International Journal of Future Generation Communication and Networking
Vol. 13, No. 1, (2020), pp. 1258-1267

Analysis of LTE and Wi-Fi Coexistence in 5GHz Unlicensed Band

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Abstract

In present and future generation mobile networks it is expected to provide higher rate throughput of data in order to fulfill the demand of exponentially increasing customers. To provide effective and quality communications is a challenging task for LTE networks due to devices heterogeneity and upcoming coexisting technology. LTE licensed band are utilized as per the standard norms and are already occupied. There is need of extension of frequency bands and increase in data rates in available unlicensed bands for handling the traffic over the networks. The most suitable unlicensed band is 5GHz frequency band that can be highlighted for its effective utilization. However, this 5GHz band is occupied by Wi-Fi networks and now special efforts may be needed for co-ordination of these two networks in spectrum sharing. In this paper the spectrum sharing and access of 5GHz unlicensed band in between LTE as well as Wi-Fi networks. Mainly it may consider the influence of the present LTE downlink and its transmission on Wi-Fi networks performance. The results from the experimental analysis has shown that LTE is degrading the performance of Wi-Fi network and there is need of some co-ordination algorithm for co-ordination of coexistence of two technologies.

Keywords: *LTE, Wi-Fi, Unlicensed Band, Co-existence, Throughput.*

1. Introduction

Mobile industry is growing exponentially over the decades, and data transfer in mobile was totally based on uses of licensed spectrum in the country. The predictions of growth in data traffic up to 2030 is in the multiples of thousands times more [1], and also significant increase in data transfer of machine to machine will be observed [2], To provide high bandwidth support as per demand is highly impossible and problematic for licensed band and its communication. The possible answer for this problem is to use unlicensed spectrum without causing interference to the licensed band which is dedicated for the operation. The GSM, LTE and DVB-T coexistence are neatly analyzed in [3]. These papers show that UHF TV band is not suitable for mobile communication and its systems. On other side for the possible bandwidth extension, unlicensed bands are found suitable. The unlicensed bands like ISM (Industrial, Scientific and Medical) and U-NII (Unlicensed National Information Infrastructure) bands occupy frequencies nearly 900MHz, 2.4GHz and 5.8GHz band and will provide 80MHz bandwidth but it has been found that this bandwidth is occupied heavily by Wi-Fi, Bluetooth and another wireless personal networks. The unlicensed band 5GHz band is providing bandwidth of 500MHz and is slightly occupied by Wi-Fi network. Wi-Fi uses 2.4GHz and 5 GHz CSMA (carrier sense multiple access) for accessing the channel, and they

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may be the victims of other technologies which is operating in same frequency band. Bluetooth is using CSMA technique for transmission of data and TDMA technique for transmission of audio which may lead to cause interference to another network. Keeping existing interference and available bandwidth in mind the 5 to 5.8 GHz band is useful to choose for the extension of bandwidth [4]. However, technology implemented must be flexible for supporting another frequency bands.

In 3GPP (3rd Generation Partnership Project) LTE was firstly defined in the Release 8 [5]. Evolution of standards of mobile communication for providing higher data rates and capacity, low latency and newer levels of experience for users. In 3GPP Release 10 [6], here improvement in LTE for fulfilling the needs of 4G networks and was named as LTE-A (LTE Advanced). The most useful thing in LTE-A is that by using CA (Carrier Aggregation) technique the multiple frequency bands can be used simultaneously. Even if the unlicensed band is available free for communication systems but still some regulations needs to be followed like DFS (Dynamic Frequency Selection) and LBT(listen-before-talking) which can use spectrum sensing or CSMA (carrier sense multiple access) [7]. Such coordination mechanisms are useful for achieving very effective co-existence in unlicensed spectrum. The proper coordination in between LTE and Wi-Fi is the main focus here. LTE was mainly designed for operating in the dedicated licensed band and hence it is not having the shared mechanism access just like Wi-Fi technology. The theoretical and simulation results of coexistence of LTE as well as Wi-Fi and the possible need of coordination in between these two technologies is given in paper [8] and [9]. The Experimental result analysis of band 2.4 GHz and Wi-Fi is duly influenced by LTE is neatly given in [10].

