Power Optimization Techniques for Next Generation Wireless Networks

Ratheesh R[#1], Vetrivelan P[*2]
[#]School of Electronics Engineering, VIT University, Chennai, Tamilnadu, INDIA
[1]ratheesh.r2014@vit.ac.in
[*] School of Electronics Engineering, VIT University, Chennai, Tamilnadu, INDIA
[2]vetrivelan.p@vit.ac.in

Abstract -- **The massive data traffic and the need for high speed wireless communication is increasing day by day corresponds to an exponential increase in the consumption of power by Information and Communication Technology (ICT) sector. Reducing consumption of power in wireless network is a challenging topic and has attracted the attention of researches around the globe. Many techniques like multiple-input multiple-output (MIMO), cognitive radio, cooperative heterogeneous communications and new network strategies such as heterogeneous networks, scattered antennas, multi-hop communication, etc., as well as radio and resource managing techniques like various sleep mode algorithms, cross layer optimization etc., have been proposed as solutions for this problem. In this paper, we present an overview of some of these techniques to optimize power in cellular network and MANET from various literatures. The green energy approaches as an alternate to grid power to optimize power consumption of BS is also reviewed. We also proposed a methodology to optimize power consumption in LTE-A network by jointly deploying RSs at cell edges.**

Keyword – Power optimization, CAR, MLA, Green energy, RS Joint deployment, CS.

I. Introduction

With the evolution of information and technology (ICT) and the rapid increase in massive data traffic, energy consumption by the network is also correspondingly increasing. The deployment of 3G systems and now 4G technology in developing counties and 4G systems in rest of the world has significantly contributed for the increasing consumption of power in communication sector. In wireless systems the high energy consumption of a wireless *base station* (BS) results in non-economical, large value of electricity bill. From [1]–[4], greater than 50% of the total energy consumption of wireless network is consumed by the radio access part, whereas 50-80% is spent for the *power amplifier* (PA). In [4], it is also mentioned that the energy bill accounts the *Operation Expenditure* (OpEx) for around 32% in India and roughly 18% in the mature European market.

Another important motivation for power optimization in wireless networks is environmental awareness. Many of the base stations (BS) in rural areas which are not connected to power grid are powered by diesel generators for complete day and night as well as backup power source for few hours per day in urban and suburban areas. These diesel generators consumes huge amount of Diesel and emits large quantity of CO_2, which is a GHG (Green House Gas). 2% of the total CO_2 emission is produced from Information and communication technology (ICT) industry throughout the world by consuming 3% of the total worldwide energy. With the exponential growth of large data transfer, it is unblemished that the ICT sector will become a major CO_2 emission sources within the next few years. Large energy consumption combined with its adversative effects on climate and environmental changes results the need for an innovative energy-saving methods for future.

In operators view the EE (energy efficiency) of wireless network not only bring ecological advantage and social benefits by solving issues for climate change but also has substantial economic benefits too. The highlights of energy efficiency wireless communications such as, low-power circuit design, high-efficiency PA and *digital signal processing* (DSP) technologies, advanced cooling systems, adequate EE metric and energy consumption models, cell-size deployment, various relay and cooperative communications, adaptive traffic pattern and load variation algorithms, and energy-efficient network resource management, as well as MIMO and OFDM techniques, are described in Table 1 with various projects carried out around the globe.

In this paper, we present an overview of some techniques to optimize power in cellular network and MANET. We also proposed an approach to optimize power by joint deployment of relay stations in cell edges of a BS and powering the relay station by estimating real time traffic and setting the BS in to sleep mode.

The remaining sections of this paper is organized as follows, the research approaches to optimize power in cellular networks are presented in section 2. In section 3 some energy efficient routing techniques for MANET are discussed. Section 4 defines few green energy approaches for cellular network, in Section 5 we propose a methodology to optimize power of a BS by joint deployment of relay stations in cell edges and finally concludes with Section 6.

II. RESEARCH APPROACHES TO OPTIMIZE POWER IN CELLULAR NETWORKS

The largest consumer of energy in wireless mobile communication is a BS or RAN (Base station, Radio Access Network), which signifies 57% of energy consumption in mobile network [11].This large consumption of power by radio access network is due to two main reasons. First reason is inefficient RF power amplifier, which consumes 60% to 70% of the total energy supplied and only a small part of the energy is converted in to useful output. The power supply unit consumes 12.5%, the air conditioning unit consumes about 17.5% and the signal processing unit consumes 10% of the total power [16]. Second reason is that the non-uniform traffic load in the network points to improper and inefficient planning of radio resources. The mobile phone traffic in a cell area (BS area) is uncertain, it changes from hour to hour and day to day [17]. An efficient method to measure and quantify these uncertain traffic load will help to manage radio resources and hence could optimize power.

