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On-Request Channel Allocation in LTE Cellular Networks

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Abstract— Long-term evolution (LTE) femtocells represent a very promising answer to the ever growing bandwidth demand of mobile applications. They can be easily deployed without requiring a centralized planning to provide high data rate connectivity with a limited coverage. Femtocell is low-power, very small and cost effective cellular base station used in indoor environment. However, the impact of Femtocells on the performance of the conventional Macrocell system leads interference problem between Femtocells and pre-existing Macrocells as they share the same licensed frequency spectrum. Frequency Reuse (FR) is an effort of manipulating the frequency resource allocation upon terminal's location to improve system capacity. In this paper, an efficient method to improve system capacity through interference management in the existing FemtoMacro two tier networks has been proposed. In the proposed scheme, a novel frequency planning for two tiers cellular networks using frequency reuse technique is used where Macro base stations allocate frequency sub-bands for Femtocells users on-request basis through Femtocells base-stations to cancel interference. Going to implement power allocation or distribution based enhance ment of channel capacity taken as throughput in this paper.

Index Terms— LTE, Terrain, Propagation Model, Monte Carlo Analysis, Cell, e Node B.

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1 Introduction

LTE is a part of the GSM evolutionary path for mobile broadband, following EDGE, UMTS, HSPA (HSDPA and HSUPA combined) and HSPA Evolution (HSPA+). Although HSPA and its evolution are strongly positioned to be the dominant mobile data technology for the next decade, the 3GPP family of standards must evolve toward the future. HSPA+ will provide the stepping-stone to LTE for many operators. The overall objective for LTE is to provide an extremely high performance radio-access technology that offers full vehicular speed mobility and that can readily coexist with HSPA and earlier networks. Because of scalable bandwidth, operators will be able to easily migrate their networks and users from HSPA to LTE over time.

The key characteristic of a cellular network is the ability to re-use frequencies to increase both coverage and capacity. As described above, adjacent cells must use different frequencies; however there is no problem with two cells sufficiently far apart operating on the same frequency. The elements that determine frequency reuse are the reuse distance and the reuse factor. The reuse distance, D is calculated as $D = R\sqrt{3N}$, where R is the cell radius and N is the number of cells per cluster. Cells may vary in radius in the ranges (1 km to 30 km). The boundaries of the cells can also overlap between adjacent cells and large cells can be divided into smaller cells.

This thesis is to develop a simple and efficient interference mitigation technique by allocating on request PRBs to Femto cells user through Femto cells base station under sectored-FFR OFDMA two tiers Macro Femto cellular system has been proposed. FFR is one of the solutions to reduce co-channel interference between Macro cell and Femtocell. So, it focuses on the interference mitigation between the Macro cell and the Femtocell by improving system throughput using 'On Request' channel allocation method in FFR approach.

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2 Parameters and Assumptions

2.1 Frequency Reuse

The simplest approach used to address this inter-cell interference problem that occurs when Reuse-l is applied is the frequency reuse-n (Reuse-n) approach. In this approach neighboring cells use different spectrum to avoid interference to users in their respective cells, The available bandwidth is split into n orthogonal sub-bands and each cell transmits on non interfering sub-bands. This ensures that the spectrum is reused at distant cells. n is called the frequency reuse factor and can be written as n = i2 + ij + p, for i, j E N. One example of Reuse-n is the Reuse-3.

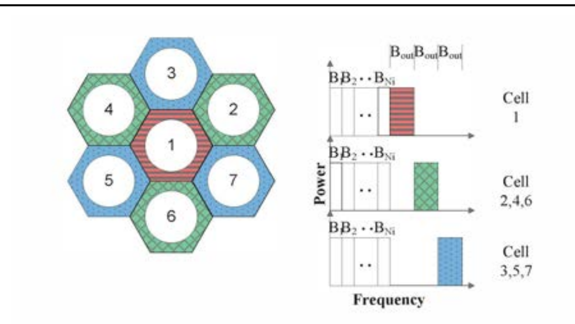

Fig. 1. FFR scheme. In FFR, the reuse factor for interior users is 1 and thereuse factor for exterior users is 3.

Fractional frequency reuse, originally proposed that, partitions the whole spectrum into two parts; namely, one with reuse factor 1, and one with reuse factor n, usually n = 3. The key idea behind FFR is to employ a reuse factor of unity for cell-center regions and a reuse factor of 3 for cell-edge regions. An example of FFR scheme is shown in Fig. 1.

