

Energy-signal quality trade-offs in a WiMAX mobile station with a booster amplifier

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Abstract. Worldwide Interoperability for Microwave Access (WiMAX) is a broadband wireless access technology that is able to provide high bit rate mobile internet services. Battery endurance remains a problem in current mobile communication. On the other hand, signal quality determines the successful run of the mobile applications. Energy consumption optimization cannot sacrifice the signal level required by the application to run smoothly. On the contrary, the application should consider battery life time. This paper examines the trade-offs between energy and signal quality in WiMAX subscriber station by adjusting signal level using a booster amplifier. Simulation evaluations show that an increment of 0.00000104% energy consumption on using amplifier adaptively produces 16.411% signal to noise ratio (SNR) increment and 10.7% bit error rate (BER) decrement. By keeping the amplifier turned on, energy consumption increases up to 0.00000136%, causing the SNR rises to 17.2638% and BER drops to 11.13%. The evaluated application is video streaming, other application may behave differently.

1. Introduction

Worldwide Interoperability for Microwave Access (WiMAX) is a Broadband Wireless Access (BWA) technology with a wide coverage area standardized by the IEEE 802.16 [1]. WiMAX was initially set for fixed wireless broadband services dominated by point to point configuration on 10-66 GHz frequency band. In order to enhance its bandwidth, but handover and roaming procedures addition enable WiMAX serving mobile users [2].

WiMAX network components are based on point to point configuration with a single base station (BS) serving many subscriber stations (SSs). BS can be connected to other BSs through TCP/IP networks developing wide cellular-like network. WiMAX works as TCP/IP infrastructure with full support high speed connection and mobility for mobile multimedia application. WiMAX utilizes a fixed uplink-downlink channel separation which enables WiMAX managing uplink and downlink bandwidth as well as differentiate multimedia quality of services. Figure 1 shows WiMAX channel allocations. Uplink and downlink channels are arranged and addressed by a short MAP message. SS requests channels using one of the following schemas: random contention, polling and reservation. These features enable WiMAX to behave differently towards clients.



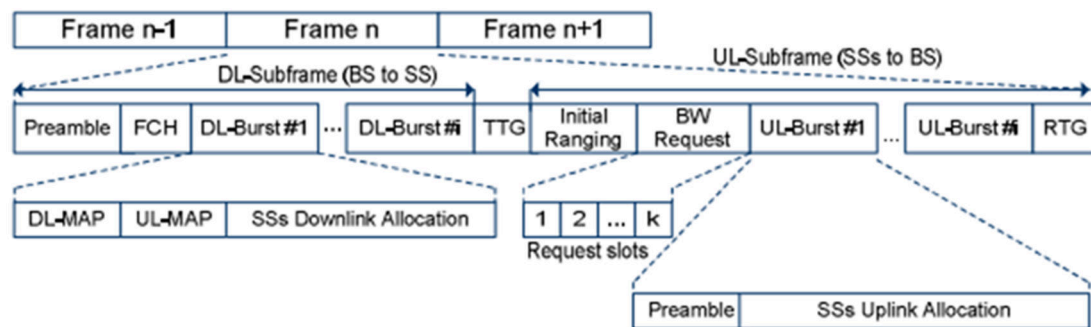


Figure 1. WiMAX Frame Structure [3]

WiMAX supports the multimedia network requirements. Multimedia packet receptions are depending upon the signal strength transmitted by the BS and received by the SS. Moreover if SS is in moving position, propagation media and obstacles influence the received signal very much. Indoor and outdoor changes cause signal variations that may generate packet loss. Amplifying signal at the receiver means increasing signal to noise ratio as well as energy consumption. Increasing signal to noise ratio improves the probability bit detection, improving the performance. However, increasing energy consumed by the amplifier means draining the battery faster. This paper assessed the trade-off between signal amplification and energy consumption on the simulated WiMAX network. Although this simulation does not necessary reflect the real implementation, the idea may be explored further in application environment.

2. Research method

In order to evaluate the trade-off between signal amplification at the receiver and receiver energy consumption, NS-2 simulator is employed. NS-2 is an event-based simulator that is flexible to make changes to some networks and protocols [4]. Network condition is set to have 7Mbps bandwidth with 4 (four) subscriber station one is in a fixed position, (0 m/s); walking speed (1.39 m/s); cycling speed (4.44 m/s) and driving speed (6.67 m/s). WiMAX coverage has 1000 m diameter with 64 QAM and two-ray ground propagation. Network configuration is depicted in Figure 2.

