An Exploratory Review of Base Station Power Optimization Techniques and Methods

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Abstract—Huge amount of data transfer in a wireless network is a very common daily process in this age of advanced technology. The signal transmission load on base stations are increasing as cell phone and other handheld devices are extensively used for voice calling, multimedia messaging, data downloading and uploading. So the growth of energy consumption in base stations is becoming a critical economic, environmental and global issue. The base station energy optimization techniques and methods are becoming more active and challenging research area of wireless technology. In this paper, several effective known techniques and methods are discussed and analyzed without degrading the quality of services (QoS) of the wireless network. In this exploratory review, finally, a new method, approach, and technique are presented to optimize the power of base station in cellular network of present technology.

Index Terms—Power Consumption, Wireless Network, Base Station, Energy Efficiency.

I. INTRODUCTION

The recent analysis indicates that the wireless access networks in modern telecommunication networks, are consuming high power and this rate is increasing due to advancement in wireless, mobile and internet technologies [1]. The electric energy consumption by cellular wireless networks and internet technology takes around 2-3 percent of global electric energy and it will increase in coming year. The base stations (BSs) of wireless access networks are responsible for a significant amount of power consumption in cellular systems [1][2][9]. The wireless communication system is fundamental and essential technology for modern social and economic evolution and global development. Information and Communication Technology (ICT) is taking major efforts in the global greenhouse gas emission as the requirement of power by Information and Communication Technology (ICT) is increasing rapidly with the growth in technological requirements. The worldwide Information and Communication Technology (ICT) industries are fast growing contributor to the worldwide power consumption [3]. The global mobile communication is expanding rapidly as the mobile phone customers are growing worldwide, so this growth is accompanied by huge electric power consumption of the mobile network [9]. Researchers are working on power efficient projects to solve high power consumption of Information and Communication Technology (ICT) industries [2][3]. The purpose of the power efficient project is to minimize energy waste and to improve energy efficiency of modern communication systems without affecting the quality of service (QoS) and the coverage of the cellular network to its customers [4][8]. Observation and analysis shows that huge amount of total electrical energy is being consumed by mobile radio approach devices and by the amplifier [4][5].

Exploration of new technologies along with protection of the environment, the problem of global climate changes and the reduction of power consumption are major challenging issues for researchers [6]. The consequences of research explain that, about 3% of the global energy is consumed by Information and Communications Technology (ICT) infrastructure which produces about 2% of global CO2 emissions and the rate will be increasing every year [6][7]. In mobile communications networks, only wireless access networks utilizes more than 50% of the total power consumption in which only base station directly consumes more than 50% power except the power consumed by the mobile stations [9]. From environmental, economic and power efficiency perspectives, minimizing energy consumption of a cellular network is a major issue [8]. The way to minimize energy wasting is to use energy aware, efficient components in the base stations and by the strategies of energy aware network deployment. The key factor for the future of the Information and Communications Technology (ICT) is a reduction in energy consumption and minimum CO2 emission [9]. The active research works are going on power consumption, reduction and efficiency in the wireless access networks, but these are not addressing the issue relating to the reusability of the reserved electrical energy. In information and communication technology, the measurement of energy consumption is estimated by ‘bits-per-Joule’ unit, which can be defined as the throughput of wireless system for unit-energy consumption. The analysis for energy-efficient communications at the base station is based on the bits-per-Joule measurement [10].

This paper presents a review on power-efficient technologies within the cellular network and investigates power consumption of base transceiver stations (BTS) strategies which can potentially minimize the power consumption without compromising the quality of service (QoS) to the user of the network explored. The review also investigates the significance of deployment of optimization techniques on power efficiency. The paper is organized as
follows; Section 2 provides the system model of base station power consumption, Section 3 discusses the literature review, Section 4 gives the problem formulation of existing power optimization methods, the theoretical proposed methodology is presented in section 5 and finally, Section 6 concludes the paper.

II. SYSTEM MODEL OF BASE STATION POWER CONSUMPTION

The system model of a common base station in a cellular network consists of major components such as antenna, signal receiver, transmitter, power amplifier, encoder, decoder, control unit, interfaces and main power supply unit as shown in figure 1. Base Transceiver Station (BTS) is a signal transmitter and receiver unit which acts as an interface between the mobile stations (MS) in the network. A modern BTS have 1 to 16 Transceivers, depending on the geographical location and demand for service on that location. A BTS can have many sectors and a cell can be serviced by many BTSs. Each sector is usually covered by sector antenna, which is a common directional antenna [8].

