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Energy Efficiency Improvement Through Cognitive Network Cooperation

Warda Ahmed[1] and M. Junaid Arshad[2]

[1,2]Computer Science and Engineering Department, University of Engineering & Technology, Lahore, Pakistan

[1]balochwara@gmail.com, [2]mjunaiduet@gmail.com

***Abstract*– The ever-increasing traffic demands have motivated mobile operators to explore, how they can boost their network capacity with a minimal increase in their capital and operating expenditures. In order to solve this problem, energy-efficient design of 4G/LTE-A system is discussed, especially with a focus on deployment architecture. One of the strategies to solve this problem is the use of already available licensed spectrum without affecting the communication of primary users. As it is proven by Shannon that Energy efficiency is increased by improving the Spectrum efficiency. In our study we focus on improving the spectral efficiency. For this purpose we use the concept of Cognitive Network cooperation. This is the combination of cognitive radio and network cooperation. Cognitive radios are exciting emerging technologies that have the potential of dealing with the demanding requirements and scarcity of the radio spectrum. Cooperative communication and networking is another new communication technology paradigm that allows distributed terminal in a wireless network to collaborate through some distributed transmission or signal processing so as to realize a new form of space diversity to combat the detrimental effects of fading channels. To resolve this issue of spectrum scarcity and power consumption we use cognitive radio which has tremendous capabilities of spectrum sensing and communicating on unlicensed spectrum, with the combination of network cooperation.**

***Index Terms*– 4G-LTE, Energy Efficiency, Cognitive Radio, TV Whitespaces and Spectrum Efficiency**

I. INTRODUCTION

THE growth of telecommunication market especially mobile market has been breathtaking since 2001. During this growth mobile phones are not just limited to receiving or making a call, they are much more than that. They are multimedia empowered, run many different types of applications like music and games etc. They also support web browsing, VoIP and also mail services. At the same time, deployment of 4G mobile services by the providers is progressing overall the world.4G is the marketing term for technologies like LTE, WiMAx & HSPA+. The 4G LTE is standard for high speed data rates up to 1Gbs.

There are many different reasons why mobile operators and mobile device manufacturers are jointly internationally finding out diverse ways to increase their network performance. Main focus of theses operators and manufactures are on overall Energy Efficiency and capacity of entire system. The number of sideline tools operating online has increased drastically so the energy consume by these tools also increased drastically that was never before. The difficulty to increase Energy Efficiency is not only completely on the side of operator, but it is also on the device manufacturer. There is great responsibility on them that, they should be capable of 1 design, and makeup more convincing solutions for the operators, to implement and for the consumers, to purchase [1]. Mobile voice traffic ratio vs. mobile data traffic ratio, step by step, is shifting more towards mobile data. Additionally, the traffic or applications that the users use online is not just usual mail services and static web pages any longer. But it is quickly moving towards the modern dynamic Web 2.0/Web 3.0 and online social video services. That plays a very big role in the consumption of high bandwidth. Increasing the emission of CO2 means that increase in the price of energy.

To reduce CO2 emission more energy is consumed by green energy plants. On the subject of power utilization 70-80 percent power is utilized by the mobile BS or the radio station [2], [3]. As discussed above mobile data traffic demands have been increasing exponentially day by day. To solve these data rates many different strategies are used.

One of the strategies to solve this problem is the use of already available licensed spectrum without affecting the communication of primary users. By doing this spectrum efficiency can be improved and Shannon proved that improving the spectral efficiency, energy efficiency can also be improved [4]. Many different techniques are used for this purpose one of which is to find the spectrum holes (unused spectrum) and then communicate via these spectrum holes e.g., WiFi, Bluetooth and TV stations etc [5]. There are four basic arrangements associated with energy efficiency on wireless networks, specifically deployment-efficiency energy-efficiency, spectrum efficiency energy-efficiency, bandwidth-power, and delay-power. Our research will focus on spectrum-efficiency energy-efficiency. Our main focus will be on the use these unused spectral bands (e.g., TV) bands to improve the spectral efficiency. In this way devices first find

the unused spectral bands with the help of cognitive radio then network cooperation is done for communication. Basic Architecture of LTE-A network is shown in Fig. 1.

