ISSN:0975-9646

An Analytical Survey of Power Consumption and Modeling in Different Areas of ICT Networks

Payel Giri, Sudhansu Sekhar Singh

School of Electronics Engineering,KIIT University,
Bhubaneswar,India

***Abstract*— A large no of studies today reflects that the amount of energy consumed in different sectors are increasing rapidly with time especially in ICT sector. This review on factors of energy cosumption will provide a glimps on right picture regarding the power consumption in different segments of wireless communication network and also suggests some network optimization techniques need to improve the energy consumption performance of the network. Main focus of this review paper is on the base station power consumptions in a heterogeneous network, compraizing both for a micro cell and macro cell concept. Based on several datasheets of GSM and UMTS, power models of micro cell and macro cell base stations have been assumed. These power models help to understand the performance of the base station better, in terms of consumed power. Power reduction techniques such as increasing the efficiency of power amplifier, switching off the power amplifier during sleep mode of operation are evaluated.**

***Keywords* — ICT, GSM , UMTS, Heterogeneous Networks.**

I. INTRODUCTION

Modern communication equipments and network topologies works with high volume of data as well as it require a high data rate of transferring information. With this extensive growth in wireless technology, utilization of energy efficiently has become a major factor that has grab the attention of the research world. Actually this growth in communication network is proportional to the increased amount of CO2 in the atmosphere. So, the main motto is to reduce this CO2 content worldwide. It is the target of the European Union to decrease the amount of consumed energy by 20%, which they have termed as Green Vision. Looking From an angle of operation near about 3% of the worldwide total electrical power which equals to almost 600 TeraWatt-Hour is absorbed by the Information and Communication Technology(ICT) sector. This value is expected to increase and according to assumption it can reach to a value of 1700TWh in the end of 2027. One third(1/3) of the total ICT's energy is consumed by the telecommunication equipments. Mobile Telephony consumed half(1/2) of the energy consumed by the telecommunication equipments. But only 10% of the total mobile phone consumption is related with the terminal-user where as the rest 90% is absorbed by the network equipments, around which 2/3rd is used by the base station itself.

So, this information and communication technology(ICT) network has become a major sector in wireless communication because of its extensive growth. In the cellular technology field the number of subscriber is increasing everyday and that creates a requirement of improved BS equipment. For efficient utilization of energy it is becoming very important to depend on renewable energy sources at certain places.

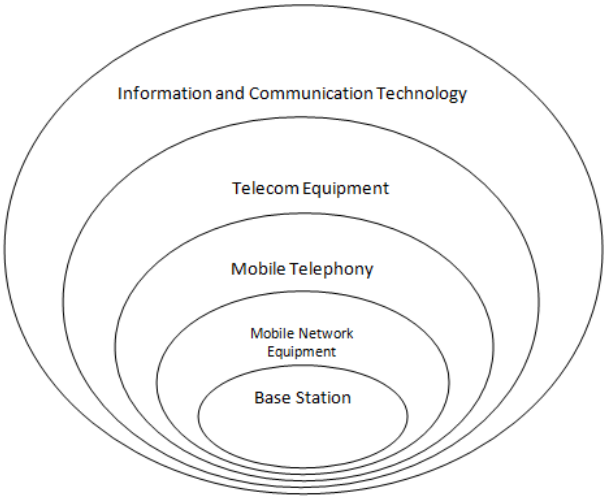

Fig 1:- Consumed energy by different sectors of ICT networks

The following figures shows a power consumption analysis in different sectors of ICT network focusing on the major area i.e. base station. In ICT sector, the major part of power is absorbed by the servers and monitoring stations in operation. From the cost point of view, only a portion of 10% of the overall cost is due to the end user but a significant portion of 90% of the overall cost is incurred by the operator as a huge amount of power is associated with it. For operating a base station properly .it is mandatory to monitor and inspect the site at regular intervals. This also adds some extra cost to the total operational expense.

