
Role of Cognitive Radio in 5G

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Abstract

There is an ever growing need for improved data transfer over the smart network device which exists. 5G is a futuristic technology which tries to achieve high data rates with reduced latency through wireless worldwide interconnections. There are many limitations related to the implementation of 5G technology. Cognitive Radio is a smart radio which addresses problems related to Spectrum Allocation where allocation is carried out dynamically. Cognitive Radio is capable of learning and adapting its operating and functional parameters according to the environment in which it operates. In order to make the concept of 5G realistic and to overcome the challenges in 5G, the flexibility and adaptability of Cognitive Radio can be of use. This chapter explores the role of Cognitive Radio technology in realizing 5G implementations. The possibility of adapting the terminals in 5G as Cognitive Radios is also investigated. Further the challenges and the commercial issues that will rise in the amalgamation of Cognitive Radio and 5G technology is also examined. Thus the chapter will look into the similarities in the two technologies and introspects the possibility of interoperability.

Keywords

5G Technology, Cognitive Radio, 5G Terminals, Interoperability, Wireless System Integration and Adaptation

Introduction

With increasing desire to make life easy, the number of smart devices is increasing every day. The available bandwidth allocation in 4G technology cannot handle such large number of devices. Further the services offered by these mobile devices also increase the mobile traffic and there is need to provide the fast and efficient services at low cost. There is an exponentially swelling in the count of devices which are hungry for bandwidth as well as there is a huge shortage in the vacant spectrum. Also, the availability of broadband access to remote areas and integration of varied networks on a common platform remains elusive. All the above mentioned factors have led to the advent of next generation mobile network technology, namely 5G technology [1]. In this technology, it is possible to achieve high data rates with minimum latency and reduced energy consumption. This technology is capable of handling heterogeneous devices. In spite of its many advantages, there are many challenges and implementation issues in 5G. Apart from the humongous increase in the mobile traffic, the nature of traffic is not only random but also diverse. The diverse variation in traffic in terms of periods of time poses difficulties in the planning of network infrastructure. The networks are unable to handle huge loads during peak traffic and become underutilized when traffic is less. Further, the services offered are also diverse such as browsing, multimedia and gaming and hence the Quality of Service requirements are different for various services. The existing cellular network are ineffective to handle high volume multimedia downloads.

The major challenge is to look into aspects to make the futuristic technology of 5G real [2]. Utilization of spectrum, consumption of energy and efficiency of cost are three major performance measures that should be majorly looked into in the development of a 5G system. In spite of the many advantages, 5G gravely experience difficult performance issues.

Cognitive Radio (CR) offers scope for optimum utilization of spectrum by secondary users who use the vacant spectrum holes. Cognitive Radio is essentially developed for Dynamic Spectrum Allocation which makes the radio smart. This radio is adaptable and flexible and has ability to change its operating parameters according to the environment in which it operates. This Cognitive Radio seems to be a capable expertise which can handle the challenges associated with 5G technologies. Cognitive radio has the ability to utilize the underutilized vacant band of frequencies while not creating any damage or intrusion to the existing users. The expenses involved in leasing the spectrum will be much lower than purchasing the spectrum. Hence the concept of spectrum on demand is popularly implemented by Cognitive Radio at a very low cost. Hence we can say that Cognitive Radio offers a

potential solution to the exploding traffic woes, with random and diverse traffic which is to be tackled by 5G technology.

Thus, this paper explores the role of Cognitive Radio in 5G technology combining the good quality of service and high data rate advantage of 5G technology with improved adaptability and flexibility of a Cognitive Radio.

5G Technology

5G is a revolutionary mobile expertise which is to succeed the 4G technology. The major objective of this technology is to introduce broadband concept in the mobile arena. However, the promises of 5G technology cannot be achieved with the existing architecture and infrastructure which is present in the current mobile technology. Towards the same, many detailing should be redefined or built from scratch [3].

There are different areas of concerns in the domain shift from 4G to 5G. The first issue is with respect to the infrastructure of the network. In 4G technology, the voice and IP based system were present as separate unit while in 5G technologies these two units are to be combined into one in order to ensure better quality of service. Another challenge to be handled is with respect to encryption. Encryption may be in accordance to the LTE principle; however the question will be on where encryption is to be applied. This technique could be made of use either in the user or device identification. In the environment of 5G, when there are millions of devices which are dynamic, most of the time it becomes cumbersome to identify the actual sender of the signal. Better Quality of Service is the main requirement of any network for which the network is divided into different layers [4]. The topmost layer is in touch with the users and its acts in turn affect the other layers of the network. Towards efficient operation the application layer of this technology should be free from errors. These 5G networks will have many networks and varied services, with every network and service having its respective charges and maintenance. Maintaining all of these and the payment issues related to all of these is a difficult work.