Here two main possible solutions for the solving the problems of LTE and Wi-Fi coexistence can be given. In the first solution modifications and adaptation of LTE standards are suggested in shared spectrum. LTE-U is proposed by forum LTE-U [11], uses LTE with duty cycle which means there is some pause in the process of transmission. Due to this way there is opportunity for Wi-Fi to transmit data in the silent interval of LTE-U. LAA (Licensed Assisted Access) is a part of standard 3GPP Release-13 [12],[13], and it includes LBT (Listen Before Talk) mechanism for transmission during the free status of channel. The detail standardization and LAA summary is given in [14]. Here the performance of system at operator level is analyzed for the different indoor offices, hotspot and outdoor cell scenarios. The result of analysis shows that there is significantly increase in LTE capacity is obtained by making the use of LAA and LBT. In the paper [15] LBT design for LAA system gives analysis of LAA influence CCA (clear channel assessment) threshold for LTE and Wi-Fi network performance. In the paper LBT algorithm is proposed for improving LAA and keeping interference low to Wi-Fi. The second solution is introduction of coordinated access for shared channel. For spectrum coordination there are two general approaches [16] reactive and proactive spectrum coordination. The most useful reactive spectrum coordination is also called wideband radio scheme [17]. This scheme uses analysis of spectrum by transmitter and selection of frequency band as well as modulation scheme having insights of higher interference level. This is very simple coordination scheme having one drawback of hidden nodes interference. Another coordination scheme is the reactive control coordination [18]. In this scheme reactive name is due to the fact that here the station changes its parameters depending on variations observed in wireless environment and its condition. All radio stations

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control its transmission power, transmission rate and transmitting frequency band for optimizing the quality of channel and levels of interference. It has been seen that proactive scheme is more complex as compare to reactive scheme. Spectrum etiquette protocol is the example of proactive scheme [19]. This etiquette approach is used for operation in more complex environment than reactive scheme. The CSCC (Common Spectrum Coordination Channel) variant etiquette approach is seen in [19],[20] with coexistence in unlicensed and shared 2.4 GHz band.

This paper clearly gives in detail experimental details regarding the interference due to LTE and Wi-Fi in the unlicensed 5 GHz band. In present scenario since LTE hardware is not available commercially which can operate in unlicensed band, here we are using Open Air Interface (OAI) a software radio based, LTE implementation [21]. OAI is meant for the licensed bands hence we need to modify the existing source code for allowing the usage in the unlicensed 5 GHz band. The entire experimentation is carried out on NITOS testbed [22]. The remaining paper is organized as follows. Section 2 presents the OAI and NITOS testbed. The total experimental description is presented in Section 3, while the experimental results are shown in Section 4. Finally, the conclusion is given in Section 5.

2. OAI and NITOS Testbed

The Open Air Interface (OAI) software provides an open-source, standards-compliant implementation of a 3GPP 4G LTE stack that runs on a commodity x86 CPU and a USRP radio device. The OAI software provides a full experimental LTE implementation (3GPP Releases 8 and 9, and partially 10 and 11) that runs in real-time and is capable of operating with commercial LTE handsets (UEs). It supports FDD and TDD configurations in 5MHz, 10MHz and 20MHz channel bandwidth. OAI is designed for working with RF platform with some modifications. Presently there are two supported platforms are available EURECOM EXMIMO2 [23], and USRP-X and B series (Universal software Radio Peripheral) [24]. We are using USRP B210 for performing our experiment along with Intel core i5 or i7 PC having USB3.0 supported port which is needed for performing the experiment.

NITOS is having integrated facility with heterogeneous testbeds that are mainly focusing on research in wired and wireless network area. The experiment has been performed on NITOS Testbed which is having Indoor RF isolated Testbed, Outdoor Testbed and Office Testbed facility available for different research experimentation scenario as shown in figure 1.

