A Survey on Green 5G Cellular Networks

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***Abstract*—In this article, we present a brief survey on green 5G cellular networks, and explore some research issues and challenges of the enabling techniques for green broadband wireless networks. The trend of achieving green power in cellular networks is driving network operators and standardization authorities to work together to reduce carbon footprint of their products in order to bring eco friendly 5G green radio cellular base stations. We will first provide an overview on 5G wireless system architecture and the corresponding new protocol stacks. Next, hybrid multiple access schemes, such as combining orthogonal (OFDMA) and non- orthogonal (CDMA) approaches, aiming at improving the both capacity and coverage performances simultaneously are discussed. Since base stations consume the maximum portion of the total energy in current cellular systems, we explore important renewable energy techniques for green base stations, We will provide a comprehensive survey on how to generate renewable energy, such as solar, wind and fuel cells, for green base stations in 5G green cellular networks.**

***Index Terms*—Open wireless architecture, Hybrid multiple access scheme, Solar and wind power cellular base stations, Fuel cell.**

I. Introduction

The Fifth Generation (5G) system is on its way to revolutionize the current generation by which consumer's access networks through smart phones. The typical 5G concept is on track to be raised somewhere around 2013-2015. However, users will go through a level of call volume and data transmission with 5G pushed over VOIP-enabled devices and other mobile applications. With increasing knowledge and awareness of technology, it is essential for the mobile manufactures to provide services for maintaining customer loyalty, and to develop the best and latest technology. We have seen a number of innovative phones from various leading smart phone manufactures with superior functionality like Apple iPhones , Samsung and HTC newest line of smart phones, for example, have enjoyed a surge in market share recently.

As wireless technologies evolved, networks became more sophisticated. Deployment became denser, and the anytime, anywhere goal had almost been achieved. However, usage of landlines and GSM-enabled phones was minimized as a result of smart phones which keep us connected to the world at any rate, anytime, anywhere, and always affordable. Every passing day from 1G to 3G and from 4G to the 5G, the world of telecommunications has seen a number of value added improvements along with enhanced performance. Wireless network subscription and network traffic is escalated enormously due to unpredictable demand, expansion of service areas and increased popularity of mobile communications growth. Developing the new technologies provides uninterrupted access to services such as voice and data, Multimedia Message Service (MMS), video chat, Mobile TV, HDTV content, Digital Video Broadcasting (DVB) and entertainment gadgets, which opens the gate that creates a new dimension to our lives and changes our lifestyle significantly.Meanwhile, the past few decades has experienced a great leap in the telecommunication industry with over 5 billion people owning mobile phones for their private and professional lives. Wireless World Research Forum (WWRF) has predicted that 7 trillion wireless devices will serve metropolitan and rural outdoor networks for over 7 billion people 24/7 by 2017 and 80-95 percent will be mobile broadband subscribers [1]. Among this 7 billion people, the majority of them will be served by High Speed Packet Access (HSPA) and LTE-Advanced (Long Term Evolution) networks. According to the statistics report, the demand for urban networks alone will increase to 1000 times more capacity by 2020. Surprisingly we are about to enter the era of Tera-Age with trillions of ICT devices, terabytes of memory storage and more computational power. These new technologies have to provide a degree of freedom in the user domain, have to bring transmitters closer to the users, and have to select the right users. These are the three critical research areas in the 5G field.

Climate change is one of the most compelling global challenges of our time. There has been a considerable increase in the average temperature of the earth in the past century. This rise in temperature is attributed to the effects of global warming brought about by the accumulation of greenhouse gases (GHG) in the atmosphere. The reason for increased GHG, mainly Carbon Dioxide (CO2), is because of the increased energy consumption which results in emission of pollutants. Natural calamities like typhoons, floods and changes in the sea levels are attributed to the CO2 fuelled greenhouse effect. It is estimated that during the last 30 years the CO2 emissions have gone up by 73 %. India is ranked 5th amongst the countries in the list of global GHG emission, with USA and China contributing about 4 times emission than that of India. The accumulation of greenhouse gas (GHG) in the atmosphere is growing faster than originally predicted.Scientistic,economists and policy makers are calling for emissions targets of at least 20 % below 1990 levels in 2020 [2]. The information and

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communications technology (ICT) industry alone accounts for about 2 % or 860 million tons of the world's greenhouse gas emissions. It is our responsibility and also first priority to minimize the GHG emissions from the information and communication technology (ICT) industries. The telecommunications industry has taken a bold position in reducing its CO2 emissions, primarily by reducing the energy consumption and replacing old with new green cellular infrastructure. The main objective of 5G networks are to motivate and create a common platform for both mobile network operators (MNO) and mobile handset manufacturers to work together to minimize the environmental footprint of their products by 40 % and 50 %, respectively. The grand features of 5G overcomes 4G in terms of maximum throughput, lower outage probability, higher bit rates in large portions of coverage area, no traffic fees due to low deployment cost, higher system level spectral efficiency and also eco-friendly" handset and network models kick-starting the concept of eco-friendly green radio cellular base station infrastructure using possible renewable energy resources.