There are main needs which are to be fulfilled with respect to 5G technology. Some of them are with respect to data rate, latency, energy utilization, costing, battery life and bandwidth requirements [5]. Data rate is with respect to the amount of data which is transferred every second for every unit area. For the existing situation there is requirement to have 1000 times more data rate in 5G networks than which is present in 4G. 4G networks have latency up to 15 ms, while due to requirement of modern services like online gaming, the latency in 5G networks should be as low as 1 ms. It is predicted that the cost and energy utilization with respect to 5G networks will fall down. Maintaining and conserving battery life is also a main issue in 5G networks. It is predicted that the battery life will reduce by 10 times in 5G networks as compared to 4G networks.

In order to meet these high end requirements there are different key enabling technologies which are to be adopted. Making the networks denser is a technique which could be adopted in 5G networks to improve the performance metrics. Denser networks are accomplished by usage of small cells which is a huge challenge. Massive MIMO is another technique which could be adopted considering the spatial dimensions when multiple antennas are available in base station. This technique makes use of multiplexing feature. In the search for free frequency band, 30-300 GHz is found to be freely available and can be utilized and the signals are called as millimeter signals. Further, to enhance performance, direct device to device technology is to be used which involves direct exchange of data between mobile devices in the absence of base stations. This subsequently reduces the load in network devices. Usage of full duplex wireless communication enables transmission of data simultaneously and increases the physical layer capacity and also results in increase in latency [6].

The main access point for connection to a 5G network is a 5G terminal. This terminal should have ability to connect to various wireless paradigms and capacity to make a choice of the most suitable one for it. Towards the same, the network should be equipped with many adaptors with different adaptor for different network such as WLAN, Wi-Fi, and Bluetooth etc. Further, to result in enhanced performance, the user terminal of 5G should have ability to toggle between various paradigms in the same session [7]. Also, the terminal should have ability to combine the different streams that are coming out from the different technologies. Such a terminal capable of high performance displays enhanced modulation and schemes capable of error correction.

Apart from the 5G terminal, the 5G network also has certain constraints and requirements. The choice of the wireless access technology which is to be adopted is the functionality with respect to first and second layer. A complete IP integration is to happen across the third layer. The network layer is to be in turn divided into three sub-layers namely lower, middle and upper layers. The kind of wireless technology to be used is decided by transport protocol. The application layer will be responsible for providing intelligent and smart Quality of Service to the end users.

Cognitive Radio

Cognitive Radio is an intelligent radio whose transceivers are reconfigurable and are capable of adapting itself according to the change in conditions [8]. Cognitive Radio could be made use in two ways either to take care of all changes in the network parameter or to perform spectrum sensing [9]. Most of the time spectrums or frequency bands remain underutilized and finding out the vacant bands is done by various algorithms in spectrum sensing. In fact, certain spectrums are underutilized most of the time and hence need to be sensed. Hence spectrum predictive algorithms are used to act as a prelude to spectrum sensing to find which of the spectrum bands need to be sensed. The basic user to whom the spectrum is allocated initially is the primary users. When the primary user is not using the spectrum which is identified by spectrum sensing algorithms, these vacant bands are allotted to others users who require them. These users to whom it is allotted dynamically as per requirements are called as secondary users. These processes are effectively performed by Cognitive Radio [10]. The allocation of the vacant spectrums is a process and is done by system called Dynamic Spectrum Allocation. After finding out the free bands, Cognitive Radio adopts a strategy known as spectrum pooling method where the available free bands are filled by OFDM sub bands.

The major objective of a Cognitive Radio is highly consistent communication as per requirement with proficient usage of available radio frequency spectrum [11]. Thus, Cognitive Radio is a smart communication system which is completely conscious of its immediate and surrounding background. It makes use of techniques to gain knowledge and to learn from the environment in which it is present [12]. It correspondingly brings in changes in its operating and functional parameters like modulation method, power transmitted, frequency of carrier etc. in accordance to the incoming radio frequency stimulus it receives.

The main advantage of a Cognitive Radio is with respect to its spectrum efficiency [13]. Achieving improvement in spectrum efficiency will result in satisfying the futuristic demands of the users to which the radio is catering to. Further, Cognitive Radio is capable of supporting higher bandwidth along with providing better Quality of Service. Further, Cognitive Radio also has capability to avoid sudden drop of services even in absence of proper network condition. Also, Cognitive Radio has the advantage of hardware platform independence where Cognitive Radio is capable of handling software of various types [14].

