JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Energy Dissipation and Optimization Framework for Mobile Devices

Shalini Prasad
Professor
Dept of electronics and communication
City Engineering College
Bangalore-560061, India
shaliniprasad5@gmail.com

ABSTRACT: Smartphones are the most important gadgets that have entered one's day to day life. This generation finds the life difficult without this gadget because not only it is used for making phone calls but also for numerous other applications such as social connectivity, paying bills, filling forms, studying, searching for location or sending the current location, etc. The setback that this device has is that it requires to be charged now and then, that is, the battery life is one big concern for this gadget. This paper presents a model for evaluation of energy dissipation in smartphones and based on the findings, an optimization framework is designed.
Keywords—Smartphone; Energy dissipation; Energy optimization.

1. INTRODUCTION

The universal cellular coverage enables the network of second, third, fourth generation to access Internet services along with Wi-Fi networks. More often, the uses of smartphones, Personal Digital Assistants (PDAs) like tablets, and several other handheld devices are supported by Internet service capabilities. Few devices that have acquired more attention among the youth are Kindle, iPods and smart devices (e.g., iPad, etc.) for book reading electronically, listening to music and to surf social networking platforms [1-3]. As the field of microelectronics is advancing, there are various efforts taken up to ensure that size is no more a limitation with the distinct process of circuitry and design optimization. Hence, it has led to a situation where various handheld devices like smartphones, iPads are more likely used for application delivery [4]. Smartphones have turned out to be a very important gadget of our life. With the use of numerous applications, its battery tends to discharge very fast and hence the need arises to charge the battery of the smartphone to continue using it further. Hence, the need of the hour is that we should be able to use our smartphone for longer duration with minimal charging of its battery. There has been lots of work in this direction.

There are works that have been carried out by improvising the traditional energy consumption schemes derived from moved information; these approaches tend towards an *out-dated* fashion of evolving present standards in systems of mobile communication. Even though there are various researches performed in favour of calculating energy utilization in smart devices, only a few have chosen empirical modelling considering the performance matrices in case of energy depletion corresponding to data routing and transfer functions [5].

The problem that a wireless protocol affects the life of the battery to a greater extent is not addressed. However, scheduling is one such method that was adopted to overcome this drawback only in specific standards such as WLAN, data connectivity established via third or fourth generation cellular networks, Bluetooth, etc.[6-7].

Scarcities in the methodologies that initiate the optimization policies are noticed. Most of the proposed solutions that target the aspect of energy depletion in mobile devices do not introduce the issue of trade-off limitation among the increasing throughout and minimized power. The researchers are very few in numbers that map the drawback of non-linear optimization. As several multimedia files are utilized by mobile cellular networks, the power seeps proportionally [8-9].

Hence in this paper, an empirical model for energy dissipation is designed exclusively for smartphones. Here, both the aspects of scheduling and data transfer are considered with respect to the current standards of communication. Based on the findings of the energy dissipation model, an energy optimization framework is presented which is as summarized in Figure 1.

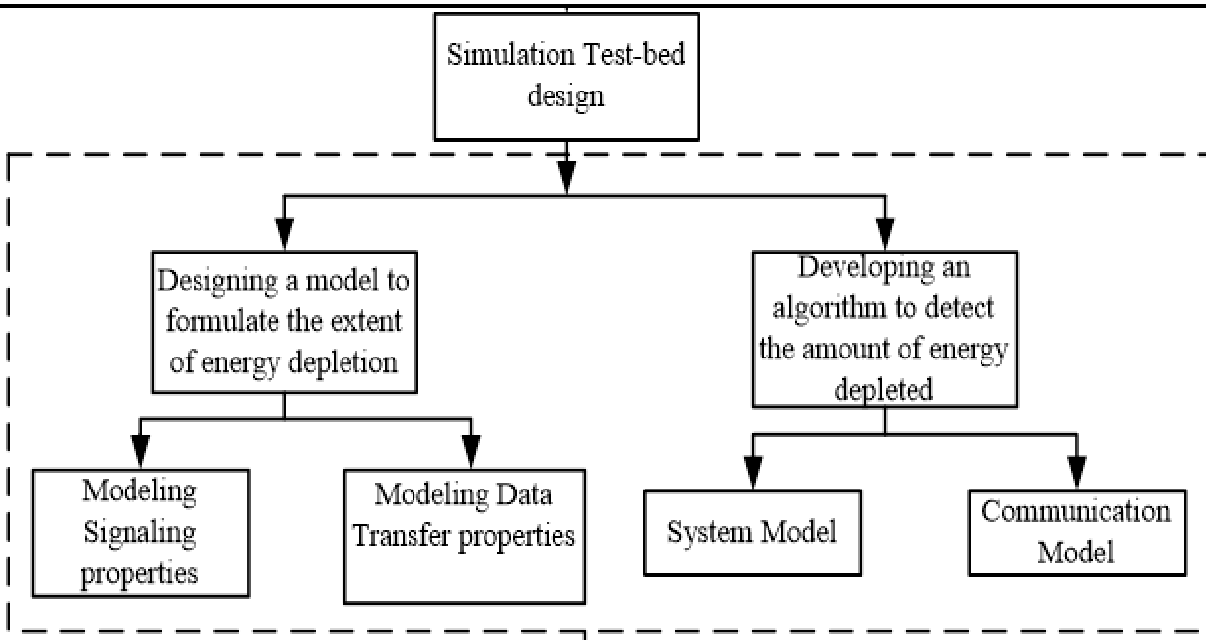

Figure 1: Illustration of Methodology for Energy Dissipation and Optimization

2. RELATED WORK

This section shows the works carried on by various researchers which can be categorized under five major section.

