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A Survey on Joint Uplink/Downlink Resource Allocation in OFDMA Networks

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ABSTRACT: Resource allocation is one of the major considerations in efficient usage of a wireless network. Emergence of new computing/ communication platforms have resulted in usage of such technologies for applications such as mobile gaming, video conferencing etc; these trends in turn places greater demand on symmetrical quality. Existing literature mainly focuses on resource allocation for uplink and downlink directions independently. In this paper, a tutorial on resource allocation for OFDMA systems for both directions is presented under various resource allocation scenarios.

KEYWORDS: OFDMA, resource allocation, uplink/downlink, scheduling.

I.INTRODUCTION

Wireless communication is enjoying its fastest growth in history, due to various technologies which support its widespread deployment. Yet the demands for capacity, driven by cellular networks, internet and multimedia services have been rapidly increasing worldwide [1]. While the demand for data rates and the performance of the signal processors increase exponentially, the spectrum and bandwidth are limited. The system thereby faces many challenges to satisfy the high expectations through the narrow pipeline of the wireless channels.

The Long Term Evolution (LTE) was introduced inorder to meet the high expectations of 50Mbps in uplink and 100 Mbps in downlink [2]. OFDMA has been selected as the multiple access schemes for downlink direction and SC-FDMA, which is a variant of OFDMA, in the uplink direction in the 4G/LTE systems. It has been generally accepted that efficient utilization of spectrum and resolution of issues such as multipath fading needs to be focus areas going forward. Multicarrier modulation technique is a promising solution for the above mentioned issues and OFDM is one of its kinds.

In earlier days, it was very difficult to implement an OFDM system due to the difficulty in implementing large number of modulators and filters. However, discovery that OFDM signals could be generated using IFFT and FFT blocks helped in reducing equipment complexity required. The available bandwidth is divided into a number of sub bands with orthogonal subcarriers. Due to orthogonality of the subcarriers, the ICI is eliminated and also guard bands are not required, thereby ensuring efficient utilization of spectrum. Dividing a wide band into a narrow band, effectively converts a frequency selective fading channel into a flat fading channel.

II.OFDMA

The main drawback in OFDM is that only a single user can transmit data through all the sub channels. Inorder to accommodate more users the channels should be multiple accessed. This refers to flat assignment of the resources to the given users. Major setback in this method is that, each user behaves differently in the same given channel. OFDMA comes into picture by allowing multiple users to transmit data simultaneously through the different subcarriers of a single OFDM symbol. Again the subcarriers maybe assigned flat to the users. But this will result in extreme fading losses in particular frequencies and a single user might lose all their data [3]. A more fair approach is necessary and such requirements motivate logical scheduling designs for next-generation wireless communication sector.

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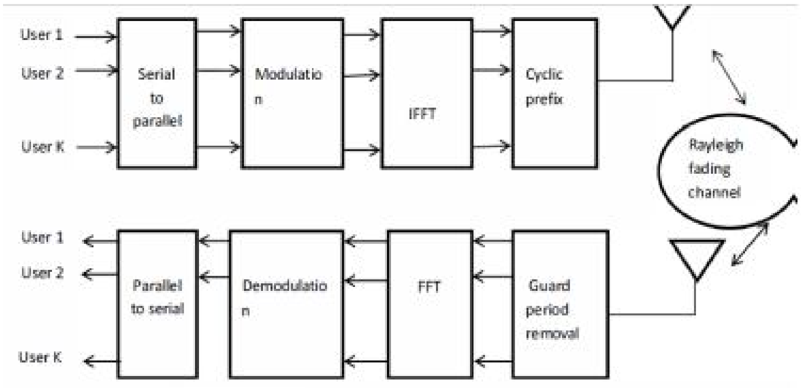

Fig 1. Block diagram of OFDMA

III.RESOURCE ALLOCATION IN OFDMA

OFDMA which is the multiple access technique of OFDM, when combined with dynamic resource allocation techniques takes care of all these issues in a better manner. Allocating the available subcarriers to the users is a great challenge since it determines the performance of the system.The resource allocation algorithms developed for uplink direction may not be applicable for downlink direction due to reasons like power constraints in uplink. Existing literature mainly focuses on optimizing the user's performance on either uplink or in downlink separately. The emergence of various services like mobile gaming, video conferencing etc demand for symmetrical quality in both directions. Such services require new approaches to meet the QoS requirement of the users.

