Energy Efficiency for Long Term Evolution Cellular Networks

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ABSTRACT

The telecommunications and information community today is facing daunting challenges along with embracing great opportunities. The unprecedented expansion of wire line and wireless networks has resulted in a tremendous increase in energy consumption and left a significant environmental footprint. The energy costs can account for as much as half of a mobile service provider's annual operating expenses. Thus, by making information and communications technology (ICT) equipment and applications energy-efficient will give a tangible positive impact on the environment, and also help telecommunications operators attain long-term profitability. This paper gives an insight of LTE and its concepts, its features, its equipments. It focuses on the need for green efficiency for LTE systems. It reviews about energy efficient advances made within the communications cycle components, network topology/operations, and incorporating renewable and alternative energy into base stations. Since base stations consume a maximum portion of the total energy used in a cellular system, so a comprehensive survey on techniques to obtain energy savings in base stations is discussed. The idea is to ensure any proposed solution to improve the energy efficiency without degrading the performance of any other part of the system. Two types of strategies one cognitive radio and another cooperative relay techniques for green communication is given. In cognitive radio we collect information on the spectrum usage and try to access the unused frequency bands intelligently, in order to compensate for this spectrum underutilization. While by using cooperative communication, well-known improvements of MIMO systems including coverage enlarging and capacity enhancement can be achieved. Cooperative techniques also combat shadowing by covering coverage wholes. My analysis reveals how proposed methodologies permit to achieve notable energy gain over traditional resource allocation techniques. Finally, an auctioning strategy is proposed for cellular networks that ensure net energy savings. Thus by discussing various technologies and analyzing them an approach is given for getting energy efficient green cellular next generation LTE systems.

Keywords: LTE systems, Energy Efficiency, Energy Savings, Green Communications, Cooperative relaying, Auctioning mechanism

I.INTRODUCTION.

Telecommunication has experienced a tremendous success causing proliferation and demand for ubiquitous heterogeneous broadband mobile wireless communications. Uptill now, innovation aimed at improving wireless networks coverage and capacity while meeting the QoS requested by users admitted to the system. During the last decade, there has been tremendous growth in cellular networks market. The number of subscribers and the demand for cellular traffic has escalated astronomically. With the introduction of Android and iPhone devices, use of eBook readers such as iPad and Kindle and the success of social networking giants such as Face book, the demand for cellular data traffic has also grown significantly in recent years. Such unprecedented growth in cellular industry has pushed the limits of energy consumption in wireless networks. Forecast on telecommunication market assumes an increase in subscribers, per subscriber's data rate, and the roll out of additional base stations for next generation mobile networks. An undesired consequence is the growth of wireless network's energy consumption that will cause an increase of the global carbon dioxide (CO2) emissions, and impose more and more challenging operational cost for operators. Communication Energy Efficiency (EE) presents indeed an alarming bottleneck in the telecommunication growth paradigm. Motivated by this scenario, we outline the main investigation axes that may significantly improve the EE of broadband cellular networks, thereby reducing the cost and environmental impact of mobile broadband services. Power consumption distribution in radio base stations in a typical LTE cellular network is shown in Fig.1.

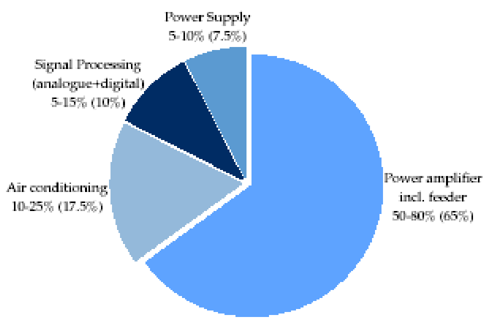


Fig.1 Power consumption distribution in radio base stations

In the above Figure the distribution of power consumption in base stations is given which shows that today's mobile networks have a strong potential for energy savings. The design of mobile networks has until now been focused on reducing the energy consumption of terminals, whose battery power imposes stringent requirements on energy consumption. This has led to a situation where terminal energy consumption is only a fraction of the energy consumption of the mobile network. Here, a description of work to achieve power efficiency of cellular networks is given, and some techniques are suggested to enable an energy efficient "green" cellular network. A special emphasis on cognitive and cooperative techniques is given, in order to bring attention of how the cellular systems can gain benefits through employing such techniques, and also highlight the research avenues in making these techniques green. A Taxonomy graph showing the design of green cellular networks given in Fig. 2.

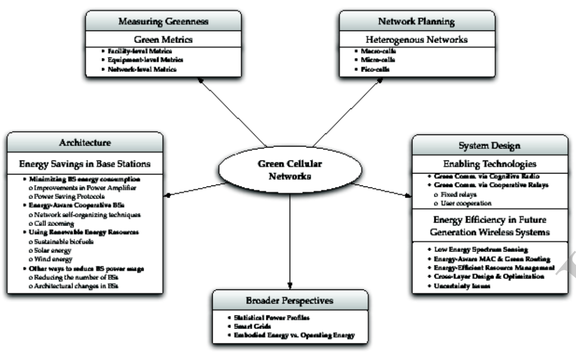


Fig 2. A Taxonomy graph for LTE Green Cellular Networks.

In the above figure, four important aspects of a green networking is shown which are defining green metrics, bringing architectural changes on base stations, network planning, and efficient system design. Energy efficient enhancement in wireless communication can be achieved only if improvements are experienced in the whole communication chain for different operational load scenarios. In order to achieve this research are carried out , ranging from energy efficient cooling of base stations to innovative energy efficient deployment strategies, and frequency planning. In this paper a brief introduction about LTE, its features, its architecture and its protocols is given in section II. In section III we elaborate on each of the issues and challenges of Base Stations BSs, since BSs consume the major chunk of input energy, we discuss the energy efficiency of BSs more at the component level in this section. Further , we study how to minimize energy consumption of BS by employing improvements in power amplifier, designing power saving protocols, implementing cooperative BS power management, using renewable energy resources and bringing some simple architectural changes. Section IV discusses the energy efficiency from a network planning perspective side and the strategies involved in it are given. An auctioning strategy for energy saving is proposed for cellular networks in Section V. Finally concluding remarks is given in Section VI.

II.OVERVIEW OF THE LONG TERM EVOLUTION SYSTEMS.

LTE stands for *Long Term Evolution* and it was started as a project in 2004 by telecommunication body known as the Third Generation Partnership Project (3GPP). SAE (System Architecture Evolution) is the corresponding evolution of the GPRS/3G packet core network evolution. The term LTE is typically used to represent both LTE and SAE. LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication System (UMTS), which in turn evolved

ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

from the Global System for Mobile Communications (GSM). Long Term Evolution (LTE) is important because it will bring up to a 50x performance improvement and much better spectral efficiency to cellular networks. LTE is different from other technologies that call themselves 4G because it is completely integrated into the existing cellular infrastructure for 2G and 3G.The LTE standard specifies an IP-only network supporting data rates up to 150 Mbps. These high data rates will enables new applications and services such as voice over IP, streaming multimedia, videoconferencing or even a high-speed cellular modem. A rapid increase of mobile data usage and emergence of new applications such as MMOG (Multimedia Online Gaming), mobile TV, streaming contents have motivated the 3rd Generation Partnership Project (3GPP) to work on the Long-Term Evolution (LTE) on the way towards fourth-generation mobile. The main goal of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. LTE network architecture has been designed with the goal to support packet-switched traffic with seamless mobility and great quality of service.