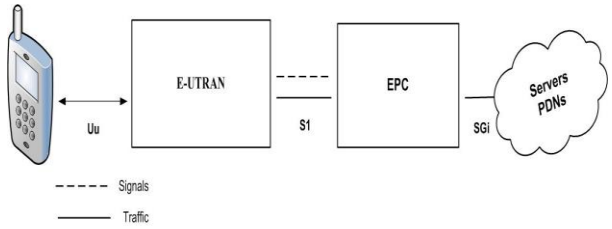

Fig. 1. Basic Architecture of LTE-A network

We implement cognitive radio in LTE Base station and TV station to the core network. We assume that our downlink transmission is done by using TV whitespace. Cognitive radio is implemented to exploit new spectrum band that is note used by the primary user. We also use spectrum broker between the core network and TV Station. Spectrum broker is basically set of rules that are implemented on request sent by cognitive radio to use specific spectrum. Spectrum broker contains spectrum database. We are proposing our method for Pakistan. So the spectrum database is maintained by Frequency allocation board (FAB) of Pakistan.

There are fundamentally two approaches to enhance the energy proficiency in a mobile network.

- The initial one is to diminish the power utilization of base station(BS) by utilizing more power-proficient equipment, advanced software to adjust power utilization to the traffic situation and in addition to adjust between energy utilization and performance.
- The second strategy is the utilization of intelligent network distribution strategies.

II. LITERATURE SURVEY

One of the techniques that are used for energy efficiency is device centric architecture. Under this architecture of base stations are studied. Reducing the power consumption at base stations (BSs) that account for heavy energy usage e.g., about 60-80% of the total energy consumption in cellular networks. This is done by switching-on/off based dynamic BS operation for potential energy saving, which allows the system to entirely turn off some underutilized BSs during low traffic periods. It can be easily seen that the traffic profile of the night time is much lower than that of the daytime. It is also observed that there is a slight difference between the traffic profiles of ordinary weekdays and weekend/holiday. Since the operators need to deploy their BSs to support the peak time traffic, it is inevitable that the BSs are under-utilized most of other times, especially, at night and on weekends. Note, however, that BSs consume most of their peak power consumption even when they are in little and no activity. This explains why potential energy savings can be achieved by dynamically switching on/off BS [6].

Another research says that not just energy efficient network lead us to green communication but spectrum efficiency also plays very important rule. For this purpose a technique called millimeter wave frequency (mm-Wave) was introduced. Mmwave provide large untapped spectrum bands through which data rate of gigabit transmission should be possible. Unlike traditional cellular system, millimeter wave transmission do not benefit from diffraction and depression making it difficult to propagate through obstacles thus resulting in higher shadowing loss. They also have less favorable link budget due to low power amplifier (PA) output powers and greater path loss at these higher frequencies. One advantage of millimeter wave, however, is that the smaller wavelengths allow for the fabrication of antenna arrays having a much higher number of antenna elements in a much smaller area than is typical at microwave bands. It is shown in this paper that Mmwave B-4G small cell technology can provide peak and cell edge rates greater than 10 Gbps and 100 Mbps respectively with latency less than 1msec for local area network [7].

I-Hong Hou and Chung Shue Chen proposed a distributed protocol for self organizing LTE systems that considers both spectrum efficiency and energy efficiency. This protocol jointly optimizes several important components, including resource block scheduling, power allocation, client association, and the decisions of being in active or sleep mode. The protocol requires small computational and communicational overheads. Further simulation results show that that the proposed protocol achieves much better performance than the existing policy [8].

Another researcher shows that the use of coordinated multi point (CoMP) is an efficient technique for increasing the energy efficiency of entire network. Coordinated Multi-Point (CoMP) is a technique, in which neighboring BSs cooperate to transmit (or receive) the same information to some individual users. This technique is currently proposed in 3GPP-LTE Rel. 11, and it is especially beneficial to users located at the cell edge. Research shows that the use of CoMP with sleep mode technique and cell zooming help to reduce the energy consumption mainly in sleep mode and cell zooming. Also this paper tells the behavior of CoMP together with both solutions, and researcher show that it helps to maintain the network quality when sleep mode or cell zooming are applied, and is thus an important contribution in the implementation of green wireless networks [9].

