Realization of Smart City Using 5G Cognitive Radio

Lalit Chettri[1], Syed Sazad[2]

Department of Electronics and Communication Engineering, Sikkim Manipal Institute of Technology
Majhitar, Rangpo, East Sikkim-737136, India

Abstract: ***The aim of this paper is to advance certain understandings and concepts for adoption in wireless systems to be deployed beyond the year 2020, providing the data rate up to 1GBPS, referred to here as "5G." and same can be used for realization of smart cities. Next generation communication systems are expected to be intelligent in nature, as well as providing a platform for operators to effectively exploit their network resources in an era where spectral resources are at a premium. The smart cities can be designed based on cognitive radio which is meant for spectrum sensing and spatial sensing. It also uses the massive MIMO and the heterogeneous network which uses small cells called Femto/Pigo cell. This paper describes how the 5G wireless communication system can be modeled with the cognitive radio and the MIMO based smart antenna and further it can be used for realizing smart cities. The 5G uses the millimeter wave access technology where the spectrum above 6GHz can be exploited. The cellular architecture is modeled and explained for smart cities, which enables the low power consumption.***

Keywords: Cognitive Radio, MIMO, mm wave access technology, smart city, FD Communication, Multiple Access, Pigo cell, Femto cell, Heterogeneous Networks.

1. Introduction

The evolution towards 5G is considered to be the convergence of internet services with legacy mobile networking standards leading to the commonly used term "mobile internet" over heterogeneous networks (HetNets), with very high connectivity speeds. The objective of cognitive radio (CR) is to sense the spectrum from the real time environment and detect the non utilized spectrum called „WHITESPACE" and these spectrums are allocated to the secondary user verifying the policies. MIMO techniques is most promising technology that offers considerable increase in data bandwidth without any extra transmission power. The three elements required to achieve the projected capacity demand beyond 2020 are increased spectral efficiency, opportunity to use new spectrum bands including those above 6 GHz and increase in spectral reuse through deploying a much increased number of smaller base stations. The main requirements for future access technologies are ultra-low latency. To meet these requirements ultra-densification of networks is required. Availability of spectrum > 6GHz is one of the key requirements for meeting the goals of 5G. This paper discusses in detail the spectrum and propagation characteristics with new measurements at bands > 6GHz In general, mm-wave communication links often require solutions that provide methods to mitigate Line of Sight (LOS) blockage. One means to achieve this is to utilize steerable, directional antenna arrays. In this paper, multiple access schemes of next generation wireless access and backhaul technologies are discussed, RF and hybrid schemes. The handover techniques are discussed which enables machine to machine (M2M) and device to device (D2D) by fulfilling the handover condition. The key challenges related to measurement, testing, and validating the performance of 5G system components are briefly discussed and the fundamental research challenges for resource management in 5G systems are highlighted. The key ideas for each of the technologies are stated, along with the potential impact on 5G requirements so as to realize the smart cities.

