*International Journal of Engineering & Technology*, 7 (3.2) (2018) 718-721

**International Journal of Engineering & Technology**

*Website: www.sciencepubco.com/index.php/IJET*

***Research paper***

# State and Duration Model of Energy Consumption in A Wimax Mobile Device

**S Suherman*, Naemah Mubarakah**

*Electrical Engineering Department, Universitas Sumatera Utara, Medan, Indonesia*
**Corresponding author E-mail: suherman@usu.ac.id*

**Abstract**

Energy consumption in a mobile device becomes a great interest as limited battery source restricts the power to activate the device. Current battery capacity displayed on a mobile phone screen is based on current state. A more precise prediction method is important as the connected application critically depends on the power availability. This paper reports the 802.16 energy assessment and modelling. A state and duration based energy consumption prediction is proposed and compared to simulated energy measurement. The evaluation showed state trend results 0.18% deviation for training data, 0.187% for test data 1 and 0.191% for test data 2. While state and duration trends result 0.194% deviation for training data, 0.211% for test data 1 and 0.215% for test data 2.

***Keywords:*** *Path loss, propagation model, outdoor to indoor propagation, Walfish-Ikegami and Multiwall combination*

## 1. Introduction

Worldwide Interoperability for Microwave Access (WiMAX) is a part of the 802.16 standard series. WiMAX provides high speed microwave radio connection either point to point or point to multipoint[1]. The 802.16e introduces mobility by providing handover services.

WiMAX works on 2-11 GHz and 10-66 Ghz frequency bands allowing high speed connection and multichannel services[2]. Working on high frequency enables WiMAX to have more frequency channels than 802.11 technologies. This is why instead of using contention scheme as carrier sense multiple access (CSMA) technologies [[3]], WiMAX uses time division duplex (TDD). Further, as more channels are available, WiMAX provides quality of services (QoS) classes. It provides five services: Unsolicited Grant Scheme (UGS) for fixed size traffic such as transport link and voice over internet protocol. Real-time Polling Service (rtPS) is to supports real-time variable bit rate traffic such as video stream, Enhanced Real-time Polling Service (ertPS) for on-demand bandwidth request and allocation application, Non Real-time Polling Service (nrtPS) is for non-real-time application, and Best Effort Service (BE) is contending application.

WiMAX usually consists of a base station (BS) connected to an IP network and mobile users or subscriber stations (SSs)[4]. Although its configuration is like a cellular network, WiMAX works as a packet based network. However, unlike 802.11, 802.16 is able to connect to other base stations as part of its subscriber stations.

WiMAX works with three different bandwidth allocation schemes: such as grant, polling, and contention. The framing format for ach channel is shown by Figure 1.WiMAX divides a channel into an uplink and a downlink streams. If grant for priority and bandwidth request or polling is given, it is informed to SS by using MAP frames within download stream. If a bandwidth request is sent, its request is allocated in uplink stream. TDD frame requires WiMAX maps every downlink and up link streams and inform them to SS. As result, wide range application can make use WiMAX.

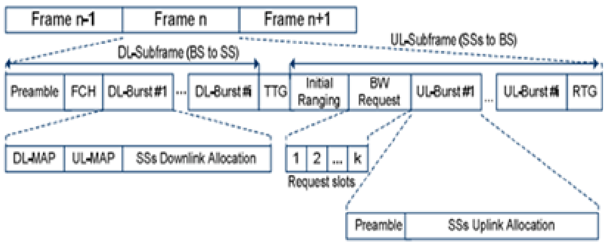



**Fig.1:** WiMAX Frame Structure [2]

WiMAX research starts from physical to the application layer[5]. In physic layer related to the use of orthogonal frequency division multiple access (OFDM), multi input and multi output antenna (MIMO), as well as channelization[6]. Link layer covers error control techniques as well as the use of adaptive modulation and coding (AMC)[7]. Channel arrangement for multiple accesses involves scheduling techniques and resource allocations [8]. Internet layer discusses mobile IP within WiMAX networks [9]. Transport layer concern with MAC support to enhance TCP or UDP performance[1], [10].