Resource Allocation Framework for Femtocell (RAFF) in which resource blocks are assigned through greedy algorithm. Even though RAFF algorithm handles co-channel interference through alternate resource assignment, it is unaware about the co-tier interference experienced between neighboring femtocells. As inter-femto-base station distance and femtocell's transmit power are not weighed by RAFF algorithm, a coverage overlapping femtocell may tend to operate at higher transmit power thereby causing co-tier interference to its neighbors.

Distributed Random Access (DRA) needs to iteratively hash resources of each femtocell. If there are more neighboring femtocells, hash collision occurs more often. When hash collision occurs, the DRA uses a iterations to find the reallocated resources. There are mainly 2 types of DRA. That are Low-Loading(LL) and High-Loading(HL). In LL arrival rates are intended for home or office usage; therefore, we called it low-loading (LL) scenario. In addition, we assume HL scenario for crowded public environments, such as department stores or subway stations. The main idea of HL is to increase the arrival rate of each QCI to ten times the arrival rate in LL.

2.2 System madel

The proposed idea of this scheme is to mitigate downlink interference from Femtocell BS to MUEs and FUEs through on request channel allocation. Soft Frequency Reuse (SFR) method is considered here. For SFR usually the cell-center users are not affected by other cell-center users even though they share the same PRB because cell-center users are limited to a lower level power and the distance between a cell-center user and the adjacent eNode Bs is usually long enough to ensure large path loss, thus further reducing the received interfering power. Therefore, we only consider the mutual interference between serving cell-edge users and cell-edge users from different cells while simultaneously using the same PRB is considered here.

A number of randomly distributed indoor and outdoor environments with Macrocells, Femtocells and mobile stations are defined. A cell layout consists of seven hexagonal Macrocells environment, each of them is divided by central zone and edge zone. Edge zone is divided into three sectors.
Each sector has 500 meters radius with 10 MHz bandwidth. The Macrocells are located in residential area where Femtocell base stations are installed in a random location within Macrocells range. Femtocell ranges are around 10 meters. Only one Femtocell user for each Femtocell BS is considered in an indoor environment. Each Macrocell contains a three floor building with a number of apartments. There is a street between the two stripes of these apartments. Assume that the Femtocell BSs from different blocks are not too close to each other. All Femtocells users are located within Femtocell range and Macrocell users are normally located randomly throughout the cell. Also some Macrocells users are located within Femtocell range. Each Femtocell operates in a closed subscriber group (CSG). CSG is chosen because when a Macrocells user enters within Femtocell range and if the user receives stronger signal at the time from the Femtocell base station then interference occurs.

The Macrocell coverage is divided into centre zone and edge zone. Edge zone has three sectors covers 120 degree each denoted by sub-area A, B, C. Each sub area has 60 degree virtual sub sectors denoted in small letters a, b and c which are allocated as the same frequency sub-band and power of A, B and C respectively. For Macrocell, different frequency sub-band (PRBs) is allocated to the each Macrocell sub-area according to the FFR. Consider the total number of PRBs is N. Number of PRB allocated for center zone is 2/3N and for edge zone is N/3. Also consider N/3 is the sum of PRB N_1, N_2 and N_3 allocated for sub-area A, B and C respectively. As mentioned above, only edge zone is considered and it is focused on only one sector, i.e. A for PRB allocation. The other two sectors are treated in a similar manner. The total number PRBs of N1 can be used at Macro layer.

2.3 Varied Power Allocation

Cell-edge users suffer from heavy ICI and relatively low performance in the multicell OFDMA networks. The cell-edge user performance can be improved by providing better signal power on cell-edge user's carrier signal, but doing so would have an adverse effect on cell-center users (possible cause of outage for center users), so an optimal power distribution design has to be developed which would provide better power and throughput to edge users simultaneously taking care of center user throughput.

This can be treated as constrained optimization problem where main objective would be maximizing cell-edge user throughput or rate equation subjected to few constrains like SNR/rate of center user maintained above certain threshold, total power distributed to the user of a cell is below or limited to serving base station maximum transmission power etc.. With these constrains an optimal solution (weight factors) for power distribution will be determined and used for rate computation. The power optimization is formulated as an iterative barrier-constrained water-filling problem and solved by using the Lagrange method. Simulation results indicate that our proposed scheme can achieve significantly balanced performance improvement between cell-edge and cell-center users in multi-cell networks compared with other schemes, and therefore realize the goal of future wireless networks in terms of providing high performance to anyone from anywhere.