Another technique was purposed known as ICIC technique to mitigate the ICI and to improve UEs throughput without largely reducing spectral efficiency. In this article, traditional ICIC techniques were described. System-level simulations are made under uniform and non-uniform UE distributions. They allow researchers to study the performance of each technique for deferent type of parameters like spectral efficiency, energy efficiency, and mean throughput per zone, throughput fairness index, and UE satisfaction. They also show that a non cooperative ICIC scheme that improves SFR performance without the need to exchange additional signaling messages between the different cells. Further they discuss a distributed cooperative ICIC scheme that adjusts resource and power allocation between the different cells in a collaborative manner. This technique makes use of the signaling messages exchanged between the adjacent cells over X2 interface [10].

Among the LTE-A communication techniques, Device-to-Device (D2D) communication which is defined to directly route data traffic between spatially closely located mobile user equipments (UEs), holds great promise in improving energy efficiency, throughput, delay, as well as spectrum efficiency. As a combination of ad-hoc and centralized communication mechanisms, D2D communication enables researchers to merge together the long-term development achievements in previously disjoint domains of ad-hoc networking and centralized networking [11].

Recently researchers show that combination of cognitive radio and network cooperation plays very important rule in energy efficiency of cellular networks. This is termed as cognitive network cooperation. In the proposed framework, cellular devices are first allowed to identify spectrum holes through spectrum sensing. Then, network cooperation is invoked for efficiently exploiting the available spectrum holes for green communications [12].

III. PROPOSED SYSTEM

Tremendous increase of mobile user in Pakistan leads us to spectrum scarcity. In Pakistan spectrum scarcity problem can be easily resolved because in here large bandwidth of 52-856 MHz is unoccupied most of the time. These bands are allocated to TV channels. In which most of the band is unoccupied like 800MHz band .These unoccupied bands are known as TV white spaces. Detailed study has done in Department of Electrical Engineering, COMSATS Institute of Information Technology Islamabad to find TV white spaces in Pakistan. After detailed experiment results they find out that Pakistan is gifted with large unoccupied band. And by the use of Cognitive radio spectrum scarcity is reduced [13].

In continuation of above research, we proposed an architecture in which these unoccupied TV white spaces are used. This is done by the use of cognitive radio. Detail research is done on the cognitive radio. In which we see that how they can be used? What are their working principles? What type of protocols they use? Cognitive radio is a term used for intelligent radios. They are adaptive to the nature which means they learn from the nature. They detect the unoccupied frequency bands and automatically shift the transmission to these bands by adjusting the protocols. Detection of these frequency bands is done by using different methods. Also Detail overview of LTE network is given. To show that how it can be used in TV white spaces, detail definition of TV white spaces is given what they are and how they can be found. The main scope of research is to use TV white spaces in terms of energy efficiency of cellular network.

To implement cellular network that utilize TV white spaces require four things

- TV white spaces are utilized same as already working in other countries. Like FCC in US approve the request of utilizing TV white spaces. Similarly spectrum management regulatory authority gives permission to the use of these TV spectrums. In Pakistan this permission is granted by FAB (Frequency Allocation Board).
- Access to database: Spectrum and database of each country is different from other country. So a database is maintained by the specific country through which device register itself and gain permission to communicate through that spectrum band.
- A data model is required in which content of the query and response to that specific query is described. This data model contains information about geolocation data base, access technology etc. This Data model is dependent to spectrum regulatory authority.
- A protocol is required to gain access to data base. This protocol is used by white space devices to gain access to data base that allow them to use white space spectrum.

In our proposed architecture the difference is TV band devices with cognitive radio capabilities communicate by using Spectrum broker which is connected to database maintained by Frequency Allocation Board of Pakistan and they also communicate in cooperative manner by using TV station for its downlink transmission. We show that by using this way spectrum scarcity is reduce and in return Energy Efficiency is improved because acceding to Shannon capacity formula:

$$C = B\,log_2(1 + |h|^2 S/N) \qquad (1)$$

According to this formula when bandwidth increases capacity also increase and with the increase in capacity power used by the transmitter to deal with traffic overloading is reduced. And Energy Efficiency of the system is increased. We are using TDD multiplexing technique for downlink transmission and for uplink OFDM is used. We are using the method of cognitive network cooperation. And by using this communicate through TV station in the same way we communicate through Bluetooth or wifi.TV station is one dimensional transmission so we are using TDD for downlink .As downlink traffic rate is high than uplink traffic.