There is growing concern on energy usage on mobile devices. Miniaturization has been considered as an effective way. However, taking steps into energy efficient usage all level of TCP/IP architecture has been proposed in many ways. One of methods that has been implemented in energy saving is in standby mode or power saving mode [11]. Other research has proposed load arrangement [12].

One way to understand energy consumption is to derive energy usage model. Since WiMAX permits the mobile unit streaming high bit rate data from distance up to 70 km, there is high battery dependency, especially for mobile unit. Energy consumption model is important to predict how much energy required supporting this connection. As study goes through energy model, it was found that the work by Bezerra, et al[13] that proposed a normalized energy consumption model in each medium access level such as transmitting and receiving, sleep mode, idle mode, turned on, uplink burst and downlink burst may fit the WiMAX energy model requirement. Bezzera et al[13] divides normalized power as depicted in Table 1. The maximum power consumption occurs in states of uplink and downlink, while transmitting burst data only consumes 17 % of it. Turning on device also constitutes to high power consumption. Meanwhile, idle mode wins the energy saving that consumes about 6% of maximum level, followed by sleep mode.

**Table.1:** Bezzera Normalized Power Consumption [13]

| Operation Mode | Normalized power consumption |
|---|---|
| *On dl subframe* | 1.00 |
| *On ul subframe* | 1.00 |
| *On sleep mode* | 0.29 |
| *On idle mode* | 0.06 |
| *Turned on* | 1.00 |
| *Transmitting ul burst* | 0.17 |
| *Transmitting ul burst* | 0.01 |

Even though, this model only presented the amount energy consumed in each operation. In order to get the predicted consumed energy, this paper proposed a trend based energy consumption model in WiMAX. The proposed model records states and durations from training data, finds the trend patterns[14], [15] for each state and duration, then predict the consumed energy for given bitrates.

## 2. Proposed Consumption Model

In order to obtain the energy consumption model, training data should be obtained at first time. Since the evaluation employed in this paper is based on simulation results, scripts for recording the energy consumption should be embedded in each state. In case evaluation performed in a real device, energy consumption for each state should be precisely recorded. Afterwards, transmission is performed for various traffic bit rates, the state frequency and duration is recorded.

Each state level is classified as in Bezzera [13] energy consumption model. Duration of each state could be constant or varied for different bit rates. The amount the consumed energy for a given bit rate is approximated by Equation 1.

$$E = \sum_{i=0}^{i=n} D_i . P_i \qquad (1)$$

*E* is predicted energy; *Di* is the duration regression equation and *Pi* is normalized power for state *i* according to Table 1. Equation 1 is applied only if the equation pattern derived from duration only. However, if both duration and state patterns are derived, then the model is expressed by Equation 2:

$$E_T = \sum_{i=0}^{i=n} S_i D_i P_i \qquad (2)$$

$S_i$ is in the frequency of state in form of equation derived from regression analysis

## 3. Research Method

This paper uses NS-2 simulator to evaluate the effectiveness of the proposed energy consumption model. WiMAX module from nation institute of science and technology (NIST)[16] is employed. The Bezzera energy consumption model scripts are embedded to 802_16SS.cc in NS-2 simulator. There are 27 states within subscriber station simulator. A sample of the equivalent states is shown in Table 2.

**Table.2:** Simulated Normalized Power Consumption

| NS-2 state | Normalized power consumption |
|---|---|
| While_dl_subframe | 1.00 |
| While_ul_subframe | 1.00 |
| while_sleep_mode | 0.29 |
| while_idle_mode | 0.06 |
| while_turned_on | 1.00 |
| while_ul_burst ratio | 0.17 |
| while_ul_burst_energy ratio | 0.01 |

As the evaluated traffics are derived from akiyo_cif.yuv video traces, the successful generated rates are limited. Rates from 40.000 Bps to 680.000 Bps if for training data, bitrates from 56.000 Bps to 696.000 Bps and from 64.000 Bps – 704.000 Bps are for test purpose.