In Figure 1, there are several electrical power consuming components. These components are used for signal processing per sector, which is responsible for system processing and coding. The transceiver and power amplifier are responsible for high power signal transmission at distant mobile station. The total power consumption of BTSs is calculated by the power consumption of each component with multiplied by the total sectors of cellular system [12]. Within these components, the transceiver and the power amplifier are one per transmitting antenna. The power consumption in each component is constant, but the air conditional system and the power amplifier consumes more power whenever required [12][13]. The power consumption in amplifier mainly depends on the working efficiency of the amplifier [13]. The efficiency of amplifier $\eta$ is defined as the ratio of output power (in watts) $P_{out}$ to the input power (in watts) $P_{in}$ as shown in equation 1:

$$\eta = \frac{P_{out}}{P_{in}} \times 100 \% \quad \ldots \ldots \text{(1)}$$

The power consumption in the amplifier $P_{amp}$ of base station can be defined as shown in equation 2:

$$P_{amp} = \frac{P_{tx}}{\eta} \quad \ldots \ldots \text{(2)}$$

$P_{tx}$ is the input power given to the sector antenna which is equal to its output power received from the amplifier. For the performance of a base station in context of power consumption, the normalized power consumption per hour is usually estimated by the equation 3:

$$P_{norm} = \frac{P_{avg} - P_{min}}{P_{max} - P_{min}} \quad \ldots \ldots \text{(3)}$$

$P_{avg}$ is average power consumption per hour, $P_{min}$ is minimum power consumption per hour and $P_{max}$ is maximum power consumption per hour in base station.

III. LITERATURE REVIEW

In this paper we reviewed, explored and analyzed some modern base station power optimization methods.

A. Power Efficiency by Improvement of Base Station Architectures and Network:

Several improvements and modifications are being pursued to minimize the power consumed by cellular base stations. The modern architecture of the cellular network is evolving towards various heterogeneous architecture which comprise base stations of several various sizes [14]. In the heterogeneous architecture of cellular system, smaller cells comprises micro and pico base stations which have lower capacity and shorter range, so these micro cellular systems are deployed throughout the network with lower power consumption mechanism [14][15]. By this architecture, the network can be adapted continuously for the usage of user, and can fulfill the subscriber demands using optimized power resources. However the entire spectral efficiency of the base station unit can be calculated by the equation 4:

$$efficiency = \frac{N_c}{BW \times A_c} \quad \ldots \ldots \text{(4)}$$

$N_c$ is the number of channels available per cell, $BW$ is the bandwidth of the cellular system and $A_c$ is the cell area. The cell area of small cell can effectively improve the efficiency of the system as compared to large cell. The smaller cells provide efficient power management over short range wireless access. The power and bandwidth available to the service provider of cellular network may be very limited which can be managed by cell spitting with micro cells [14]. Improvements and modifications to the main processor of the baseband unit can provide data-handling efficiency within the base station. The scalability and extension of the processor architecture for use in macro cells and smaller
basestations allows the same energy efficient power-saving techniques which can be applied cost effectively and quickly throughout the cellular network.

B. Power Optimization by Efficient Power Amplifier:

The power amplifiers of linear radio frequency play a major role in the context of heat dissipation and base station energy consumption. More efficient power amplifiers of base station are a crucial factor in the context of cellular mobile system evolution. Minimizing the energy consumed by the radio base stations will also minimize the environmental and economic impact of the radio access wireless network. The power amplifier requires large quantity of power whenever required for signal amplification [11][16][17]. The radio frequency consumes more than 50% of the total power of the base station. As the requirement for larger bandwidth and maximum data rates which force the power amplifier to operate on its non-linear mode which can consume greater amount of energy mainly because of inefficiency in the power amplifier [11]. The efficiency of power amplifier is usually measured by the peak to average power ratio (PAPR) [17]. To presents the efficiency of power amplifier, it has to operate in its lower peak to average power ratio (PAPR) for reducing the significant amount of power consumption. The digital pre-distortion (DPD) technique which pre-compensates the non-linearity of the power amplifier can significantly reduce the power consumption in base station [16][17]. The crest factor reduction (CFR) which usually clips the signal peaks to normal condition for reducing the error vector magnitude. The digital pre-distortion (DPD) and the crest factor reduction CFR together increase the efficiency of amplifier to above 50% [11].

