Analysis of LTE Wireless Network Using Joint Subcarrier and Power Allocation Optimization Algorithm

Kamaljit Kaur, Er. Sonia
Department of Electronics and Comm. Engg, Baba Banda Singh Bahadur College of Engg Fatehgarh sahib, INDIA.
kamalkaur732@gmail.com, sonia.malhotra@bbsbec.ac.in

Abstract: Different low complexity algorithms for proportional resource allocation in LTE and Wireless Network using OFDM signal are used by different researchers already. In this paper, the optimization algorithm is analyzed for a joint subcarrier and power allocation method for LTE Wireless Network using OFDM signal. It is used for the improvement of the spectrum efficiency and check tradeoff between capacity and fairness The impact of imperfect spectrum is introduced so that sensing can be discussed in the proposed problem. In the optimization algorithm, the main issue for discussion is fairness related and it is analyzed by defining a lower bound of allowable number of subcarriers allocated to the wireless network. Here, the target of the optimization algorithm is to provide the sub-carriers assignment and power allocation for each user, assuming that the modulation type is the same for all subcarriers. However, in order to increase the efficiency of the algorithm and reduce the optimization delay, it has been assumed that the power is equally distributed among the sub-carriers. Efficiency before and after applying optimization algorithm is analyzed.
Keywords: LTE ,OFDM, Optimization algorithm, spectrum efficiency, capacity, fairness.

1. Introduction

In this paper,the goal is to introduce a joint subcarrier and power allocation method for LTE Wireless Network using OFDM signal. As this is new standard for transmission so it is necessary to find out the parameters under which this technology can perform better. In this work, objective is to find the impact of imperfect spectrum sensing to study the decrease in capacity of the LTE Wireless network. To fulfill the objective of this research work, joint subcarrier and power allocation optimization algorithm is introduced for LTE wireless Network based on OFDM signals. Then LTE wireless network is studied for imperfect spectrum sensing when the network is imperfect and the condition is to check the decrease in capacity of the network. After that the fairness factor of the network by using the optimization algorithm is studied when the lower bound of allowable number of subcarriers allocated to the wireless network is defined beforehand. The optimization algorithm will be analyzed for the improvement of the spectrum efficiency and check tradeoff between capacity and fairness for wireless networks in a low algorithm complexity. Performance of network before and after applying joint subcarrier and power allocation optimization algorithm is also analyzed.

For this, a modulation is designed that integrates network coding and dynamic subcarrier assignment in OFDM wireless networks [2]. The subcarrier assignment scheme is formulated , and optimized algorithm is proposed . The simulations in the frequency selective fading environment and under 802.16 like settings have demonstrated that network coding can more efficiently utilize the available subcarriers in the base paper. The coding-aware scheme results in considerably higher network throughput without causing additional overhead when compared with adaptive assignment algorithms without network coding.

Simulations for the minimum user's capacity are done and then compared with other parameters [1]. In this paper a suboptimal algorithm is proposed to achieve near optimal capacity using adaptive subcarrier allocation. However, the suboptimal algorithm assumes that equal power is distributed into every subcarrier and same thing is considered for the subcarriers with the difference that the number of subcarriers are chosen to be more as compared to the base paper. Here, the algorithm also behaves differently when the number of users changes. When the number of users increases, equal power distribution does not equalize every user's capacity. By transferring power from the users with high capacity to the users with low capacity, the minimum user's capacity could be even increased. Also, fairness and capacity parameters are calculated for base 64 allocation/modulation method. The change in capacity and fairness is shown with respect to the various subcarriers. This paper is organized as follows. Sec. 2 presents a literature review of existing work on resource allocation and optimization algorithm. Sec. 3 describes the system model and then designed proposed algorithm in Sec. 4. Simulation results are presented in Section 5. Conclusions are drawn in Section 6.

