame Size vs. System Capacity (Number of Supported SS's)

Also, FIGURE 2 shows that, for the same uplink throughput and tolerable delay, a larger MAC frame size results in better system capacity in terms of the number of supported SS's.

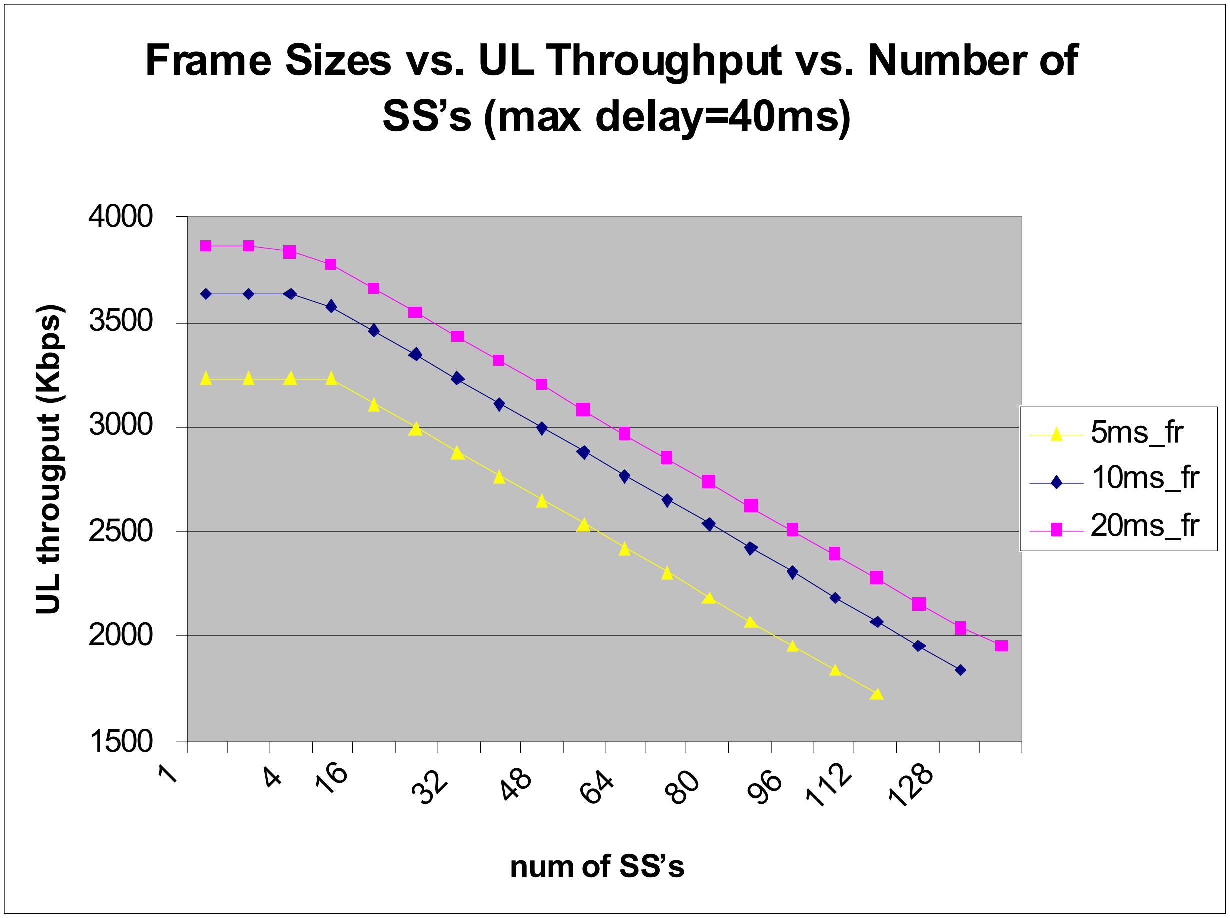

FIGURE 1 MAC Frame Size vs. Uplink Throughput and Number of Supported SS's

5. MAC Frame Size vs. TCP Performance

The MAC frame size affects the TCP round trip delay of the TCP applications over an 802.16a system. For a given TCP window size, when the available network bandwidth is high, the TCP round trip delay may affect the TCP throughput. The TCP window size is the amount of data that can be buffered at the receive side of a TCP connection. The sending host can send only that amount of data before receiving an ACK from the receiving host. In Microsoft Windows 2000 TCP/IP implementation, the TCP window size is normally (by default) set to 17,520 bytes (16K rounded up to 12 1460-byte segments).

Using the parameter values given in Table 197, page 135, of P802.16a/D2 document, for the OFDM PHY with 3.5MHz channel, 256-FFT, and 16QAM, an 802.16a OFDM TDD system can provide an uplink throughput about 3.22 Mbps to 3.86 Mbps depending on the MAC frame size. Using 4Mbps as the available uplink throughput and 17,520 bytes as the TCP window size, FIGURE 2 shows MAC frame size versus TCP throughput and number of users, under the consideration that the TCP one-way end-to-end delay is the sum of the MAC frame size and a fixed delay representing other network elements in the connection. The fixed delay is 30ms in FIGURE 2.