Techniques like mathematical optimization, auction theory, game theory etc. for resource allocation have been investigated in literature and is seen that they exhibit poor performance when applied for joint conditions. Suppose a user has good downlink conditions, it can receive data properly; but if the uplink condition is bad most of the resources get allocated to the users with good channel conditions and therefore his data cannot be received by others. Dynamic subcarrier allocation techniques improve the average throughput of an OFDMA system [4]. In most of the works of resource allocation for joint conditions, a utility function is described and attempts to minimize the divergence in the utility function is performed so that the throughput is maximized.

Hence, in this paper, we present a survey of resource allocation and scheduling techniques in OFDMA wireless networks applicable for both uplink and downlink directions. The various network scenarios like: centralized and distributed, instantaneous and ergodic, single cell and multicell, are also discussed.

IV.RESOURCE ALLOCATION SCENARIOS

The problem of resource allocation can be approached in two ways, namely, margin adaptive and rate adaptive [5]. When the aim is to maximize the data rate keeping into consideration the power constraints it is rate adaptive; and when the aim is to reduce the minimum transmit power it is classified as margin adaptive.

A. *Single cell scheduling*

1) Centralized and Distributed Scheduling: In Centralized Scheduling approach the base station is responsible for allocating resources, both in uplink and downlink directions. Decision made by the base station is then communicated to the mobile users. Margin adaptive and rate adaptive approaches under this scenario have been widely investigated in literature. For margin adaptive approach, the classical Shannon capacity theorem is used to model the rate, while in rate adaptive approach, bit loading is performed to minimize the transmit power. Most of the work have been done with the assumption that channel state information (CSI) is known.

In distributed schemes, mobile users have more autonomy in making decisions. Distributed scheduling is mainly focused on relay based and sensor networks [6]. It is seen to increase coverage and capacity of a network in a cost effective manner. The central base station is connected to a number of remote relay heads (RRH). Using this kind of scheduling technique, the maximum ratio combining (MRC) in uplink will increase the capacity but on contrary the

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performance is degraded due to the presence of intercell interference [9]. To overcome this problem the RRH with best channel condition is only selected.

A novel distributed resource allocation algorithm suitable for both uplink and downlink directions is proposed in [10]. The problem is modelled as a two sided stable matching game. The subcarriers are allocated in order to maximize a utility function which captures the Quality of Service requirements of joint uplink and downlink directions. CSI is assumed to be known only to the transmitter. A constraint on the difference between the rates in uplink and downlink directions is set. Deferred acceptance algorithm is performed to achieve a matching and then the evaluation of the utility function is performed. This is repeated until a stable matching outcome is achieved.

The resource allocation problem is formulated as a social gaming paradigm named as SIRA [11]. The users are considered as players interacting with the base station which takes the role of the referee. It also introduces a penalty based feedback mechanism.

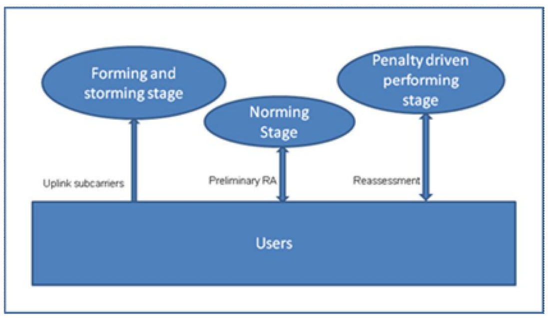

Fig 2. Workflow in SIRA

The workflow basically takes place in a number of stages namely: forming and storming stage, norming stage and the penalty driven performing stage.

2)Ergodic and Instantaneous Scheduling: In instantaneous kind of scheduling certain utility function is maximized at each scheduling instant, while in ergodic scheduling a long term performance is evaluated. The water filling algorithm proves to have better throughput for instantaneous scenario while it fails in ergodic scenario [12].

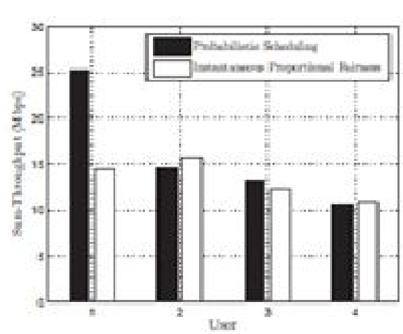

Fig 3. Rate comparison between proportional fairness and probabilistic scheduling [13]

A probabilistic approach for resource allocation in uplink and downlink directions is considered in [13], where long term average of SNR values at the base station is required. A lagrangian function is formulated and dual optimization technique is used to find the optimal distribution. Two targets are formulated: the first one is the users with high rates but least probable to be higher for transmission and the second one is to favor users with highly coupled queue lengths. The throughput achieved is comparable with that of the instantaneous scheduling. Results show that instantaneous and probabilistic fairness based resource allocation gives similar performance.