In the future, the major challenges will be cost effective operation, spectrum sharing, infrastructure sharing, supporting all radio technologies in a common platform and creating a platform for renewable energy infrastructure to make our world greener.

This paper initially gives a detailed statistical analysis that will lead to the roadmap of recent research and developments in 5G cellular networks. The rest of the paper is organized as follows: section II is an overview of 5G system architecture, Section III covers the radio technology aspect of 5G issues, Section IV analyses renewable energy resources the future issues and challenges in cellular base stations, and section V provides a conclusion.

II. OVERVIEW OF 5G SYSTEM ARCHITECTURE

Fourth generation (4G) and 5G are two potential candidates for the next generation of wireless communication, and they are distinguished by service-centric and user-centric qualities. 4G adopts open wireless architecture (OWA) for its mobile terminals with higher performance, enhanced bandwidth, high data rates, interoperability, fully converged service, user friendly interface, scalability, crisis-management application and low system complexity. Key concepts of 5G beyond 4G are Pervasive networks, Group cooperative relays, cognitive radio technology, Dynamic Adhoc Wireless Networks (DAWN), Vendermonde-subspace frequency division multiplexing (VFDM), Hybrid multiple access scheme with new reuse partitioning, High-altitude stratospheric platform (HAPS) systems, Wearable devices with AI capabilities and IPv6.

To overcome the 4G, 5G was initially proposed by Toni Janevski [4] and it has become a reality. As per the present status all over the world, wireless manufactures are rapidly transforming from a closed wireless system architecture to more flexible, robust, cost effective open architecture systems. International Data Corporation (IDC) has predicted that smart

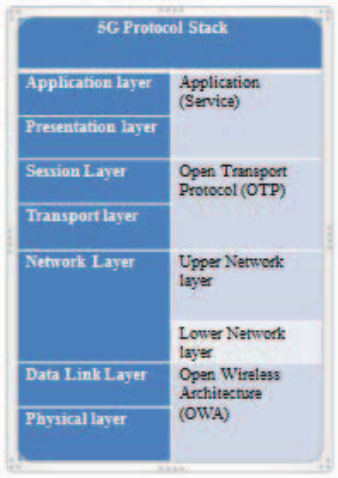

Fig. 1. 5G protocol stack [4].

phone shipments will grow from the 494 million in 2011 to 1.16 billion in 2016 including Media Tablets, PCs and Smart Phones [3]. This transition provides a roadmap and healthy challenges for next generation mobile hand held devices from a traditional transmission-specific radio terminal to an interface-based open wireless architecture (OWA) [5]. The newly deployed OWA virtualizes the operating system and RTT (Radio Transmission Technology), and can easily support the multiple different wireless standards like GSM, EDGE, WCDMA, TD-CDMA, WiFi, LTE/LTE-Advanced, WiMAX 802.16m in single platform. Our target is to converge multiple standards in a single device and single platform. We also need to ensure that at all times the system architecture remains open otherwise overall performance will be low in the closed architecture. The Protocol stack for the 5G mobile phone has been modified specially in the network layer and transport layer. This will reflect a healthy performance in future mobile communication.

In this regard, the author proposed that the network layer is sub-divided into two layers, namely upper network layer and lower network layer to provide seamless connection, and to balance the virtual multi-wireless network environment by using fixed IPV6 standard [5].5G protocol stack as shown in the figure Fig.1. In the case of transport layer, higher bit error ratio in the radio interference will cause unpredictable network congestion and will lead to lost segments. The proposed open transport protocol (OTA) layer resolves wirelessly though software the issue of lost segments damage. The Ideal 5G model should accommodate the challenges and accommodate the short falls of the 4G Technology and 4G deployment experiences.