II.I Features of LTE

LTE is the successor technology not only of UMTS but also of CDMA 2000.LTE is important because it will bring up to 50 times performance improvement and much better spectral efficiency to cellular networks. LTE was introduced to get higher data rates, 300Mbps peak downlink and 75 Mbps peak uplink. In a 20MHz carrier, data rates beyond 300Mbps can be achieved under very good signal conditions. LTE is an ideal technology to support high date rates for the services such as voice over IP (VOIP), streaming multimedia, videoconferencing or even a high-speed cellular modem.LTE uses both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) mode. In FDD uplink and downlink transmission used different frequency, while in TDD both uplink and downlink use the same carrier and are separated in Time. LTE supports flexible carrier bandwidths, from 1.4 MHz up to 20 MHz as well as both FDD and TDD. LTE designed with a scalable carrier bandwidth from 1.4 MHz up to 20 MHz which bandwidth is used depends on the frequency band and the amount of spectrum available with a network operator .All LTE devices have to support (MIMO) Multiple Input Multiple Output transmissions, which allow the base station to transmit several data streams over the same carrier simultaneously. All interfaces between network nodes in LTE are now IP based, including the backhaul connection to the radio base stations. This is great simplification compared to earlier technologies that were initially based on E1/T1.

II.II Advantages of LTE

a) *High throughput:* High data rates can be achieved in both downlink as well as uplink. This causes high throughput.

b) *Low latency:* Time required to connect to the network is in range of a few hundred milliseconds and power saving states can now be entered and exited very quickly.

c) *FDD and TDD in the same platform:* Frequency Division Duplex (FDD) and Time Division Duplex (FDD), both schemes can be used on same platform.

d) *Superior end-user experience***:** Optimized signaling for connection establishment and other air interface and mobility management procedures have further improved the user experience. Reduced latency (to 10 ms) for better user experience.

e) *Seamless Connection:* LTE will also support seamless connection to existing networks such as GSM, CDMA and WCDMA.

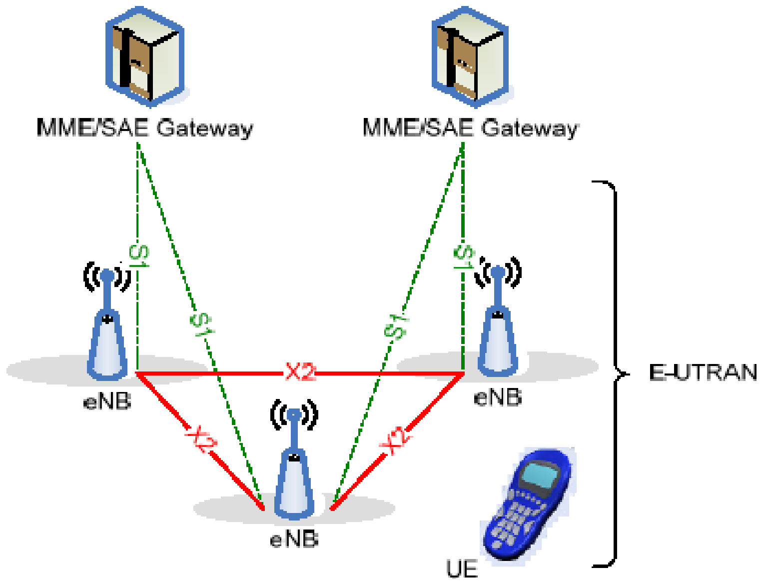
f) *Plug and play:* The user does not have to manually install drivers for the device. Instead system automatically recognizes the device, loads new drivers for the hardware if needed, and begins to work with the newly connected device.

g) *Simple architecture:* Because of Simple architecture low operating expenditure (OPEX).

II.III LTE Architecture

The network architecture of LTE is comprised of following three main components:

A) The User Equipment (UE).
B) The Evolved UMTS Terrestrial Radio Access Network (E-UTRAN).
C) The Evolved Packet Core (EPC).



- **eNB**: Enhanced Node B, or base station
- **UE**: User Equipment
- **EPC**: Evolved Packet Core
  - **MME**: Mobility Management Entity (Control Plane)
  - **SAE**: System Architecture Evolved (User Plane)
- **E-UTRAN**: Evolved Universal Terrestrial Radio Access Network

Fig. 3. LTE Architecture Overview.

2.3.1 The User Equipment (UE). The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment (ME). The mobile equipment comprised of the following important modules:

(i) Mobile Termination (MT): This handles all the communication functions.

(ii) *Terminal Equipment (TE):* This terminates the data streams.

(iii) Universal Integrated Circuit Card (UICC): This is also known as the SIM card for LTE equipments. It runs an application known as the Universal Subscriber Identity Module (USIM). A USIM stores user-specific data very similar to 3G SIM card. This keeps information about the user's phone number, home network identity and security keys etc.

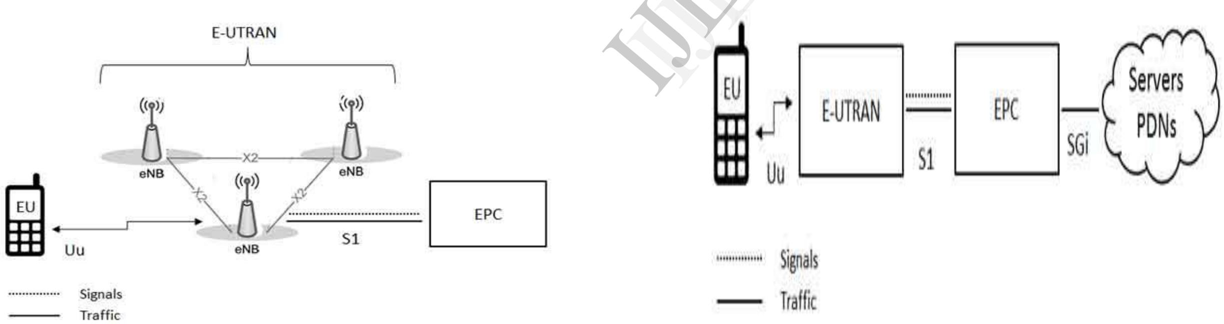


Fig. 4. E-UTRAN Architecture

ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

2.3.2 The E-UTRAN (The access network). The architecture of evolved UMTS Terrestrial Radio Access Network (E-UTRAN) has been illustrated above in Fig.4.The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem. The interfaces between the different parts of the system are denoted Uu, S1 and SGi . The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called eNodeB or eNB. Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB. LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB: The eNB sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface and secondly the eNB controls the low-level operation of all its mobiles, by sending them signaling messages such as handover commands. Each eNB connects with the EPC by means of the S1 interface and it can also be connected to nearby base stations by the X2 interface, which is mainly used for signalling and packet forwarding during handover. A home eNB (HeNB) is a base station that has been purchased by a user to provide femtocell coverage within the home. A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