2. Related work

A cross layer approach towards a network coding aware subcarrier assignment algorithm is adopted in [3] for the uplink and downlink of OFDMA based wireless networks. Here ,the optimization algorithm is applied to compare three subcarrier allocation schemes: The coding aware dynamic subcarrier assignment (CADSA) algorithm, Adaptive subcarrier assignment without network coding (NOCODE), Randomized subcarrier allocation mechanism (RAND) but not for base 64 allocation.
In [1,2] simulations for the minimum user's capacity are done and then compared with other parameters. In this paper a suboptimal algorithm is proposed to achieve near optimal capacity using adaptive subcarrier allocation. However, the suboptimal algorithm assumes that equal power is distributed into every subcarrier and same thing is considered for the subcarriers with the difference that we have chosen the number of subcarriers to be more as compared to the base paper. Here the algorithm also behaves differently when the number of users changes. Also, the performance of the proportional fairness algorithm in realistic conditions with large numbers of users with scattered locations throughout the cell is examined [5].Comparison of proportional fairness algorithm is carried out with sum rate maximization algorithm. Whereas in this work, change in capacity and fairness are shown with respect to the various subcarriers. In [6,13] an algorithm is proposed that performs both joint subcarrier and power allocation and this algorithm is used here for capacity and fairness.

3. Present work

A. System model

In the algorithm used for this work, at the base station, all channel information is sent to the subcarrier and power allocation algorithm through feedback channels from all mobile users. The resource allocation scheme made by the algorithm is forwarded to the OFDM transmitter. The transmitter then selects different numbers of bits from different users to form an OFDM symbol. The resource allocation scheme is updated as fast as the channel information is collected. The perfect instantaneous channel information is assumed to be available at the base station and only the broadcast scenario is included. It is also assumed that the subchannel and bit allocation information are sent to each user by a separate channel. The above two assumptions are not practical in real wireless environments. Effective methods to relax these assumptions are also included in the algorithm. Subcarriers and power is allocated jointly to achieve the optimal solution. However, this had posed an extremely heavy computational burden at the base station in order to reach an optimal allocation. Furthermore, the base station has to rapidly compute the optimal subcarrier and power allocation if the wireless channel changes quickly. Hence suboptimal algorithms with lower complexity are preferred for cost-effective implementations.

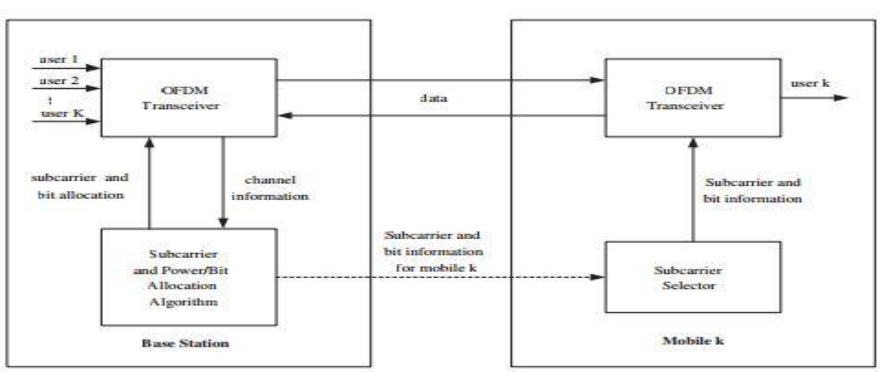

Fig 1. Multiuser OFDM System

Separating the subcarrier and power allocation is a way to reduce the complexity since the number of variables in the objective function is almost reduced by half. Since the subcarrier allocation is performed before the power allocation, the optimization problem considered in this thesis is formulated on the basis of the following equations:

$$\max_{p_{k,n}} \sum_{k=1}^{K} \sum_{n \in \Omega_k} \frac{1}{N} \log_2 \left(1 + \frac{p_{k,n} h_{k,n}^2}{N_0 \frac{B}{N}}\right)$$

$$\begin{aligned} \text{subject to:} \quad & \sum_{k=1}^{K} \sum_{n \in \Omega_k} p_{k,n} \leq P_{total} \\ & p_{k,n} \geq 0 \text{ for all } k, n \\ & \Omega_k \text{ are disjoint for all } k \\ & \Omega_1 \cup \Omega_2 \cup ... \cup \Omega_K \subseteq \{1, 2, ..., N\} \\ & R_1 : R_2 : ... : R_K = \gamma_1 : \gamma_2 : ... : \gamma_K \end{aligned} \qquad (1)$$

where K is the total number of users; N is the total number of subcarriers; $N0$ is the power spectrum density of additive white Gaussian noise; B and $Ptotal$ are the overall available bandwidth and power, respectively; pk,n is the power allocation for user k in the subcarrier n; hk,n is the channel gain for user k in subcarrier n; Ωk is the set of subcarriers for user k and in Ωk; Rk is the channel capacity for user k Rk is the channel capacity for user k