2.1 TECHNIQUES FOR ASSESSING THE ENERGY CONSUMPTION OF MOBILE SERVICES

Perrucci et al. [10] focused on battery life degradation and demonstrated that mobile devices should switch the network in the enslavement of the service utilized to save the maximum quantity of energy. Choi et al. [11] evaluated the performance of the Power Saving Mode (PSM) where the outcomes demonstrated that the proposed PSM for VoIP significantly decreases the power consumption while satisfying the packet drop from end to other limiting VoIP association. Du et al. [12] demonstrated typical QoE and 5W model and consumer opinion template was defined and applied to the precise customer survey. Gross et al. [13] presented energy consumption model which illustrated the energy consumption might be intended as a mean error of ±4.7%. Vergara et al. [14] concentrated on data broadcast energy consumption. Here, an energy box over the most standard wireless interfaces (3G and Wi-Fi) detains the parameters controlling the energy utilization the most. Balasubramanian et al. [15] evaluated advantage of Tail-Ender for three various case study applications — web research, news and the email content based on real user logs. Kelényi et al. [16] analyzed that utilizing a mobile device in a full-peer is possible only for a couple of hours due to the high power consumption. Damasevicius et al. [17] estimates energy consumption over a mobile computer using 3DMark06 Benchmarking software.

2.2 TECHNIQUES OF ENERGY CONSERVATION IN MOBILE DEVICES

Jambli et al. [18] focused on Transmission Power Control (TPC) Technique. The outcomes present noticeable effects of TPC implementation method on mobile ad-hoc sensor network with respect to transmission energy utilization and packet received ratio at low node mobility. Abolfazli et al. [19] Illustrated a comprehensive survey over mobile augmentation procedure and reviewed several Cloud-based Mobile Augmentation (CMA) approach. Ravichandran et al. [20] proposed an energy consumption reduction technique which may be utilized for both current and future procedure tools. Pyles et al. [21] illustrated that Blue-saver is capable to adapt to changing network states by routing network traffic between different PHY interfaces. Lastly, they have demonstrated that it can save up to 25% energy on existing consumptions for certain kinds of network traffic. Bala et al. [22] described online power assessment. The outcomes by Tang et al. [23] demonstrate that it may extensively develop the energy efficiency of mobile phones while sustaining smallest overhead. Nagaraj and Sarkar [24] proposed a unique sub-optimal algorithm for power optimization at the base station end in an OFDMA based downlink cellular communication system.

2.3. TECHNIQUES OF REAL-TIME DISSIPATION IN ENERGY SCHEME FOR MOBILE DEVICES

Paek et al. [25] represent RAPS, a Cell-ID Aided positioning system. Ding et al. [26] demonstrated the design of their Smart Energy Monitoring System (SEMO). Sun et al. [27] focused on Power Consumption in smartphones and indicate that a non-linear model may expand the correctness in the two cases.

2.4 TECHNIQUES OF ENERGY CONSERVATION FOR MULTIPLE RADIO INTEGRATED SMART DEVICES

Hsu et al. [28] performed a study on the problem of spectrum-energy efficiency in broadband wireless networks under multiple Base Stations (BSs). Nigus et al. [29] demonstrate that a vital channel capacity improvement may be brought about at the cost of several additional resources and method difficulty. The outcomes by Haverinen et al. [30] advise that particular protocols, such as IPv4 and IPsec mechanisms require extremely frequent keep-alive that may guide to unacceptably short battery lifetimes. Lane et al. [31] presented Piggyback Crowd-Sensing (PCS), a system for the crowd-sourcing mobile sensor data.

2.5 TECHNIQUES FOR MITIGATING THE ENERGY ISSUES ON MOBILE PHONES

Harvey et al. [32] presented dead reckoning simulator. It shows that the proposed algorithm may attain up to 36% power savings for mobile phones. Zeng et al. [33] showed the possibility of explicit control of the battery resource and demonstrated that ECO technique can hit a target battery lifetime and for, sensible targets, may do so with the suitable show. Flinn and Satyanarayanan [34] using power scope technique decrease the energy utilization in an application integrated with adaptive video playing by a factor of 46%. Xiao et al. [35] presented linear regression model. On analysis, it showed 2.62% median error. Constandache et al. [36] ensure localization correctness with Energy-Efficient Localization (EnLoC). Hoque et al. [37] obtained the energy-aware reception of multimedia for Cinder operating system. Johnson and Hawick [38] worked on Reception of energy-aware multimedia. It saves energy over power maintenance scheme. Polla et al. [39] presented E-Loupe where vision of natural model happens to be viable.

3. ENERGY DISSIPATION MODEL

Based on the studies carried out in the previous section, it can be seen that most of the research established on energy dissipation model considered the traditional method, which were based on the amount of data transferred. Even though some of the researchers considered energy dissipation model but it was related to only some specific form of network either Wi-Fi or 3G. Hence, from the findings of literature survey an energy dissipation model is designed which considers not only data transfer but also considers the energy dissipated during scheduling for current standards of mobile communication. The two energy consumption factors involved when mobile equipment performs network operations are: (i) Signalling and (ii) Media transfer. An energy consumption model is presented in Figure 2 which shows an estimate of energy consumption that arises due to network operations in wireless mobile equipment.

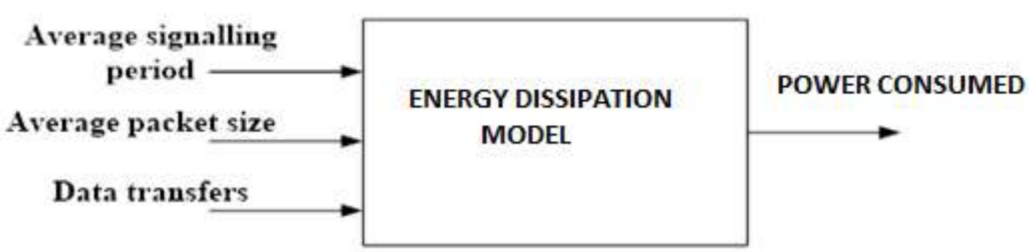

FIGURE2: ENERGY DISSIPATION MODEL FOR MOBILE DEVICES

The parameters to the model are average transmission interval, packet size and amount of data transferred. The energy consumption model involves the calculation of some of the factors that contribute to the total energy consumption while transferring or receiving data. These factors include ramp energy, transfer energy and tail energy. Energy consumed while transiting from idle to data transfer state is termed as ramp energy. The energy consumed while transferring data through wireless network interface is termed as transfer energy. The energy consumed in intermediate states after transmission is termed as tail energy.

With Signalling, the transfer energy time contributes lesser to the total energy consumption as a small time is involved in transferring a single packet, say around a few milliseconds. However, the ramp and tail times are usually more compared to transfer energy time and hence contribute majorly towards total energy consumption.