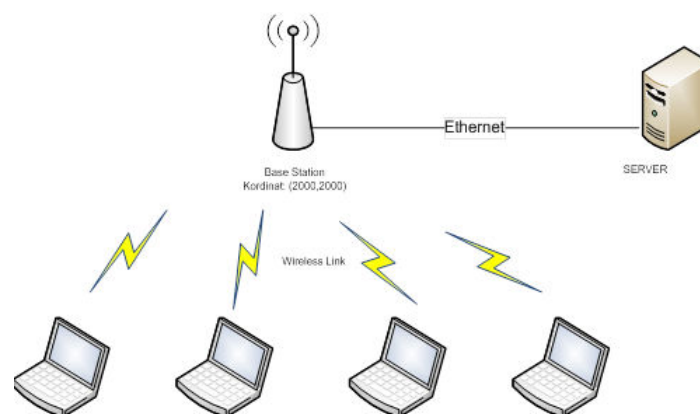


Figure 2. Network configuration

Energy consumption evaluation uses mathematical model proposed by Bezerra, et al. [5] that normalized energy consumption level in some states: downlink (dl) subframe, uplink (ul) subframe, sleep mode, idle mode, turned on, ul burst and dl burst as described in Figure 3. WiMAX scheduler is set to be round robin [7].

<i>Operation Mode</i>	<i>NS-2 state</i>	<i>Normalized power consumption</i>
<i>On dl subframe</i>	<i>While dl subframe</i>	1.00
<i>On ul subframe</i>	<i>While ul subframe</i>	1.00
<i>On sleep mode</i>	<i>while sleep mode</i>	0.29
<i>On idle mode</i>	<i>while idle mode</i>	0.06
<i>Turned on</i>	<i>while turned on</i>	1.00
<i>Transmitting ul burst</i>	<i>while ul burst ratio</i>	0.17
<i>Transmitting ul burst</i>	<i>while ul burst energy ratio</i>	0.01

Figure 3. WiMAX Normalized Power Consumption [5]

The signal amplification was realized by inserting amplifier model proposed by Kumar et al. [6]. The amplification is modelled by using mathematical equation as in Equation 1 [6]. Where $x(t)$ is input signal and $y(t)$ is output signal. Parameter a_1 , a_2 and a_3 are designed based on the type of amplifier IC employed.

$$y(t) = a_1 * x(t) + a_2 * x^2(t) + a_3 * x^3(t) \quad (1)$$

Amplifier inserted to SS is designed by using amplifier IC HMC413QS16G/ HMC413QS16GE from Hittit Electronics with specifications [6]:

- Gain, $G_{db} = 23db$, Saturated Output Power, $P_{sat} = 29.5dbm$
- Output Power at 1db Compression point, $P_{1db} = 27dbm$ for supply voltage = +2.75V to +5V
- Output power at 3 rd Interception Point, $P_{IP3} = 40dbm$

Kumar et al analyzed that the output depending on a_1 and a_3 so that Equation 1 is simplified to:

$$y(t) = a_1 * x(t) + a_3 * x^3(t) \quad (2)$$

It can be proved that $a_1 = 14.13$ and $a_3 = -0.4858$. So that Equation 2 be:

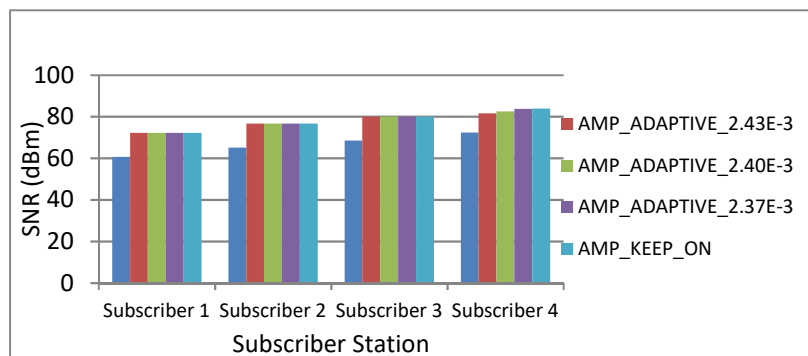
$$y(t) = 14.13 * x(t) + (-0.4858) * x^3(t) \quad (3)$$

This equation is inserted to WiMAX code in NS-2. Parameter signal to noise ratio (SNR), bit error rate (BER) and energy consumption are evaluated and analyzed.