Navrati Saxena et al. in the paper "Traffic-aware energy optimization in Green LTE Cellular system" [12] proposed an information theoretic approach to capture the dynamics and uncertainty of network traffic in a 4G LTE system with eNBs. In this letter an online stochastic game theoretic algorithm is also proposed to communicate among eNBs themselves to optimize traffic awareness. The LTE eNBs use their present traffic data's to build future traffic estimations. So with past and present data's of active mobile phone traffic of each eNBs, the future traffic profile can be predicted with probabilistic analyses and accordingly for minimum network traffic durations the BS can be made in to safe mode or power saving mode to optimize power. The accurate and efficient estimation of this uncertain network traffic plays an important role in power optimization of cellular network.

Mehmet Aykut Yigitel et al. [13] proposed an innovative nonlinear programming model to find the best possible network topology which reduces the power consumption of the network without compromising grade of service (GoS) and solved it by proposing an FastWISE algorithm for the green dynamic BS planning (GDBP) problem. They have consider crowded urban areas where there is a large number of BS which is the best appropriate places for GDBP, comparing a suburban or rural areas. They have classified crowded urban area in to four region for GDBP to be implemented as: Town centers (business), Town centers (entertainment), Residential areas and Seasonal tourism centers.

The application site for GDBP should have unbalanced distribution of network traffic and highest base station density. Even though with GDBP and FastWISE algorithm they clams saving significant amount of energy in highly dense urban area, much research work is needed to extent this effort to suburban and rural areas.

Antonio Capone et al. [18] proposed a new architecture by separating signaling and data network. This makes two advantages, the first is that the data BS can be switches off if no user is active. Secondly signaling BS can ensure "always connected" and can be nominated for low data transmission. This proposal needs more study and analyses in Qos perspective. The deployment and area of coverage for signaling BS and data BS need to be investigated. How to manage handoff with this proposal is also to be studied. Several international research projects were carried out which are stanch to energy-efficient wireless communications. In Table I the main solutions dealing with EE from Green Radio [3], EARTH [5], [6], OPERANet [7], [8], and eWIN [9], [10] are shown.

TABLE I. Major Projects and Results for Energy-Efficient Wireless Communication

S.NO	Project Name	Solutions
1	Green Radio [3]	1. Energy Metrics and Prototypes: ▪ Energy metrics to exactly compute consumption ▪ Models for communication energy consumption 2.Efficient Hardware: ▪ Circuit design and advanced PA techniques ▪ Efficient DSP Methods ▪ Base Station re-use 3. Power-Efficient Architectures: ▪ Big cell and small cell placement comparisons ▪ Cooperative networking technology and overlay source such as microcell, picocell, femtocell & relay deployment ▪ Energy requirements by strict end-to-end QoS and resourceful backhaul 4. Efficient Resource Management: ▪ Distinguished QoS, developing delay tolerant applications and user mobility for energy minimization. ▪ SISO and MIMO technic analysis with packet scheduling

		▪ Energy-efficient cooperative physical layer architecture using evolving information theory ideas to lessen interference ▪ Applying dynamic spectrum access (DSA) to minimize energy consumption ▪ Green energy approaches.
2	EARTH [5],[6]	1. Energy-Efficient Metrics and Targets - Analysis ▪ Total Life phase analysis and energy consumption by telecommunications products ▪ Energy-efficient metrics 2. Energy-Efficient Architectures: ▪ Cell size adaptation ▪ Heterogeneous network deployment ▪ Relay and cooperative communications 3. Energy-Efficient Resource Management: ▪ Dynamic load review and transmission scheme adaptation ▪ Cooperative scheduling, interference coordination, and joint power and resource provision ▪ Multi-RAT (radio access technology) coordination 4. Radio resources and Components: ▪ MIMO, OFDM, adaptive antennas and other progressive transmission techniques ▪ Power scalable transceiver and power control on component, front end and system level
3	OPERA- Net [7],[8]	1. Power-Efficient Radio Access Network: ▪ Defining main performance indicators for energy efficiency ▪ Energy saving in base stations, network uncertain traffic, cell zooming based on network loads, and sleep mode ▪ Efficiency from the managing of MAC, DC power, cooling system, etc. 2. Link Level: ▪ Optimization techniques for link-level energy efficiency (scalable MIMO-detection, fountain codes and amplitude modulation, scalable turbo-decoding) ▪ Energy-aware device (terminals and infrastructure) design 3. Technology Enhancement: ▪ Develop new high-efficiency power amplifier ▪ Innovative energy recovering technique 4. Network Devices: ▪ Integration of devices ▪ Mobile radio access network's end-to-end efficiency
4	eWin [9],[10]	1. Energy-Efficient Architectures: ▪ Designs of low-power wireless access Architectural "novel" stabilities between spectrum, service quality, and power consumption ▪ Architecture and new networking standards for delay-tolerant services 2. Energy-Efficient Resource Management: ▪ Auto(re)-configuration of control software and networking resources, in response to variations in infrastructure and demand ▪ Vibrant and flexible spectrum management schemes ▪ Radio resource management for cooperative and competitive heterogeneous environments ▪ Policy-driven management that implements business-level objectives

Major research approaches to optimize power in cellular wireless network can be broadly classified as Cell Area Revision methods (CAR), efficient transmission schemes, Radio Recourses Managing and Module Level Approach (MLA)

A. Cell Area Revision methods (CAR)

As discussed above the largest consumer of energy in cellular network is a BS and the mobile phone traffic in a cell area (BS area) is uncertain, it changes from hour to hour and day to day to peak to low and vice versa. Considering this, the revision of transmission area of a cell (BS area) by estimating real time network traffic will be an optimal solution for conservation of power. We can categorize the CAR methods in to three.