In the algorithm defined below, for a certain user k, there is no power allocation if Vk > Pk,tot. This situation could happen when a subcarrier is allocated to a user who does not have a high channel gain in that subcarrier. The greedy capacity algorithm would rather stop using this subcarrier. In case this situation happens, the set of Ωk, as wellas the corresponding values of Nk, Vk and Wk, would need to be updated and the power allocation algorithm used in this work should be executed again. In the case where the channel-to-noise ratio is high, there is one and only one solution to equation given above. Since every term in the summation monotonically increases and system has different signs at P1,tot = 0 and P1,tot = Ptotal. The complexity of finding the solution will primarily rely on the choice of the numerical algorithm and the precision required in the results. After P1,tot is found, {Pk,tot}Kk=2 can be calculated. Then the overall power allocation scheme is determined.

4. Proposed Algorithm

In the simulations presented in this paper, the suboptimal algorithm is used to allocate the subcarriers and then apply the optimal power allocation scheme proposed.

The suboptimal optimization algorithm is as follows:

1) Initialization

set Rk = 0 , Ωk = . for k = 1, 2, ...,K and A =

{1, 2, ...,N}

2) for k = 1 to K

a) find n satisfying | Hk,n |≥| Hk,j | for all j ∈ A

b) let Ωk = Ωk ∪ {n} , A = A − {n} and update Rk

according to (2)

3) while A _= .

a) find k satisfying Rk ≤ Ri for all i , 0 ≤ i ≤ K

b) for the found k , find n satisfying | Hk,n |≥| Hk,j |

for all $j \in A$

c) for the found k and n , let $\Omega k = \Omega k \cup \{n\}$, $A = A - \{n\}$ and update Rk

By taking into consideration the power allocation, perform the following steps of the optimization algorithm:

1. repeat

2. for all session r do

3. if current uplink rate <= downlink rate then

4. Assign the best subcarrier to the uplink of r

5. end if

6. end for

7. Let Mr = uplink rate − downlink rate of session r .

phi is the set of sessions that have coding opportunities.

8. for all session r 2 _,Mr > 0 do

9. Initialize Rmax = 0, Dmin = unlimited.

10. for all s > r and s can be encoded with r do

11. for all unused subcarrier c do

12. T = min(R(c, rdst),R(c, sdst)),

D = |R(c, rdst) − R(c, sdst)|

13. if T > Rmax OR

(T == Rmax and D < Dmin) then

14. Rmax = T,Dmin = D, phi= c, phi= s .phi

15. end if

16. end for

17. end for

18. Encode session r and phi . Assign subcarrier phi to both.

19. end for

20. for all session r /2 phi do

21. Allocate the best unused subcarrier to its downlink.

22. end for

23. until No subcarrier is allocated in the last loop.

5. Simulation Results

A. Capacity increase of the LTE wireless network

In figure, the capacity increase of the LTE wireless radio network is shown. Goal is to generate baseband multi-frequency signal with maximum capaciyu when there are proper input parameters for the subcarriers are considered. The bandwidth of the used signal is 10MHz which contains 64 subcarriers. If we increase the number of subcarriers then the noise level increases and the capacity being indirectly proportional to noise decreses.