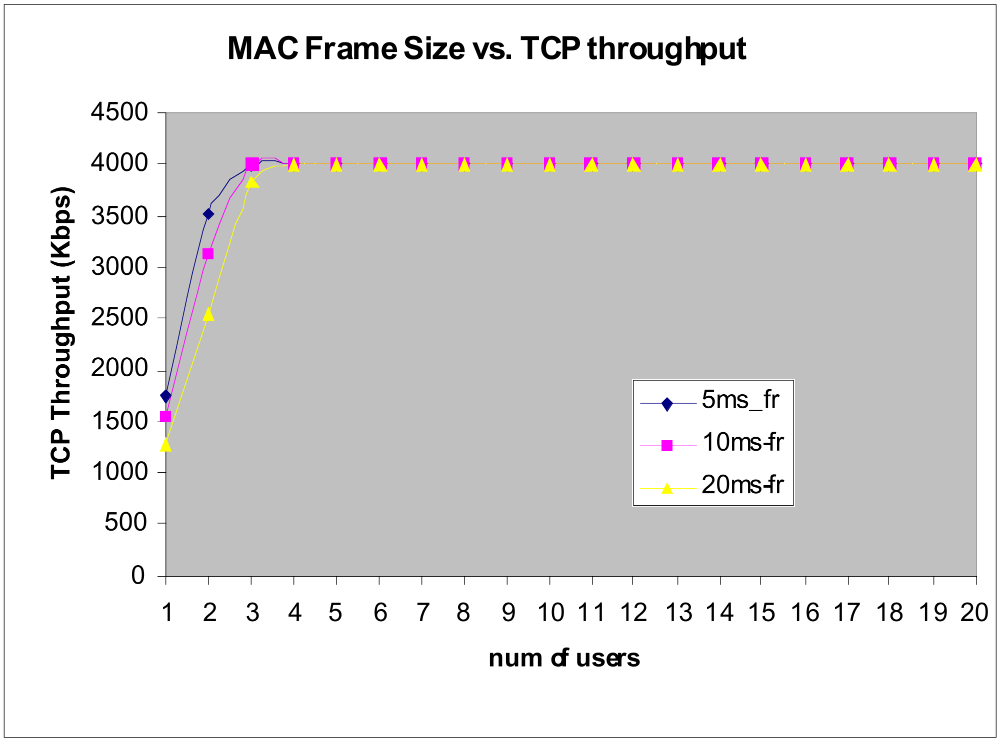

FIGURE 2 MAC Frame Size vs. TCP Throughput

Note that only when the number of users is very small, e.g., smaller than 4, different MAC frame sizes result in slightly different TCP throughputs. In any practical 802.16a networks, the number of users will be more than 4.

6. MAC Frame Size vs. Transmission Efficiency

The transmission efficiency here refers to the ratio of the overhead in a transmission on the wireless link. The overhead includes PHY preambles and control costs such as downlink FCH (frame control header), uplink initial ranging slots, uplink bandwidth request slots. The control messages, such as DCD, UCD, MAPs, are overhead, too. However, for simplicity, they are not considered in calculations reported here.

For the OFDM PHY systems, assume that each MAC frame has one initial ranging slot and one bandwidth requesting slot, each with 3 OFDM symbols.

Table.1 MAC Frame Size vs. Overhead Ratio (OFDM 256-FFT)

MAC Frame Size	5 ms	10 ms	20 ms
DL transmission overhead ratio	8.6%	4.3%	2.1%

UL transmission overhead ratio	If 1 regular UL Tx per MAC frame	20%	10%	5%
	If 2 regular UL Tx per MAC frame	22.9%	11.4%	5.8%
	If 4 regular UL Tx per MAC frame	28.6%	14.3%	7.1%

Note that a larger MAC frame size results in a smaller overhead ratio, i.e., a more efficient transmission. This is also true for the OFDMA PHY 2k-FFT systems, as shown in Table.2, with the assumption that each MAC frame has one subchannel for ranging and one subchannel for bandwidth requesting.

Table.2 MAC Frame Size vs. Overhead Ratio (OFDMA 2k-FFT)

MAC Frame Size	5 ms	10 ms	20 ms
DL transmission overhead ratio	25%	14.3%	6.3%
UL transmission overhead ratio	29.7%	16.7%	11.5%

7. MAC Frame Size vs. Buffer Size

Depending on implementation, buffers may be required to temporarily store the data received or to be transmitted at a unit (either a BS or a SS) in an 802.16a system. Table 3 shows the required buffer sizes for different MAC frame sizes, with 64QAM OFDM/OFDMA systems.

Table.3 MAC Frame Size vs. Buffer Requirement (64QAM OFDM/OFDMA)

	OFDM (256-FFT)			OFDMA (2k-FFT)		
MAC frame size	5 ms	10 ms	20 ms	5 ms	10 ms	20 ms
Buffer size for buffering one MAC Frame	6,588 bytes	14,148 bytes	29,484 bytes	5,022 bytes	10,044 bytes	25,110 bytes

Note that a larger MAC frame needs a larger buffer. However, even with 64QAM, buffering a 20ms-MAC frame only needs about 15K bytes more than buffering a 10ms-MAC frame. 32Mbytes of memory costs about $8. In addition, often implementations are available that do not require buffering entire frame.

8. Conclusion

In conclusion, the analysis results presented above strongly supports the comments of changing the max MAC frame size from 10ms to 20ms for the 802.16a OFDM PHY systems, because of:

a) Better throughput;

b) Better system capacity (number of supported SS's);

c) More efficient transmission (smaller overhead ratio);

d) Negligible impact on TCP performance when the number of users is very small (less than 4); no impact at all when the number of users is more than 4;

e) Very small buffer requirement increase (negligible cost increase with currently available commercial memory chips, also it is easily implementable in custom ASIC);

f) Good alignment with VoIP packetization rate (1pkt/20ms);

g) Only suggested as max MAC frame size (allowing smaller sizes, such as 2ms, 2.5ms, 3ms, …).