3. Evaluation results

3.1. SNR

Figure 4 shows that SNR increases as amplifier inserted. For instance, SNR of subscriber 4 increases from 72.31 dBm (without amplifier) to 83.81 dBm (amplifier works continuously). Generally, signal amplification results SNR improvement.

**Figure 4.** SNR of 4 subscribers

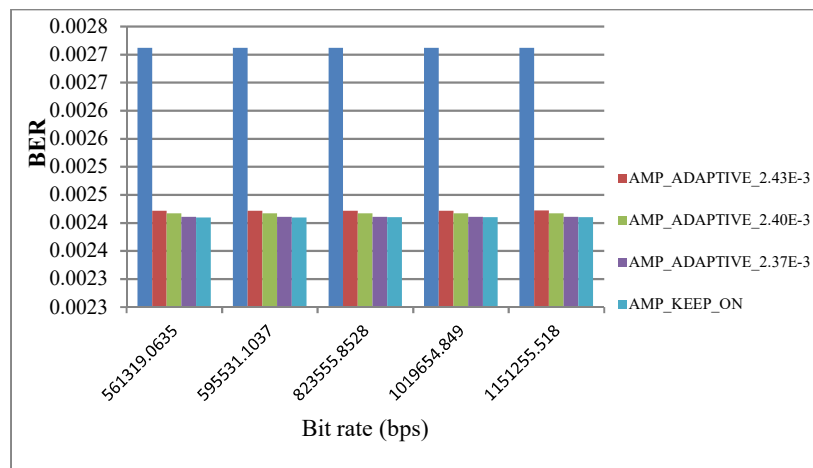


Figure 5. BER of all bitrates

3.2. Bit Error Rate

Bit error rate (BER) decreases when the received signal amplified as shown in Figure 5. BER has the lowest figures when amplifier keeps on. BER remains stable for different traffic rates. BER determines number of error bits. Figure 6 shows that the average error bit are inline to BER values.

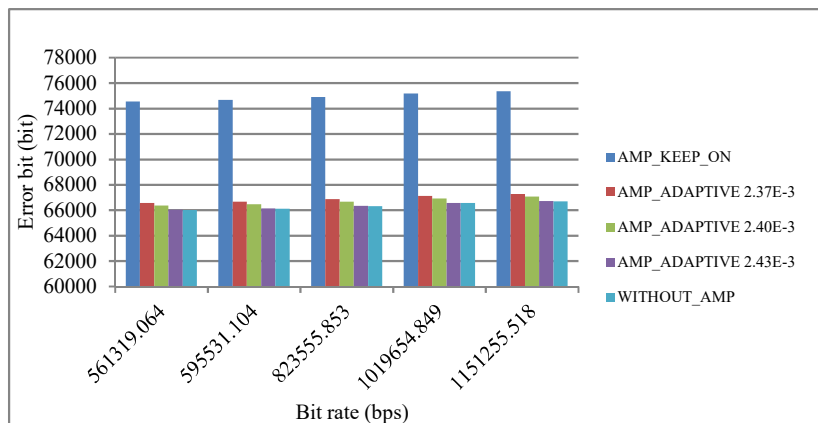


Figure 6. Error bits of all bitrates

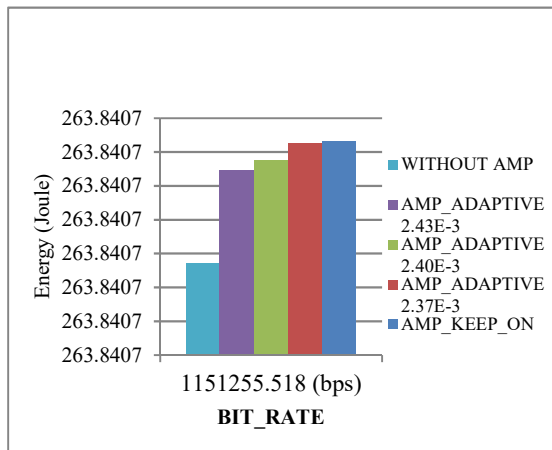
3.3. Energy Consumption

Energy consumption increases as amplifier applied. For bit rate 1151255 bps, without amplifier, SS consumes 263.84 Joule. Energy consumption increases to 263.841 Joule and 263.842 Joule when amplifier adaptively applied with BER 2.43×10^{-3} and 2.40×10^{-3} . Keeping the amplifier results the biggest energy consumption (Figure 7).