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The Fig 3. shows that the probabilistic scheduler achieves similar performance in terms of rate with proportional fairness algorithm. The probabilistic scheduling algorithm yields a good tradeoff between rate and delay.
In [14], a rate adaptive approach is considered. A regularization term is added to account for the coupling of uplink and downlink. The difference in rate/user should be maintained and this is verified by the regularization term. Fig 4 shows that the regularization of the resource allocation process bridges the gap between the uplink and the downlink rates for each user in the system. The rate difference between the two users is due to the channel conditions and the dynamic variations of the queue states.

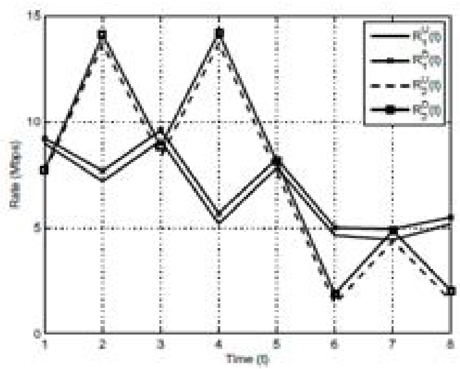

Fig 4. Achieved uplink and downlink rates for the two user system using joint uplink/downlink resource allocation[14]

B. Multi Cell Scheduling

While considering a single cell scenario, the intercell interference need not be considered. At the same time while considering the multicell scheduling, intercell interference is a major issue [15]. Therefore along with scheduling, emphasis on mitigation of intercell interference is also considered in most works.

In [16], a multicell scenario with distributed protocol design is considered. A continuous rate and power adaption model is formulated. It combines a cross decomposition technique with a strategic non cooperative game formulation of power and subcarrier allocation problem. The interference plus noise levels of various base stations are calculated and greedy algorithm is used to allocate power and subcarriers to users within the cell to maximize throughput.

The uplink and downlink traffic is considered on a frame by frame basis (instantaneous) [17]. The uplink and downlink time share is performed using online updated estimates of the average data rates in both directions. The instantaneous rates is initially calculated and then used to update the average rates using the exponential averaging filter. The decision to change the switching point can be done over a longer time period. Fast implementation was derived using sequential quadratic programming since it reduces computational complexity compared to subgradient method. Different interference scenarios are considered: BS to BS, BS to UE, UE to BS, UE to UE. Traffic considered is a mix of elastic and non elastic flows.

V. CONCLUSION

A survey on joint uplink/downlink resource allocation for OFDMA system has been presented. The major topics discussed are centralized and distributed scheduling, ergodic and instantaneous scheduling within single cell. Efficient interference mitigation techniques are required in multicell scheduling to mitigate the effect on intercell interference.

REFERENCES

[1] Somsak, Kittipiyakul, Tara, Javidi, " A fresh look at optimal subcarrier allocation in OFDMA systems", 43rd IEEE Conference on Decision and Control, Vol. 3, pp. 3289-3294, 2004.
[2] Jingtao, Zhang, David, W., Matolak. "Performance Evaluation of OFDMA and Multicarrier CDMA Systems on Airport Surface Area Channels", IEEE Conference on Integrated Communication, Navigation and Surveillance, Vol. 32, Issue 3, pp. 492-500, 2008.