2.3.3 The Evolved Packet Core (EPC) (The core network).
The architecture of Evolved Packet Core (EPC) has been illustrated in Fig 5. A brief description of the components is given below:

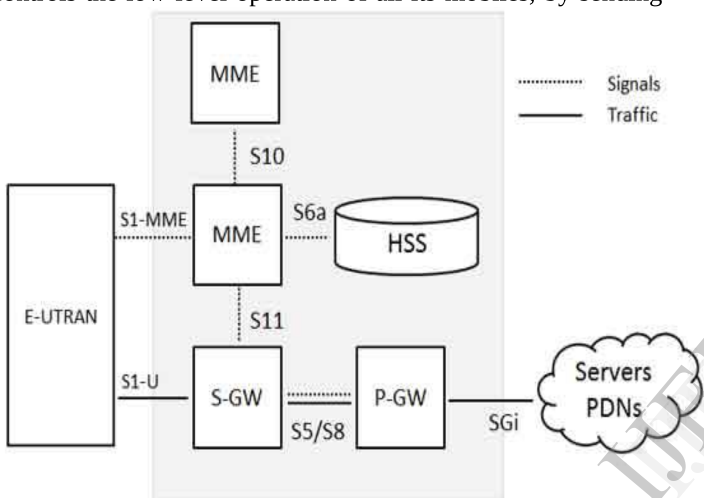


Fig. 5. The Evolved Packet Core (EPC) Network Architecture.

(i) The Home Subscriber Server (HSS) component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.

(ii) The Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world ie. packet data networks PDN, using SGi interface. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.

(iii)The serving gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.

(iv)The mobility management entity (MME) controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server (HSS).

(v) Another component is the Policy Control and Charging Rules Function (PCRF), which is responsible for policy control decision-making, as well as for controlling the flow-based charging functionalities in the Policy Control Enforcement Function (PCEF), which resides in the P-GW. The interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different networks.

II.IV LTE Protocol Architecture

LTE Protocol Architecture consists of two Planes one User Plane and another Control Plane.

2.4.1 The User Plane. An IP packet for a UE is encapsulated in an EPC-specific protocol and tunneled between the P-GW and the eNodeB for transmission to the UE. Different tunneling protocols are used across different interfaces. A 3GPP-specific tunneling protocol called the GPRS Tunneling Protocol (GTP) is used over the CN interfaces, S1 and S5/S8.1. The LTE user plane protocol stack is shown in Fig 6.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

It consists of Packet Data Convergence Protocol (PDCP), Radio Link Control (RLC) and Medium Access Control (MAC) sub layers that are terminated in the eNodeB on the network side.

Fig. 6. The LTE User Plane Protocol Stack.

2.4.2 The Control Plane. The protocol stack for the control plane between the UE and MME is shown in Figure 7. The blue region of the stack indicates the AS protocols. The lower layers perform the same functions as for the user plane with the exception that there is no header compression function for the control plane. The Radio Resource Control (RRC) protocol is known as "layer 3" in the AS protocol stack. It is the main controlling function in the AS, being responsible for establishing the radio bearers and configuring all the lower layers using RRC signaling between the eNodeB and the UE. Thus a brief introduction of the LTE systems and its architecture, features, etc is given in this section to discuss about the systems and to get know how about the systems, now how these systems can be made energy efficient will be discussed in next section.

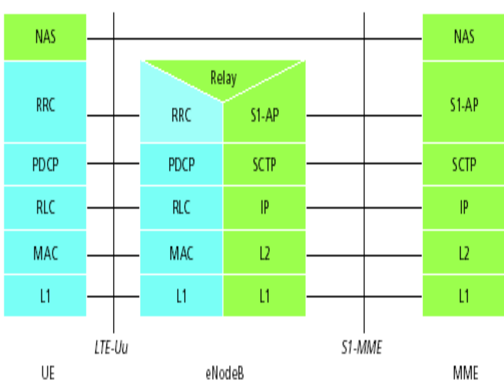


Fig. 7. The LTE Control Plane Protocol Stack.

III.ENERGY SAVINGS IN BASE STATIONS.

In this section we will discuss about the parameters which will be useful for energy savings in LTE systems. It was found out by the environmental studies that due to tremendous growth of the mobile industry the emissions caused by the equipments contribute around 1% of the entire world's carbon footprint, so there has been an emerging need of Green Communications being felt by the industry experts. The term 'Green Communications' has been marketed as a solution for the growing cost and environmental impact of telecommunications. There are several hurdles that must be overcome in order to truly realize the improvements in energy efficiency in communications. Figure 8 illustrates the concept by highlighting the relative power consumption of various components and operational aspects of a base station. Currently, most of the advancements in energy efficient communications focuses within a narrowly defined aspect of the communications cycle such as power amplifiers or incorporating renewable energy sources. Here energy efficient communications are analyzed from an overall holistic system perspective rather than at singular levels.

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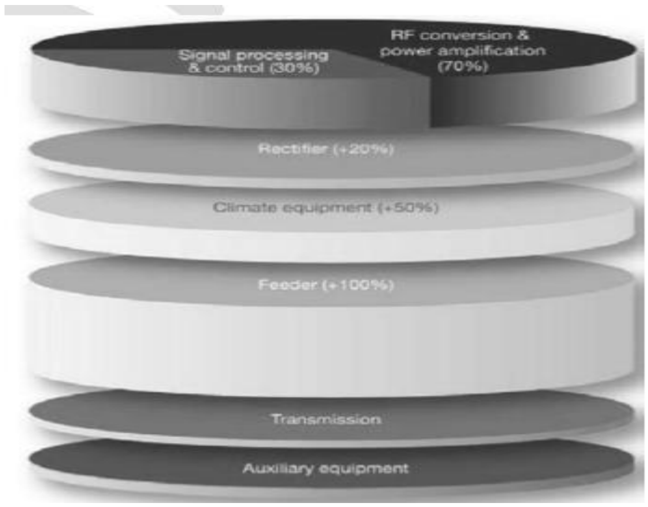

Fig. 8. Energy Consumption at a macro base station

Due to the rapidly growing demand for mobile communication technology, the number of worldwide cellular BSs has increased from a few hundred thousand to many millions within a last couple of years. Such a substantial jump in the number of BSs that power a cellular network accounts for the sudden increase in greenhouse gases and pollution. With the advent of data intensive cellular standards, power-consumption for each BS can increase up to 1,400 watts. Moreover the radio network itself adds up to 80% of an operator's entire energy consumption. Hence, eco friendly solutions to reduce power demands of BSs are a necessity nowadays. A typical cellular network consists of three main elements a core network that takes care of switching, BSs providing radio frequency interface, and the mobile terminals in order to make voice or data connections. As the number of BSs increases, it becomes crucial to address their energy consumption for a cellular network. Two different strategies to reduce energy consumption due to BSs are given.