A) Network Architecture

LTE network have flat architecture in which Base station known as eNodeB communicate with user equipment. It is responsible for all radio communication. It is connected to serving gate way through S1-u interface mean S1 interface in user plan. And it is connected to mobility management gateway with S1-c interface means S1 interface in control plan. Multiple S/GW and MME make the core of LTE network. eNodeBs communicate with each other with X2 interface. Core network is connected to cloud data centre which is further connected to spectrum broker. TV station is also connected to this cloud data centre which is also said to be backhaul network of LTE. TV station and BS are connected to the backbone network with wired and wireless connection

Base station known as eNodeB is the basic component in cellular network. It consists of tower on which three antennas are mounted in triangular direction. In which two are used for receiving and other one for sending information. These antennas vary according to the base station provider company. The equipment associated with antennas is located in the container below at the base of the tower. Beside this cellular

system have many other elements that are use to make the network and then establish connection to PSTN system to make calls on wireless or wired phones. Different types of cellular networks have different types of network architecture. But basic mechanism is same in all of them. Like, we are dealing with LTE network, so our cellular architecture is same as LTE. LTE has well defined architecture. By this they provide ease to product manufacturers that they can standardize them.

B) Cellular Architecture

Cellular network consist of User terminal which is basically mobile phone equipment. An antenna known as Base Transceiver station (BTS) is installed on the top of the tower use to send and receive radio signals. This antenna is connected to Base Station Controller (BSC) and Mobile switching centre (MSC) which routes to the location register and then link to the PSTN. Antenna, which is known as BTS in cellular networking, is one unit that makes direct interaction with the mobile equipment by sending radio signals to the mobile equipment. It means that BTS directly communicate with mobile terminal. It act as small centre and provide route to the calls for specific base station which is best suited for that call. BTS is link to BSC through microwave links. Base Transceiver System consists of number of elements.

The first element is the electronics section enclosed in the container located at the base of tower. It contains a lot of electronic circuits like radio frequency amplifiers, frequency combiner, radio transceivers, control communication links and electric supply. Second element of BTS is antenna along with its feeder which is use to connect antenna with BTS. Antennas are mounted on tall towers and buildings. So, they cover more area. BTS communicate with BSC through MSC is the brain of the cellular system which coordinates with BSCs provide controls and act like switch to make connection with public telephone network. MSC is connected to BSC which is connected with different types of links like fiber optics, copper wire and sometimes microwave links. It contains many important things like home location and visitor location registers along with last known position of user equipment [14].

C) Base Station

In our methodology Cognitive radio base station is installed .During busy hours cognitive radio base station (eNodeB) sense the spectrum holes which lies between 700-800 MHz in Pakistan. And shift some traffic to these bands. These spectrum bands are detected by using dynamic spectrum access. Cognitive radio use different techniques to detect these bands. Here we are using energy detection technique; this is very simple and affective cognitive radio technique for detecting these bands. In this band cognitive radio continuously monitor the band and when there is no primary user detected they assign these bands to secondary users. It is also communicating with database to ensure that this spectrum is free at that time. This is known as cognitive capability of the network. Another thing in cognitive network is cooperation. In which data and information is send using other standard like WiFi, WiMax etc. In our proposed methodology our main purpose is to achieve higher Energy Efficiency. For this purpose we involve TV Station in our cellular network. TV station is also connected to backhaul network as cellular base station (eNodeB). During peak hours when traffic is very high some information is shifted to TV Station to provide services to the mobile users by doing these new bands are being utilized. Cognitive radio antenna senses the spectrum using Dynamic spectrum access mechanism.

LTE-A is itself self organizing network. It means that, LTE A network adapts the protocols of other networks (WiFi, Bluetooth) and communicate through these networks. So LTE A network is also adaptable to use TV whitespaces. For this purpose some kind of antenna is required that is capable of dynamic spectrum access and Cognitive radio is that kind of thing. It senses the environment set protocols according to environment then send data or information on that spectrum.