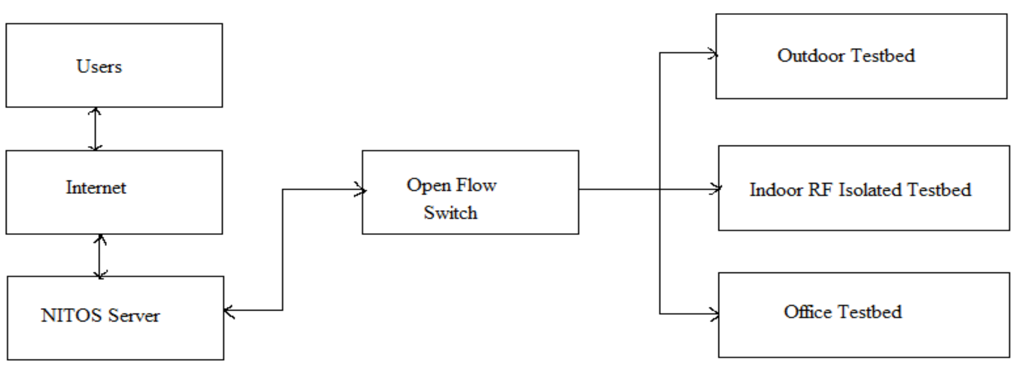

Fig.1 Block diagram of NITOS Testbed

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For the observation of LTE and Wi-Fi coexistence we have used the open source Network Implementation Testbed i.e. NITOS Testbed [12] with the extension of enabling the open access to LTE and its network components [13]. NITOS is a very good and widely used Wireless Testbed which consists of 50 indoor and 50 outdoor RF isolated nodes having the interfacing features for wired as well as wireless interfaces and software defined radio and its components. The experiment is carried out at Indoor RF Isolated Testbed having 4x11 nodes that are placed in a grid fashion (4 nodes each and in 11rows) shown in the figure 2. The distance is 1m in between each neighboring node. The all indoor nodes are numbered from 50 to 93 as the previous 1 to 49 nodes are used in Office and Outdoor Testbeds.

Fig.2 Indoor RF Isolated Testbed topology

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Each node is having a PC with different types of RF devices are attached like USRP, WiFi, Bluetooth as well as LTE. After making a reservation for selected date and time slot every node can be accessed in online mode by user as per availability and the required software can be executed within that slot.

3. Experimental Setup and Topology: -

The set up and topology used for performing experiment is shown below in figure 3. The nodes 50 to 68 are used for creating Wi-Fi network. Qualcomm Athers AR9580 wireless network adapters are used here. Due to regulatory domain for Wi-Fi cards, channel 36, 40, 44 and 48 are available at 5GHz frequency band. It has been decided to choose channel 48 having 5.24 GHz central frequency. The output power for Wi-Fi adapters has been set to 0 or 10dBm for making it less or equal to the USRP devices output power. The throughput of TCP (Transmission control protocol) using iPerf V2 has been generated and measured in between these two stations for 60 seconds application and with no parallel streams. Using OAI software node 59 and 60 are used for execution for LTE eNB and LTE UE [26]. Here it has been observed that LTE nodes are near to each other. This is due to the fact that presently OAI is under development phase and the quality of linking among eNB and UE is not so good. Presently EURECOM is giving maximum attention towards the OAI eNB development for making its proper working and with different types of commercial devices using LTE for e.g. mobile phone. The channel width of LTE can be configured by using the NRB (Number of resource block) parameter. The probable and possible channel widths are accordingly 1.4,3,5,10,15,20MHz for NRB =6,15,25,50,75,100. The OAI software is properly configured for working in mode FDD and having channel bandwidth 5MHz hence NRB is set to 25 as OAI is having the best performance in channel width 5MHz. For channel 48 central frequency is 5.24GHz and the downlink frequency is set equal to channel 48 and set 100MHz uplink frequency offset i.e.5.14GHz uplink frequency.