III. RADIO TECHNOLOGY ASPECT OF 5G

In general, the cellular system can be classified into orthogonal and non-orthogonal approaches. First and second generation cellular systems are dominated by orthogonal multiple access approaches. The main advantage of these approaches is the avoidance of intra-cell interference, sensitive to cross

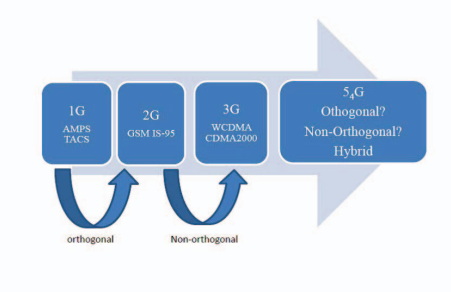

Fig. 2. Technical roadmap for Cellular Generation with respect to Orthogonal and Non-Orthogonal Approaches: A Historical View .

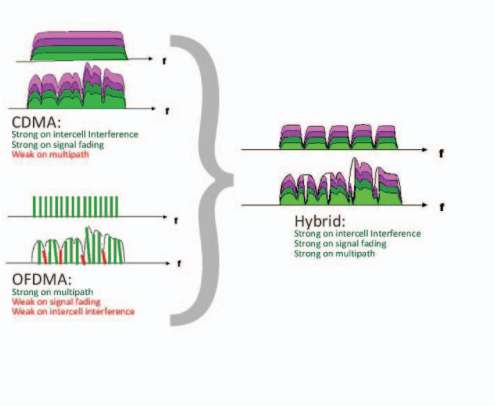

Fig. 3. Hybrid spectrum of CDMA and OFDMA .

cell interference, insensitive with near far effect, free window for synchronization and treatment for ISI using cyclic-prefix method. The Technical roadmap for cellular generation with respect to orthogonal and Non-orthogonal approaches: a historical view is shown in Fig.2. In Orthogonal approaches, signal from different end users are orthogonal to each other and their cross correlation is zero, which can be achieved by FDMA (frequency division multiple access) and OFDMA (orthogonal frequency division multiple access). OFDMA is good for high data rates, but not efficient for inter-cell interference and low transmission power [6].

Non-Orthogonal CDMA scheme has been adopted in second and third generation cellular systems like WCDMA, CDMA2000. In non-orthogonal approaches is sensitive with intra-cell interference, mitigate cross-cell interference, sensitive with near far effect, no need for synchronization. These schemes allow non-zero cross correlation among the signals from different users such as in code division multiple access (CDMA) and IDMA (interleave division multiple access). CDMA is most dominant multiple access technique for present 3G cellular networks. Compared with its orthogonal counterparts, CDMA is good for cancelling inter-cell interference, is robust against fading but not scalable for high data rate transmission in asynchronous transmission environments and also its bandwidth is much larger than the data rate used to suppress the interference.

In the case of hybrid multiple access schemes, proper combinations of (orthogonal and non-orthogonal approaches) CDMA and OFDMA will greatly improve performance. The initial idea proposed by author split the cellular system into two regions, namely inner region and outer region with new reuse partitioning [7]-[8]. The inner region joins with OFDMA and the outer region joins with cyclic-prefix-code division multiple access (CP-CS-CDMA). CP-CS-CDMA provides free to MAI (Multiple Access Interference) without consideration channel CODEC [9]. The concept of cyclic prefix was initially developed in OFDM system. Later on CP-CS-CDMA enjoyed the limelight with its better performance and reduced the system complexity. CP-CS-CDMA can greatly enhance the system performance using partial-band FFT calculations instead of Full-band FFT calculation in the traditional CDMA system [10].

The main feature of CS (comb spectrum) code is that each code group can only occupy a part of all the frequency points. Suppose if one of the CS code group is not present in CP-CS-CDMA system that shows some frequency points are idle and ready to use. The idle frequency point allotted to OFDMA sub carrier to transmit OFDMA signals. Hybrid multiple access scheme works by properly combining CDMA and OFDMA in the same band without interference. Hybrid spectrum of CDMA and OFDMA is shown in Fig.3.

The key reason to keeping OFDMA in the inner region is because of the systems weakness in resisting the co-channel interference. However even if the co-channel interference is too small, we can still achieve a good performance with proper channel coding. On the other hand, the major reason for CP-CS-CDMA system in the outer region to maintain reuse factor 1 by averaging co-channel interference. The purpose of reuse partitioning is to increase system capacity over that can be achieved with a single reuse factor. These is the great time to decide research issue in the radio technology aspect of 5G perspectives is important to determine whether we are going to adopt either orthogonal or non-orthogonal or hybrid scheme because each approaches their own respective advantage and disadvantage to mitigate multiple access interference (MAI), inter-symbol interference (ISI).