1) Cell Zooming Techniques

This technique is adopted to vary cell area with respect to mobile station traffic profiles, the transmission power level can be increases or decreased accordingly. Fig 1, shows an example of cell zooming technique.

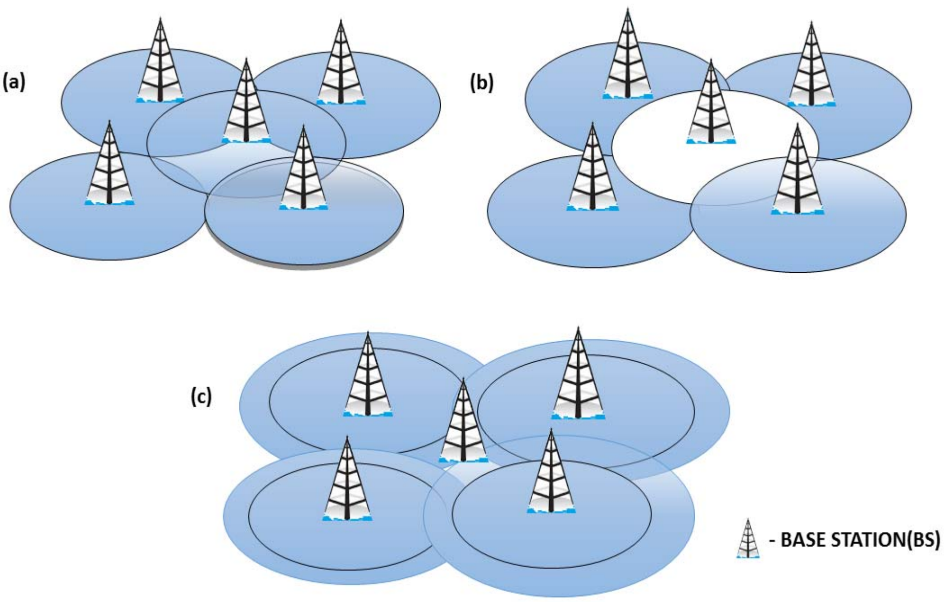

Fig 1. Cell zooming Technique (a) Always ON configuration (b) Analyzing phase (Possibility of BS sleep mode) (c) Final configuration with cell zooming and sleep mode

Margot Deruyck et al [14] proposed a power consumption model for a network deployed with macro cell base stations by calculating the exact network traffic of the base station transmission area. The comparison of power consumption profile between two networks, one with introducing sleep modes and cell zooming to the other network without sleep modes and cell zooming shows the reduction in power consumption by up to 14.4%. The proposed model by Margot Deruyck et al developed a power-efficient wireless access network by conjoining the GRAND tool, which is a continuously-ON network with very less energy consumption for a well-defined area. An algorithm to introduce sleep modes and cell zooming for a base station is also proposed in this work. However the computational power consumption for this method is not considered in this paper.

Eunsung Oh et al [15] propose an algorithm called SWES, which can be practically implemented in distributed manner with less computational complication to switch BS on/off. The important principal to design this algorithm is to turn off BS one after the other that will negligibly affect the network by using a newly presented concept of network-impact, which consider the additional load increments carried by its neighboring BSs when a BS is in power saving mode. In order to further reduce the signaling and implementation overhead they also offered three other versions of this heuristic SWES algorithm over the air and backhaul, which use the estimated values of network-impact as their decision metrics. Since this algorithm is online distributed it can be operated without any centralized control. The results shows that by this algorithm eighty percentage of power saving is possible.

Even though there are enough number of publications which proposes algorithms for cell zooming and sleep modes there is still more works can be done to consider handoff strategies during sleep modes especially for a group handoff and transition of network states. Quality of services (Qos) is also an important parameter which is needed to be considered and compared with the network with and without save mode algorithms implemented. A detailed study with this parameter is to be done.

2) Macro-femto cell deployments

In some CAR techniques we finds there is a joint deployment of Femto cells in order to compensate the load or mobile traffic in the network of a macro base station area, when the BS is in sleep mode or power saving mode. This technique also requires an efficient method to estimate or compute the network traffic .We consider this approach is relevant topic at present for researchers to explore. An example of Macro-Femto cell deployment is shown in Fig 2.