A. Minimizing BS energy consumption: The energy consumption of a typical BS can be reduced by improving the BS hardware design and by including additional software and system features to balance between energy consumption and performance. In order to improve hardware design of a BS for energy consumption, we need to address the energy efficiency of the power amplifier (PA). A PA dominates the energy consumption of a BS and its energy efficiency depends on the frequency band, modulation and operating environment. Some typical system features to improve BS energy efficiency are to shut down BS during low traffic or cell zooming. Besides hardware redesign and new system level features, there are various site level solutions that can be used in order to save energy. Outdoor sites can be used over wider level of temperatures, and thus less cooling would be required. Another solution is to use more fresh air-cooling rather than power consuming air conditioners for indoor sites. In addition, RF heads and modular BS design can be implemented to reduce power loss in feeder cables.

(i) Improvements in Power Amplifier: There are three essential parts of a BS: radio, baseband and feeder. Out of these three, radio consumes more than 80% of a BS's energy requirement, of which power amplifier (PA) consumes almost 50%. Out of this, 80-90% of that is wasted as heat in the PA, and which in turn requires air-conditioners, adding even more to the energy costs. The total efficiency of a currently deployed amplifier, which is the ratio of AC power input to generated RF output power, is generally in the range from 5% to 20% (depending on the standard viz. GSM, UMTS, CDMA and the equipment's condition) . Modern BSs are terribly inefficient because of their need for PA linearity and high peak-to-average power ratios (PAPR). The modulation schemes that are used in communication standards such as WCDMA/HSPA and LTE are characterized by strongly varying signal envelopes with PAPR that exceeds 10dB. To obtain high linearity of the PAs in order to maintain the quality of radio signals, PAs have to operate well below saturation. Depending on their technology (e.g Class-AB with digital pre-distortion) and implementation, the component level efficiency of modern amplifiers for CDMA and UMTS systems is in the order of approximately 30% to 40% . Since these technologies have reached their limits, PAs based on special architectures such as digital pre-distorted architectures

ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

and GaN (Aluminum/Gallium nitride) based amplifiers seem to be more promising by pushing the power efficiency levels to over 50%. PAs that consist of a carrier and a peak amplifier is advantageous by providing easy additional linearization using conventional methods such as feed-forward and envelope elimination and restoration (EER). Since GaN structures can work under higher temperature and higher voltage, they can potentially provide a higher power output. Additional improvements in efficiency can be obtained by shifting to switch-mode PAs from the traditional analog RF-amplifiers. Compared to standard analog PAs, switch-mode PAs tend to run cooler and draw less current. While amplifying a signal, switch-mode amplifier turns its output transistors on and off at an ultrasonic rate. The switching transistors produce no current when they are switched off and produce no voltage when switched on, therefore generate very little power as heat resulting in a highly efficient power supply. It is expected that overall component-efficiency of these energy efficient devices could be around 70%. One more significant setback in increasing power efficiency with PAs is that they perform better at maximum output power in order to maintain the required signal quality. However, during the low traffic load conditions (e.g night time), lot of energy is routinely wasted. Therefore, design of flexible architectures that would allow a better adaptation of the amplifier to the required output power needs to be addressed. In addition to this, proper modulation scheme has to use as modulation affects the efficiency i.e., by focusing more on higher modulation schemes that require additional filtering in order to prioritize the data over voice, linearity of PA is more desirable because of the non-constant envelope of the signal.

(ii) Power Saving Protocols: In the present cellular network architecture based on WCDMA/HSPA, BSs and mobile terminals are required to continuously transmit pilot signals. Newer standards such as LTE, LTE-Advanced and WiMAX have evolved to cater ever-growing high speed data traffic requirements. With such high data requirements, although BSs and mobile units (MU) employing newer hardware (such as multiple-input and multiple-output (MIMO) antennas) increase spectral efficiency allowing to transmit more data with the same power, power consumption is still a significant issue for future high speed data networks and they require energy conservation both in the hardware circuitry and protocols .A fairly intuitive way to save power is to switch off the transceivers whenever there is no need to transmit or receive. The LTE standard utilizes this concept by introducing power saving protocols such as discontinuous reception (DRX) and discontinuous transmission (DTX) modes for the mobile handset .DRX and DTX are methods to momentarily power down the devices to save power while remaining connected to the network with reduced throughput.

Continuous transmission and reception in WCDMA/HSPA consumes significant amount of power even if the transmit powers are far below the maximum levels, and therefore power savings due to DRX and DTX is an attractive addition. There are three power-saving classes with different on/off cycles for the WiMAX standard. Unfortunately, such power saving protocols for BSs has not been considered in the current wireless standards. The traffic per hour in a cell varies considerably over the time and BSs can regularly be under low load conditions, especially during the night time. In future wireless standards, energy saving potential of BSs needs to be exploited by designing protocols to enable sleep modes in BSs. By making use of downlink DTX schemes for BSs by enabling micro-sleep modes (in the order of milliseconds) and deep-sleep modes(extended periods of time),switching off in active hardware of BSs during these sleep modes can potentially save a lot of power, especially under low load conditions. A breakup of power consumption is given in Fig.9 which shows that large portion of energy saving is required at the power amplifiers side.

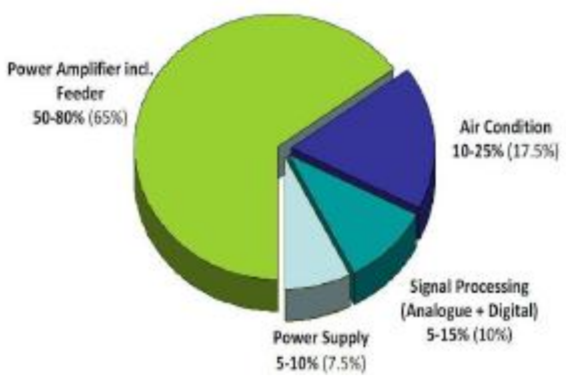

Fig. 9. Breakdown of Power Consumption in radio base station

B. Energy-Aware Cooperative BS Power Management. The recent evolution of mobile communication systems from GSM to the Long Term Evolution of 3GPP leads to continuous rise of the peak-to-average power ratios (PAPR), which will further increase by using multicarrier and multistandard solutions. The undistorted transmission of such signals requires operating the power amplifiers on average levels far below their maximum signal output power and thus strongly limits their power efficiency. To be up to the requirements of an energy efficient system, future power efficient transceivers need more complex amplifier architectures with improved energy efficiency combined with measures to reduce the signal PAPR parameter. By implementing new interfaces and an algorithmic intelligence, the transceiver can adapt to the system load by analyzing the incoming base band signals. In energy efficient systems it is possible to switch off some of the baseband boards or other components. This capability of the