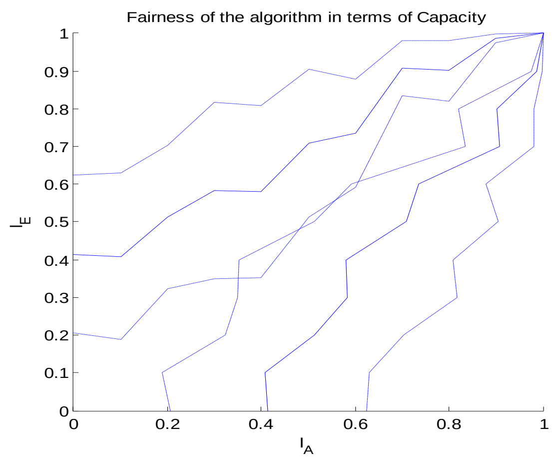

Fig 2. Capacity increase

B. Fairness of Network based on Optimization Algorithm

In the graph shown below (fig.3), the behavior of different subcarriers is shown. If it is straight line diagonally then it means that both efficiency and fairness are increasing. But if it is horizontal or vertical line then one parameters in increasing while the other parameter is constant. The subcarriers in which the value are plotted at different levels, there the efficiency is increasing/ decreasing with different parameters.

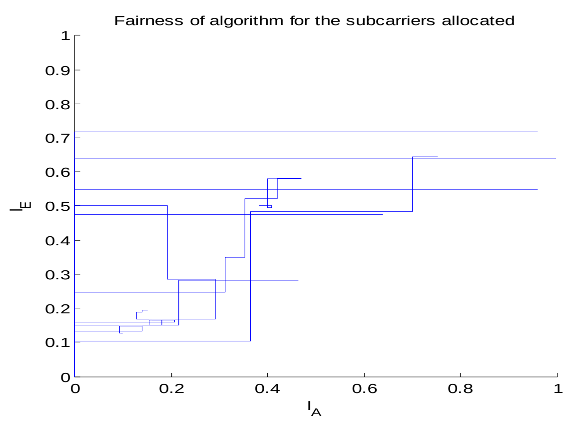

Fig 3. Fairness based on subcarriers

The optimization algorithm is implemented and its performance is analyzed for the improvement of the spectrum efficiency and check tradeoff between capacity and fairness for wireless networks in a low algorithm complexity. However, the change in parameters is not drastic but still we have tried and tested the parameters so that we can get results based on the solution which is provided by the optimization module. The optimization algorithm had been iterated to check the change in the values with time and the graph shown below is one snapshot of the graph (fig.4).

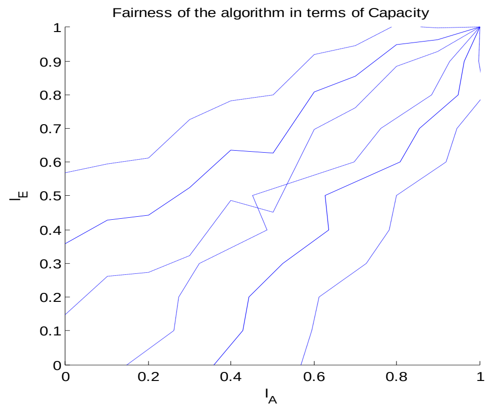

Fig 4. Fairness in terms of capacity

D. Optimization results

Fairness of SubCarrier	Change in value
67	4
79	5
85	3
100	2
91	3
64	4
76	3
88	4
97	3

Table1. Fairness

The fairness of the subcarriers is shown after the optimization of the algorithm was performed. The fairness for one of the sub carriers is 100% and the lowest value is 67% which can be improved further if the more number of iterations are performed.

E. Performance of the LTE wireless network

The efficiency of the 16 subcarriers is calculated before the optimization algorithm is applied. For the un-optimized network, when the network is tested for efficiency then its final value is 1.0000 after it diverges to a value in which all the subcarriers reaches their ideal stage. After that, using optimization algorithm optimizes the wireless network and efficiency value increases up to 1.3274 before all the subcarriers reaches their ideal stage. So the increase in the efficiency is a factor of 0.3274 or approx. 33%.

In figure 5, the performance of the subcarriers is shown after the optimization algorithm is applied. The performance is maximum when the subcarrier is 1, remains constant when the numbers of subcarriers are increased but decreases when it reaches 5.