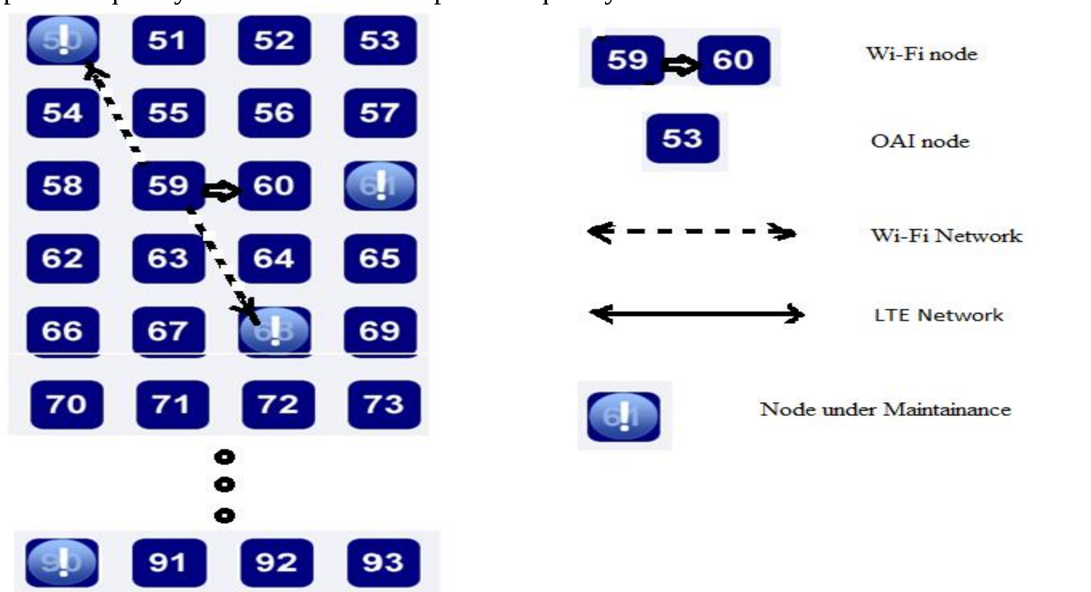

Fig. 3 The set up and topology used for experiment

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The round trip time RTT and throughput in between Wi-Fi stations is measured constantly and LTE traffic has been varied and noted. After that iperf is neatly used for generation of UDP (User Datagram protocol) traffic LTE downlink network. We are not having the physical access of NITOS Testbed hence we cannot put WiFi cards on any of the node and due to that changing the distance in LTE and Wi-Fi is not implemented.

4. Experimental Analysis: -

This section describes the experimental analysis which will show the effect of LTE on Wi-Fi network and based on discussed scenarios: No LTE Network scenario, LTE eNB scenario, 1Mb/s scenario and 10 Mb/s scenario of LTE downlink traffic. The output power of USRP B210 is 10dBm hence Wi-Fi output power has been chosen equal to USRP i.e. 10dBm and lower 10dB i.e. 0dBm. It has been noted here that when LTE throughput is higher at that time Wi-Fi throughput is lower because here Wi-Fi senses LTE transmission and due to that Wi-Fi delays own transmission. On the contrary LTE is not using carrier sensing and transmits in a continuous mode. Wi-Fi transmission power has no effect on Wi-Fi throughput except for small LTE traffic in eNB as stronger packets of Wi-Fi are about to reach to the scheduled destination even though they are hitting to LTE signal while in the phase of transmission.