ISSN: 2278-0181
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transceiver allows it to follow energy saving measures on a system level with a minimum of signaling between different layers. Another source of energy wastage is due to reflections of the antenna back to the transceiver. These reflections depend upon the impedance matching of the amplifier, which in turn depends on the power level and the antenna environment. Active tuning of the matching network can cancel these reflections. Traffic load in cellular networks have significant fluctuations in space and time due to a number of factors such user mobility and behavior. During the daytime, the traffic load are generally higher in office areas as compared to residential while it is the other way around during the night. Therefore, there will always be some cells under low load, while some others may be under heavy traffic load. Hence, a static cell size deployment is required for fluctuating traffic conditions. For the next generation cellular networks which are based on microcells and picocells and femtocells, such fluctuations can be very serious .While limited cell size adjustment called "cell-breathing" currently happens in most of the deployed CDMA networks (a cell under heavy load or interference reduces its size through power control and the mobile user is handed off to the neighboring cells), although a more network-level power management technique is required **C.Other ways to reduce BS power consumption.** The energy consumption of the entire cellular network includes the summation of energy used by each BS, thus reducing the number of BSs has a direct impact on energy consumption of a cellular network. However, efficient network design and finding an optimal balance between cell size and BS capacity can be very challenging. Features such as 2-way and 4-way diversity, feeder less site, extended cell, low frequency band, 6-sector site and smart antenna can be used to minimize the number of BS sites. Another way to improve power efficiency

where multiple BSs coordinate together. Since operating a BS consumes a considerable amount of energy, selectively letting a BSs to go to sleep based on their traffic load can lead to significant amount of energy savings. When some cells are switched off or in sleep mode, the radio coverage can be guaranteed by the remaining active cells by filling in the gaps created. Such concepts of self-organizing networks (SON) have been introduced in 3GPP standard to add network management and intelligence features so that the network is able to optimize, reconfigure and heal itself in order to reduce costs and improve network performance and flexibility. In LTE systems, concept of Cell-Zooming has to be incorporated. Cell zooming is a technique through which BSs can adjust the cell size according to network or traffic situation, in order to balance the traffic load, while reducing the energy consumption. When a cell gets congested with increased number of users, it can zoom itself in, whereas the neighboring cells with less amount of traffic can zoom out to cover those users that cannot be served by the congested cell. Cells that are unable to zoom in may even go to sleep to reduce energy consumption, while the neighboring cells can zoom out and help them to serve the mobile users cooperatively.

of a BS is to bring some architectural changes to the BS such as low power RF-cables should be used and RF-amplifier has to be kept closer to the antenna. This will improve the efficiency and reliability of the BS. Thus in this section we have seen that BSs consumes maximum power in LTE networks and strategies in order to minimize their consumption is also given, in next section we will discuss different planning strategies for green communication in LTE systems. .

IV. NETWORK PLANNING STRATEGIES.

With the exponential growth in demand for higher data rates and other services in cellular networks these networks requires a more dense deployment of base stations within network cells. On the other hand conventional macro-cellular network deployments are less efficient, it may not be economically feasible to modify the current network architectures. Macro cells are generally designed to provide large coverage and are not efficient in providing high data rates. One obvious way to make the cellular networks more power efficient in order to sustain high speed data-traffic by decreasing the propagation distance between nodes, hence reducing the transmission power. Therefore, cellular network deployment solutions based on smaller cells such as micro, pico and femtocells are very promising in this context. A typical heterogeneous network deployment is shown in Fig. 10.

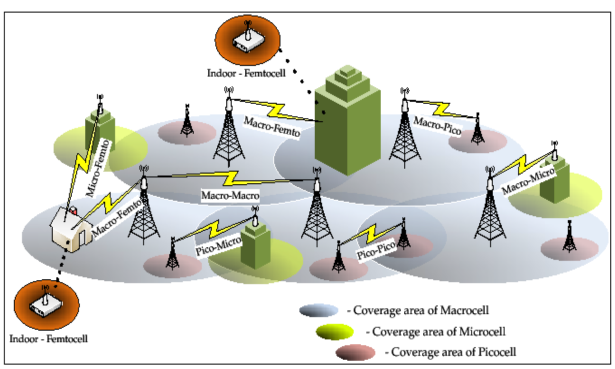

Fig.10. A typical heterogeneous network deployment

A micro/picocell is a cell in a mobile phone network that served a low power cellular BS that covers a small area with dense traffic such as a shopping mall, residential areas, a hotel, or train station. A typical range of a micro/picocell is the order of few hundred meters, femtocells are designed to serve much smaller areas such as private homes or indoor areas. The range of femto cells is typically only a few meters and they are generally wired to a private owners' cable broadband connection. Smaller cells because of their size are much more power efficient in providing broadband coverage. Simulations show that by joint deployment of macro cell and picocell in a network can reduce the energy consumption in the network by up to 60% compared to a network with macro cells. Another advantage of smaller cells is that they can use higher frequency bands suitable to provide high data rates and also

IV.I. Network Topology and Operations. In order to achieve Green communications for GSM Base Transceiver Station (BTS) efforts for energy efficiency have to done on several fronts including power amplifier improvements, operational strategies, and cooling requirements. Traditionally, all radio equipment was located in an enclosure at the ground level with connection to antennas achieved through feeder cables. Feeder cables can produce over 50% of loss into the system. Hence, modular base station designs should locate the RF transmitter closer to the antenna thereby reducing the loss incurred from the cable. This type of architecture enables maintaining the same quality of service and a lower transmit power. Topology specific design perspectives and improved planning methodologies are yielding improved power efficiency through reduction in the number of sites. These smaller, more agile base stations dovetail to a distributed base station architecture, which can replace larger more power hungry macro base stations. Actual deployments of these more agile base stations have achieved more than a 40% power decreasing geographically around business districts in the evenings and weekends. BTS equipment can learn from these patterns and turn off completely or decrease the number of transmitting antennas. Such site-level turn off approach for managing power has significant potential to lower power usage however it requires coordinated management of base stations in order to maintain desired capacity and customer quality of service. The modulation scheme utilized also affects the PA efficiencies. For example, the changing priority of data over voice within the cellular community has placed more emphasis on higher order modulation schemes. In Enhanced

IV.IIENABLINGTECHNOLOGIES:COGNITIVERADIO AND COOPERATIVE RELAYING. In order to achieve above objectives, technologies such as cognitive radio and cooperative relaying should be given a significant attention. In cognitive radio, there is an intelligent and adaptive wireless communication system that enables us to utilize the radio spectrum in a more efficient manner, while cooperative relays provide a lot of improvement in throughput and coverage for futuristic wireless networks. However, developments in both these technologies also enable us to solve the problem of energy efficiency via smart radio transmission and distributed signal processing.