2. Block Diagram of 5G Wirelesses Communication Design

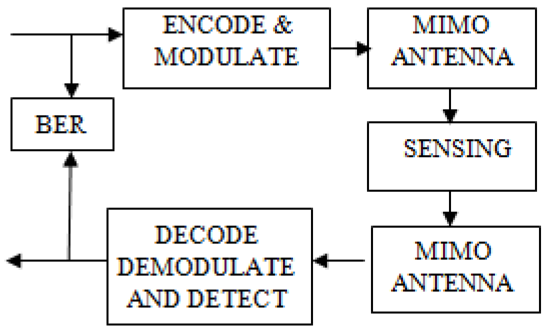

Figure 1: block diagram of 5G communication system

5G system is normal to that of basic communication system but the magic part is that it uses smart antenna with massive *MIMO* and the *sensing*. The key technologies includes MIMO integration to emerging technologies like device to device support, heterogeneous networks, base centric architecture for millimeter wave range for developing future generation 5G standard for wireless cellular. The system modeling design is also illustrated thereby providing a direction for meeting high data and bandwidth needs in future by employing massive MIMO cellular networks. The advance digital signal processing such as channel estimation and interference cancelation are the basic part of this smart antenna. As there are two types of smart antenna technology, switched beam antenna and adaptive beam forming which provides the peaking of the desired user and nulling the interference. Since the switched beam antenna doesn"t give the perfect peaking of the user so both this antenna pattern can be combined to form a hybrid antenna pattern. Sensing is used to detect the user in the spatial domain so as to reduce the interference to the secondary user to the primary user. The beamforming approach detects signals and searches for transmission opportunity in the spatial domain. The spatial domain processing will further reduce the interference caused by SUs to PUs after processing in the spectral domain. The massive MIMO provides the higher channel capacity and the spectral efficiency and low BER. Since it uses the SDMA, so it reduces the delay spread. So overall the 5G communication system is the intelligent technology which provides higher flexibility and efficiency.

2.1 Spectrum Sensing

Generally, Cognitive radio is the intelligent technology which senses the spectrum and location. The main goal of the cognitive radio is to sense the underutilized spectrum by the secondary user. In 5G communication system the devices such as smartphones, which searches the occupied spectrum in the form of base station downlink signals and takes the instruction from the cellular system. Cellular system is quite sophisticated and achieves high spectral efficiency. 5G systems will be based on dynamic spectrum sharing such as detect and avoid (DAA) and the dynamic frequency selection. The secondary user search for the underutilized spectrum which is called „WHITESPACE". Initially the spectrum is sensed and the location and the information are stored at the emitter database. Actually the radio/ modem are operated on the basis of behavior and control block. N6841A is a sensor which is used to detect the whiespace and it is allocated to secondary user with zero interference as primary user has the right to access the spectrum. The simulation is done using the systemvue. The range between the first peak and the last peak of the spectrum is the whitespace, which is vacant and the same can be used by the secondary user without interfering the primary user.

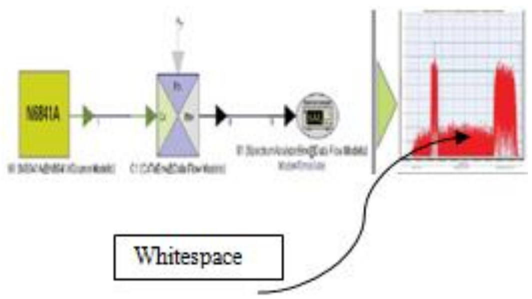

Figure 2: Spectrum sensing through cognitive radio

2.2 Spatial Sensing

Spatial technique such as MUSIC (multiple signal classification) and CAPON algorithm can be used for DOA (direction of arrival) of the transmitted signal. By using these techniques the co-channel interference between the primary user (PU) and the secondary user can be greatly reduced. In such cases the location of the primary user should be known and the transmission by the secondary user can be estimated by the MUSIC algorithm. Further, combining both the spectrum sensing and the spatial sensing the interference by the SU to the PU will be further reduced.

3. MIMO Antenna

Massive MIMO is defined as a system where all antenna configurations is made in the digital domain and hence, can simultaneously be configured for multi beams and array antenna is utilized at BS/AP side only. In 5G system the multiple antennas can be considered in both the TX and the RX section because it has the capability to reduce the co channel interference. The MIMO has the tendency to direct the transmitted power in only one direction. As the 5G system uses the small cell base stations which the delay spread can be greatly reduced. MIMO techniques is evolving technology that offers considerable increase in data bandwidth without any extra transmission power. Due to these properties MIMO technology will be a vital aspect for future cellular and wireless communication standards. The cellular architecture will compose of heterogeneous network where the device to device (D2D) and machine to machine (M2M) is possible in each FDMA and TDMA may be applied for multiple UEs that are scheduled in one eNB downlink or uplink antenna beam. Thus increasing the number of array in antenna with advanced digital signal processing tools could transmit huge information which would be the requirement of 5G cellular.