Cognitive radio network can be implemented in different type's networks architecture i.e. ad hoc or Infrastructure. In ad hoc architecture there is no central device for decision making. Device to device communication is an example of ad hoc architecture. In infrastructure mode some kind of central device is used that makes the decision and then routs the traffic. In our methodology we are using infrastructure mode .In this mode traffic first goes to base station which is connected to spectrum broker with backhaul network, which decides that spectrum is available for communication or not, then further send to user equipment.

When LTE A network is implemented in TV white Spaces LTE A user equipment and eNodeB act as white space devices. There are two types of white space devices Mode I and Mode II devices. Mode I devices are those devices that do not have geo location capability. Mode II devices are those devices that have geo location capability. Mode I device are dependent on Mode II devices for communication because Mode II devices provide them list of available spectrum. But in Pakistan we do not have geo location database so we detect the spectrum using energy detection technique of cognitive radio. Then send request to the spectrum broker to implement the spectrum rules in this band and send us acknowledgment to communicate on this band.

TV white spaces are dynamic in nature so white spaces devices (i.e., UEs and eNodeBs) must aware of availability of these bands. To meet this dynamic allocation of channel LTE A provides a mechanism know as carrier aggregation. In carrier aggregation affected band is expanded, that is, delivered to the user by utilizing multiples carries on concurrent radio resources.

It is well known fact that when traffic is high and band width is low more power is consumed by the base station. By using cognitive radio techniques new bands are sensed to increase the bandwidth of spectrum .So that extra traffic is shifted to that band. And the extra power consume by the base station is low.

D) Backhaul Network

In our architecture after base station backhaul network comes. Now what is back haul network? There is still contradiction in the definition of backhaul network. We said

backhaul network as a cloud backbone of the cellular system. In LTE it is Evolve Packet Core network. It contains the entire data related to user and network. User data means user Ids through which user communicate with network and network setup call and other services for the users. Network related data mean what type of network it is? What services are provided by network? It also has information about modulation techniques and the frequency bands used by the system. Architecture of Cognitive radio enodeB is shown in the Fig. 2.

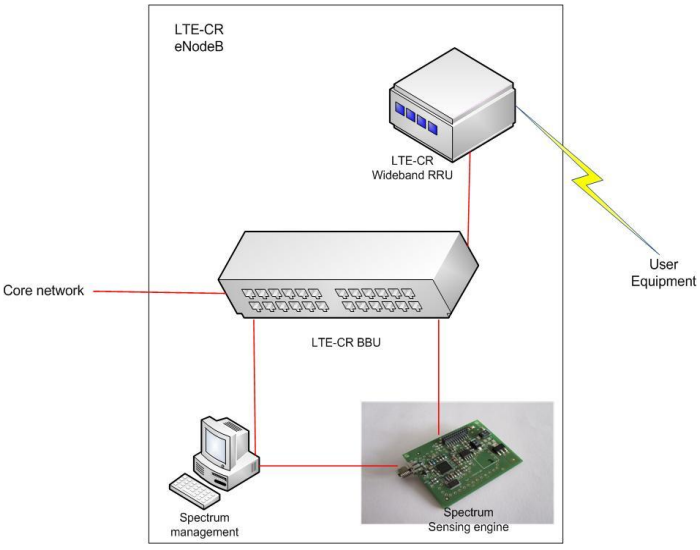

Fig. 2. Architecture of Cognitive Radio enodeB

E) Spectrum Broker

Spectrum broker lie between Back haul network and TV Station. Spectrum broker is basically set of rules .These rules are define by FCC or any company that provides spectrum for different types of communication. In Pakistan these rules are set by FAB (frequency allocation board) of Pakistan. Spectrum broker is connected to Database most of the time. Database provides information about spectrum under space, time and frequency. Spectrum broker is updated once in a day.

F) TV Station

TV station is like base station of mobile network. This station operates on 65 to 800MHz. It used for sending TV information or signals to the user. In our proposed method TV station is used for sending mobile information and serving mobile users. To improve energy efficiency of the system, it connected to the Backhaul network. And between TV station and Backhaul network spectrum broker is present which implement the spectrum rules defined by spectrum providing organization. TV station provides one way communication.