A) ***Green Communication Using Cognitive Radio Technique:*** Bandwidth efficiency has always been a crucial concern in wireless communication, also it has been realized that the allocated spectrum is highly underutilized, and this is where

offer localization of radio transmissions However, deploying too many smaller cells within a macro cell may reduce the overall efficiency of the macro cell BS, since it will have to operate under low load conditions. Moreover under full traffic load scenarios, the use of micro BSs has a rather moderate effect on the area power consumption of a cellular network and it strongly depends on the offset power consumption of both the macro and micro cell. Depending upon the voice traffic model, this mechanism can provide an average power saving of 37.5% and for high traffic scenario, it can achieve five times reduction in the occurrence of mobility events as compared to a fixed pilot transmission.

savings without affecting overall output signal power, other techniques such as transmit diversity and higher receive sensitivities are also yielding improved power savings. Femtocells and picocells are relatively new technologies that have a potential to reduce overall power usage while still optimizing capacity and service. A fundamental pathway for improving cellular capacity is to reduce the distance between a mobile unit and transmitter. Femtocells enable this vision by connecting miniaturized, lower power base stations to wired backhauls such as home digital subscriber lines (DSL) or cable modems. Femtocells output very low power compared to a full size base station, yet can achieve improved capacity through large scale deployment. By joint deployment of macro base stations with publicly accessible residential picocells can reduce energy consumption up to 60% .Fluctuations in cellular usage are often correlated spatially and temporally with location and time of day. For example, during evening, rush hour usage is high and decreases later in the night while also

Data Rate for GSM Evolution (EDGE), 8PSK modulation is favored over the original Gaussian Minimum Shift Keying (GMSK) used in the GSM. The amplitude variations of the modulation require concern with regard to the PA utilized in the system. Linear PA, which has poor efficiency, is usually desired in order to maintain the non-constant envelope of the signal. The design objectives also differ from extending the lifetime to maximizing the system availability. Additionally, the overall network design must take into consideration the redundancy in coverage area.

cognitive radio comes into the picture. The main purpose of cognitive radio is to collect information on the spectrum usage and to try to access the unused frequency bands intelligently, in order to compensate for this spectrum underutilization. However, the question is why using spectrum more efficiently is important and how it can reduce power consumption? The answer lies under Shannon's capacity formula, where we can see the tradeoff between the bandwidth and power. The capacity increases linearly with bandwidth, but only logarithmically with power. This means that in order to reduce power, we should seek for more bandwidth, or in other words, manage the spectrum optimally and dynamically, and this falls into the scope of cognitive radio. In fact, up to 50% of power can be saved if the operator dynamically manages its spectrum by activities such as dynamically moving users into particularly active bands from other bands, or the sharing of spectrum to allow channel bandwidths to be increased.

ISSN: 2278-0181
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However, efficient spectrum usage is not the only cognitive radio. Actually, in cognitive radio, every possible parameter measurable by a wireless node or network is taken into account (Cognition) so that the network intelligently modifies its functionality (Reconfigurability) to meet a certain objective. One of these objectives can be power saving. It has

B) Cooperative Relays Technique to deliver green communication: In infra-structured wireless networks, extending coverage of a BS is an important issue. Considering well-known properties of the wireless channel, including large path losses, shadowing effects and different types of signal fading, covering very distant users via direct transmission becomes very expensive in terms of required power in order to establish a reliable connection. This high-power transmission requirement further translates into the high power consumption and also introduces high levels of interface at nearby users and BSs. On the other hand, in recent years, cooperative communication techniques have been proposed to create a virtual MIMO system. Thus, by using cooperative communication, well-known improvements of MIMO systems including coverage enlarging and capacity enhancement can be achieved. Cooperative techniques also combat shadowing by covering coverage wholes. Multi-hop communication divides a direct path between mobile terminals and BS into several shorter links and where wireless channel impairments such as path loss are less destructive, hence lower transmission power can be assigned to the BS and relays. While two-hop communication consumes less energy than direct communication and by using multi-hopping in CDMA cellular networks can reduce the average energy consumed per call. Delivering green communication via cooperative techniques for delivering green communication as well a general improvement of network performance. Installing new BSs in order to have a higher BS density can be very expensive. Therefore, we can install relays instead of new BSs, which is economically advantageous, and does not introduce much complexity to the network. First of all, relays need not be as high as BSs, because they are supposed to cover a smaller area with a lower power. Secondly, relays can be wirelessly connected to a BS, instead of being attached to the backhaul of the network by wire using a complicated interface. And finally, in cellular systems, unlike ad-hoc peer-to-peer networks, complex routing algorithms are necessary. All these reasons make installing relays a potential solution for getting more energy efficient cellular networks. Hence, relays provide a flexible way to improve the spatial reuse, as they are less complex than BSs and therefore cheaper to deploy, and the relays reduce the power in the system compared to systems based on direct transmission.

C)*Green Communications in Cellular Networks via User Cooperation:* User cooperation in cellular networks not only increases the data rate, but also makes the system more robust, i.e., the achievable rates are less sensitive to channel variations. However, despite all these advantages, energy efficiency issues of user cooperation render this paradigm

been shown in recent works that structures and techniques based on cognitive radio reduce the energy consumption, while maintaining the required quality-of-service (QoS), under various channel conditions. Thus cognitive radio gives us a way for getting feasible, less complex green communication in LTE systems.

can be achieved by two different approaches. The first approach is to install fixed relays within the network coverage area in order to provide service to more users using less power. And the second approach is to exploit the users to act as relays. In this work, a relay is roughly defined as one of the network elements which can be fixed or mobile, much more sophisticated than a repeater, and it has capabilities such as storing and forwarding data, and cooperating in scheduling and routing procedures. While the second scenario eliminates the cost of installing relay nodes, it increases the complexity of the system, mostly because centralized or distributed algorithms must be designed to dynamically select relays among the users, as well as new user mobile terminals have to be designed such that they support relaying. In the two following sub-sections, we discuss these two scenarios.

D) ***Enabling Green Communication via Fixed Relays:*** Nonlinear signal attenuation or path loss is an interesting property of a wireless channel. This property helps to concentrate power on specific locations in a network, hence, leads to spatial reuse of various resources within a wireless network. In other words, a higher density of BSs leads to less energy consumption as well as a higher special reuse. In fact, this is the key point which makes fixed relays good candidate

unappealing in wireless mobile networks. The reason is increased rate of one user comes at the price of the energy consumed by another user acting as a relay. Moreover, the limited battery life time of mobile users in a mobile network leads to selfish users who do not have incentive to cooperate. It is found that user cooperation has the potential of simultaneously improving both user's bits-per energy efficiency under different channel conditions but User cooperation in which selfish users find cooperation favorable to their energy concerns, is difficult to get it .So , this new approach can be a promising technique in Green communication to increase the system performance in terms energy efficiency in future wireless mobile networks depending upon the control on the behavior of the mobile users. Thus in this section network planning strategies are discussed showing the necessity of micro, pico and femto cells. Further two technologies of achieving green communication is given. Now in next section an auctioning mechanism for getting energy savings in LTE cellular systems isgiven.

V. ENERGY SAVING STRATEGY FOR CELLULAR SYSTEMS.

Greenhouse gas (GHG) emissions have risen sharply with the industrial revolution and they are projected to further increase dramatically if significant measures are not taken

ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

to prevent this. Currently, the telecommunication industry accounts for about 2% of the GHG footprint and for the wireless communications, most of the significant environmental impact is due to high energy consumption in cellular base stations (BSs). There is considerable current interest in reducing the energy consumption in the wireless sector. Here, my approach for energy efficiency from the perspective of optimized downlink communications is given by reducing energy consumption at the base station.