Swati Agarwal, Neeti Gupta [21] has studied the power consumption of Femto cell using an optimized heuristic algorithm and analyzed the results with other heuristic algorithms. The results shows this method saves power.

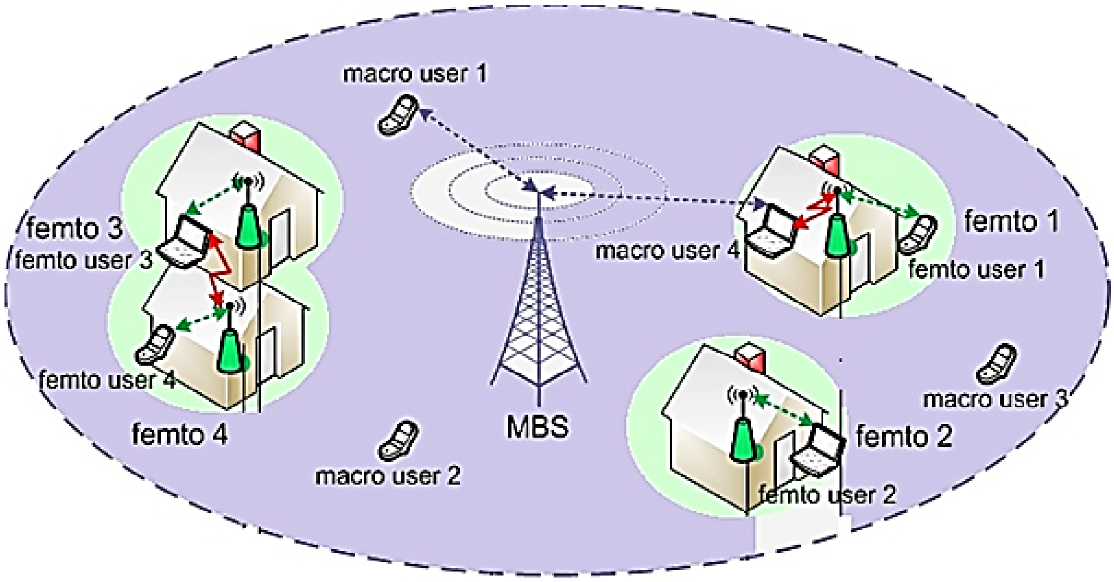

Fig 2. Macro-Femto Cell Deployment

Yao-Liang Chung et al [22] proposed a power-saving transmission method which efficiently saves power for a two-tier LTE macro - femtocell network by vigorously managing the transceivers at femtocell BSs (FBSs) to enhance the energy-saving criteria. The proposed method allows clustered FBSs to quickly on/off according to the uncertain traffic loads, and to report the problem of energy minimization for transceivers at both MBSs and FBSs, while retaining a pre-determined data rate. To measure the uncertain network traffic a methodology can be included in this work.

3) Relay deployment

Relay deployment was first proposed and implemented in order to increase the cell capacity and coverage area, but now this is a hot topic amount the researchers to optimize power consumption of the network. To optimize power consumption of the network the optimal placement of relays plays an important role. Even though many publications are already existing, there is a scope for good works in this topic in future. By using this technique and with an efficient method to evaluate network traffic we can make a BS to power saving mode efficiently. Optimal placement of Relays also plays an important role in handoff management strategies. Fig 3 describes a Relay aided Cellular network where three RS's are deployed in a BS transmission area.

Power optimization methods in wireless network is analyzed by Rakesh Kumar Jha et al. [18] on the bases of three case study: 1) Relay based approach 2) Battery model and 3) Routing Protocol. They shows critically in terms of relative transmission power the FRS (Fixed Relay Station) has important role in power minimization. This work did not mentioned regarding the capacity of relay station that is how many MS can be associated to a RS at the maximum etc... To detect the number of MS associated to a BS or RS an online network traffic estimation method is required. The power source for RS mentioned in the paper is battery it makes more complex system as the battery need to be charged frequently. Handoff strategies and QoS parameters need to be investigated more for this proposal.