The transmission power is allowed to be independently allocated on each active PRB that has been assigned to users in the network. Hence, dynamic or fixed power allocation can be performed depending on different given schemes. The sum of the overall allocated power in each cell cannot exceed the maximum transmission power of the BS. We assume that all BSs in the network are given the same maximum transmission power. Here we allocate power according to SINR which is computed as a function of distance based pathloss systems.

2.4 Calculations

For Femtocell user FUE F received SINR is given as follows:

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$$SINR_{F,K} = \frac{P_{F,k} * P_{l,F,m,k} * X_{F,k}}{N_0 + \sum_{F'} P_{F',k} * P_{l,F',m,k} * X_{F',k} + \sum_{M} P_{M,m,k} * P_{l,M,m,k} * X_{M,m,k}} \quad (1)$$

where,

$P_{F,k}$, $P_{F',k}$ and $P_{M,m,k}$ denote the transmit powers from serving Femtocell Base Station (SFBS), neigbour Femtocell Base Stations (NFBS) and Macrocell Base Stations (MBS)respectively on PRB k. $P_{l,F,m,k}$ represents the path loss between FUE F and its serving BS l. $P_{l,F',m,k}$ represents path loss between FUE F and its neigbour Femtocell BS which is known as interfering signal on F. $P_{l,M,m,k}$ represents path loss between FUE and neighbor Macrocell BS. $X_{F,k}$ = 1, when FUE F requests PRB k from Macro BS through Femto BS to occupy PRB k and then SINR will be calculated for FUE F on PRB k. When $X_{F,k}$ =l, then $X_{F',k}$ = 0 and $X_{M,m,k}$ = 0 because one PRB cannot be shared by more than one user at a time. If $X_{M,m,k}$ = 0, it means there is no PRB occupied by the user F and then SINR for the user F will be zero.

Path loss models are used to represent indoor, outdoor, and indoor-to-outdoor (and vice versa) channel environments. These are best suited for a dense urban Femtocell deployment. Path loss LS is determined by the distance between the transmitter and receiver for each subcarrier. Three models for the channel path loss are described here.

- UE to Femto-BS: The path loss LS for interfering and non-interfering links between a Femto UE or a Macro UE and a Femto-BS is expressed as

  $$LS = 127 + 30log10\,(d/1000) \quad (2)$$

  where path loss LS is in dB, d (meters) is the distance between transmitter and receiver. Macro cell propagation model for urban area is applicable for scenarios in urban and suburban areas outside the high rise core where buildings are of nearly uniform height (3GPP TR 36.942). Assuming that the base station antenna height is fixed at 15 m above the rooftop, and a carrier frequency of 2 GHz is used, the path loss L can be expressed as above. (3GPP TR 136.931).
- Outdoor UE to Macro-BS: Path loss for non-interfering link between outdoor M-UE and serving M-BS as well as interfering links between outdoor Macro-UE and neighbouring Macro BS is calculated as

  $$LS = 15.3 + 37.60log10\,(d) \quad (3)$$

  (3GPP TR 36.814) Heterogeneous system simulation baseline parameters.
- Indoor UE to M-BS: This path loss model takes into account the wall penetration loss (L W) as the signal travels from indoor to outdoor and vice versa between an indoor located UE (Macro-UElFemto-UE) and MacroBS. This is calculated as

  $$LS = 15.3 + 37.60\ log10\,(d) + Lw \quad (4)$$

  (3GPP TR 36.814) Heterogeneous system simulation baseline parameters.

3 Results

The transmission power is allowed to be independently allocated on each active PRB that has been assigned to users in the network. Hence, dynamic or fixed power allocation can be performed depending on different given schemes. The sum of the overall allocated power in each cell cannot exceed the maximum transmission power of the BS. We assume that all BSs in the network are given the same maximum transmission power. Here we allocate power according to SINR which is computed as a function of distance based pathloss systems.