Network configuration consists of 4 mobile nodes transmitting similar traffics as explained previously. Power is adjusted to give 1 km coverage with 64 QAM and two-ray ground propagation model.

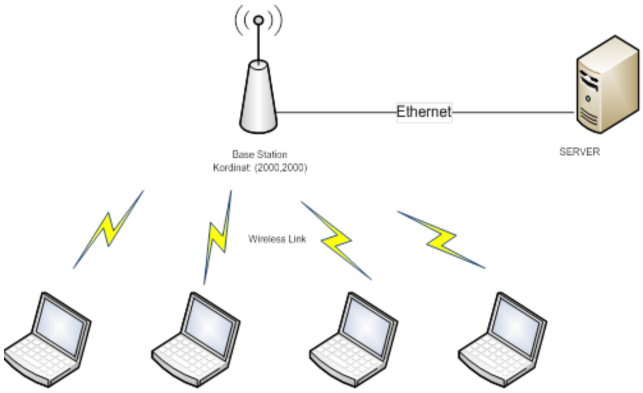



**Fig.2:** Network configuration

## 4. Results and Analysis

### 4.1 Duration Trend

Training data generation from 40.000 Bps to 680.000 results 15 out of 27 states involved within subscriber station device. There are 15 states active in communication. Eight of them have constant states duration for all bit rates. Seven states experience various lengths for different bit rates. Table 3 and Table 4 show the constant and varied state durations.

**Table.3:** Constant States

| No | State Name | Duration (s) |
|---|---|---|
| 1 | MAC initialization | 0.001 |
| 2 | Mac arrangement | 0.000263 |
| 3 | DL-MAP processing | 1.411993 |
| 4 | DCD Processing | 0.005981 |
| 5 | UCD Processing | 0.004005 |
| 6 | Ranging | 0.000026 |
| 7 | Registration | 0.000005 |
| 8 | NBR_ADV | 0.003587 |

**TABLE 4.** DURATION OF VARIABLE STATES

| | | |
|---|---|---|
| 9 | Outgoing Packet | $y = 58.627\, e^{-0.004\left(\frac{bit\ rate - 40000}{40000}\right)}$ |

| | | |
|---|---|---|
| 10 | Sending Packet to Phylayer | $y = -0.0084\left(\frac{bit\ rate - 40000}{40000}\right)^2 + 1.3799\left(\frac{bit\ rate - 40000}{40000}\right) + 6.4381$ |
| 11 | Incoming packet | $y = 0.0144\ e^{0.0263\left(\frac{bit\ rate - 40000}{40000}\right)}$ |
| 12 | Process packet internally | $y = 0.0001\left(\frac{bit\ rate - 40000}{40000}\right)^2 + 0.0127\left(\frac{bit\ rate - 40000}{40000}\right) + 3.5168$ |
| 13 | UL_MAP processing | $y = 0.0001\left(\frac{bit\ rate - 40000}{40000}\right)^2 + 0.0127\left(\frac{bit\ rate - 40000}{40000}\right) + 2.0896$ |
| 14 | Time adjustment | $y = 101.66\ e^{-0.011\left(\frac{bit\ rate - 40000}{40000}\right)}$ |
| 15 | Frame initialization | $y = -0.0091\left(\frac{bit\ rate - 40000}{40000}\right) + 101.1$ |

By using Equation 1, the energy consumed can be calculated. From this training data and simulation record, it is obtained that as shown in Figure 3.