With media, the contributions of tail and ramp components are less than transfer energy as there is no change in states during data transfer. Thus, the total power consumption can be calculated as a function of both Signalling and media energy consumption.

Pt=fn (Psig, Pmed] Watts

Psig → Power consumed during Signalling operation

Pmed → Power consumed during media transfer operation

The presented model is capable of estimating the energy dissipation for Wi-Fi and 4G wireless standard. The protocol of the model is as shown in Figure 3 which can be divided in to four sections: (i) The communication block, (ii) The data handling block, (iii) The Proposed Model and (iv) The performance analysis block. The communication block is prototyped to have a router as a controller that mimics the Base Station (BS) of a telecommunication cell or range of IP Cores, where many mobile devices get registered with their addressing mechanism. The data handling block deals with uploading the entire bit stream into the network from a particular mobile device. The proposed model consists of two different blocks: (a) Signal Modeling Block and (b) Data Routing Block. The signal modeling block represents a paradigm which is responsible for estimating the energy usage during the beacon packet transmission over a MIMO channel for mobile devices. The Data Routing block deals with transmission of test-data packet from source to destination for transactional time and event ordering.

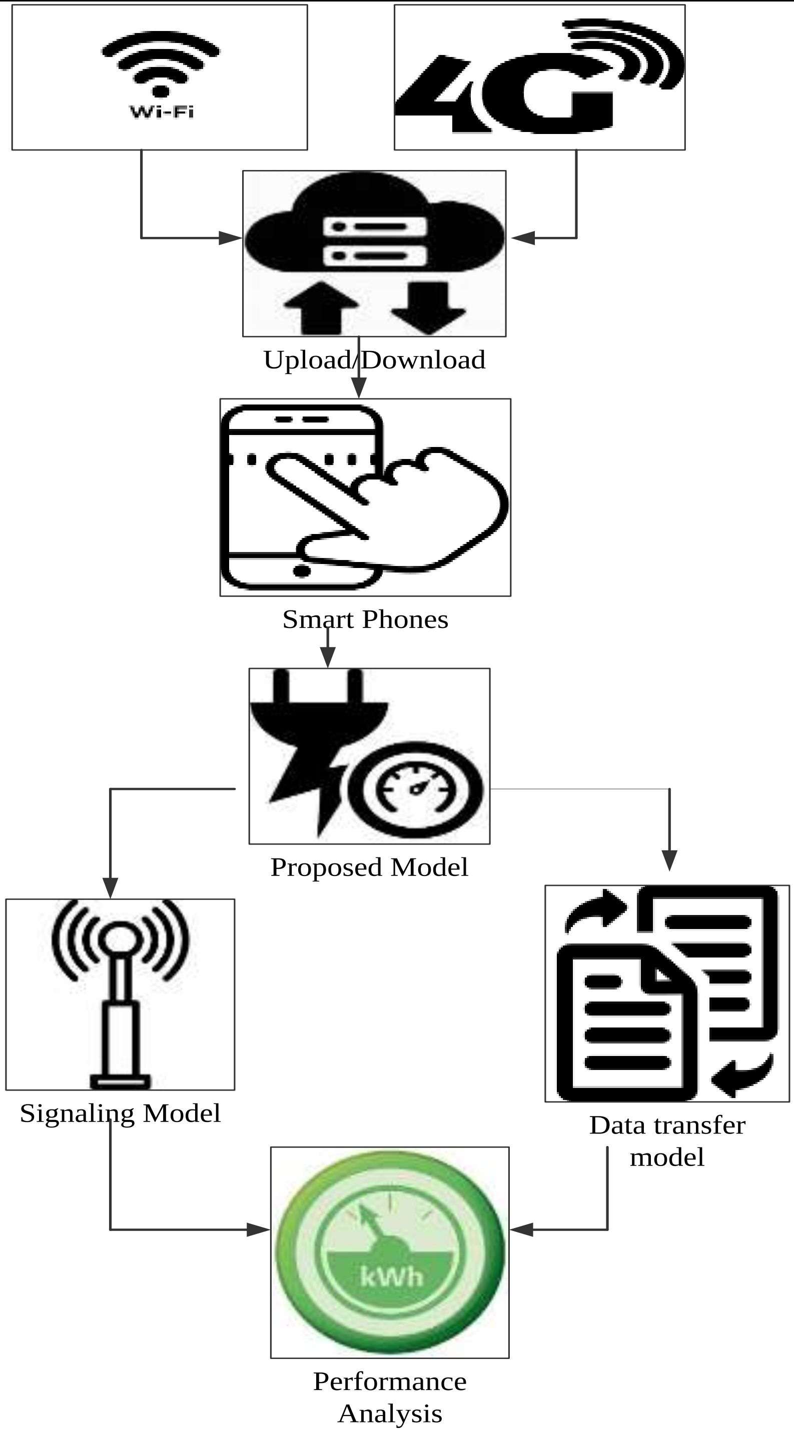

Figure 3: The Block diagram of Energy Dissipation Model

The experimental setup to evaluate the energy dissipation is as shown in Figure 4. The system is evaluated on two Windows PCs and designed using MATLAB software tool. Here, the first PC designated as the server mimics the base station and the second PC designated as client represents the user equipment. A link is established between the two using either Wi-Fi network or 4G Network.