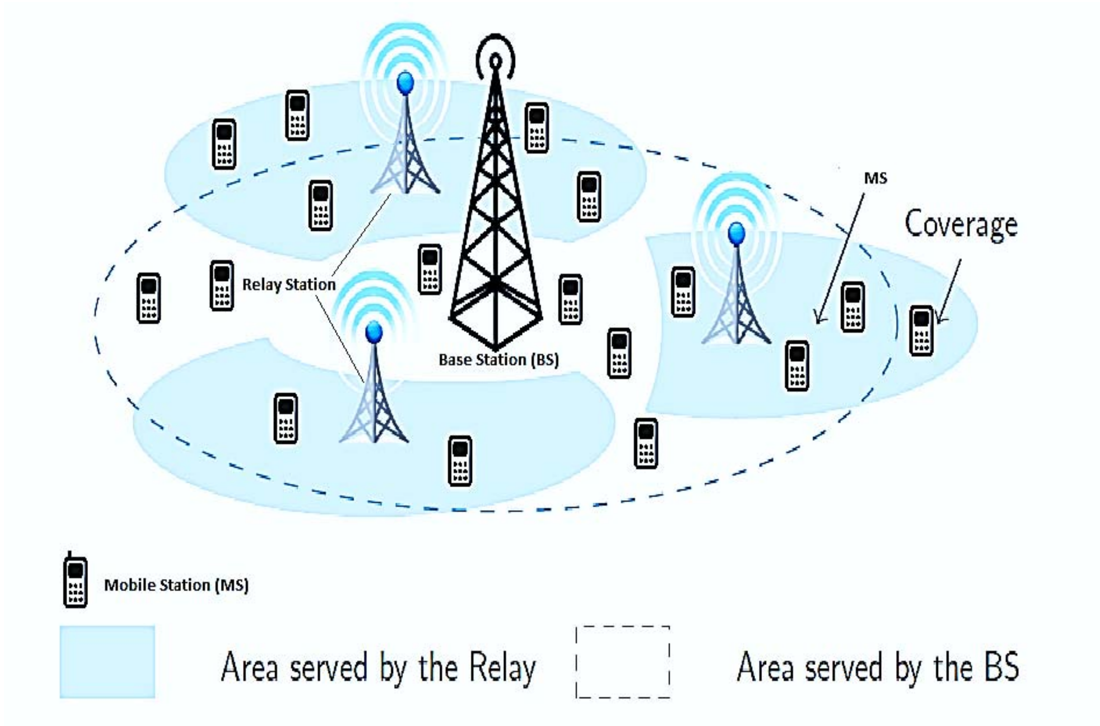

Fig 3. Relay aided Cellular network

Ziaul Haq Abbas et al, [19] have proposed and analyzed a power consumption estimation method for user equipment in a hybrid Rely-aided wireless network. The power consumption of the mobile stations (MSs) are examined with respect to the quantity of data transferred and the operation time of the Mobile station's battery. Even though with this method the time of battery operation for UE can be found out for various ranges of uplink and downlink paths for the MS/RS from and to the Internet, the mobility factors and the modulation scheme has not considered in this paper.

B. Efficient transmission schemes

The energy efficiency by transmission schemes are widely discussed in many surveys, in that too energy efficiency of MIMO systems are extensively reviewed. Multi-cell MIMO where multiple access points cooperatively serve the user terminals are probable to use in near future. Wireless networks are likely to get implemented with MIMO-related techniques such as MIMO broadcast channels and MIMO multiple access channel to a range of materially separated antennas in future. Multi-cell MIMO techniques may also be used for interference cancellation and relaying in order to enhance the spatial resource reuse and hence to provide the essential data rates while minimizing energy consumption in mobile communication systems.

In [20] EV Belmega et al has presented the relation between data rate, transmission power and energy efficiency for SISO and MIMO systems. The performance analysis for SISO system illustrations that in order to decrease the energy per joule transmitted, the system only needs to transmit at very low data rates (i.e. less transmission power). As discussed in [20] this is allowable for some systems with delay tolerant like a sensor network, but for some others such as mobile telephony this cannot be implemented in order to promise Quality of Service.

C. Radio Recourses Managing

Another significant technique found in literatures to optimize power in wireless system is managing and scheduling the radio resources that is, electromagnetic spectrum. The main impression is to optimize the distribution and utilization of transmission resources like bandwidth in order to minimize energy consumption of the network. The optimization problem of radio resource management is to be solved considering some limitations of channel conditions, Quality of Service and characteristics of transmission and receiver system. Cognitive Radio technology plays a vital role to utilize free bandwidth in the spectrum and hence to optimize power of a wireless system. With cognitive and cooperative communication, the utilization of bigger spectrum band and resourceful revision of the spectrum use lead to more effective interference management, better spatial and temporal reuse and hence reducing the consumption of power.

Even though cognitive radio is proposed for spectral efficiency, the concept of Green Cognitive Radio has been elaborated in [23] where as an alternative of work to maximize the bandwidth efficiency and increasing the convolution of the systems continuously, the effort is spent to increase the power efficiency using low power modulation techniques and get optimized bandwidth efficiency.

Grace et al. [23] discusses different concepts for green cognitive radio based systems. In particular, it discusses the complexity with respect to the spectrum sensing process, which is important in CR networks. As a matter of fact, spectrum sensing is a time and power consuming process.

D. Module Level Approach (MLA)

Module level approach deals with some hardware level approaches to optimize power of a wireless system mainly a BS. This investigation includes the internal BS architecture, putting idle components to power saving mode and hardware level approach of designing energy-efficient systems. One of the biggest concerns at this level is the efficiency of RF power amplifier.