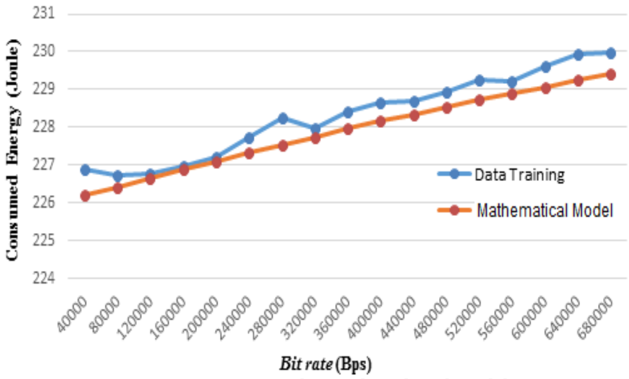
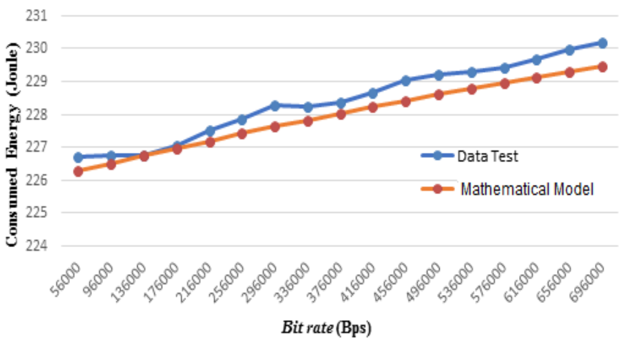


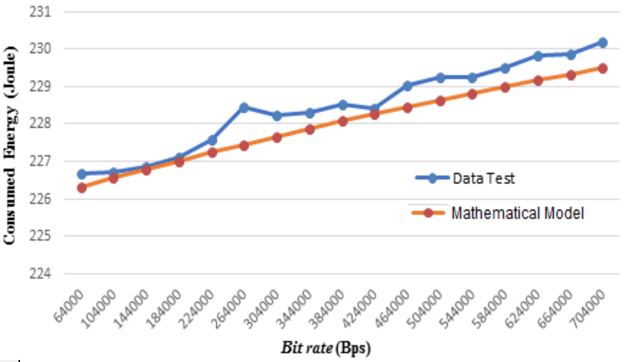

**Fig.3**: Training data and predicted model

The model and the simulation have similar pattern, however, some variation occurred in most points. Deviation in average 0.18% occurred during modelling. The training data energy consumption is closed to the predicted model with deviation 0.180 %.

Model is then tested for different rates: 56KBps to 700 KBps and 64KBps to 704KBps. The results are plotted in Figure 4a and b. Prediction for both 56 KBps to 696 KBps and from 64KBps to 704 KBps have close values to simulation results. The average deviations are 0.187% and 0.191%.




(a) 56.000 Bps to 696.000 Bps




(b) 64.000 Bps – 704.000 Bps

**Fig.4:** Test Data and Prediction

## 4.2 State frequency and Duration Trends

When both state duration and state frequency are approximated by using regression techniques, the additional frequency per total values are plotted in Table 4 and 5 for both constant and variable values.

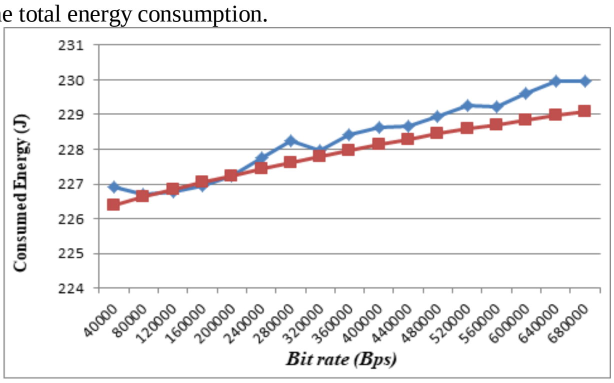
**Table.5:** States Frequency

| No | State Name | Frequency per total duration |
|---|---|---|
| 1 | MAC initialization | 0.001 |
| 2 | Mac arrangement | 4.38333E-05 |
| 3 | DL-MAP processing | 2.08035E-05 |
| 4 | DCD Processing | 0.000108745 |
| 5 | UCD Processing | 7.28182E-05 |
| 6 | Ranging | 0.000026 |
| 7 | Registration | 0.000005 |
| 8 | NBR_ADV | 6.61808E-06 |