Simulation Settings and Parameters In this work an LTE based cellular system is simulated. The simulation follows the LTE downlink described in the above .A 1 tier (7-cell) system layout is simulated with users randomly distributed in each cell. Each cell is assumed to have a base station with a 3 sector antenna system at the center of a cell. This can easily be extended to a smart antenna or Tower Mounted Amplifier (TMA) based cell layout, but since the purpose of this thesis is to demonstrate the performance of varied power PRB scheme, we focus only on the trisector setting. The radius of each of the hexagonal cells is R = .6 km. The inner radius for FFR schemes is given as αR, where alpha takes values from 0 to 1 as discussed in above section. Consider cell radius ratio of 60%. The total bandwidth of the system is 10 MHz. The spectrum is divided into 25 RBs each having a bandwidth of 375 KHz. The total transmit power is set to 43 dBm / 20 W. There are 6 users in each cell and are randomly placed over the cell system. There are 2 users with every Femto Access Points (FAP). The number of femto cells varies from 0 to 270. Here too tri-sector FFR scheme is used with FAP power of 13.01 dBm / 20 mW. The PRB allocation scheme is above mentioned with virtual sectors and are allocated with varied power for femto cells too. The scheduling method used for all of the four schemes is Round Robin (RR) scheduling algorithm, where users take turns using RBs over a period of time (frame).

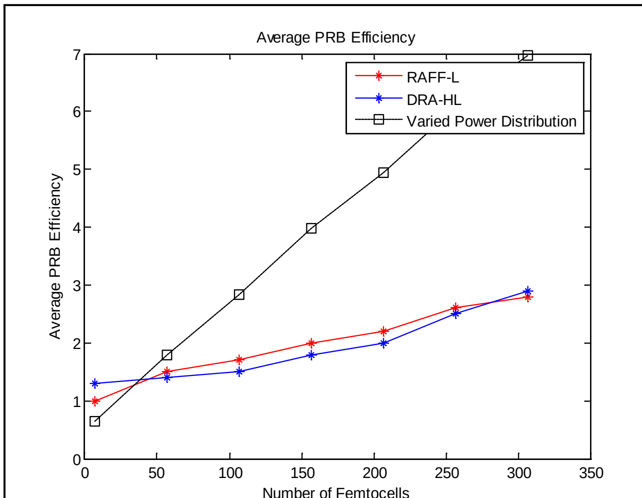

Fig. 2. Average PRB Efficiency in Femto system

Figure 2 shows the average PRB efficiency with respect to the number of femtocells. The simulation result shows a significant improvement by proposed method in the average PRB efficiency. Our proposed scheme has lower average PRB effi-

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ciency compared with DRA-HL and RAFF-LL when the number of femtocells is between 0 and 45. After 45 the PRB efficieny increases tremendously; however, the average PRB efficiency still improves 41 % by the varied power PRB allocation method. The PRB efficiency is higher when the number of femtocell is between 50 and 250 compared with DRA-HL and RAFF -LL. The computations needed for the proposed scheme needs more skill and it also needs improved hardware designs like smart antennas. Algorithm is not simple like DRA-HL and RAFF –LL but the throughput in terms of spectral efficiency is very high. This is because as the number of femto cells increases the allocation of PRBs in macro cells as well as femto cells become efficient and it is based on distance based power allocation which is needed for a user.

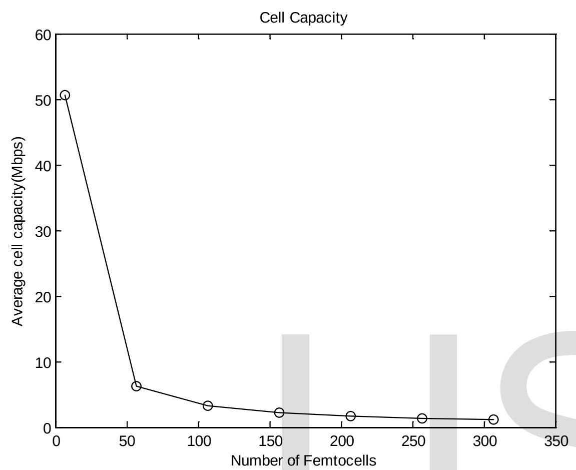

Fig. 3. Average Cell Capacity for Proposed system

Figure 3 shows the average cell capacity of macro cell system with number of Femto cells. The average system capacity is increased when the number of femtocell users is reduced in the macro cell edge zone area. Specifically for the case of 50 to 100 Femto users, the capacity of the Femto user is satisfactory as up to this number of femtocells is enough to share a specific number of frequency channels without any interference. Thus the average cell capacity of the proposed scheme is higher. As the number of femto cells increases from 0 to 50 the capacity decreases from 50 Mbps to 10 Mbps. Almost 70% decrease in capacity. This is because as the number of femto cells increases the interference of signals in macro cells as well as femto cells increases due to inter and intra e Node Bs as well as FAPs.