A. Energy based Utility Models for Base Station

A significant part of the energy consumption for network operators is the operating energy for the base stations, with about 57% of the energy consumption being used for radio access. For efficient communications efficient resource management algorithms are key components. By analyzing the base station power model consumption , we can see that significant energy is consumed in transmit power, which results in even higher energy consumption due to the inefficiency of the linear power amplifiers (LPAs). Consequent, for each watt of output power, approximately 3.5W are required at the LPA input. Thus, the effective gains in reducing output power at the base station need to be multiplied by the inverse of the LPA efficiency at the base station, η_B . As 3G services mature, the revenue of

It is conjecture that cooperation between end users and network operators may result in significant overall energy savings. So here an auction based pricing system is proposed that incentivizes both parties to cooperate for energy savings. In this formalism, the nodes' cooperative options include employing better signal processing/interference cancellation techniques, flexible QoS requirements, and relaying packets for remote nodes.

mobile network operators is expected to grow at a much slower rate than the corresponding increase in the amount of data traffic, with the starkest difference seen so far with the companies that offer more aggressive pricing for data services. One way to improve revenues for the operators is to reduce their energy costs, so that becoming "greener" for environmental reasons is also financially beneficial for network operators. Now assuming an effective cost per unit energy to be *c*, the cost of transmitting 1 bit for a connection can be expressed as

$$C_b = \frac{\eta_B P_t c E[K]}{r} = \frac{\eta_B P_t c}{r P_c(\gamma)} \qquad (1)$$

where r is the transmission rate, $E[K]$ = average number of required retransmissions per packet, and $P_c(\gamma)$ is the probability of correct reception of a packet, with γ being the signal-to-interference-plus-noise ratio (SINR) at the receiving node. $P_c(\gamma)$ is determined by the receiving node characteristics e.g., current interference and noise levels, interference cancellation capabilities, etc. and on the node's QoS specifications (e.g. transmission rate, modulation level, etc.).
The cost as given in (1) can be reduced by:
(i) Better interference management at receiving nodes,
(ii) Reduced QoS requirements in terms of transmission rates, or by
(iii) Support of external terminals for relaying, with an effect of reducing P_t, by using a smaller effective transmission range for the base station.
From the above discussion, it is apparent that cooperation from mobile terminals may potentially result in gains for the

network operators. One way to incentivize such cooperation is to introduce reward pricing for cooperating nodes. These rewards will encourage the nodes to trade off their QoS requirements or energy (for the case of relaying nodes) for monetary rewards from the system operator. In designing such a pricing scheme, the green energy savings goal is to reduce the overall energy consumption per transmitted bit, rather than simply move the energy burden from the base station (BS) to the mobile terminals. The network operator's utility per transmitted bit is proportional to the revenue obtained from the transmission. A higher transmission power will result in higher energy costs, while a higher price per unit energy λ for the end user, will result in more revenue. A reimbursement price per bit R can be used to reward intermediate nodes that facilitate transmission with reduced energy costs. Thus the utility function perceived by the base station operators is a measure of revenue per bit and can be expressed as

$$U_{BS} = E_b(\lambda - c) - R \qquad (2)$$

where E_b is the energy per transmitted bit consumed by the BS and E_b is defined as $E_b = \eta_B (P_t) P_t / r P_c(\gamma)$, and R is the monetary reward for relaying which could be expressed as $R = E'_b \mu$, with E'_b = energy per bit consumed by a relaying node, and μ= unit price per energy expenditure. E_b can be reduced by either reducing the required throughput, improving the packet success rate (better interference management), or reducing the

transmitted power (e.g., using relays). A profit margin ε per unit energy expenditure for the BS can be defined, which will guarantee the network operator's revenue in the absence of helper terminals. Consequently, the price charged by the operator for the unit energy expenditure bit is given by
$\lambda = c + \varepsilon$. Hence, the BS utility function can be written as

$$U_{BS} = E_b \varepsilon - E'_b \mu \qquad (3)$$

B. Utility Models for Mobile Terminals

Here for mobile terminals two different terminal types should be considered for modeling: (i) the intended receiver (destination node) and a relaying terminal.

(i)The intended receiver (destination node): At the receiving node, the utility of the terminal measures the level of satisfaction a customer gets from the service it receives. A general valuation

function $\Gamma(T_D, \lambda E_b, q)$ is proposed to capture the following performance metrics that are relevant to the destination terminal: throughput (T_D), price charged by the BS per correctly received bit (λE_b), and energy expenditure for advanced signal processing (q). The function Γ should be: (i) monotonically increasing in throughput T_D; (ii) monotonically decreasing in λE_b and q. Consequently, the destination node's utility can be determined to be equal to its valuation function:

$$U_D = \Gamma(T_D, \lambda E_b, q) \quad (4)$$

The selection of function Γ will determines the relative preferences given by a user to these three metrics. Given the price λ announced by the BS, and the user's profile parameters, the destination terminal optimizes its utility function, for a set of choices in the following areas: signal processing algorithms for better interference management at the receiver, and QoS specifications in terms of throughput requirements for the connection. The destination node can trade off required throughout for lower payment, or can choose to implement sophisticated signal processing at the receiver (e.g. multiuser detection, diversity, beam forming, etc.) to reduce the interference level with a direct impact in reducing the required transmission power for the base station (for a given SINR requirement).

(ii)A relaying Terminal: Using relaying nodes can be beneficial for reducing the overall energy consumption of the transmission. The operator can reward cooperative behavior of the nodes, by paying a reimbursement price for the energy expended by relaying terminals. The utility of a relaying terminal will depend on the reward gained R, and on the energy expenditure of the terminal E'_b, through the valuation function $\theta(E'_b, c)$.

Definition: *The valuation function $\theta(E'_b, c)$ is the minimal reward price the potential relaying terminal would accept to be paid for its energy expenditure E'_b.*

V.I AUCTION MECHANISM FOR ENERGY SAVINGS:

The network operator can potentially gain additional revenue and save energy by enlisting the support of helper nodes for relaying. Here an auction based mechanism is proposed for selecting a relaying node for a given connection. An auction is a negotiation mechanism or a set of trading rules for exchange of goods between sellers and buyers. Various auctioning mechanisms lead to a variety of properties and outcomes of the bidding process. Some important properties to be specified in an auction are: (i) open versus sealed-bid (bids are known or not); (ii) number of bids allowed (one time bidding versus successivebidding), (iii) winning rules and (iv) payment (e.g. highest price, second highest price, etc.). In case of dynamic resource allocation problems, time bidding with sealed-bids reduces drastically the amount of information needed for bidding, and hence reduces overhead and resource allocation delays. For these kind of applications, the Vickrey auction is an appealing choice, as it has been shown to have desirable properties such as a dominant equilibrium strategy for the bidders to bid their true valuation of the goods. In a Vickrey auction, the highest bid wins, but pays the second-highest price. For our relaying allocation problem, we consider a more complex two-dimensional bidding, in which bidders specify the estimated energy gains they provide for the base station, and their monetary reward requests. As such, a bidder i will specify its bid as

$$s_i = (\Delta\hat{E}_b(i), R(i)) \quad (5)$$

The base station receives all the bids from all users and computes its utility gain from selecting node j as

$$\Delta U_{BS}(j) = \Delta\hat{E}_b(j)\varepsilon - R(j) \quad (6)$$

The base station considers for final selection only those bids for which its utility gain (6) is positive. The base station's utility gain is maximized by selecting an auction winner node j^*, such that

$$j^* = \arg\max_j \Delta U_{BS}(j) \Big|_{\Delta U_{BS}(j)>0} = \arg\max_j \Delta U_{BS}(j)\{\Delta\hat{E}_b(j)\varepsilon - R(j)\} \Big|_{\Delta U_{BS}(j)>0} \quad (7)$$