4. Capacity Achievement

The capacity can be achieved by the combination of the three parameters, spectral efficiency, spectrum, and spectrum reuse. The spectral efficiency can provide the capacity of 5X and it can be achieve through the use of massive MIMO. Recent innovations in cellular air-interface design, through 3GPP LTE, provide spectral efficiency performance that is very close to the Shannon limit. Spectral efficiency can be improved through techniques such as Coordinated Multi-Point (CoMP), Massive MIMO, Interference management and cancellation schemes etc. At the higher frequencies, where the wavelength and antenna elements are smaller, large arrays are feasible for beam forming and low order MIMO to achieve system capacity and throughput gains. To meet the growing traffic demand, the system capacity per square meter must be increased by either adding more network nodes (densification) or making additional spectrum available. To that end, it is mandatory to deploy dense networks by means of heterogeneous networks of low-power nodes, small cells such as Pico cells and Femto cells. The performance of local area networks targeted towards carrier frequencies below 6 GHz. However, the available spectrum below 6 GHz is limited and there are practical limits due to propagation for how small these cells can shrink. Therefore it is necessary to use the spectrum above 6 GHz for higher capacity.

5. Waveform Selection

As we have noticed that the LTE-A uses the OFDM technology which has the major disadvantages such as high PAPR (Peak to Average Power), and less sensitive to carrier frequency, which results to the low spectral efficiency and bandwidth utilization. So to overcome these disadvantages in 5G wireless communication system it uses the FBMC waveform. The FBMC reduces the inter symbol interference

(ISI) and inter channel interference (ICI) because it uses the OQAM processing. The FBMC uses the synthesis filter bank in the transmitter side, which uses the polyphase networking and the IFFT operation of the multicarrier signals and analysis filter bank in the receiver side and this section uses the sub channel equalizer by which perfect signal recovery is possible under ideal channel conditions. FBMC does not use the cyclic prefix so it can conserve the bandwidth. Two notable drawbacks of OFDM are a loss in spectral efficiency due to cyclic prefix insertion and the presence of significant out-of-band emissions. In comparison, FBMC may offer advantages in efficient usage of allocated spectrum as well as the ability to create or occupy spectral "holes" for spectrum-sensing applications. In this paper the FBMC for 5G communication is designed using the OQAM modulation techniques and the polyphase networking.

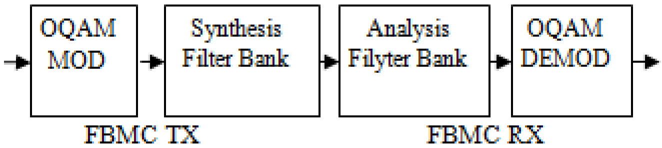

Figure 3: Block diagram of FBMC

6. Cellular Architecture of 5G Communication System

The 5G networks will consist of nodes/cells with heterogeneous characteristics and capacities (e.g., macro cells, small cells such as Femto cells and Pico cells, D2D user equipments and M2M USERS etc.), which will result in a multi-tier architecture. Due to increasing complexity in network management and coordination among multiple network tiers, the network nodes will have the capability of self-organization such as interference cancellation, spectrum sharing and the power management. The communication efficiency in 5G systems will be improved by incorporating techniques such as heterogeneous networks, interference cancellation and spectrum reuse. FD communication and energy harvesting capabilities will breed many challenges for designing and testing the internal chips and front-end modules for 5G devices. 5G system will be suppose to use full duplex communication scheme which is capable of transmitting and receiving on the same frequency at the same time. With the recent advancements in the antenna and digital baseband technologies as well as the RF interference cancellation techniques TDMA can also be considered wherein the devices can be assigned with all frequency resource allocated in the eNB antenna beam. SDMA is another option and can be combined with FDMA. SDMA offers the advantage that multiple links from a single antenna may operate simultaneously and on the same frequency given that spatially separated UEs can be paired. The ability to pair UEs can be enhanced with interference mitigation receivers or MU-MIMO techniques to remove interferences. The heterogeneous networks can be applied for all the uses such as traffic services, residential use, smart grid, e health services and many more.