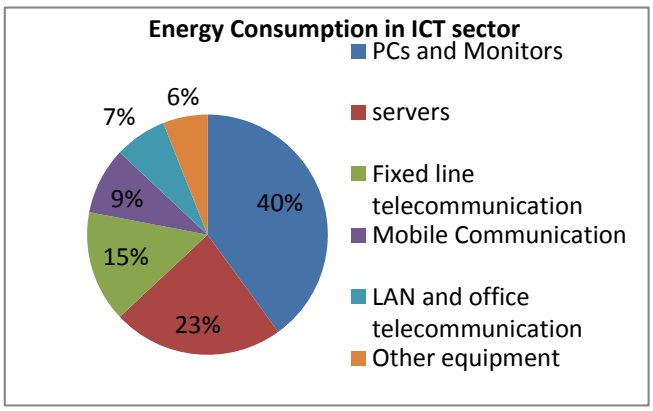

Fig 2: Power consumption analysis in ICT sector

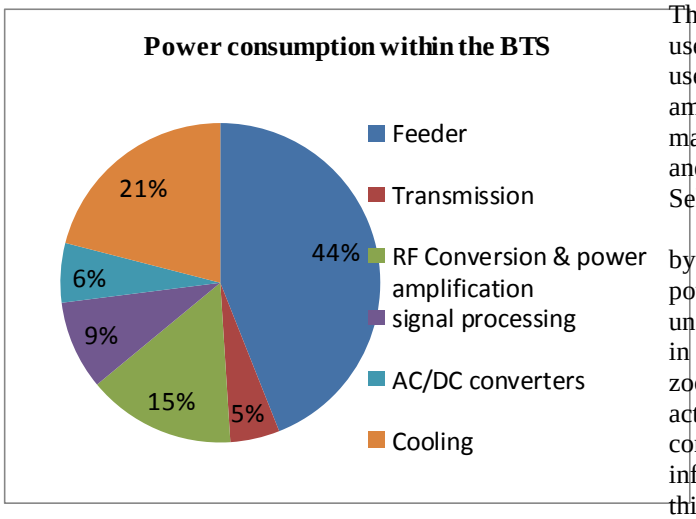

Fig 3: Power Consumption inside the Base Station (BS)

So, it is obvious from the previous figure that a large portion of the power is consumed for cooling of the components and operation and maintenance of the BS. Inside the base station, a huge power is taken by the feeder lines i.e. required for radio signal transmission, rectifier sections, Power amplifiers (PA), Digital signal processing (DSP) units. Several electronic apparatus are there which adds up to the overall power consumption. For example, air conditioners and other auxiliary equipments.

Depending on several datasheets of GSM and UMTS base stations we have emphasized on power models of micro cell and macro cell base stations in the following sections. Based on these power models different power saving mechanism is adopted by the network operators. As the traffic distribution in a certain area is not constant with time, this inhomogeneous behavior of traffic pattern needs to properly studied to lay a proper traffic management plan. In that way a lot of power can be saved from wastage. In [3], the basic power analysis of a macro and micro cell in numerical figure in given. An improvisation of the base station power model by taking into consideration the power consumed by several components of BS is provided in [4]. A complex model of power compared to the previous one is described in [5] so that a parameterized model can be developed.

According to these power models, to reduce the cost of service and to reduce the harmful effects on environment various base station deployment strategies have been adopted so that total consumed power can be reduced to a great extent. As, already mentioned base station consumes about 90% of the total power consumption of a network which leads to 147W to 10kW and it depends on the size, area of coverage and the technology employed[6]. Most basic strategy that have been adopted is the use of sleep-mode i.e. BS will be operating but with a very minimal amount of power[7,8]. While using sleep mode of operation at the mobile user side, a trade off is there among the disconnection of users and preserving of energy and as discussed in[9]. A very important characteristics of mobile networks is that the traffic behavior is drastically different between day and night. So, using this day-night behavior of the consumers one can use the sleep mode to save energy. There are some efficient software available which can be used properly to switch off the BS completely or can be used to put the BS into sleep mode thereby saving a certain amount of power[10]. Most specifically, NSN[7] have made some software for observing the profile of load traffic and naturally switching BSs in off mode of operation in Self Organized Networks(SON).

Few new papers also explained the preserving of power by switching off under loaded BS. In [10], the volume of power saving is calculated by shutting down unused or undesirable active cells because of lesser load traffic while in another paper a proper regulatory scheme called cell zooming is introduced to lessen this number of unused active cells. Several network operators can share a common topology between them like sharing the information regarding the day-night behavior of the user. In this way a network wide sleep mode can be employed and all the traffic load can be transferred to a single operator's network. This causes a significant reduction in power consumption and also in OPEX.

In the following sections of the paper, an investigation of the total power consumption by both micro and macro cell BS have been performed and it can be shown that the power reduction strategies can be applied to macro cell BS to a great extent. Depending on that, one can decrease the utilization of power for several base station components focusing on power amplifiers(PA) mostly by optimizing its operating point and determining the optimum switching frequency during the sleep mode..