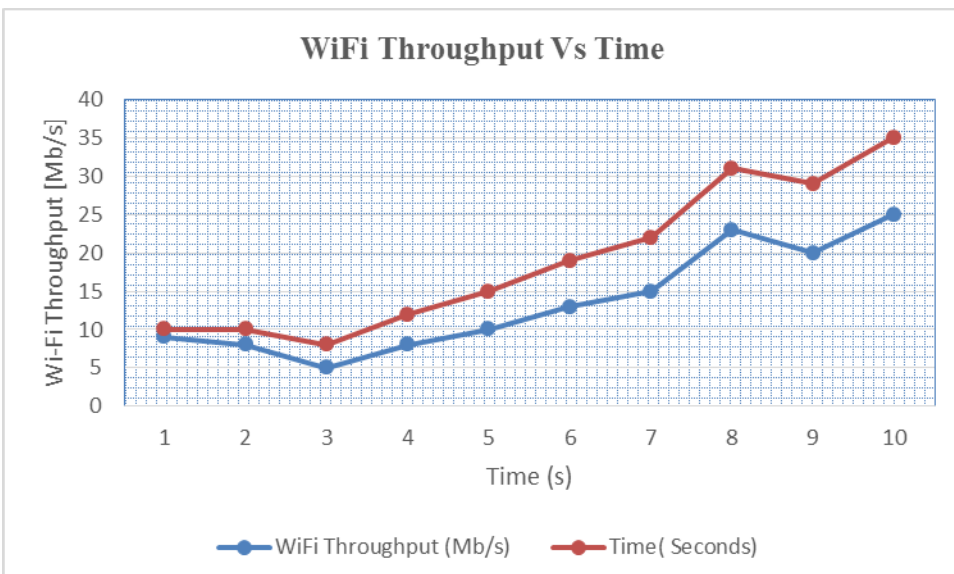

Fig.4 Wi-fi throughput vs Time for LTE traffic scenario
a) No LTE scenario b) LTE eNB scenario c) 1Mb/s scenario d) 10 Mb/s scenario

Apart from the throughput the delay in transmission is a key parameter in the communication network. For Wi-Fi network the round trip time RTT means the total time required for the packet to travel from the source to required destination and then again back to the source is shown in figure 5. It has been measured by using the ping application which will send ICMP

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(Internet Control Message Protocol) packets of Echo request and will wait for response of Echo response packets. The RTT will be considered for dense LTE traffic and for various ICMP packet size like 100, 1000 and 10000 bytes accordingly. Figure 5 shows the average value as well as standard deviation of round trip time RTT. It has been observed that as there is increase in throughput of LTE there will be increase in average value and standard deviation of round trip time RTT has been observed. It has been seen that the increase in average value for LTE Throughput 10Mb/s. Also the exponential rise in RTT standard deviation is observed as per increase in LTE throughput.