Hauke Holtkamp [24] in the paper "on minimizing base station power consumption" proposed A Power and Resource Allocation Including Sleep (PRAIS) method associates resource sharing, Power Control (PC), and Discontinuous Transmission (DTX), such that downlink power consumption is lessened. Unlike conservative approaches with objective to reduce transmit power, in this work the BS total power supply is selected as the appropriate metric. Based on a linear power model, which records a certain transmit power to the required mains supply power, the authors compute the limits of PRAIS in terms of reachable BS power savings. The central limits are mathematically calculated on link level for 4 sets of BS power model factors illustrative of envisaged future hardware developments. Depending on the rate target per link PRAIS provides 63% to 34% energy savings over conventional resource allocation schemes**.**

III. Energy Efficient Routing Techniques For Manets

MANET is an infrastructure less and easy to deploy network comparing the other methods of communications. Due to this advantage it has its applications in various emergency services such as battle fields, various rescue operations due to natural calamities etc. During these emergency applications the uninterrupted communication is mandatory. Power is an important criterion in MANET to provide this uninterrupted communication. In one of our earlier work [28] we proposed an energy efficient LANDMARK selection process for E-LANMAR routing protocol in group mobility for a moderate networks size. In group mobility model the header selection process need not to be done frequently, this saves power of the nodes.

In [25], a source initiated on demand based energy efficient routing protocol is proposed. Their simulation result shows that the proposed protocol achieves good throughput, less delay, high packet delivery ratio and good energy efficiency than the existing protocol PEER. The power limitation of a route is decided by the node which has the minimum energy in that route. So compared with the minimum node energy in any other route, the minimum node energy in the minimum power limitation route has more energy. In this method if we consider the chance of including the node which has the minimum energy in various number of paths how the power limitation of the routs are decided need to be considered for analysis. The power consumed by handshake procedures and how often the procedures need to be done can be considered for better results.

In [26] Anuradha Banerjee et al proposed an Experience Based Energy Efficient Reactive Routing Protocol (EXERP) for Mobile Ad-Hoc Networks. EXERP allots weights to those paths depending probable duration of their links, number of links existing in the path and energy efficiency of the routers. One of the path with highest weight is selected as the optimal path for communication between the corresponding pair of source and destination nodes. This concept is efficient method for power consumption optimization however there are possibilities for same weightage for a link or for a path, in such cases how to decide an optimal path is a topic to discuss.

Xu Zhang et al, [27] proposed an adaptive efficient hop count route finding protocol in which the node can dynamically allot transmission power to nodes along the route in route finding stage. Node who received the route request packets compares its power with the threshold power value, and then selects a reasonable route by discriminating algorithms. More work in this proposed method can be done in terms of QoS parameters and route recovery with sudden link failures.

IV. Green Energy Approaches For Cellular Network

The service providers are compiled to deploy more number of BSs in-order to satisfy growing mobile phone users and data network utilization with worthy service. Most of the BSs in rural areas, where there is no grid power are powered with diesel generators which emits a large amount of CO_2. This increase in the density of BSs results to the direct impact of greenhouse gases on the earth environment and the climate change, there has been an agreement on limiting per-nation CO_2 emissions [29]. As an outcome, governments are likely to control the CO2 emissions of specific industries in their countries. In this situation, mobile service providers may be given a total per-month or per-year energy budgets in terms of CO_2 emissions [30].

With the development of green energy technologies, a Base Stations (BSs) can be powered by green energy sources such as sustainable biofuels, solar and wind energy in order to reduce the consumption of on-grid power, and consequently reduce the carbon footprints. Utilization of green energy sources economically benefits, by reducing fossil fuel demands and cost. Providing a BSs with a green energy system deserves additional capital expenditures (CAPEX) that are determined by the size of the green energy generator, the battery capacity, and other installation expenses.

Tao Han et al [31] introduce and investigate the Green Energy Provisioning (GEP) problem which aims to minimize the CAPEX of deploying green energy systems in BSs while satisfying the Quality of Service (QoS) requirements of cellular networks. They also proposed a green energy provisioning solution consisting of the provision-cost aware traffic load balancing algorithm and the binary energy system sizing algorithm to solve the sub-problems and subsequently solve the GEP problem.

Dantong Liu et al [32] propose a joint user association and green energy allocation algorithm which aims to lexicographically minimize the on-grid energy consumption in HetNets, where all the base stations (BSs) are assumed to be powered by both the power grid and renewable energy sources. The optimization problem involves both the user association optimization in space dimension, and the green energy allocation in time dimension. Simulation results indicate the proposed algorithm significantly saves on-grid energy as well as reduces peak-to average on-grid energy consumption ratio. However this proposal requires an efficient estimation of network traffic for better performance which is not precisely mentioned by the authors.

Qiao Kong and Bang Wang et al [32] proposed study the energy cost saving problem and propose an adaptive range expansion algorithm in green heterogeneous network considering that base stations of future cellular networks are heterogenous and can be powered by hybrid energy supplies: on-grid energy and green energy. The key impression of this algorithm is to adaptively set the biasing factor for each pico BS with respect to the estimated energy drain ratio to make utilization of the green energy more for energy cost saving.