As we have mentioned previously, a Vickrey auction implementation is preferable, due of its desirable equilibrium property: all users have a weakly dominant strategy of bidding their own valuation of the resources. For the Vickrey auction implementation, the equilibrium strategy for an arbitrary bidder j is to select its reward $R(j)$ to

$$R(j) = \theta(j) \quad (8)$$

ISSN: 2278-0181
Vol. 2 Issue 10, October - 2013

We can see that depending on the difference between the first and second utility gains for the base station and first and second highest price requests, the base station may end up with a lower than second highest utility gain. We are considering two possible cases for Node j:

a) Node *j* loses the auction so that $U_R(j) = 0$, which implies that the lower bid does not change the outcome of the auction, and hence node *j* does not have an incentive to underbid its true valuation of resources.

b) Node *j* wins the auction. If the action of underbidding changed the outcome of the auction, then the payment:

$R(j) = \theta(j) - y + x'$, where x' is the difference between node *j*'s utility gain and the next highest one. If node *j* would have bid its true valuation, then the difference in the utility gain for the If node *j*'s action changed the outcome of the auction in its favor (i.e., node *j* wins) by underbidding, then node *j* gets as a reward $R(j) = \theta(j) - y + x'$, where x' can be determined as $x' = \Delta E_b(j)\varepsilon — R(j) + y – \Delta E_b(k)\varepsilon — R(k) = y — x$, with $x = \Delta E_b(k)\varepsilon — R(k) — (\Delta E_b(j)\varepsilon - R(j)) > 0$. Then the actual reward for node *j* can be determined to be $R(j) = \theta(j) - y + y - x < \theta(j) \Rightarrow U_R(j) < 0$ .Similarly, if underbidding wins the auction, but bidding true valuation would also have won, the node utility is $U_R(j) = x'$-y,with $x' = \Delta E_b(j)\varepsilon - R(j) + y - \Delta E_b(k)\varepsilon - R(k) = y + x$, which implies $U_R(j) = x$, which does not increase with underbidding and thus node *j* does not have an incentive to underbid its true valuation of resources

V.II RESULTS OF ENERGY SAVINGS

The above proposed auctioning mechanisms ensure that both BS operators and terminals experience utility gains, we need to show under what conditions these individual utility gains result in real overall energy savings and are not merely a shift of energy consumption from the base station to the mobiles. Assume that the true valuation of an arbitrary mobile node *j* for its energy expenditure can be captured by a price per unit energy parameter $\mu(j)$, such that $\theta(j) = E_b'(j)\mu(j)$. In order to achieve overall energy savings, when a node *j* wins the auction, we need to satisfy the following condition:

$$\Delta E_b(j) - E'_b(j) > 0 \qquad (9)$$

If node *j* wins the auction then the base station has a positive gain in utility:

$$\Delta U_b = \Delta E_b(j)\varepsilon - E'_b(j)\mu(j) - x > 0 \Rightarrow$$

$$\Delta E_b(j) - E'_b(j)\mu(j)/\varepsilon — x/\varepsilon > 0 \Rightarrow \qquad \text{where } x/\varepsilon > 0$$

$$\Delta E_b(j) - E'_b(j)\mu(j)/\varepsilon > 0$$

If $\mu(j)/\varepsilon > 1$, or equivalently, $\mu(j) > \varepsilon$, the above inequality guarantees effective green energy savings. Thus, for a given cost per unit energy resource, *c*, we require

$$\mu(j) > \delta = \max\{c, \lambda - c\} \qquad (10)$$

We can define δ to be the reserve price for the relaying terminals, such that no resource is sold under this reserve price. The reserve price δ ensures true net energy savings for the system.

VI. CONCLUSIONS.

This paper is based on LTE systems, it gives its in-depth knowledge of LTE systems, its features, concepts and its architecture. It also addresses about the energy efficiency of LTE systems, nowadays, a major concern for network operators is not only to reduce the operational costs, but also to reduce their environmental effects. Since BSs represent a major chunk of energy consumed in a cellular network so improvements in power amplifier technology that can be used to bring energy savings in BSs is explained. Improvements in the power amplifier will not only decrease the power consumption of the hardware system, but will also make the BS less dependent on air-conditioning. In this paper an overview of Long term Evolution Systems is given, detail description of its features, its advantages and its components is given and finally its protocol architecture is discussed. Next, energy-aware cooperative BS power management is discussed where certain BSs can be turned off depending on the load. A recent concept called "Cell zooming" appears to be a promising solution in this regard. Heterogeneous network deployment based on smaller cells such as micro, pico and femtocells is another significant technique that can possibly reduce the power consumption of a cellular network. Then two emerging technologies such as cognitive radio and cooperative relaying which are useful for obtaining "green" network communication is given. Further auction mechanism that ensures overall effective energy savings for the cellular systems by combining signal processing, with energy efficient resource management, relaying, and pricing is proposed. In this paper we assume that each link requires a certain BER (bit error rate) performance (which, in conjunction with error correcting codes, is directly linked to the probability of correct packet reception in the utility function definitions). The required BER can be mapped into an SINR target γ. Hence, for a fixed transmission rate, the energy per bit gains that a mobile terminal can induce at the BS, are given by the power transmission gains due to link quality improvements:

$$\Delta P_t = P_t - P_t^d = \gamma \frac{(c_i^T c_i)\sigma^2 + \sum_{k \neq i} P_k h_{ki} (c_i^T s_k)^2}{h_{Bi} (c_i^T s_i)^2} - P_t^d \quad (11)$$

The energy improvements ΔE_b can be estimated by a potential relaying terminal by assessing ΔP_t, based on initial knowledge of transmitted power required by the BS for the direct connection, P_t^d (broadcast by the BS with the call set-up request at the auction initiation phase), and by estimating the downlink path gain for the new transmission and the current interference level at terminal, together with the impact of possible improvements from signal processing (e.g., multiuser detection mitigating the interference). Thus in all in this paper a holistic strategy for Green Communications in LTE systems is presented discussing various technologies and finally giving an auctioning scheme to enforce energy gains into Long Term Evolution networks. Some issues to develop specific implementations and to analyze and simulate the performance for the pricing scheme in combination with various resource allocations and signal processing algorithms are there which will be covered as a future work. Thus, we conclude that the industry has reached the tipping point for considering energy efficiency and green communications in Next Generation Long Term Evolution Systems.

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