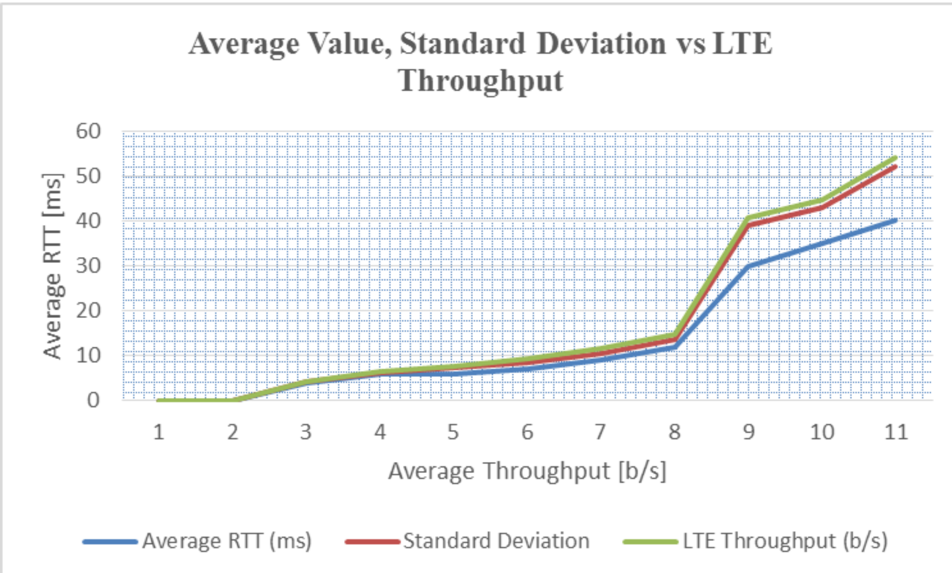
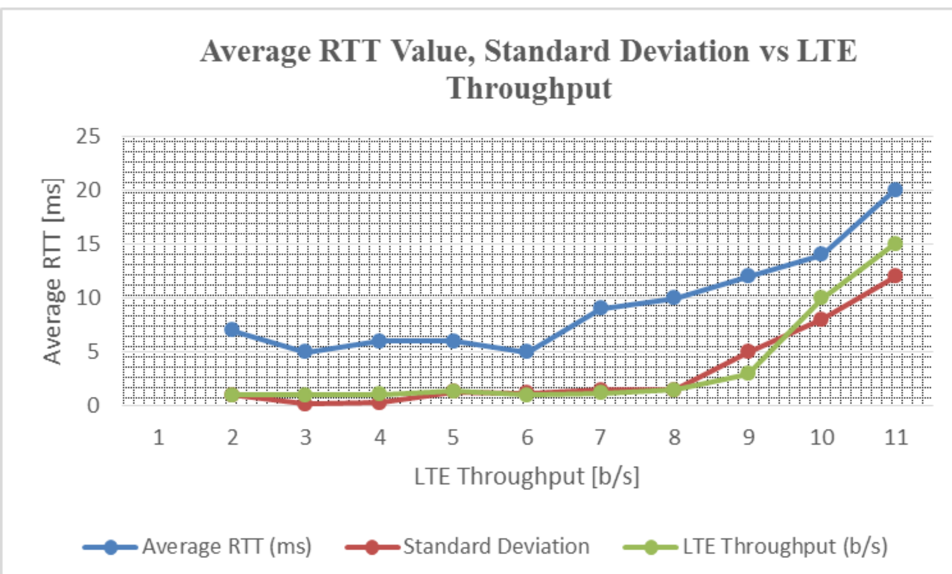


Fig.5 Wi-Fi network and RTT acting as a function of LTE throughput for various packet size values



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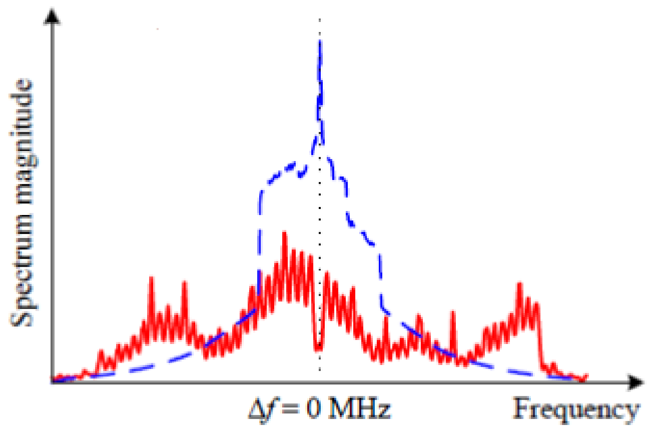
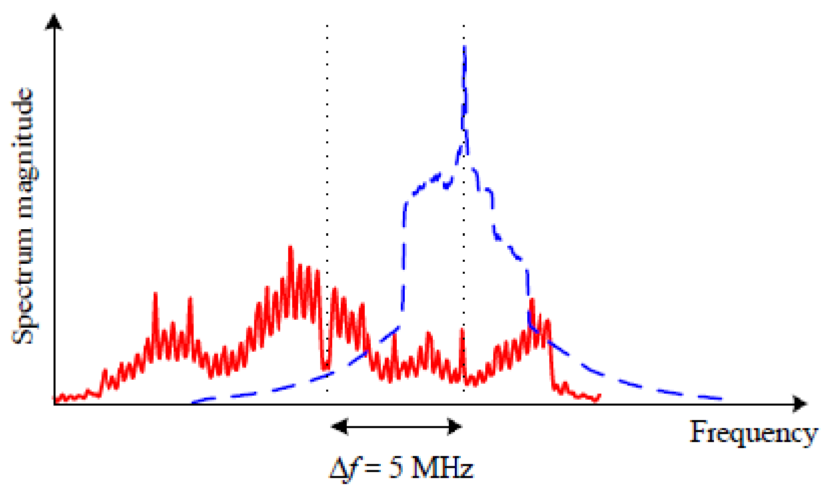
International Journal of Future Generation Communication and Networking
Vol. 13, No. 1, (2020), pp. 1258-1267