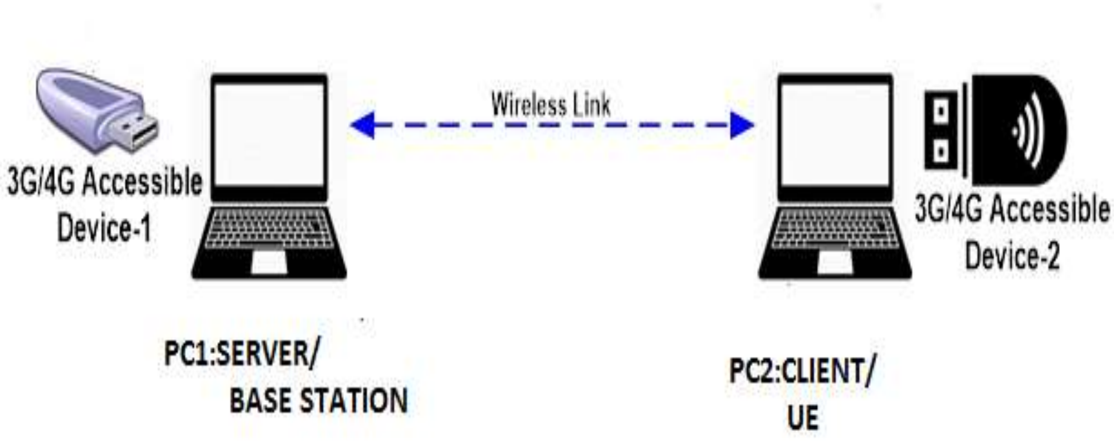

Figure4: Experimental Setup for Energy Dissipation

The design parameters for the above-mentioned model is as shown in Figure 5. A number of clients can connect to the server. A wireless link is established between the two by specifying the communication standard of either Wi-Fi or 4G, the Remote IP, the Remote Port No., Received Port No., Avg. Signal Frequency, Avg. Packet Size and Data Transfer Rate.

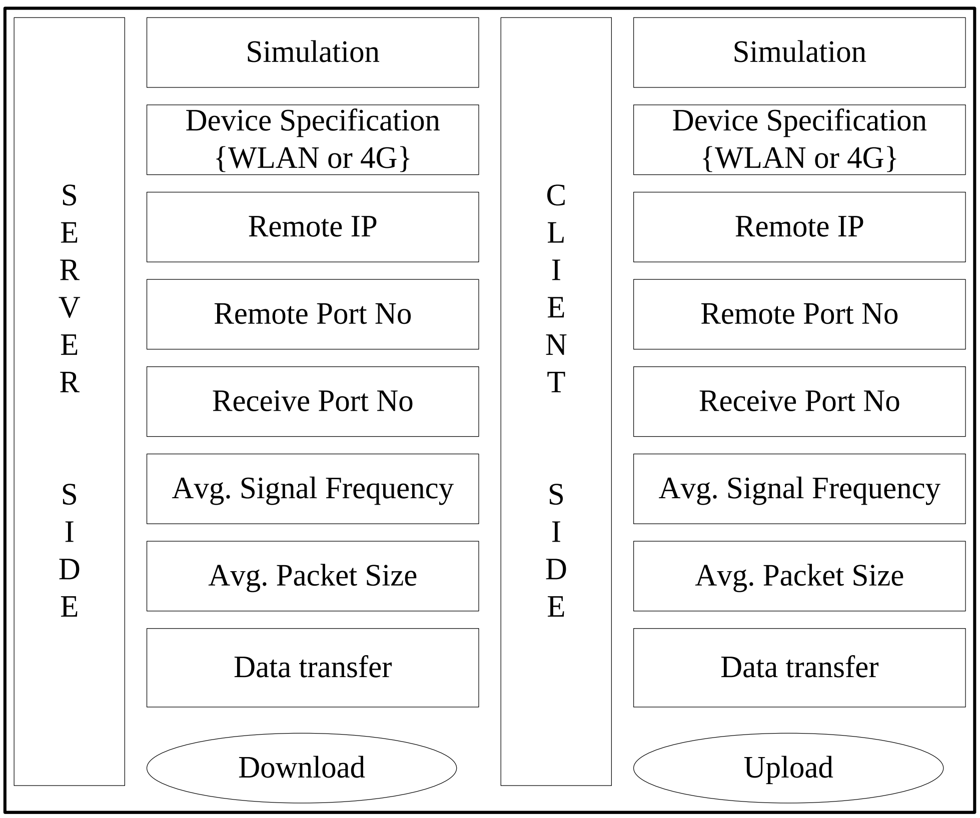

Figure5: Architecture of the Proposed System

The MATLAB Graphical User Interface (GUI) for server side as shown in Figure 6 contains the simulation model for which we need to specify the Wi-Fi or 4G network. Then the remote IP can be set for remote access with remote port number and receive port. Later the average signal frequency for data transfer is set and then the average packet size is set. Then the data over the network is downloaded by clicking Download button. At the client-side shown in Figure 7 similar blocks exists except that the remote port number and receive port will be interchanged from that mentioned at the server side. Another change in the client module is that the data will be uploaded.