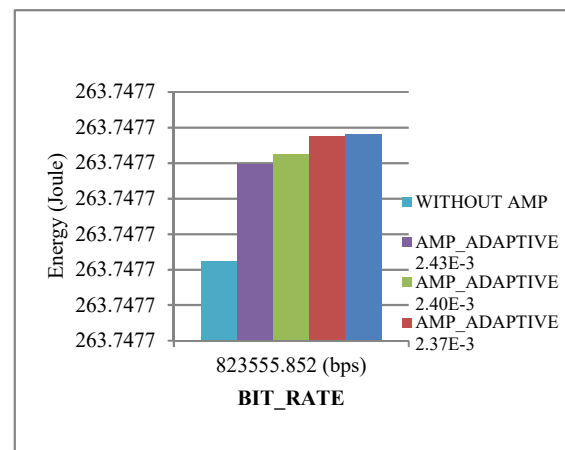
3.4. Signal Quality vs Energy Consumption

An increase of 16.411% signal to noise ratio (SNR) results 0.00000104% energy consumption increment when using amplifier adaptively. By keeping the amplifier turned on, energy consumption increases up to 0.00000136%, causing the SNR rises to 17.2638% and BER drops to 11.13%.

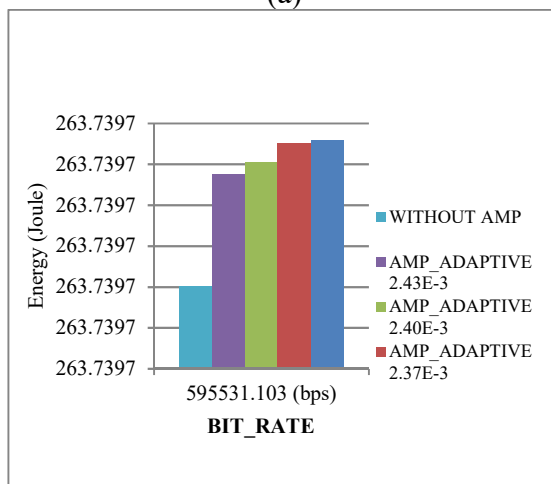
Based on this figure, the percentage of energy consumption increment is very low compared to SNR increment or BER decrement.



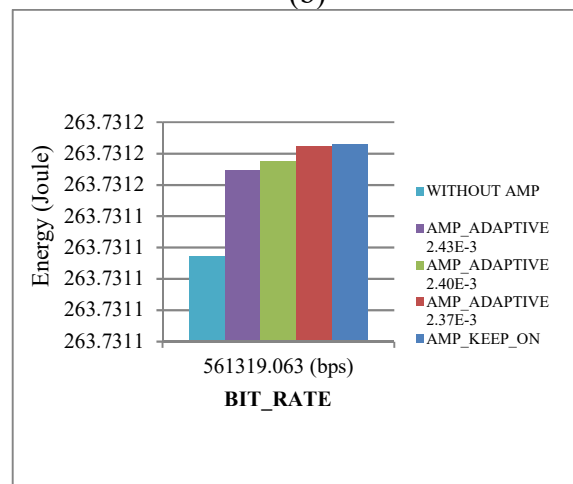
(a)



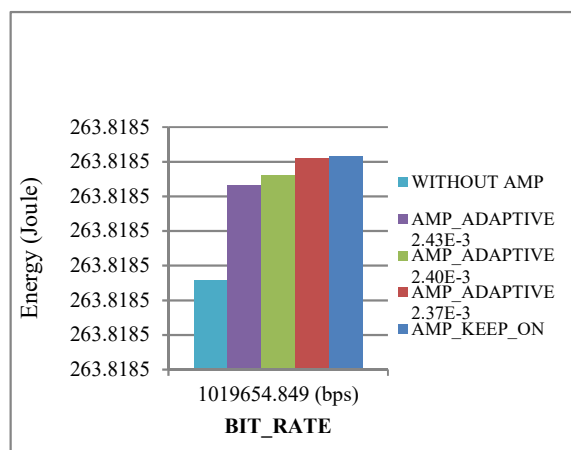
(b)



(c)



(d)



(e)

Figure 7. Energy consumption of all bitrates

4. Conclusion

Amplifier insertion increases signal quality (SNR) from 66.62 dbm to 78.123 dbm. The consumed energy also increases about 0.0000013589%. Using amplifier adaptively is able to reduce the consumed energy with smaller SNR increment.

References

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