II. Modelling of Power Consumption

It is the goal of power consumption model to make available more realistic parameters for input purpose, with which the proper simulation can be done for total power consumption in heterogeneous BS deployments. In this section the main parameters are summarized for two deployments of BS. It can be observed that this parameters determines the input values for a network infrastructure only, and several other parameters are also required. For each simulation this additional parameters are also needed and they are determined by the condition of the environment, technology used.

Every Base station consist of these important components, such as, Air conditioning, Rectifier circuit, Power amplifier, feeder, digital signal processing unit etc. Out of which some components are independent on traffic load and some are dependent on traffic load to a great extent. This load independent components constitutes the static part of power consumption and load dependent components constitutes dynamic power consumption. So, it is clear that the power consumption of a BS is divided in two parts, one part describes the static power consumption i.e. a power figure which is consumed by BS irrespective of traffic load condition. Based on traffic load situation, a dynamic power consumption part adds to the static power and it is the other part. These provide a relative small dynamic contribution to power consumption and the optimum cell size is strongly affected by the static part. We will compare the result to today's macro cell deployment.

A. Power Consumption of a Macro Cell Base Station

The power consumption of a GSM and also an UMTS BS is modeled and then compared in the next section. The observation is done for a couple of days. It can be seen that the power consumption varies about 3% for a UMTS and 2% for a GSM base station over time. Due to the negligible amount of dynamic power, the power model of today's typical macro base station can be reduced to the static part. Base stations with dynamic power saving features have appeared only very recently and are not yet wide spread in the networks. The efficiency of a power amplifier on the input side is mainly determined by the applied modulation schemes and by its crest factor.

For modelling the power consumption, the following formula is used[4]:

$$P_{BS,Macro} = N_{Sector}.N_{PApSec}.\left(\frac{P_{TX}}{\mu_{PA}} + P_{SP}\right).(1+C_C).(1+C_{PSBB})$$

TABLE I:- PARAMETERS THAT ARE NEEDED FOR MODELLING THE BS POWER CONSUMPTION ARE AS FOLLOWS

Parameter/Attributes	Description
N_{Sector}	Number of Sectors
N_{PApSec}	Number of Power amp/ sector
P_{TX}	Transmission power
μ_{PA}	Efficiency Power Amplifier
P_{SP}	Signal Processing Overhead
C_C	Loss due to Cooling
C_{PSBB}	Loss due to battery back up and power supply

The parameters that are required to form the power model equation is discussed in the previous table[4].

B. Power Consumption of a Micro Cell Base Station

A micro base station is therefore comprises of one sector with one power amplifier and transceiver in it. As it is micro BS, power consumption needs to be considered both for static and dynamic case. The power consumption here is of more changing nature, as the cell size is small the number of user vary statistically. For this reason the power amplifier is made adaptive during for a particular time period when the load is low. So, in general the equation for power consumption in a micro cell BS is written as the following[4]:

$$P_{BS,Micro} = P_{static,Micro} + P_{dynamic,Micro}$$

In case of micro cell BS, digital signal processing unit is the main contributor to the dynamic part of power which can be considered in the power model by changing the consumed power according to the traffic load. As not a very large amount of power is required, there is no need for battery back up here. The loss due to power supply here is only 10% and it also depends on the used technology. As already mentioned consumed power is low, so heat generated is also very low, so air conditioning is not required in case of a micro BS. Here, number of active links scales the digital part and the number of time slots and frequency used affects the power consumption. Encapsulating the properties of a micro base station, the formula for the static power consumption can be derived as,

$$P_{static,Micro} = \left(\frac{P_{Tx}}{\mu_{PA}} C_{TX,static} + P_{SP,static}\right).(1+C_{PS})$$

and for the dynamic power consumption the equation is written as,

$$P_{dynamic,Micro} = \left(\frac{P_{Tx}}{\mu_{PA}}(1-C_{TX,Static}).C_{TX,NL} + P_{SP,NL}\right).N_L.(1+C_{PS})$$