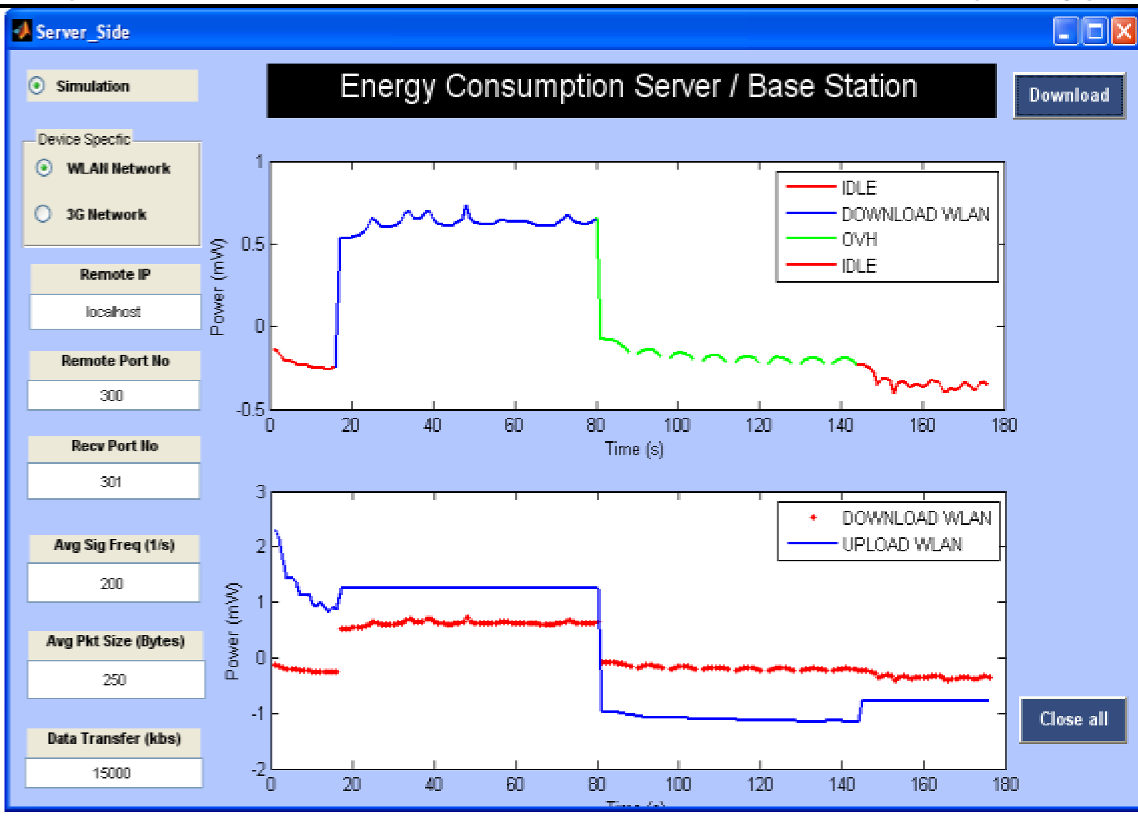

FIGURE6: Graphical User Interface for Server Side

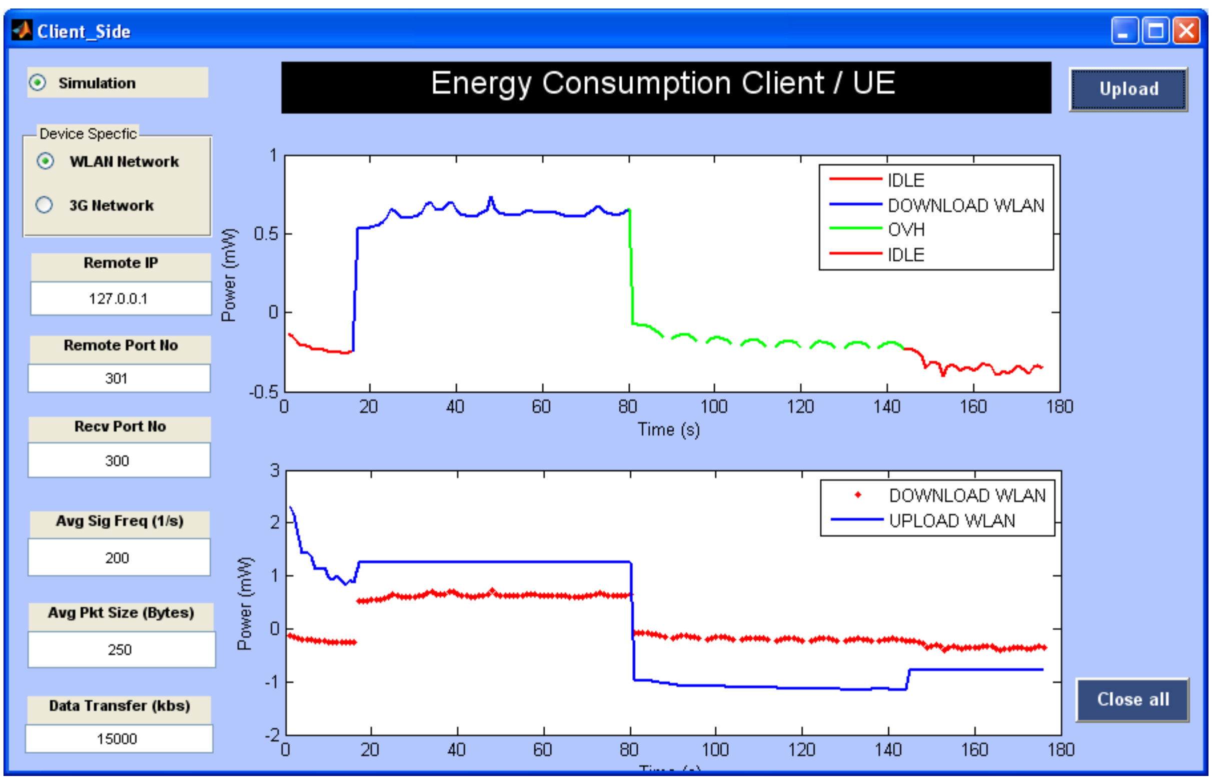

FIGURE7: Graphical User Interface for Client Side

The outcomes show that energy dissipation for 4G network is higher than Wi-Fi network. The outcomes which are discussed in detail in [40][41] showed that energy dissipation for 4G is comparatively higher compared to Wi-Fi network as shown in Figure 8.

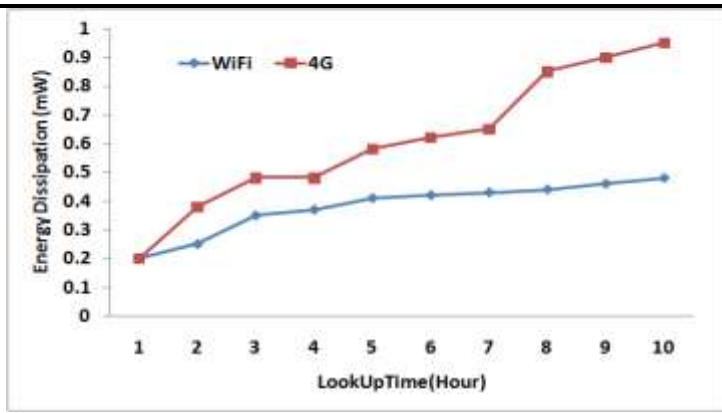

Figure 8: Comparative Analysis of Energy Dissipation for Wi-Fi and 4G Network

Investigations led to the fact that 4G network is very likely to rely on multi-carrier principles (typically the ones based on OFDM), which is also susceptible to limitations like signal attenuation and interferences. As we are performing the experiments, we prefer to accomplish the downloading process of test-information and in parallel update the numerous applications. Therefore, these networking principles may permit the Internet access on a faster basis in smart devices, but leads to huge consumption of bandwidth resulting in the mobile phone to heat up unlike in the case of Wi-Fi. Updating multiple applications, identical test-data packets are executed through Wi-Fi to search the resource that enables faster operation when compared to a 4G network and outcomes in minimized heating in the device. Even though Wi-Fi consumes energy, utilizing a test-file of the same size would incorporate transmission in uplink and downlink at a lower extent at which energy is dissipated as in comparison with 4G. The primary cause for this is the switching over of network platform in a 4G network to acquire the dedicated channel from forward access channel. The switchover happens mainly to obtain bigger data packets, leading to heating up of the device rapidly causing energy dissipation. Hence, the proposed model is effectively in a position to calculate the amount of energy dissipated in a scenario depending on real-time mobile usage. The calculation of transmission in the mean intervals is performed by adopting a specific threshold factor. The system encounters an energy dissipation drop in the Wi-Fi network mostly when the mean interval time of the transmitted data packet is found to be more than the adapted threshold value. Moreover, the data transmission principle is not the same as that of 4G. When we consider bigger size of the data packet being subjected over downlink transmission the system of 4G networks executes forward access channel transition to the dedicated channel. Due to this, the small size data packet also contributes towards the smartphone energy consumption.