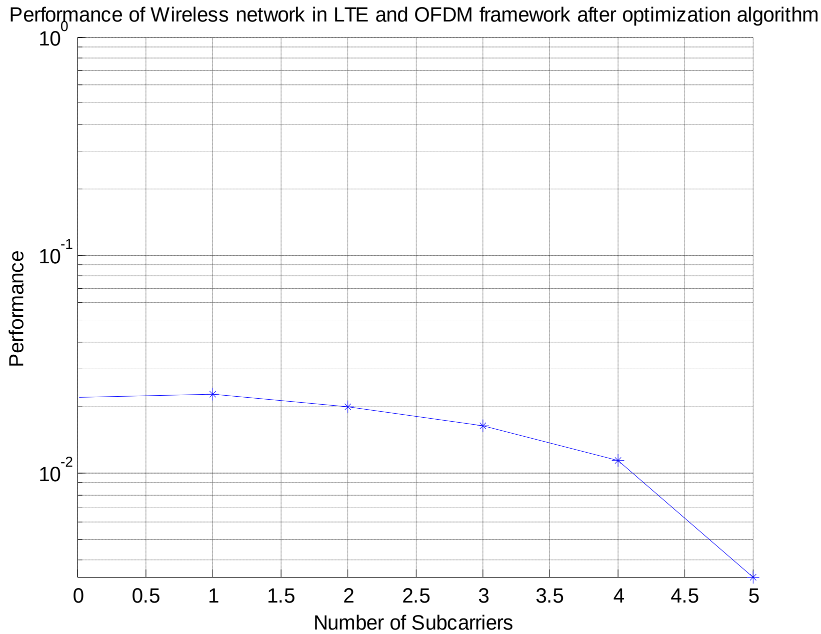

Fig 5. Performance after optimization algorithm

In figure 6, the performance of the subcarriers is shown before the optimization algorithm is applied. The behaviour of the subcarrier remains the same but the performance parameter decreases as compared to optimized network. Performance is maximum when the subcarrier is 1, remains constant when the numbers of subcarriers are increased but decreases when it reaches 3.

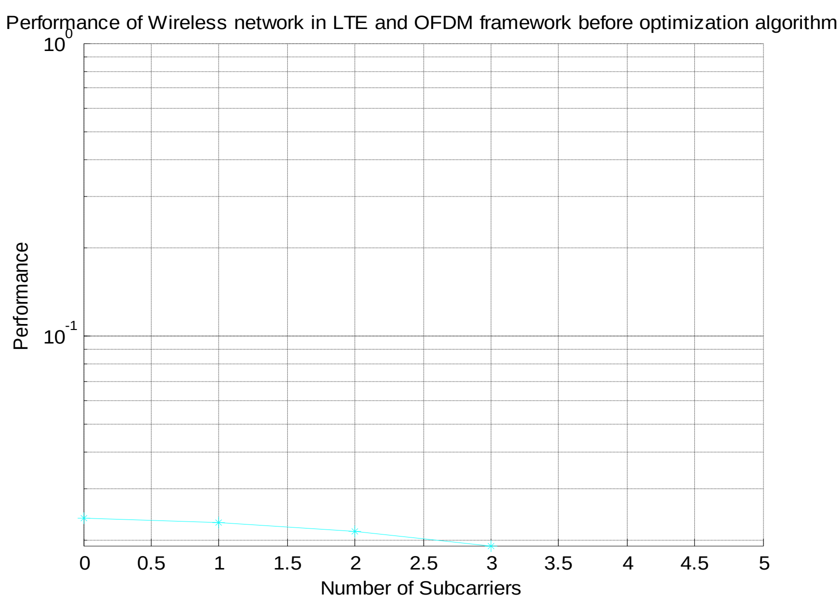

Fig 6. Performance before optimization algorithm

6. Conclusions

This paper presents the vision and challenge for the implementation and simulation of the wireless sensor network to wireless radio network. The goal of the conceptual design is utilize the key features of the wireless radio network as possible as it can, like the efficient spectrum utilization, software defined radio, etc. Although the simulation is based on the single transmitter and receiver, it had shown the big potential of large scale wireless sensor network based on the wireless radio network. The fairness of the subcarriers is shown after the optimization of the algorithm was performed. The fairness for one of the sub carriers is 100% and the lowest value is 67% which can be improved further if the more number of iterations are performed.