V. Joint Deployment Of Relay Stations In Cell Edges To Optimize Power

The LTE-Advanced standard has specified the usage of relay stations (RSs) as a cost efficient means to extend the service coverage area of a base station (termed eNB) and to optimize power. The optimal placement of relay stations in BS transmission area called a “Cell” is also an important criteria while deploying relay stations. In this proposal we opt to deploy RSs on cell edges is to make this as a multi-objective solution which addresses power consumption, efficient Hand off management and deployment cost. The central objective of our work is to implement power optimization technique in LTE-A network by jointly deploying RS’s at cell edges. The BS’s in the proposed work are evolved node B (eNB) which are capable of communicating with other BSs and RSs deployed in the transmission area of selected BS through an X2 link. The number of RSs to be deployed depends up on the overlapped area covered for the selected BS. The cell Zooming server (CS) placed at the selected BS computes the algorithm to make BS to sleep mode.

The performance of this approach strongly depends on an efficient network traffic estimation method. The real time network traffic can be obtained efficiently by a feedback process to each RS as well as to BS. The CS (cell Zooming server) collects these information’s, of all users (MSs) which are associated to the corresponding RS, from all RS’s deployed in the transmission area of selected BS through the X2 link and computes safe mode algorithm. Computing this real time network traffic a safe mode algorithm can be implemented in order to put the BS and RS to power saving mode to save power. Our future work is to implement this proposal using MATLAB to obtain relevant results for power consumption and compare its efficiency with the existing. The deployment of Relay Stations on the cell edges of Base station meets an efficient strategy for Handoff especially a group Handoff. Our future work is to implement the proposed methodology and analyze its performance with the existing methods.

VI. Conclusion

Several power optimization techniques in cellular network such as cell area revision techniques, efficient transmission schemes, radio resource management, modular level approaches are reviewed in this paper from relevant literatures. We also discussed some energy optimization routing techniques for MANET. An emerging technique “Green energy approach for cellular network” is also presented in this paper. We proposed a methodology to optimize power by joint deployment of Relay stations along the cell edges of a Base Station in LTE-A network and an efficient method to estimate real time network traffic. Our future work is to implement the proposed methodology and analyze its performance with existing methods.