4. Algorithm for Energy Optimization

The methodology comprises of modeling the operation of a multi-antenna mobile transceiver system and achieves power reduction in transceiver systems. A software modeling of the mobile transceiver system is performed here which consists of multi-antenna transmitter-receiver system. The system is designed in such a way that all the antennas operate simultaneously and hence there is maximum circuit power consumption. For such as system the power usage is controlled by using algorithms for antenna management. The antenna management mechanism helps in reducing the power consumption by choosing the pair of antenna in a multi-antenna environment that uses the least energy/bit for transmission.

The key idea behind using such a mechanism is that the mobility of systems facilitates different propagating environments. These propagating conditions encourage using different number of antennas to achieve the minimum power usage. So algorithms are developed here for antenna management which reduces power by minimizing the energy for transmitting or receiving a single bit. Two algorithms are presented here: one for finding the active antennas and the other for finding the minimal power for the active antennas for various data rates. These algorithms will be part of the power control part of the system model for power reduction. The system is tested by transmitting and receiving an image and measuring the power reduction achieved. The methodology is as shown in Figure 9.

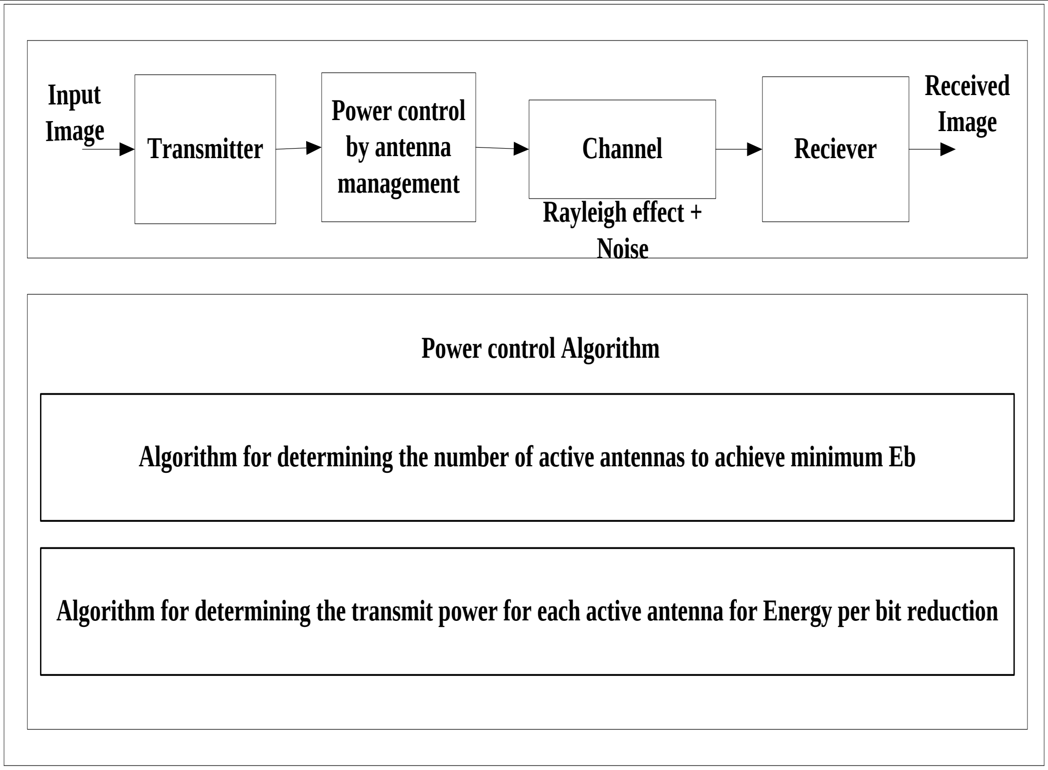

Figure9: Methodology for Power Control Algorithm

The detailed algorithms and outcomes of the framework are discussed in [42].

5. COMPARISON

The power reduction performance of the proposed methodology is compared with that adopted by Zhang et al. The work of Zhang et al presented a framework, called E-MiLi that uses sleep-scheduling based optimization for restricting the idle listening power of node in wireless networks. For comparative analysis, the E-MiLi variable was fit into the proposed optimization system with minor amendments to the variables. The comparative results of the proposed approach and that of Zhang et al is depicted below in Figure10.

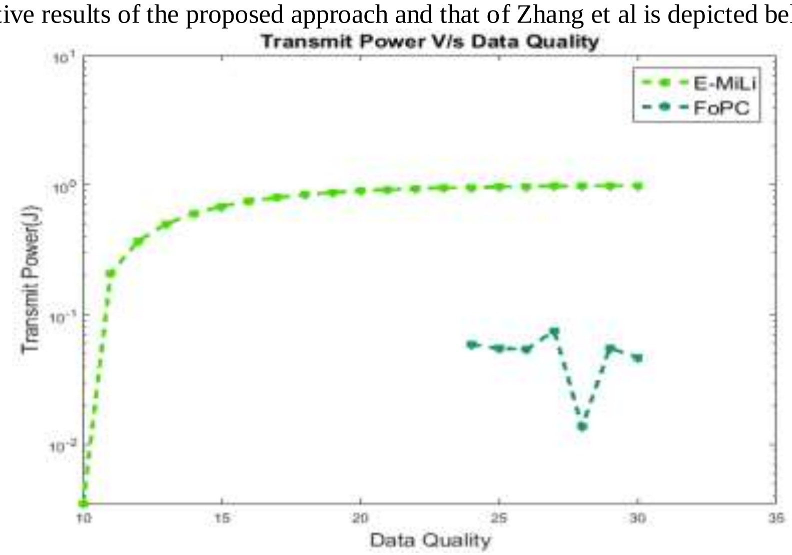

Figure10: Comparative Analysis

The graph indicates that the proposed methodology offers a better performance with respect to power reduction compared to the E-MiLi system with rise in data quality. This may be due to the reason that E-MiLi does not consider the different traffic situations for resource allocation which is done in the proposed methodology.