TABLE II:- SEVERAL PARAMETERS THAT ARE REQUIRED FOR MODELLING THE POWER EQUATION ARE LISTED IN THE FOLLOWING TABLE

Parameters/ Attributes	Description
$P_{Static,Micro}$	Static Power Consumption
$P_{Dynamic,Micro}$	Dynamic Power Consumption
P_{TX}	Maximum transmission power per power amplifier(PA)
μ_{PA}	Efficiency of the power amplifier
N_L	Number of active links
$C_{Tx,static}$	Static Transmission power
$C_{Tx,NL}$	Dynamic Transmission power per link
$P_{SP,Static}$	Static Signal Processing
$P_{SP,NL}$	Dynamic Signal Processing Per link
C_{PS}	Loss due to Power Supply

III. DISCUSSION

All In this simulation procedure, different components of the BS of GSM and UMTS are considered and compared also. Each BS is assumed to be divided into 3 sectors. Firstly, a high capacity i.e. 6 carrier frequencies per sector and then a medium capacity i.e. 2 carrier frequency per sector GSM macro BS is compared in terms of power amplifier efficiency. First one is GSM1 and second one is GSM2. Secondly, two UMTS BS is also compared one with one carrier frequency and another with two carrier frequency is considered. Those are UMTS 1 and UTS 2. In figure 2, it is shown that, as the efficiency of the power amplifier is increasing the overall power consumption decreases drastically. The parameters we have used for the simulation purpose is listed below in the table format.

TABLE III:- VALUES OF THE PARAMETERS REQUIRED FOR SIMULATION OF AREA POWER CONSUMPTION FOR BOTH MICRO AND MACRO BASE STATIONS

	GSM1	GSM2	UMTS1	UMTS2
P_{BS}	3700 W	1430 W	1450 W	1568W
N_{Sector}	3	3	3	3
N_{PApSec}	6	2	1	2
P_{TX}	40 W	40 W	40W	20 W
P_{SP}	36.4 W	54.8W	73.5W	127.7W
C_C	0.23	0.27	0.28	0.29
C_{PSBB}	0.11	0.11	0.11	0.14

Considering these parameters here we have compared depending on the efficiency of the used power amplifier(PA) at the BS, how the total consumed power of the BS for

GSM1, GSM2, UMTS1, UMTS2 for a macro cell scenario in reduced is shown in figure 2. Only static power consumption is considered for a macro cell BS. In contrast to that, for micro BS an additional part is added termed as dynamic power consumption. When an operator required to give services in a certain area he needs to use a proper deployment planning so that minimum number of BS is used and in effect power consumption is also reduced. The power consumed by different components of both macro and micro cell BS are given in numerical figure in table IV[11]. However, the term of static power adds to the macro BS deployment additionally. So, it is clear that power consumption in a heterogeneous deployment is higher than the only macro deployment.

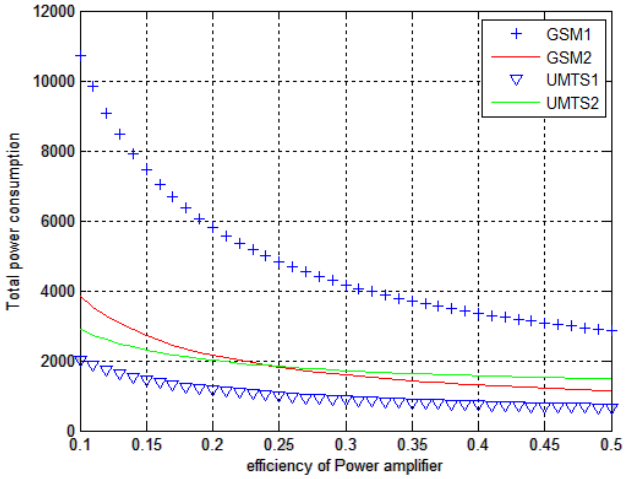

Fig 4:- Total power consumption as a function of PA

It is clear that in a macro cell deployment if we increase the efficiency of the power amplifier which happens to consume the maximum power, a significant reduction in power consumption will be achieved.

TABLE IV:-POWER CONSUMED BY DIFFERENT EQUIPMENTS OF TWO BS DEPLOYMENT:-

Components	Macro cell	Micro Cell
Digital Signal Processing	100W	100W
Power Amplifier	156.3 W	16.6W
Transceiver	100W	100W
Rectifier	100W	100W
Air Conditioning	225W	60W
Microwave link	80W	NA

This concept is needed to be further investigated and currently a lot of researches are going on this section. If one can measure how many times a power amplifier can be turned off without hampering the desired QoS that many times the power amplifier can be turned off. So a huge amount of power can be saved. Based on that, if the BS can be completely turned off and the load of it is distributed among the nearby BS, concept of cell zooming is employed. This techniques falls under the project called Energy Aware Radio and Network Technologies (EARTH)".