C. Power Optimization by Efficient Baseband Processing:

A modern basestation unit supports modern wireless protocols such as WCDMA, LTE, LTE-A and WiMAX in large scale cellular system and WiFi in small cell basestations. The application-specific integrated circuit (ASIC) and field-programmable gate array (FPGA) are useful baseband processing integrated equipment for power optimization in base station [18]. More recently, the large integrated multi-core CPU withsignal processing devices operate at a high clock frequency which have been positioned as an efficient baseband processing solution. The established modern FPGA or ASIC options support modern emerging standards, technologies and protocols, with the high performance and efficiency. However, the increasing performance tends to ubiquitous mobile data services but provides the scalability and flexibility to utilize and optimize the efficient baseband processing and also supports efficient power management [18][19].

An architecture of reconfigurable baseband processor with power efficiency approaches modern dedicated hardware implementations. The power efficiency is obtained by utilizing the coarse-grain configurable hardware and capturing parallel processing in hardware. The flexibility is provided by matching the specific configurable hardware to the specific application domain for efficient base band processing [19]. For designing the network dynamically by the configurable hardware, the immediate feedback technique can be utilizes from that underlying physical implementation of base station. As the hardware implementation of the baseband processor is generally application specific, so the software part can be embedded which should also be application specific [19][20]. The implementation of software for common security and transport protocols such as IPSec, LTE, IPV4, IPV6 and MAC is already provided in wireless communication, which gives extra flexibility to enhance power and performance of base station. In addition, the architecture of reconfigurable baseband processor is dynamically scalable to address the processing demands for both of smaller cells and of macrocells used to improve overall network efficiency.

IV. PROBLEM FORMULATION

Different wireless signal processing techniques in base station approaches succeed and fail at widely different conditions. Usually one method that is highly suitable for a certain kind of geographical area cannot be used under different conditions. On the other hand, base station architecture conditions needed for a useful specific geographical condition often cannot be constrained enough to suit other specific geographical condition. There are so many factors which should be fulfill to design a dynamic technique to assess the overall performance result of base station. In contrast to efficient hardware approach of signal transmission, there are limitations of the software approaches. The technical limitations of current wireless cellular network which can be illustrated as following points:

1. Most of the wireless cellular network techniques tend to enhance bandwidth, throughput, and quality of services (QoS) without considering on energy consumption of network devices of base station.
2. At normal condition, practically some base station network devices are not utilized with their full capability except the peak times, so the power consumed by these devices is wasted.
3. There is limitations of lack of software approaches in base station devices which should be dynamically autonomous by efficient algorithms.

V. PROPOSED METHODOLOGY

Some limitations can be found and observed even in more efficient power optimization methods for base stations. There are dynamic soft computing techniques and algorithms which may overcome some limitations of power efficiency. Modern wireless technology involves the solutions of many hard optimization problems which may remain in other situations which can only be inefficiently modeled. Hardware embedded algorithms do not perform efficiently in such situations.

Soft computing algorithms which are based on genetic algorithms, artificial intelligence, neural networks and fuzzy logic provide the making process like human decision to provide some heuristic solutions to great challenging problems in wireless mobile computing. Some analysis and observation show that the different soft computing approaches can be effectively combined with efficient hardware device to enhance the power optimization
at base station.

VI. CONCLUSION

In this review of base station power optimization techniques and methods, we presented the exploratory and comprehensive review and theoretical analysis of different methods. In this survey, we analyzed power efficiency by improvement of base station architectures and network, power optimization by efficient power amplifier and power optimization by efficient baseband processing. A general time-line based power optimization techniques at base station along with factors affecting the quality of system (QoS) in different aspects as efficiency, accuracy, performance are discussed and analyzed. It is observed that analyzing different factors as device efficiency, network architecture, efficiency of power amplifier, efficient baseband processing and different techniques are used independently. Similarly some integrated approaches of hard and soft computing techniques are used to tackle power efficiency. So in order to develop a power efficient base station system which can handle all factors, the integrated approach of soft computing with efficient devices and hardware could be a choice.

REFERENCES