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REFERENCES

[1] T. Edler and S. Lundberg, “Energy efficiency enhancements in radio access networks,” Ericsson, Ericsson Review, 2004.
[2] “Improving energy efficiency, Lower CO2 emission and TCO,” Whitepaper, Huawei energy efficiency solution, Huawei Technologies, 2010.
[3] P. Grant, MCVE Core 5 Programme, “Green radio -the case for more efficient cellular Base stations,” presented at the Globecom’10, 2010.
[4] D. Lister, Vodafone Group Research & Development, “An operator’s view on green radio,” presented at the Proc. IEEE Int. Workshop on Green Communications, 2009.
[5] EARTH, “Energy aware radio and network technologies project,” https://www.ict-earth.eu/default.html.
[6] “Most promising tracks of green network technologies,” INFSO-ICT- 247733 EARTH Deliverable D3.1, Earth, WP3-Green Networks, 2010, https://bscw.ict-earth.eu/pub/bscw.cgi/d31509/EARTH WP3 D3.1.pdf.
[7] OPERA-Net, “Optimising power efficiency in mobile radio networks project,” http://opera net.org/default.aspx.
[8] “Optimising power efficiency in mobile radio networks,”OPERA-Net PROJECT STAND # 42, 2010 NEM Summit Towards Future Media Internet, Barcelona,Spain, Oct 2010, http://opera-net.org/Documents/5026v1 Opera-Net e-NEM% 20Event%20Barcelona%202010 Demos%20Presentation 290710.pdf.
[9] wirelessnetworking,”http://www.wireless.kth.se/research/projects/19-ewin.
[10] “Energy efficiency enhancements in radio access networks,” Wireless@KTH Research Strategy Document 2008-2010, Wireless@KTH, 2008, http://www.wireless.kth.se/images/stories/ Strategy/Research plan08.pdf.
[11] PJ Chung, Green Radio—the case for more efficient cellular base stations, (slides) UK-Taiwan ICT Workshop: Smart & Green Communications, (University of Taiwan March 2010).
[12] Navrati Saxena et al, Traffic-Aware Energy Optimization in Green LTE Cellular Systems IEEE communications letters, vol. 18, no. 1, January 2014
[13] Yigitel et al, Dynamic base station planning with power adaptation for green wireless cellular networks. EURASIP Journal on Wireless Communications and Networking 2014, 2014:77 http://jwcn.eurasipjournals.com/content/2014/1/77
[14] Deruyck et al, Characterization and optimization of the power consumption in wireless access networks by taking daily traffic variations into account. EURASIP Journal on Wireless Communications and Networking 2012, 2012:248 http://jwcn.eurasipjournals.com/content/2012/1/248
[15] Mehmet Aykut Yigitel et al, Dynamic Base Station Switching-on/off Strategies for Green Cellular Networks. IEEE transactions on wireless communications, vol. xx, no. xx, month 2013
[16] PJ Chung, Green Radio—the case for more efficient cellular base stations, (slides) UK-Taiwan ICT Workshop: Smart & Green Communications, (University of Taiwan March 2010).
[17] E Oh, B Krishnamachari, Energy savings through dynamic base station switching in cellular wireless access networks, in Global Telecommunications Conference (GLOBECOM 2010), IEEE, pp. 1–5, Miami, 6–10 December 2010
[18] Rakesh Kumar Jha, Varun Mishra, Kuldeep Yadav, Shubham Manhas, Power Optimization of Wireless Network, Annual IEEE India Conference (INDICON)
[19] Ziaul Haq Abbas and Frank Y. Li Power Consumption Analysis for Mobile Stations in Hybrid Relay-assisted Wireless Networks, 2010 5th International Symposium on Wireless Pervasive Computing (ISWPC)
[20] EV Belmega, S Lasaulce, M Debbah, A survey on energy-efficient communications, in PIMRC 2010 Workshop. Istambul, Turkey, 289–294 (2010)
[21] Swati Agarwal, Neeti Gupta, Power Consumption Analysis in Femtocell Networks, International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) Volume 3, Issue 11, November 2014
[22] Yao-Liang Chung, An Efficient Power-Saving Transmission Mechanism in LTE Macrocell-Femtocell Hybrid Networks, ICOIN 2014, IEEE
[23] Grace, D., Chen Tao Jiang, J., & Mitchell, P. D. (2009). Using cognitive radio for delivering green communications. In 4th international conference on cognitive radio oriented wireless networks and communications, 2009. CROWNCOM ‘09, June.
[24] Hauke Holtkamp, Gunther Auer and Harald Haas, On Minimizing Base Station Power Consumption, EU funded research project EARTH (Energy Aware Radio and network tecHnologies), FP7-ICT-2009-4-247733-EARTH, Jan. 2010 to June 2012. https://www.ict-earth.eu
[25] Energy Efficient Routing Protocol for MANET, IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 2, No 1, March 2012 ISSN (Online): 1694-0814 www.IJCSI.org
[26] Anuradha Banerjee,Paramartha Dutta, Subhankar Ghosh Experience Based Energy Efficient Reactive Routing Protocol (EXERP) for Mobile Ad-Hoc Networks, Arab J Sci Eng (2014) 39:891–901,DOI 10.1007/s13369-013-0813-9 research article - computer engineering and computer science, Springer.
[27] Xu Zhang, Zhi-Hong Qian, Yu-Qi Guo, Xue Wang, An Efficient Hop Count Routing Protocol for Wireless Ad Hoc Networks, International Journal of Automation and Computing, 11(1), February 2014, 93-99, DOI: 10.1007/s11633-014-0770-0
[28] C. P. Koushik*, P. Vetrivelan and R. Ratheesh, Energy Efficient Landmark Selection for Group Mobility Model in MANET, Indian Journal of Science and Technology, Vol 8(26), IPL0529, October 2015
[29] “Kyoto protocol to the united nations framework convention on climate change.” [Online]. Available: http://unfccc.int/resource/docs/convkp/kpeng.pdf
[30] J. Kwak, K. Son, Y. Yi, and S. Chong, “Greening effect of spatiotemporal power sharing policies in cellular networks with energy constraints,” IEEE Transactions on Wireless Communications, vol. 11, no. 12, pp. 4405–4415, 2012.
[31] Tao Han and Nirwan Ansari, Provisioning Green Energy for Base Stations in Heterogeneous Networks, DOI 10.1109/TVT.2015.2466101, IEEE Transactions on Vehicular Technology
[32] Dantong Liu, Yue Chen, Kok Keong Chai, Tiankui Zhang, Kaifeng Han, Joint User Association and Green Energy Allocation in HetNets with Hybrid Energy Sources, 2015 IEEE Wireless Communications and Networking Conference (WCNC): - Track 3: Mobile and Wireless Networks.

AUTHOR PROFILE

R Ratheesh received his BE degree in Electronics and Communication Engineering from Anna University, Chennai, India and his ME degree in Computer Science and Engineering from Anna university of Technology, Trichy, India in the year 2010.He served as assistant professor in various Engineering colleges. He is currently pursuing his Ph.D in School of Electronics Engineering, VIT University Chennai Campus, India. His research interests are in wireless communications and networking, Green heterogeneous networks, and energy-efficient wireless network design.

Dr.P.Vetrivelan received B.E. degree from Madras University, M.E. degree and Ph.D. degree both from Anna University, Chennai. Currently he is a full time faculty in School of Electronics Engineering, VIT University Chennai Campus. His research interests are seamless mobility in Heterogeneous 4G Wireless Networks, Wireless Sensor Networks, VANETS, Cloud Computing, IoT and Embedded Systems.