Figure 4 shows the cell center capacity of macro cell system with number of Femto cells. The cell radius ratio have a key role in cell-center as well as cell-edge capacity of macro as weel as femto cells. That is because as a increases, the number of inner RBs increase and the increase in resource could mitigate the resource shortage by the increase in inner cell area, which increases the number of inner cell users. Form the figure it is clear that while the femto cell number increases from 0 to 50 the cell-center capacity get decreases from 26 Mbps to 4 Mbps. The reason is same in both cases and is because as the number of femto cells increases the interference of signals in macro cells as well as femto cells increases due to inter and intra e Node Bs as well as FAPs. So the increase in femto cell can limit the over all cell capacity which were also discussed in previous studies. Here the decrease in capacity is 44% for the 50 FAPS. But from 50 to 100 its changing from 4 Mbps to 2 Mbps and the decaying rate is 4% and for the increment in next 50 femto cells the decay rate is lower.

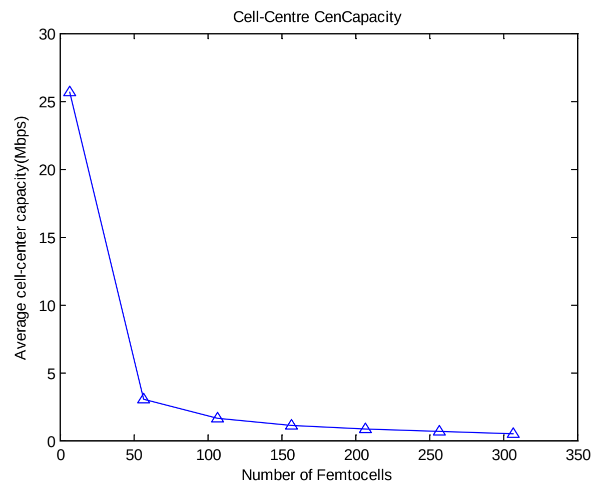

Fig. 4. Cell center Capacity for Proposed system

Figure 5 shows the cell edge capacity of macro cell system with number of Femto cells. The cell radius ratio have a key role in cell-center as well as cell-edge capacity of macro as weel as femto cells. That is because as the cell radius ratio increases, the number of inner users increases leading to an increase in interference for cell-edge users between adjacent cells. Similarly, the SINR for inner cell users decreases as the ratio increases. Form the figure it is clear that while the femto cell number increases from 0 to 50 the cell-center capacity get decreases from 4.2 Mbps to 0.2 Mbps. The reason is same in both cases and is because as the number of femto cells increases the interference of signals in macro cells as well as femto cells increases due to inter and intra e Node Bs as well as FAPs.

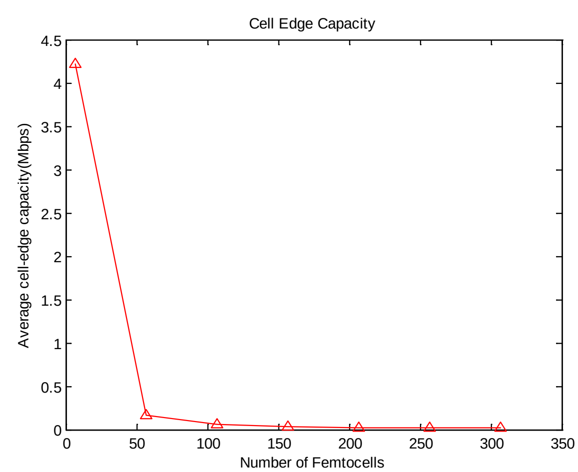

Fig. 5. Cell edge Capacity for Proposed system

4 Conclusion

Femtocell technology can provide many advantages to the mobile subscribers and the service providers. Thus, femtocells could be viewed as a promising option for next generation wireless communication networks such as OFDMA-based LTE networks. However, there is interference problem due to lack of proper frequency band allocation method. In this thesis, an interference mitigation technique based on channel allocation knowledge is proposed that allows the Femtocells or Macro-cell edge users to access PRBs ON REQUEST with VARIED POWER basis to satisfy the increasing demand on higher data rate. The main advantage of the proposed method is that it can save more spectrum as it is on request based PRB allocation. The simulation results have shown that the proposed 'On Request Varied power' method can reduce the interferences through increasing the throughput. Furthennore, this increase is obtained without any decrease in the quality of service. If the bandwidth allocated to the system is large, the number of opportunistic sub-channels would be increased and system performance will also be improved.