So finally summing this, we can get the total power consumption for this 3 types of base stations[11].

TABLE V: TOTAL POWER CONSUMPTION FOR THREE DIFFERENT TYPES OF BASE STATION:-

Base Station Type	**Total Power Consumption**
Macro Base Station	1278.1 W per base station for mobile WiMAX 1671.6 W per macro cell base station for HSPA and LTE (Advanced)
Micro Base Station	376.6 W per microcell base station

IV. CONCLUSION

Until now the sector that has gained maximum attention of the researchers is the reduction techniques of power at end-user side, but now more focuses need to given to the base station and network access equipments. So, as per the discussion we can see that the maximum power is consumed in air conditioning system and this power is needed to maintain the operating temperature of the electronic equipments. When we operate the electronic components the power consumed by them is dissipated as heat which needs to be reduced by this air conditioning system or by any means of cooling. That is why, we need to reduce the power consumption of the other equipments, so that cooling system require less power. Considering all these situations, a power consumption figure of these two typical base stations can be obtained based on the information available from several datasheets. It is a clearly observed fact that, after air conditioning the maximum power is consumed by the power amplifier (PA). So, more viable techniques should be explored to reduce the power consumption of power amplifier to achieve a significant power utilization performance.

REFERENCE

[1] "EARTH (Energy Aware Radio and neTwork tecHnologies", EU funded research project FP7-ICT-2009-4-247733-EARTH, Jan. 2010 to June 2012.

[2] A. Fehske, J. Malmodin, G. Biczok, and G. Fettweis, "The Global Carbon Footprint of Mobile Communications - The Ecological and Economic Perspective", IEEE Communications Magazine, 2011.

[3] George Koutitas, Panagiotis Demestichas "A Review of Energy Efficiency in Telecommunication Networks", , Telfor Journal, Vol 2, No. 1, 2010.

[4] Oliver Arnold, Fred Richter, Gerhard Fettweis, Oliver Blume "Power Consumption Modelling of Different Base Station Types in Heterogenous Cellular Networks", Future Network and Mobile Summit 2010 conference proceedings.

[5] Hauke Holtkamp, Gunther Auer, Vito Giannini, Harald Hass ,"A Parameterised Base Station Power Model", , IEEE Communications Letters, Vol. 17, No. 11, November, 2013

[6] A. Hikuma, Y. Fuke, N. Nakaninami, H. Ohyane, H. Kobayashi, *Radio Base Stations Equipments toward Economical Expansion of FOMA Coverage Areas*, NTT DoCoMo.Technical Journal, Jun. 2004.

[7] NSN, *Introducing the NOKIA Siemens Network SON suite* - An efficient future-proof platform for SON, white paper, nov 2009

[8] NEC, *NEC's approach towards Energy-efficient Radio Access Networks*, white paper, Feb. 2010.

[9] S. Alouf, E Altman, and A Prasad Azad, M/G/1 Queue with repeated inhomogeneous vacations Applied to IEEE 802.16e Power Saving, ACM Sigmetrics 2008.

[10] M. Ajmone-Marsan, L. Chiaraviglio, D. Ciullo, M. Meo, *Optimal Energy Savings in Cellular Access networks*, GreenComm 2009, Dresden.

[11] M. Deruyck, W. Vereecken, W. Joseph, B. Lannoo, M. Pickavet, and L. Martens, "Reducing the power consumption in wireless access networks: overview and recommendations, Progress In Electromagnetics Research", Vol. 132, 255,274, 2012

[12] Khin Cho Tun*, Kunagorn Kunavut,"An Overview of Cell Zooming Algorithms and Power Saving Capabilities in Wireless Networks", *KMUTNB Int J Appl Sci Technol, Vol.7, No.3, pp. 1-13, 2014.*

[13] N. Zhisheng, W. Yiqun, G. Jie, et al. "Cell zooming for cost-efficient green cellular networks," *IEEE Communications Magazine*, vol. 48, pp. 74-79, Nov. 2010.

[14] L. KyeongMin, L. Joohyung, P. GwangHui, et al., "QoS and power consumption analysis of cooperative multicast scheme with cell zooming," in *Proc. APCC*, 2012, pp. 238-242.