The intelligence in Cognitive Radio is attributed to the presence of Cognitive Engine. The Cognitive Engine is the brain of CR which has components of knowledge base, Learning and Reasoning Engine [15]. This engine has ability to learn and reason and store the acquired knowledge based on learning and reasoning in the knowledge base. The learning engine can be realized using different soft computing techniques [16][17]. The learning and reasoning done through usage of such techniques enable the attribute of adaptability, flexibility, predictive ability and capacity to interoperate. These attributes of Cognitive Radio make it most suitable for blending in 5G environment.

Confluence of Cognitive Radio and 5G

Looking into the characteristics and features of 5G as well as Cognitive Radio there are many similarities between both the technologies. The main similarity being both the systems are capable of inter working with other systems or networks. Further, they are capable of adaptation and have ability to work with new and flexible protocols [18]. The physical and MAC layers associated with both layers are advanced. The terminal used in the technology is advanced and is capable of resource management. Since the technology is in nascent stage of development, security challenges are a major issue in both 5G and Cognitive Radio.

In a nutshell, 5G looks into integrating various wireless technologies while Cognitive Radio is a powerful tool capable of self integration in the wireless domain which is varied [19]. Thus, Cognitive Radio is very apt and ideal for usage as 5G terminal. 5G terminal is a common terminal bestowed with acumen having capability to work with different types of wireless systems and toggle to different paradigms during same session [20]. 5G terminals are capable of supporting various data types with improved quality of service. The Cognitive Radio technology provides 5G terminal sufficient development methods. The different developmental methods in a Cognitive Radio will vary depending on the Cognitive Engine design which uses various methods and algorithms such as genetic algorithms, particle swarm optimization and other bio inspired algorithms. Statistical learning techniques could also be adopted in the Cognitive Engine design. Apart from these, Cognitive Engine design could also be implemented using some advanced methods. FPGA, FFT Processors, MIMO technology and nano-scale processing are some of the examples of advanced techniques which could be employed in the implementation of Cognitive Engine.

5G technology promises to offer personalized services [21][22]. In order to offer personalized services identity, location and privacy issues need to be addressed. Addressing these issues become a challenge when Cognitive Radio is used as a 5G terminal and inter technology spectrum transfer takes place. Towards finding solution to these problems, Context Aware Cognitive Radios are to be used. These Cognitive Radios are capable of sharing various information such as personal, environmental observations, preferences regarding sharing, spectrum and technology

[23]. The monitoring and adaptation features in 5G technology is incorporated through the Cognitive Radio Networks.

The main focus in 5G networks is creation of systems which have the necessary wireless communication background for interactions at large data rates. The architecture created should be flexible and capable of operating dynamically. In order to acquire such a system, CR technology is the best way. The cognition acquired by Cognitive Radio will enable 5G networks implement the systems. Such systems are capable of providing connectivity, co-operation, content and convergence at all time and at any place. The presence of Cognitive Radio in 5G will try bringing in the wired and wireless paradigms together and will work towards providing a global environment.

Conclusions

5G and CR technologies and their advancements have been described and detailed in this paper. Interconnecting different technologies has been key aspect in 5G technology, while ability to adapt to interconnected networks is the main characteristics in Cognitive Radio. Also, many resemblances in characteristics of 5G and Cognitive Radio have been found. Based on the common characteristics, 5G network using Cognitive Radio functionality is proposed. The functionality is based on using Cognitive Radio terminal as 5G terminal. Such a 5G network is empowered to integrate and interconnect different wireless network paradigms. Further it has also been seen that the presence of CR based protocols in the network increases the performance. Though CR terminal adapts itself well in wireless environment, its flexibility and ability to connect to the wired networks is a challenge. Also, obtaining maximum data rates in 5G networks while using Cognitive Radio technology at the access level is another area which needs scope for improvement. In spite of such disputes, it is concluded that the usage of Cognitive Radio in 5G is the first step towards providing interoperability and connectivity between various communication technologies and varied network types. In the quest of establishing a real 5G network, Cognitive Radio based 5G is a flourishing amalgamation which has been found to outperform existing arrangements.