REFERENCES

[1] S. Srikanth, P. Murugesa Pandian, and X. Fernando, "Orthogonal frequency division multiple access in WiMAX and LTE: a comparison," Communications Magazine, IEEE, vol. SO, no. 9, pp. IS3-161, 2012.

[2] I. Katzela and M. Naghshineh, "Channel assignment schemes for cellular mobile telecommunication systems: a comprehensive survey," Personal Communications, IEEE, vol. 3, no. 3, pp. 10-31, 1996.

[3] J. Choi and S. Choi, "Multichannel sharing and joint detection for cell-edge users in downlink multicell OFDMA systems," Vehicular Technology, IEEE Transactions on, vol. 60, no. 4, pp. 1894-1898,2011.

[4] 3GPP, TR2S.814 V l.O.2, "Physical layer aspects for evolved UTRA,"January 2006.

[5] S. Cicalo, V. Tralli, and A. Perez-Neira, "Centralized vs distributed resource allocation in multi-cell ofdma systems," in Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd, 2011, pp. 1-6.

[6] Y. Yu, E. Dutkiewicz, X. Huang, M. Mueck, and G. Fang, "Performance analysis of soft frequency reuse for inter-cell interference coordination in Ite networks," in Communications and Information Technologies (ISCIT), 20]0 International Symposium on, 2010, pp. S04-S09.

[7] R. Y. Chang, Z. Tao, J. Zhang, and C.-c. J. Kuo, "Dynamic fractional frequency reuse (D-FFR) for multicell ofdma networks using a graph framework," Wireless Communications and Mobile Computing, vol. 13, no. 1, pp. 12-27, 2013. [Online]. Available:http://dx.doi.org/10.1002/wcm.1088

[8] A. Hamza, S. Khalifa, H. Hamza, and K. Elsayed, "A survey on inter-cell interference coordination techniques in ofdma-based cellular networks," pp. 1-29,2013.

[9] R. Kwan and C. Leung, "A survey of scheduling and interference mitigation in lie," lECE, vol. 2010, pp. 1:1-1:10, Jan. 2010. [Online]. Available: http://dx.doi.org/IO.IISSI2010/273486

[10] M. Sternad, T. Ottosson, A. Ahlen, and A. Svensson, "Attaining both coverage and high spectral efficiency with adaptive ofdm downlinks," in Vehicular Technology Conference, 2003. VTC 20OJ-Fall. 2003 IEEE 58th, vol. 4, 2003, pp. 2486-2490 Vol.4.

[11] Ericsson, "R 1-0S0764: Inter-cell interference handling for E-UTRA," 3GPP TSG RAN WG] Meeting #42, 200S.

[12] C. He, F. Liu, H. Yang, C. Chen, H. Sun, W. May, and 1. Zhang, "Co-channel interference mitigation in mimo-ofdm system," in Wireless Communications, Networking and Mobile Computing, 2007. WiCom 2007. International Conference on, 2007, pp. 204-208.

[13] Huawei, " RI-0S0S07: Soft frequency reuse scheme for UTRAN LTE," 3GPP TSG RAN WG] Meeting #42, May 200S.

[14] T. Novlan, 1. Andrews, I. Sohn, R. Ganti, and A. Ghosh, "Comparison of fractional frequency reuse approaches in the OFDMA cellular downlink," in Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE, 2010, pp. I-S. [lS] 3GPP, TR36.942 V 8.2.0, "Evolved universal teristerial radio

[15] [15] Jayasankar.S, Surya Narayanan, Linu.R.Venu, Aswin Prasannan, Lekshmi Gangadhar, " LTE Access network simulation " , IJLTET , July 2013

[16] Dodd.A.Z., Eylert.B., Scrase.A, " The WiMAX (IEEE 802.16 standard)" Xichun Li, Abdullah Gani, Lina Yang, Omar Zakaria, Nor Badrul Anuar, "Migration towards 4G wireless communications".

[17] Toni Janevski , " 5G Mobile Phone Concept , Consumer Communications and Networking Conference ", 2009 6th IEEE.

[18] E. Dahlman , " 3G Evolution: HSPA and LTE for Mobile Broadband ", 2nd ed., Academic Press, 2008

[19] Development of 3G mobile services , OECD Report, Sept. 2004.