Fig.6 Wi-Fi network and average RTT acting as a function of LTE throughput for various frequency offset between LTE carrier frequency and Wi-Fi and here Wi-Fi packet size is a)100 bytes b) 1000bytes c) 10000bytes

Finally in figure 6 the influence of carrier frequency offset in between Wi-Fi channel central frequency and LTE downlink frequency has been analyzed.



a)



b)

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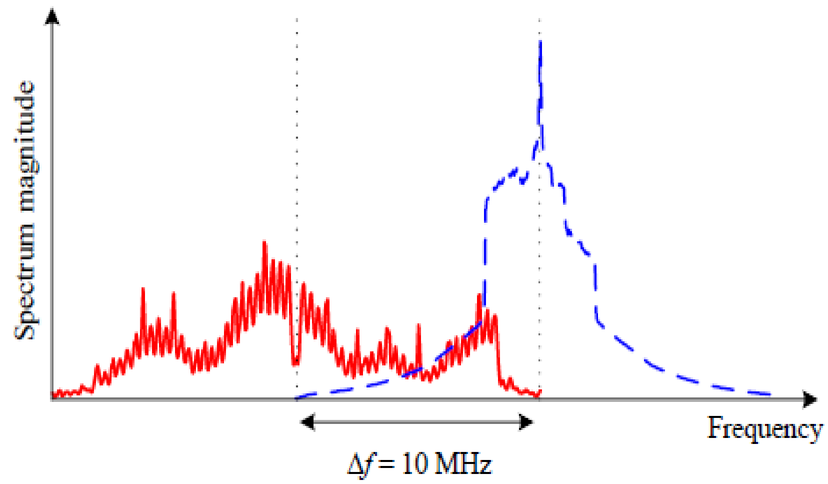

c)

Fig. 7 Wi-Fi signal position shown by solid lines and LTE signal position is shown by dashed lines. Different Spectra for carrier frequency offsets scenario a) 0 MHz b) 5 MHz c) 10 MHz

We should keep in mind that Wi-Fi uses 20MHz bandwidth and LTE uses 5MHz bandwidth and it is shown in figure 7. It is seen that for 0MHz offset the entire LTE spectrum is overlapping with WiFi spectrum for 5MHz offset value 25% of Wi-Fi channel is overlapped by LTE and in 10MHz offset, half LTE spectrum overlaps with Wi-Fi spectrum and LTE carrier is just on edge. The final result shows that if the offset value is on higher side then the influence of LTE on the Wi-Fi network is lower. For offset 10MHz LTE is having very less influence over Wi-Fi network.

5. Conclusion:

The experimental analysis of coexistence of LTE and Wi-Fi has been carried out using NITOS Testbed. It has been observed in 5GHz frequency spectrum that if the LTE throughput is higher then the Wi-Fi throughput is lower. The LTE is influencing the round trip time RTT of the Wi-Fi network. The influence is very high when the downlink frequency of LTE is exactly equal to central frequency of Wi-Fi Channel else if the difference between two frequencies is higher then the influence is found to be lower. The overlapping of LTE and Wi-Fi signal can be avoided by using proper frequency offset and difference needs to be maintained for getting the best coexistence results. The LTE and Wi-Fi coexistence is very useful and can be implemented by using proper spectrum coordination based framework. The centralized coordination server will be useful for processing the coordination process. The centralized server will communicate and provide all required information to LTE and WiFi clients for successful co-existence.

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