References

1. A. Gupta, R. K. Jha: Survey of 5G Network: Architecture and Emerging Technologies, IEEE Access, Volume 3, 2015.
2. Federico Boccardi, Robert W. Heath Jr., Angel Lozano, Thomas L. Marzetta, Bell Labs, Alcatel-Lucent Petar Popovski, Five Disruptive Technology Directions for 5G, 5g Wireless Communication Systems: Prospects And Challenges, IEEE Communications Magazine • February 2014.
3. Mohammad Meraj ud in Mir et al, Evolution of Mobile Wireless Technology from 0G to 5G, International Journal of Computer Science and Information Technologies, Vol. 6 (3) , 2015, 2545-2551
4. Cornelia-Ionela Badoi · Neeli Prasad · Victor Croitoru · Ramjee Prasad, 5G Based on Cognitive Radio, Wireless Pers Commun (2011) 57:441–464
5. Akshita Abrol, Rakesh Kumar Jha, Power Optimization In 5g Networks: A Step Towards Green Communication, Special Section On Green Communications And Networking For 5g Wireless, IEEE Access, Volume 4, 2016.
6. Carolina Fortuna, Peter Ruckebusch, Christophe Van Praet, Ingrid Moerman, Wireless Software and Hardware platforms for Flexible and Unified radio and network control, 2015 European Conference on Networks and Communications (EuCNC)
7. Sergio Fortes , Raquel Barco and Alejandro Aguilar-Garcia, Location-based distributed sleeping cell detection and root cause analysis for 5G ultra-dense networks, Fortes et al. EURASIP Journal on Wireless Communications and Networking (2016) 2016:149
8. Linda Doyle, Essentials of Cognitive Radio, Cambridge Wireless Essential Series, May 2009.
9. Kwang-Cheng Chen, Ramjee Prasad , Cognitive Radio Networks, Wiley Publications, April 2009.
10. Simon Haykins, Cognitive Radio: Brain-Empowered Wireless Communications, IEEE Journal on Selected Areas in Communications, Vo. 23, No.2, February 2005.
11. Ian F. Akyildiz, Won-Yeol Lee, Mehmet C. Vuran, Shantidev Mohanty, Next generation dynamic spectrum access cognitive radio wireless networks: A survey", Computer Networks 50 (2006) 2127-2159.
12. Simon Haykin, Cognitive Dynamic Systems", Proceedings of the IEEE , Vol. 94, No. 11, November 2006, 1910-1911.
13. Carlos Cordeiro, Kiran Challapali, and Dagnachew Birru, IEEE 802.22: An Introduction to the First Wireless Standard based on Cognitive Radios", Journal of Communications, vol. 1, no. 1, April 2006.

14. Charles Clancy, Erich Stuntebeck, Applications of machine learning to Cognitive Radio Networks", IEEE Wireless Communications , August 2007.
15. Asma Amraoui, Badr Benmammar, Francine Krief, Fethi Tarik Bendimerad, Intelligent Wireless Communication System Using Cognitive Radio", International Journal of Distributed and Parallel Systems (IJDPS) Vol.3, No.2, March 2012
16. Mithra Venkatesan, Dr.Anju.V.Kulkarni and Dr.Radhika Menon "Artificial Neural Network based Learning in Cognitive Radio" Proc. of Int. Conf. on Advances in communication, Network, and Computing,2013.
17. Mithra Venkatesan, Anju Vijay Kumar Kulkarni "Comparative Performance Investigation of Supervised and Unsupervised Learning Outlines applied in Cognitive Radio Systems" Wireless Personal Communication, December 2016, Volume 91, Issue, pp 1393–1417.
18. Xuemin Hong, Jing Wang, Cheng-Xiang Wang, and Jianghong Shi, Cognitive Radio in 5G: A Perspective on Energy-Spectral Efficiency Trade-off, IEEE Communications Magazine , July 2014.
19. Jose F. Monserrat, Irene Alepuzl, Jorge Cabrejas, Vicente Osa, Javier López, Roberto García, María José Domenech and Vicent Soler, Towards user-centric operation in 5G Networks, Monserrat et al. EURASIP Journal on Wireless Communications and Networking (2016) 2016:6
20. Parnika De and Shailendra Singh, Journey Of Mobile Generation And Cognitive Radio Technology In 5g, International Journal Of Mobile Network Communications & Telematics (IJMNCT) Vol. 6, No.4/5/6, December 2016.
21. Chungang Yang, Jiandong Li, Mohsen Guizani, Alagan Anpalagan and Maged El Kashlan, Advanced Spectrum Sharing in 5G Cognitive Heterogeneous Networks, IEEE Wireless Communications , April 2016.
22. Rajwinder Singh, Jasvir Singh, A.S. Kang, Cognitive Radio New Dimension in Wireless Communication – State of Art, International Journal of Computer Applications (0975 – 8887) Volume 74– No.10, July 2013.
23. Mohammad Patwary, Shree Krishna Sharma,, Symeon Chatzinotas, Yunfei Chen, Mohamed Abdel-Maguid, Raed Abd-Alhameed, James Noras, Björn Ottersten, Universal Intelligent Small Cell (UnISCell) for next generation cellular networks, Digital Communications and Networks 2 (2016) 167–174.