Also,the LTE wireless network using OFDM is optimized by using an algorithm. The efficiency and performance of this network is improved approx. by 33%. The number of subcarriers also affects the performance of the network. Initially with minimum number of subcarriers, the performance is highest, after that it remains constant for certain number of subcarriers and then it performance starts decreasing. We can optimize the LTE network and increase its performance by using less number of sub carriers and by increasing its efficiency. The basic simulation done here can be extended further to improve its various parameters. In the simulation of this research work, multi-frequency signal is used instead of real OFDM signal. In future, the real OFDM signal can be implemented to find more issues if real wireless radio network is used as wireless sensor network.

References

[1] Zukang Shen; Andrews, J.G.; Evans, B.L. Evans,"Optimal power allocation in multiuser OFDM systems" in Proc. Global Telecommunications Conference, vol. 1,pp. 337-341,Dec 2003.

[2] W. Rhee and J. M. Cioffi, "Increasing in Capacity of Multiuser OFDM System Using Dynamic Subchannel Allocation," in *Proc. IEEE International Vehicular Technology Conference*, vol. 2, pp. 1085-1089, May 2000.

[3] Xinyu Zhang; Baochun Li "Joint Network Coding and Subcarrier Assignment in OFDMA-Based WVireless Networks" in Proc. Network Coding, Theory and Applications, 2008. NetCod 2008. Fourth Workshop ,pp.1-6, Jan 2008.

[4] C. Wong, R. S. Cheng, K. Letaief, and R. Murch, "Multiuser OFDM with Adaptive Subcarrier, Bit, and Power Allocation," in IEEE JSAC, vol. 17, no. 10, Oct 1999.

[5] Z. Shen, J. G. Andrews, and B. L. Evans, "Adaptive Resource Allocation in Multiuser OFDM Systems With Proportional Rate Constraints," IEEE Transactions on Wireless Communications, vol. 4, no. 6, 2005.

[6] C. Mohanram, S. Bhashyam," A sub-optimal joint subcarrier and power allocation algorithm for multiuser OFDM" in IEEE Communications Letters, 9(8) ,pp.685-687,Aug 2005.

[7] E. Dahlman, H. Ekstrom, A. Furuskar, A. Kangas, J. Karlsson, M. Lundevall, and S. Parkvall, "The 3g long-term evolution – radio interface concepts and performance evaluation", in Vehicular Technology Conference, 2006, vol. 1, pp. 137–141.

[8] K. Kim, Y. Han, S. L. Kim,"Joint subcarrier and power allocation in uplink OFDMA systems", IEEE Communications Letters, 9(6), Jun. 2005, 526-528

[9] C. Ng, C. Sung, "Low complexity subcarrier and power allocation for utility maximization in uplink OFDMA systems", IEEE Transactions on Wireless Communications, 7(5), May 2008, 1667-1675

[10] R. Hoshyar, M. Shariat, R. Tafazolli, "Subcarrier and power allocation with multiple power constraints in OFDMA systems", IEEE Communications Letters, 14(7), Jul. 2010, 644-646

[11] C. Wong, R. S. Cheng, K. B. Letaief, R. D. Murch, Multiuser OFDM with adaptive subcarrier, bit, and power allocation, IEEE Journal on Selected Areas in Communications, 17(10), Oct. 1999,1747-1758

[12] D. T. Ngo and L. N. Tho, "Distributed resource allocation for Wireless networks with spectrum-sharing constraints," *IEEE Transactions on Vehicular Technology*, vol. 56, no. 7, pp. 3436-3449, September, 2011. Article (CrossRef Link)[13] Y. Zhang and C. Leung, "Resource allocation in an OFDM–based Wireless system," *IEEE Transactions on Communications*, vol. 57, no. 7, pp. 1928-1931, July, 2009. Article (CrossRef Link)