An analysis performed on the graph reveals that E-MiLi maintains data quality right from 10 db whereas the proposed system starts to maintain the data quality from 25 db. However the proposed system performs better due to lower power consumption than E-MiLi. The transmit power increases gradually with data quality and remains constant for higher data quality for E-MiLi whereas the proposed system shows a steep reduction of power at few points. Thus the proposed approach can achieve power reduction at higher data quality requirement.

6. CONCLUSION

There are numerous applications running in a smartphone because of which the energy dissipates. Some applications are running in the foreground and some in the background. It is difficult for a common user to identify the idle processes running in the background to suppress them. Energy can be optimized only when one has knowledge as to where and how the energy is being dissipated. The proposed empirical energy dissipation model can evaluate the energy being dissipated at the network specially using Wi-Fi and 4G standards. Based on the findings an energy optimization framework is presented which can optimize energy for multicarrier systems. The system is designed and tested on Windows PC using Matlab. The results were analyzed for various conditions of the channel (in case of continuous and intermittent traffic) and a comparative analysis with exiting techniques was done and presented.

REFERENCES

[1] P.Zheng, L.Ni. 2010. *Smart Phone and Next Generation Mobile Computing*. Elsevier, pp.350.

[2] T.Himmelsbach. 2013. *A Survey on Today's Smartphone Usage.* GRIN Verlag, pp. 140.

[3] M.A. Matin. 2014. *Handbook of Research on Progressive Trends in Wireless Communications and Networking*, IGIGlobal, pp. 592.

[4] Lin, Ying-Dar. 2015. 'Time-and-energy-aware computation offloading in handheld devices to coprocessors and clouds', *IEEE Systems Journal*, Vol. 9(2), pp. 393-405.

[5] Y. Xiao, P. Savolainen, A. Karppanen, M. Siekkinen, and A. Yl¨a- J¨a¨aski, "Practical power modeling of data transmission over 802.11g for wireless applications," in Proceedings of the 1st International Conference on Energy-Efficient Computing and Networking, ser. e- Energy'10. New York, NY, USA: ACM, pp. 75–84, 2010.

[6] N. Balasubramanian, A. Balasubramanian, and A. Venkataramani, "Energy consumption in mobile phones: a measurement study and implications for network applications," in Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference, ser.IMC '09. New York, NY, USA: ACM, pp. 280–293, 2009.

[7] A. Rice and S. Hay, "Decomposing power measurements for mobile devices," in Pervasive Computing and Communications (PerCom), IEEE, 2010.

[8] Hsu, C.-C., Chang, J.M., Chou, Z.-T., Abichar, Z.: Optimizing spectrum-energy efficiency in downlink cellular networks. IEEE Trans. Mob. Comput. **13**(9), 2100–2112 (2014).

[9] Nigus, H.R., Kim, K-H., Hwang, D., Hussen, H.R.: Multi-antenna channel capacity enhancement in wireless communication. In: Seventh International Conference on Ubiquitous and Future Networks (ICUFN), pp. 77–82 (2015).

[10] G. P. Perrucci, F. H. P. Fitzek, G. Sasso, W. Kellerer and J. Widmer. 2009. 'On the impact of 2G and 3G network usage for mobile phones' battery life', *European Wireless Conference,* Aalborg, pp. 255-259.

[11] Choi, Hyun-Ho, Jung-Ryun Lee, and Dong-Ho Cho. 2009. 'On the use of a power-saving mode for mobile VoIP devices and its performance evaluation', *IEEE Transactions on Consumer Electronics*, Vol.55(3).

[12] Du, Yu, Wenan Zhou, Jian Liu, and Junde Song. 2009. 'A study on the extraction and application of customer perception indexes in the mobile network', *In IT in Medicine & Education, ITIME'09. IEEE International Symposium*, Vol. 1, pp. 436-440.

[13] C. Gross, F. Kaup, D. Stingl, B. Richerzhagen, D. Hausheer and R. Steinmetz. 2013. 'EnerSim: An energy consumption model for large-scale overlay simulators', *38th Annual IEEE Conference on Local Computer Networks,* Sydney, *NSW*, pp. 252-255.

[14] Vergara, Ekhiotz Jon, and SiminNadjm-Tehrani. 2013. 'Energybox: A trace-driven tool for data transmission energy consumption studies', *In European Conference on Energy Efficiency in Large Scale Distributed Systems, Springer, Berlin, Heidelberg*, pp. 19-34.

[15] Balasubramanian, Niranjan, Aruna Balasubramanian, and ArunVenkataramani. 2009. 'Energy consumption in mobile phones: a measurement study and implications for network applications', *In Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference*, pp. 280-293.

[16] I. Kelenyi and J. K. Nurminen. 2008.'Energy Aspects of Peer Cooperation Measurements with a Mobile DHT System', *ICC Workshops - IEEE International Conference on Communications Workshops*, Beijing, pp. 164-168.

[17] Damaševičius, Robertas, VytautasŠtuikys, and JevgenijusToldinas. 2013. 'Methods for measurement of energy consumption in mobile devices', *Metrology and measurement systems*, Vol. 20, No. 3, pp. 419-430.

[18] Jambli, MohamadNazim, HalikulLenando, Kartinah Zen, SinarwatiMohamadSuhaili, and Alan Tully. 2012. 'The effects of transmission power control in mobile ad-hoc sensor networks', *Procedia Engineering*, Vol. 41, pp.1244-1252.

[19] S. Abolfazli, Z. Sanaei, E. Ahmed, A. Gani and R. Buyya. 2014. 'Cloud-Based Augmentation for Mobile Devices: Motivation, Taxonomies, and Open Challenges', in *IEEE Communications Surveys & Tutorials*, Vol. 16, No. 1, pp. 337-368.