IV. GREEN POWERED CELLULAR BASE STATIONS USING RENEWABLE ENERGY RESOURCES OF 5G

Energy consumption and greenhouse gas (GHG) emissions have recently become hot topics of particular interest across the future green mobile telecommunication industry. Green energy is one of the top expense items for mobile network operators (MNO). Fixed line networks and mobile networks operates different power consumption pattern. Concerning the fixed line networks, 70 % of the overall power consumption occurs in the end user segment and only 30 % is due to the OPEX (Operation Expenditure). On the other hand for mobile networks, 90 % of the overall power consumption occurs in the OPEX, a small portion of 10 % overall power consumption towards to mobile user as shown in Fig.6. In this regards, 5G networks will face great challenges to providing electricity

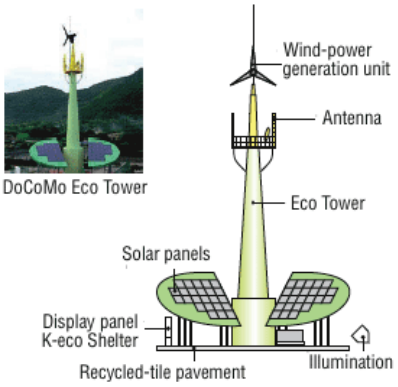

Fig. 4. Solar/Wind-powered cellular base station [11].

to these expanding networks. In developing countries many of the base stations are located in remote locales that have limited access, while some places have no access to use grid power. This situation is moving 5G towards the introduction of renewable sources of energy, such as solar energy, wind energy, fuel-cell.

Most of the electric power supply required to run cellular base stations comes from burning diesel. However, making use of the diesel on a mass level and keeping its reserves flowing for the continuous use and for a time period which has no limit, can be a very challenging task. Besides, the fact that our fuel reserves are depleting at a very fast pace makes the situation all the more worse. The availability and possible combination of renewable energy resources at cellular base station sites is essential in future to deploy the hybrid system. This has resulted in researchers looking out for brand new proposal for green 5G networks to be implemented worldwide.

A. Solar energy / wind energy

The sun delivers 1.2×10^{14} kW energy on the Earth, which is about 10,000 times more than the present energy consumption. The energy that the Earth receives from the sun in just one hour is equal to the total amount of energy consumed by humans in one year. There are many advantages, and some minor disadvantages, to installing solar energy based cellular base stations. Solar energy technologies still remain a costly alternative to the use of readily available fossil fuel technologies.

In July 2004, Japanese leading cell phone operator NTT DoCoMo initially began operating an experimental 32.5 meter FOMA-service, 3G base station called the DoCoMo Eco Tower [11]. In consideration for the global environment, the eco tower does not use commercial power and it is completely self-powered, using solar and wind power at same time, as shown in Fig.4. The solar panels are located at the bottom of the cellular base station plant and are designed to look like tree leaves, while the tower windmill vanes are designed to like flower petals.

With the combination of solar and wind turbine energy saving model, the maximum generated power capability of NTT DoCoMo from solar power is 8.5 kWh and 6.0 kWh from wind power. In 2012, NTT DoCoMo plans to install more robust eco-friendly base stations nationwide that will lead other network operators worldwide to incorporate green communications. The main objective is greening Information Technology to achieve 50 % reduction in CO2 emissions from data centres by 2020. Meanwhile, China Mobile has one of the world's largest deployments of green technologies to power its base stations. China Mobile had 2,135 base station powered by alternative energy in 2008. Of these 1,615 were powered by alternative solar energy, 515 by solar and wind energy and 5 by other alternative sources. According to a study low-carbon telecommunications solutions saved China 48.5 million metric tons of direct carbon dioxide emissions in 2008 and 58.2 million metric tons in 2009 and projected to deliver as much as 615 tons in carbon savings by the year 2020[12].

Typically, a renewable solar energy saving system installation requires a large area for the system to be efficient in providing a source of electricity. This may be a disadvantage in areas where space is limited and expensive. The location of solar panels can also affect performance due to possible obstructions from the surrounding buildings or landscape. Pollution is a major issue because it can degrade the efficiency of photovoltaic cells. Clouds also create the same effect, as they can reduce the energy of the sun rays. There are several parameters that influence the solar energy generation, such as latitude, season, PV panels slope angle, and temperature [13].Solar energy is only useful when the sun is shining. However the use of solar battery chargers can solve problem. During the winter season the backup wind turbines will continuously generate power by using sufficient wind speed in day and night.