G) Cognitive Radio Mobile Equipment

Cognitive radio mobile station is user equipment with cognitive radio antenna like other antennas of WiFi and Bluetooth to communicate with these technologies. Similarly to communication via TV bands user terminal have cognitive radio antenna to receive those signals send on TV bands. As according to IEEE 802.22 LTE-A transmission is allowed to use TV whitespaces.

H) Working of Proposed System

Working of proposed architecture is given as: First of all eNodeB with cognitive radio detects the spectrum hole and send this information to EPC. EPC send this request to spectrum broker. Spectrum broker apply spectrum rules on it. It also calculate the transmit power of eNodeB. If band is free for transmission acknowledgment is send to EPC and EPC send this information back eNodeB. After the acknowledgment is received eNodeB send data on this spectrum band. This scenario is depicted in Fig. 3.

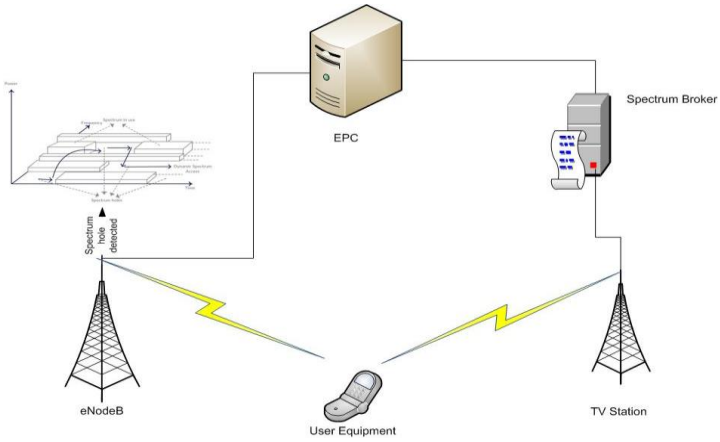

Fig. 3. Working of Proposed Architecture

User equipment with TV station receiving antenna detects the transmission and start receiving it. In it transmitting power of base station becomes half. BS and TVS are simultaneously communicating with the user equipment.

An algorithm is implemented on cognitive radio base station and also on cognitive radio UE which tells them about the spectrum is empty or not. In our proposed method spectrum is sensed by energy detection technique and then this information is sent to the spectrum broker it contains data base of spectrum maintained by Frequency allocation Board of Pakistan. If this spectrum is under the rules to utilize this spectrum than Cognitive radio eNodeB send data on this link. On the user side cognitive radio accept this data through TV station. In this cognition is done by cognitive radio and then eNodeB cooperatively communicate with User Equipment. Downlink link data is sent on TV white space through TV station and uplink is done with BS station. Transmission through TV station is done by using Alamouti space time coding. Alamouti space time coding is a technique used in communication to send different copies of same data through different antennas. It is a very complex coding technique.

IV. SIMULATION AND RESULTS

To validate that our proposed architecture is Energy Efficient, We use SEAMCAT 4.1.0. It is the abbreviation of Spectrum engineering advance Monte-Carlo Analysis tool. It is statistical simulation tool based on Monte Carlo Method. It takes some initial parameters like antenna height, propagation model, frequency on which two links are communicating. One of the links is victim link and other is interfering link. By using the parameters provided it simulate and provide the results in the form of snapshots. It shows dRSS means desired signal intensity and iRSS (Interfering signal intensity). It is shown in the Fig. 4 and Fig. 5.

We find different results by inputting different values of power of sending signal. Than calculate the signal to noise ratio of simulated parameters by using formula:

$$C/I = dSRR/iSRR = SINR \qquad (2)$$

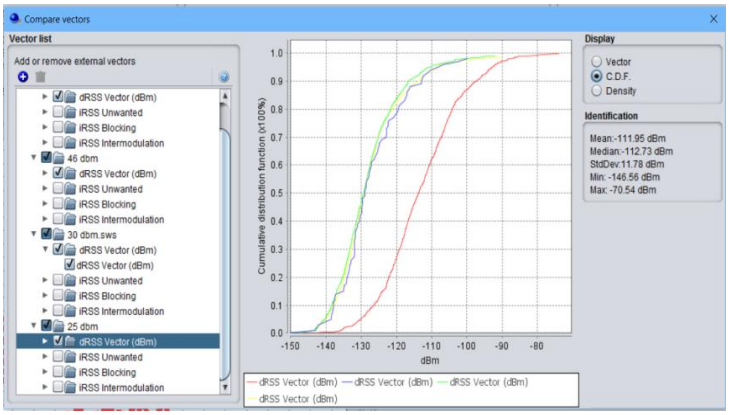

Fig. 4. Desired Signal Intensity

According to this formula we find the SINR of system in dBm. Bit rate loss is less if this value is less than the threshold value of SINR. And system is energy efficient. dSRR and iRSS is shown in Fig. 4 and Fig. 5.

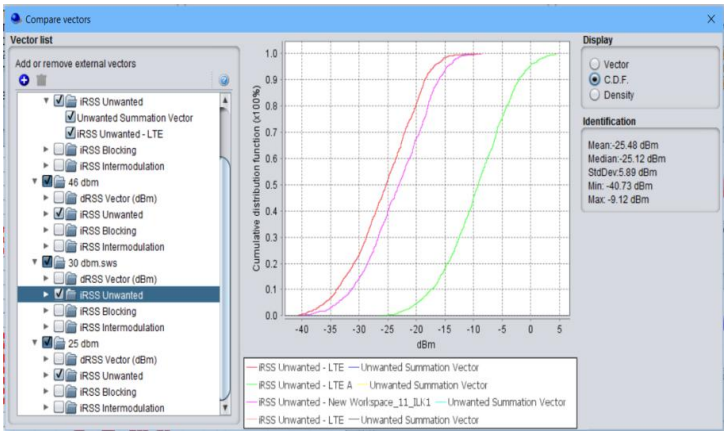

Fig. 5. Interfering Signal Intensity

Parameters used by us to simulate are shown in Table I. Relationship between transmit power and SINR is shown in Fig. 6.

Table I: Simulation Parameters

Transmit power of BS(dBm)	C/I> -80 dBm	Victim link coverage radius	Interfering link Coverage radius (km)	Frequency (MHz)
46	-5.568	10	10	800
30	-5.140	10	10	800
25	12.226	10	10	800

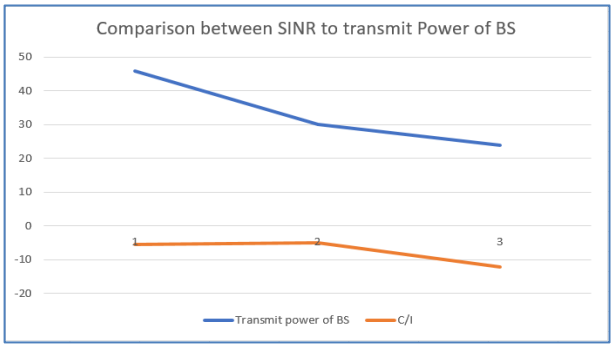

Fig. 6. Relationship between transmit power and SINR

V. CONCLUSION

In this work, we study energy efficiency in cellular networks especially in LTE networks. We study different energy efficiency techniques which are proposed to reduce the power consumption in cellular networks. We took a detail literature survey on techniques that are used to improve the energy efficiency of cellular networks. While doing this survey we see that cognitive radio is an emerging technology used help in the reduction of energy consumption. This led us to the use of TV whit spaces. These are unused TV spectrum. We follow the idea of Shannon that when spectrum efficiency is improved, energy efficiency is also improved. So in this work our main focus is on spectrum efficiency. For this purpose we use Cognitive radio to find the spectrum bands that are unused. We propose our method for Pakistan. For this purpose, first we took a detailed survey of spectrum used by Pakistan and number of mobile phone operators in Pakistan. While doing this we see that there is a huge amount of spectrum bands i.e., from 700-800 MHz are free. Mean that, they become unoccupied most of the time. So we utilize these bands by using cognitive radio. At the end simulation results show two things. First one is that, LTE-A efficiently communicate on 800MHz .Secondly on different power scenario, bit rate loss is less, which shows that efficient transmission will be done at low power.

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