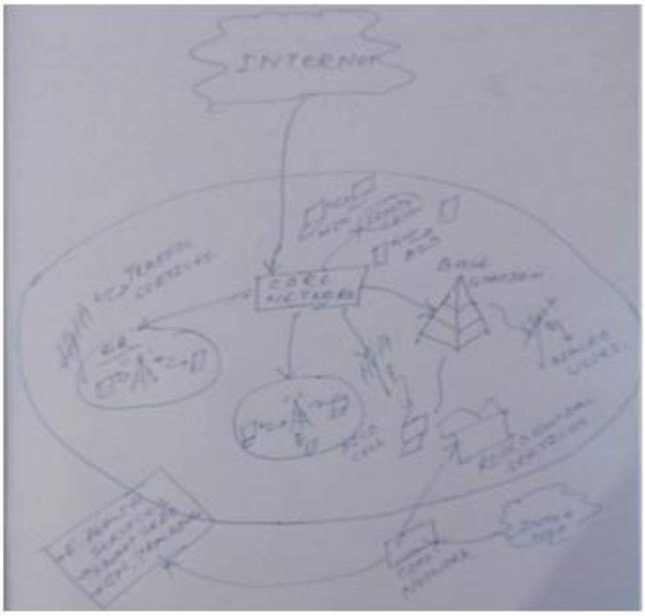

Figure 4: Heterogeneous network for Smart Cities

7. Conclusion

This paper reinforces the notion of smart cities based on the context platform for a major role in next generation networks. This paper explores the opportunities for context information that not only supports ubiquitous mobile network access, but beyond that allows efficient use of radio access technology. The energy consumption can be reduced at the end-user side by exploiting several features provided by smart phones including multi-RAT, cooperative, cognitive sensing, and context-aware information. We consider smart phone as a mobile device that supports multi-RAT, has various sensors embedded, and is capable of learning its environment and of providing rich user-centric context-information. A specific market case is the use of GPS information for navigation services. With the increasing development and popularity of the smart phone, it will set the stage for even more meaningful knowledge that can be measured, collected, or derived at the user handset. We have provided an overview of several emerging technologies for 5G cellular wireless networks. Some of the open research problems have been outlined including those related to testing and measurement of 5G systems. In addition to the technologies discussed above, technologies such as mm-wave and massive MIMO will also impact the design and development of 5G networks. In general, mm-wave communication links often require solutions that provide methods to mitigate Line of Sight (LOS) blockage. One means to achieve this is to utilize steerable, directional antenna arrays. Future 5G cellular wireless networks will definitely be a combination of different enabling technologies. Thus, this paper discusses about how the future cellular technology can be used for realizing smart cities which enables the data rate of 1GBPS and more connected devices at the low density users.In this article, the performance requirements of 5G wireless communication systems have been defined in terms of capacity, spectral efficiency, energy efficiency, data rate, and cell average throughput. We have also discussed some potential key technologies that can be deployed in 5G wireless systems to satisfy the expected performance requirements, such as CR networks, Femto/Pigo cells, and green communications, along with some technical challenges.

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Author Profile

Lalit Chettri received the B.E. degree from Visvesvaraya Technological University, Karnataka, India. Recently he is pursuing the M. Tech degree in Digital Electronics and Advance Communication from Sikkim Manipal University. He has published several papers in International Journals and various conferences proceedings. His research area includes Cognitive Radio, wireless communication, and Advance Digital Signal Processing and Electronics devices. Recently he is working on his thesis on 5G wireless communication for Telemedicine System.

Syed Sazad received the B.E. degree from Vinayaka Missions University, Tamil Nadu, India. Presently pursuing M.Tech in Digital Electronics and Advance communication at Sikkim Manipal University. His research area includes RF Optimization, Cognitive Radio. He is currently working on his thesis on WI-FI ac and Systemvue.