[20] R. Ravichandran and V. Muralidharan. 2016. 'A dynamic algorithm to improve power efficiency in smartphones', *International Conference on Computer Communication and Informatics (ICCCI),* Coimbatore, pp. 1-6.

[21] A. Pyles, D. T. Nguyen, X. Qi and G. Zhou. 2015. 'Bluesaver: A Multi-PHY Approach to Smartphone Energy Savings', *IEEE Transactions on Wireless Communications,* Vol. 14, No. 6, pp. 3367-3377.

[22] Bala, Rimpy, and AnuGarg. 2013. 'Battery power saving profile with learning engine in Android phones', *International Journal of Computer Applications*, Vol.69, No. (13), pp.38-41.

[23] Z. Tang, S. Guo, P. Li, T. Miyazaki, H. Jin and X. Liao. 2015. 'Energy-Efficient Transmission Scheduling in Mobile Phones Using Machine Learning and Participatory Sensing', *IEEE Transactions on Vehicular Technology*, Vol. 64, No. 7, pp. 3167-3176.

[24] S. Nagaraj and M. Sarkar. 2014. 'A novel power allocation technique for 4G cellular networks', *International Conference on Computing, Networking and Communications (ICNC)*, Honolulu, HI, pp. 616-620.

[25] Paek, Jeongyeup, Kyu-Han Kim, Jatinder P. Singh, and Ramesh Govindan. 2011. 'Energy-efficient positioning for smartphones using cell-id sequence matching', *In Proceedings of the 9th international conference on Mobile systems, applications, and services*, pp. 293-306.

[26] F. Ding, F. Xia, W. Zhang, X. Zhao and C. Ma. 2011. 'Monitoring Energy Consumption of Smartphones', *International Conference on Internet of Things and 4th International Conference on Cyber, Physical and Social Computing*, Dalian, pp. 610-613.

[27] Sun, Li, Ramanujan K. Sheshadri, Wei Zheng, and Dimitrios Koutsonikolas. 2014. 'Modeling Wi-Fi active power/energy consumption in smartphones', *Distributed Computing Systems (ICDCS), IEEE 34th International Conference*, pp. 41-51.

[28] C. Hsu, J. M. Chang, Z. T. Chou and Z. Abichar. 2014. 'Optimizing Spectrum-Energy Efficiency in Downlink Cellular Networks', *IEEE Transactions on Mobile Computing*, Vol. 13, No. 9, pp. 2100-2112.

[29] H. R. Nigus, K. H. Kim, D. Hwang and H. R. Hussen. 2015. 'Multi-antennae channel capacity enhancement in wireless communication', *Seventh International Conference on Ubiquitous and Future Networks*, Sapporo, pp. 77-82.

[30] H. Haverinen, J. Siren and P. Eronen. 2007. 'Energy Consumption of Always-On Applications in WCDMA Networks', *IEEE 65th Vehicular Technology Conference - VTC2007-Spring*, Dublin, pp. 964-968.

[31] Lane, Nicholas D., Yohan Chon, Lin Zhou, Yongzhe Zhang, Fan Li, Dongwon Kim, Guanzhong Ding, Feng Zhao, and Hojung Cha. 2013. 'Piggyback CrowdSensing (PCS): energy efficient crowdsourcing of mobile sensor data by exploiting smartphone app opportunities', *Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems*, pp. 7.

[32] R. C. Harvey, A. Hamza, C. Ly and M. Hefeeda. 2010. 'Energy-efficient gaming on mobile devices using dead reckoning-based power management' *9th Annual Workshop on Network and Systems Support for Games*, Taipei, pp. 1-6.

[33] Zeng, Heng, Carla Schlatter Ellis, Alvin R. Lebeck, and Amin Vahdat. 2003. 'Currentcy: A Unifying Abstraction for Expressing Energy Management Policies', *USENIX Annual Technical Conference, General Track*, pp. 43-56.

[34] Flinn, Jason, and MahadevSatyanarayanan. 1999. 'Powerscope: A tool for profiling the energy usage of mobile applications', *Mobile Computing Systems and Applications, Proceedings. WMCSA'99. Second IEEE Workshop*, pp. 2-10.

[35] Xiao, Yu, Petri Savolainen, ArtoKarppanen, MattiSiekkinen, and AnttiYlä-Jääski. 2010. 'Practical power modeling of data transmission over 802.11 g for wireless applications', *Proceedings of the 1st International Conference on Energy-efficient Computing and Networking*, pp. 75-84.

[36] I. Constandache, S. Gaonkar, M. Sayler, R. R. Choudhury and L. Cox. 2009. 'EnLoc: Energy-Efficient Localization for Mobile Phones', *IEEE INFOCOM*, Rio de Janeiro, pp. 2716-2720.

[37] M. A. Hoque, M. Siekkinen and J. K. Nurminen. 2014. 'Energy Efficient Multimedia Streaming to Mobile Devices — A Survey', *in IEEE Communications Surveys & Tutorials*, Vol. 16, No. 1, pp. 579-597.

[38] Johnson, M. J., and K. A. Hawick. 2012. 'Optimising energy management of mobile computing devices', *Proceedings of the International Conference on Computer Design (CDES), The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp)*, pp.1.

[39] M. La Polla, F. Martinelli and D. Sgandurra. 2013. 'A Survey on Security for Mobile Devices', in *IEEE Communications Surveys & Tutorials*, Vol. 15, No. 1, pp. 446-471.

[40] Shalini Prasad, S. Balaji. 2016. 'Energy Dissipation Model for 4G and WLAN Networks in Smart Phones', *International Journal of Advanced Computer Science and Applications (IJACSA)*, Vol. 7, No. 7, pp. 62-68.

[41] Shalini Prasad, S. Balaji. 2018. 'Computational Model to find Energy Dissipation and Optimization in Smartphones', *Jour of Adv Research in Dynamical & Control Systems*, Vol. 10, 11-Special Issue, pp. 257-263.

[42] S. Prasad, S. Balaji, "Novel Optimization to Reduce Power Drainage in Mobile Devices for Multicarrier-based Communication", published in the International Journal of Electrical and Computer Engineering (IJECE, ISSN: 2088-8708,) Vol 7, No 5: October 2017.