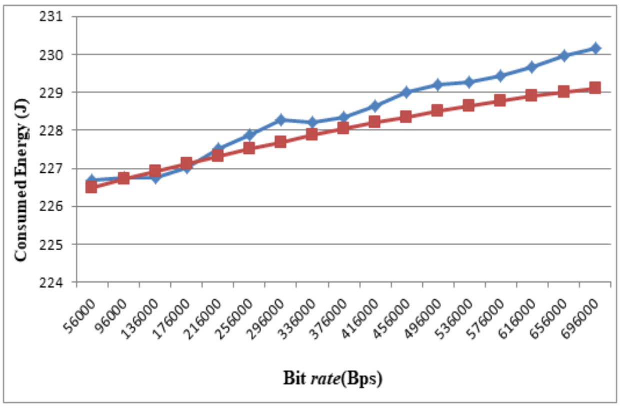
**Table.6:** Duration of variable states

| | |
|---|---|
| 9 | $0.0012e^{-0.0000001\left(\frac{bir\ rate - 40000}{40000}\right)}$ |
| 10 | $-36.646\left(\frac{bit\ rate - 40000}{40000}\right)^2 + 2070.9\left(\frac{bit\ rate - 40000}{40000}\right) + 54040$ |
| 11 | $0.0061\left(\frac{bit\ rate - 40000}{40000}\right)^2 + 0,2365\left(\frac{bit\ rate - 40000}{40000}\right) + 136445$ |
| 12 | $-0.0015\left(\frac{bit\ rate - 40000}{40000}\right)^2 + 622\left(\frac{bit\ rate - 40000}{40000}\right) + 136429$ |
| 13 | $0.00000000000000000009\left(\frac{bir\ rate - 40000}{40000}\right)^2 + 0.000000000005\left(\frac{bit\ rate - 40000}{40000}\right) + 0.00003$ |
| 14 | $0.0015e^{0.0000003\left(\frac{bit\ rate - 40000}{40000}\right)}$ |
| 15 | $0.0000000000000000000000009\left(\frac{bit\ rate - 40000}{40000}\right)^2 + 0.000000000003\left(\frac{bit\ rate - 40000}{40000}\right) + 0.0015$ |

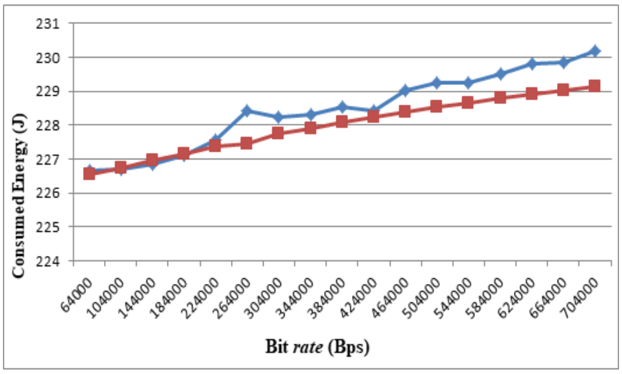
Prediction results for training data and two test datum are shown in Figure 5. By using frequency and duration of the state the deviation of predicted and simulation results produce 0.194%, 0.211%, 0.215% subsequently for training data, test data 1 and test data 2. It seems additional pattern analysis is not necessary. The duration of the state has been representative for predicting the total energy consumption.




(a). Training Data




(b). Test Data 1




(c). Test Data 2

**Fig.5:** Prediction results using duration and frequency trends

## 5. Conclusion

This paper has proposed energy consumption model based on state frequency and duration. The model gathers consumption data as a training data to form regression trends of every state. Trends can be generated by using state duration only or both state frequency and duration.