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[3] N., Y., Ermolova. B., Makarevitch." Power and subcarrier allocation algorithms for OFDMA systems", 2005 IEEE 16th International Symposium on personal, Indoor and Mobile Radio Communications, Vol. 1, pp. 352-356, 2005.
[4] Dapeng, Zhang, Laurie, Cuthbert, "Dynamic subcarrier and power allocation in LTE networks", IEEE 5th International Conference on Wireless Communication, Networking and Mobile Computing, pp 1-4, 2009.
[5] Richard, O., Afolabi, Aresh, Dadlani, Kiseon, Kim, "Multicast scheduling and resource allocation algorithms for OFDMA based systems: A survey", IEEE communications surveys & tutorilas, Vol.15, pp. 240-254, 2013.
[6] Shenghong, Li., Ross, D., Murch, "Realizing cooperative multiuser OFDMA systems with subcarrier resource allocation", IEEE Transcations on wireless communications, vol.12, No 4, pp. 1923-1935, 2013.
[7] Zheng, Chang, Tapani, Restaniemi, "Asymmetric resource allocation for OFDMA networks with collaborative relays", The 10th Annual IEEE CCNC-Wireless Networking track, 2013.
[8] Md., Shamsul, Alam. Xuemin, Shen. "Relay selection and resource allocation for multi –user cooperative OFDMA networks", IEEE Transactions on wireless communications,Vol,12, No 5, pp. 2193-2205, May 2013.
[9] Nidhal, Odeh, Mehran, Abolhasan, Frazad, Safaei, "Low complexity interference aware distributed resource allocation for multi-cell OFDMA cooperative relay networks", Wireless Communications and Networking Conference, pp. 1-6, 2010 IEEE.
[10] Ahmad, M., El-Hajji, Zaher, Dawy, and Walid, Saad, "A stable matching game for joint Uplink/Downlink resource allocation in OFDMA wireless networks", IEEE ICC Wireless network Symposium, pp. 5354-5359, 2012.
[11] Ahmad, M., El-Hajji, Mariette, Awad. Zaher, Dawy. "SIRA:A socially inspired game theoretic uplink/downlink resource aware allocation in OFDMA systems", IEEE International Conference on Systems, Man and Cybernetics, pp. 884-890, 2011.
[12] Somsak, Kittipiyakul. Tara, Javidi, " Subcarrier allocation in OFDMA systems:beyond water filling", 38th Asilomar Conference on Signals, Systems and Computers, Vol. 1, pp. 334-338, 2004.
[13] Ahmad, M., El-Hajji, Zaher, Dawy, "On Probabilistic Queue Length based Joint Uplink/Downlink resource allocation in OFDMA networks", ICT, pp. 1-6, 2012.
[14] Ahmad, M., El-Hajji, Zaher, Dawy, "On optimized joint uplink/downlink resource allocation in OFDMA networks", IEEE Symposium on Computers and Communications. pp. 248-253, 2011.
[15] Zhao, Hou, Dan, Wu, Yueming, Cai, "Subcarrier and power allocation in uplink multi-cell OFDMA systems based on game theory", 12th International Conference on Communication Technolgy,pp. 1113-1116, 2010 IEEE.
[16] Ahmad, M., El-Hajj, Zaher, Dawy, "Dynamic Joint Switching Point Configuration and resource allocation in TDD-OFDMA wireless networks", IEEE Globecom proceedings, pp 1-6, 2011
[17] Dan, Wu, Yueming, Cai, Chengkang, Pan, "Joint subcarrier and power allocation in uplink OFDMA systems with incomplete channel state information", International conference on networks security, wireless communications and trusted computing, Vol. 1, pp. 47-51, 2009.
[18] Xiao, Han, Huifang, Chen, Lei, Xie, Kuang, Wang,"A resource allocation scheme for the heterogeneous OFDMA system with Ad Hoc Relay", IEEE International Conference on Communication Technology, pp. 1794-1799, 2011.
[19] Elias, Yaacoub, Zaher, Dawy, "A survey on uplink resource allocation inOFDMA wireless networks", IEEE Communications surveys and tutorials, Vol 14, No 2, pp. 322-337, second quarter 2012.
[21] Leandro, D'Orazio, Massimiliano, Panizza, Claudio, Sacchi, "A multi-user multi-rate OFDMA transmission system based on orthogonal subcarrier grouping", IEEE International Conference on Communications Workshops, pp. 1-5, 2009.
[22] Ying, Peng, Simon, M., D., Armour, Joseph, P., McGeehan," An investigation of dynamic subcarrier allocation in MIMO OFDMA systems", IEEE Transactions on Vehicular Technology, Vol 56, No 5, pp. 2990-3005, Sept 2007.
[23] Y., Rahulmathavan, K., Cumanan, R., Krishna. S., Lambotharan, "Adaptive Subcarrier and bit allocation techniques for MIMO OFDMA based uplink cognitive radio networks", First UK-India International Conference on Cognitive Wireless Systems. pp. 1-5,2009.
[24] Tao, Peng, Wei, Wang, Qianxi, Lu, Wenbo, Wang,"Asymptotic Performance of Uplink resource allocation for OFDMA based cognitive radio networks", 11th IEEE Singapore International Conference on Communications Systems,pp. 1509-1513, 2008.
[25] Bo, Bai, Wei, Chen, Zhigang, Cao, Khaled, B., Letaief. " Achieving high frequency diversity with subcarrier allocation in OFDMA systems", IEEE Globecom, pp. 1-5, 2008.

BIOGRAPHY

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