Telekom Austria Group has started operations on the first wind turbine-powered mobile phone base station in Eibesthal in Lower Austria. Solar and wind equipment has become more cost effective in the last few years, and renewable energy will be an increasingly attractive option for 5G cellular base station power, in combination with batteries and fuel cells. The solar panels have 20-25 years of lifespan, and the wind turbine requires annual maintenance plus an overhaul every 15 years. Payback periods for mobile network operators will become shorter as more power is produced by wind and solar. Renewable energy will power 4.5 % of the world's mobile stations by 2014. In developing countries the percentage will be more than 8 % by 2014. However, off-grid base stations are primarily located in Africa, South Asia (including rural India), South America, Latin America, and the Caribbean, therefore, solar- and wind-powered cellular base stations are likely to become rather popular due to lack of power grids, as well as insufficient amount of fuel.

B. Fuel cell based energy server

In general renewable sources can be split into two groups namely controlled sources and uncontrolled sources. Controlled sources mean primary energy sources giving possibility to control electrical power production. On the other hand

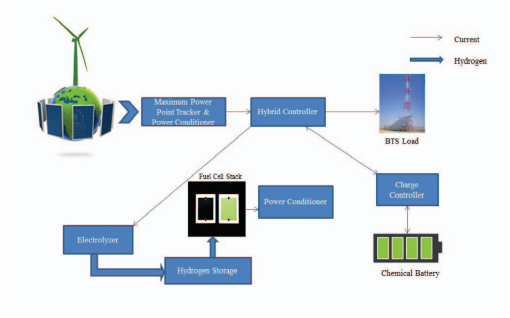

Fig. 5. Future hybrid renewable Base Transceiver Station (BTS) module.

power production of uncontrolled sources is unpredictable and human independent. Solar and wind power plants are uncontrolled sources. Sun and wind do not meet this requirement. So, special kind of power generation should be built to overcome shortages of power to utilize all of the available sun or wind power. These major problems will be overcome by fuel-cell based energy server. Fuel-cell Energy Server is a new class of distributed power generator, producing clean, reliable, affordable electricity at the customer site [14]. The Future hybrid renewable Base Transceiver Station (BTS) module as shown in Fig.5.The modular architecture provides easy and fast deployment, inherent redundancy for fault tolerance, high availability, mobility and practically anywhere. Fuel cells are devices that convert fuel into electricity through a clean electro-chemical process rather than dirty combustion. Energy Server consists of thousands of fuel cells. Each cell is a flat solid ceramic square made from a common sand-like powder.

Fuel cell is capable of producing about 25W enough to power a light bulb for more power, the cells are sandwiched, along with metal interconnect plates into a fuel cell stack. A few stacks, together about the size of a loaf of bread, is enough to power an average home, office building, cellular base station networks, etc. In an Energy Server, multiple stacks are aggregated together into a ”power module”, and then multiple power modules, along with a common fuel input and electrical output are assembled as a complete system and for more power, multiple Energy Server systems can be deployed side by side. World population will increase 10-20 % by 2020. This will make it more and more unsustainable to provide grid power by burning fossil fuels.Electricity plays a vital role in future mobile communications in handling 7 trillion wireless devices and other general systems by 2020. There is no denying the fact that we have to face huge challenges - fossil fuel depletion and CO2 emissions. Recently some countries have slowly begun to stop producing electricity generated from nuclear energy because of the nuclear crisis in Fukushima, Japan in 2011. Similarly, Germany decided to close all its reactors by 2022; Italy has banned its nuclear power plants and many countries are rethinking nuclear energy. It is the right time to shift general systems and information technology into possible or hybrid renewable green (solar, wind, fuel cell) energy.

Today, alternate power solutions are not commonly used in mobile telecommunication systems but will be actively be evaluated in near future 5G networks. The circumstance of each method was studied in detail from various perspectives in order to decide on a feasible combination (solar-wind-fuel-cell) of alternative energy resources. Hybrid energy systems model are the most viable power solutions for 5G mobile base station to overcome conventional diesel generator, also proving the most eco-friendly and cost-effective solutions for many challenging situations.

V. Conclusion

This paper has examined a detailed survey and explanation of future 5G open architecture beyond 4G. The convergence of multiple standards in single device and single platform, hybrid multiple access scheme by properly combing CDMA-OFDMA improves the performance. The new reuse partitioning system of HMA will increase cellular capacity. By 2020, 5G cellular networks will be modified in terms of real green powered base station sites using cost effective and more efficient hybrid renewable energy resources like solar, wind turbine, and fuel-cells systems towards will reduce energy consumption and greenhouse gas (GHG) emissions to provide energy efficient green technologies.

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