The state duration based results an average 0.18% deviation between predicted and measured energy consumptions for training data. It also produces about 0.187% and 0.191% for test data 1 and test data 2. The state frequencies and durations produce 0.194 %. 0.211% 0.215% subsequently for training data, test data 1 and test data 2.

## References


[1] S. Marwan Al-Akaidi, "A transport layer protocol for uplink WiMAX video streaming," *Int. J. Multimed. Ubiquittous Eng.*, vol. 10, no. 1, pp. 19–32, 2015.

[2] M. Suherman, S., & Al-Akaidi, "Increasing uplink broadband video streaming protocol performance in WiMAX network.," *Int. J. Internet Protoc. Technol.*, vol. 7, no. 3, pp. 176–185, 2013.

[3] S. Suherman, "WiFi-Friendly Building to Enable WiFi Signal Indoor," *Bull. Electr. Eng. Informatics*, vol. 7, no. 2, 2018.

[4] L. A. L. Hai Vu, S. Chan, "Performance Analysis of Best-Effort Service in Saturated IEEE 802.16 Networks," *EEE Trans. Veh. Technol.*, vol. 59, no. 1, p. 460–472., 2010.

[5] E. Mubarakah, N., Al-Hakim, M. Y., & Warman, "Energy consumption model on WiMAX subscriber station.(2018, February). Energy consumption model on WiMAX subscriber station. In IOP Conference Series: Materials Science and Engineering (Vol. 309, No. 1, p. 012002). IOP Publishing," *Energy Consum. Model WiMAX Subscr. Station. IOP Conf. Ser. Mater. Sci. Eng.*, vol. 309, no. 1, p. 012002, 2018.

[6] S. R. AV. Wale, "WIMAX Performance Analysis Using Different Antenna Configurations with MIMO-OFDM.," 2017.

[7] M. S. KL. Huang, VC. Gaudet, "A hybrid ARQ scheme using LDPC codes with stochastic decoding.," in *49th Annual Conference on In Information Sciences and Systems (CISS)*, 2015, pp. 1–4.

[8] M. Fakhrizal, S. R., & Al-Akaidi, "A subjective scheduler for subjective dedicated networks," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 237, no. 1, p. 012019, 2017.

[9] R. A. R. Al-Hiti, A. S., Latip, R., Sahbudin, R. K., & Mahmood, "Comparative Analysis of Routing Protocols Over WiMAX," *Adv. Sci. Lett.*, vol. 24, no. 2, pp. 1303–1306, 2018.

[10] D. Subramaniam *et al.*, "A Stacked Planar Antenna with Switchable Small Grid Pixel Structure for Directive High Beam Steering Broadside Radiation," *Int. J. Eng. Technol.*, vol. 7, no. 2.5, pp. 122–127, Mar. 2018.

[11] M. O. A. Belghith, A. Walha, B. Cousin, "Synchronized power saving mechanism for WiMAX networks," in *IEEE International Conference on Communications (ICC)*, 2017, pp. 1–6.

[12] N. Mubarakah, "Reducing mobile device energy consumption in transmitting multimedia content by arranging transport protocol load," in *Technology of Information and Communication (ISemantic), International Seminar on Application for*, 2016.

[13] N. S. Bezerra, "Modelling Power Consumption in IEEE 802.16e WiMAX Mobile Nodes," in *The 7th International Telecommunications Symposium*, 2010.

[14] U. Khair, H. Fahmi, S. Al Hakim, and R. Rahim, "Forecasting Error Calculation with Mean Absolute Deviation and Mean Absolute Percentage Error," *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 012002, Dec. 2017.

[15] R. Rahim, "Man-in-the-middle-attack prevention using interlock protocol method," *ARPN J. Eng. Appl. Sci.*, vol. 12, no. 22, pp. 6483–6487, 2017.

[16] Suherman, "Reducing Transmission Control Protocol Delay in 802.11 Network by Prioritizing the Acknowledgement Packets," in *The 6th International Conference on Information Technology for Cyber and IT Service Management (CITSM )*, 2018.