Improving QoS in the Downlink of OFDMA Networks

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Abstract — In wireless cellular networks using Orthogonal Frequency Division Multiple Access scheme, the bandwidth, power, QoS have to be optimized to improve the network throughput. There are several resource allocation algorithms available to optimize the bandwidth, power, QoS and provide fairness among the users of the network. The channel quality information is shared between the various users in the network and the base station for the resource allocation purposes. The resource allocation is optimized as per the average channel quality and the user's bandwidth needs in existing algorithms. They maximize the bandwidth allocated for the users with good channel conditions and attempts to provide reasonable bandwidth to the users with poor channel conditions. In the proposed method, we provide a resource allocation algorithm which will try to allocate resources based upon the QoS requirements. By handling different set of QoS requirements differently, the algorithm tries to optimize the network performance . The algorithm results are collected and compared with the existing solutions to evaluate the algorithm performance under different network traffic and channel conditions. The algorithm improves the performance as well as ensures the fairness among the different types of users.

Keywords — OFDMA, Resource allocation, Wireless Cellular Networks, Inter cell interference, Channel Quality Information

I. INTRODUCTION

The third, fourth and fifth generation mobile wireless cellular networks use Orthogonal Frequency Division Multiple Access (OFDMA) as the access scheme. Each carrier is split into smaller subcarriers in Orthogonal Frequency Division Multiplexing (OFDMA) based mobile wireless cellular networks. Different subcarriers are assigned to different users. Factors like user mobility, inter-cell interference, signal to noise (S/N) ratio, frequency reuse approach, number of users present in the network, bandwidth demand etc. affect the performance of the network. Resource allocation has to be carried out taking into account all these factors to optimize the performance of the network.

Several types of resource allocation algorithms have been implemented for OFDMA based wireless cellular networks [20]. Margin adaptive resource allocation algorithms try to reduce the transmit power in accordance with the transfer rate constraints. The rate adaptive algorithms try to maximize the transfer rate in accordance with the transmit power constraints. Also, the algorithms implemented should ensure fairness for the users with poor channel conditions. While some algorithms try to maximize the throughput without ensuring fairness for the users with poor channel conditions, some algorithms try to assure reasonable bandwidth allocation for the users with poor channel conditions.

The resource allocation often has to be performed with limited availability of feedback data and imperfect channel conditions. Since too much information in feedback data will cause control signaling overhead, various algorithms will try to rely on limited feedback data to reduce the overhead. Also, channel prediction can be used to predict the inter cell interference during resource allocation [17]. Imperfect channel conditions will cause more resource allocation overhead since the network state will change frequently necessitating resource reassignments and reevaluation of approaches [5], [6], [9] and [12].

In this paper, we propose a QoS aware algorithm that will improve the network throughput at the same time supporting the QoS requirements of the users. Based upon the QoS requirements, the algorithm will attempt to satisfy the user requirements at the same time ensuring fairness among the various users in the network.

This paper is split into several sections. Section II describes about various works done on the OFDMA resource allocation in downlink. Section III describes proposed algorithm in details. Section IV discusses the results obtained. The future directions are discussed in Section V.

II. Related Works

Margin adaptive scheduling algorithms for OFDMA networks have been proposed in [1] and [16]. They provide linear and suboptimal solutions to use the multi-user diversity of OFDMA systems.

Rate adaptive algorithms have been described in [2], [3], [4], [10] and [19]. They provide scheduling based upon full and limited feedback to improve the network performance ([13] and [15]). The network performance has been improved considerably but the fairness is not achieved.

Proportional Fair scheduling algorithms are described in [7], [14] and [18]. These algorithms try to allocate bandwidth to all users such that fairness across the network users is ensured when bandwidth is optimized.

Maximum throughput scheduler is described in [5]. This algorithm maximizes the throughput of the entire network by allocating the resources to the users with best available channel condition. While this approach increases the throughput of the network, users with poor channel conditions will suffer and fairness is not achieved.

Throughput to average scheduler is described in [6]. Unlike the Maximum throughput scheduler, it tries to maximize the throughput with respect to the average throughput and hence tries to increase the network throughput and ensure the fairness for the users with poor channel conditions.

Blind Average Throughput scheduler is described in [7]. It tries to provide equal throughput to all users in the network. While this ensures fairness among the users, the overall network throughput may not always be optimal.

QoS Aware Schedulers are described in [8] and [11]. They perform resource allocation based upon the QoS requirements and channel conditions. They consider the Head of Line delay, bit rate parameters and channel conditions for resource allocations. Such algorithms ensure fairness as well as try to optimize the throughput of the network. But often due to the complexity of such algorithms, they run slower and hence runtime memory requirements and processor utilization are very high.

III. Proposed Solution

The proposed method is a QoS aware resource allocation scheme in the downlink of the OFDMA networks. The algorithm classifies the bandwidth requirements of the various users and assigns different flows accordingly. During resource allocation, the flows which will require immediate response will be given the highest priority followed by the flows which will require guaranteed throughput. For users with non QoS requirements, fairness will be ensured across the nodes first followed by allocation of remaining bandwidth in round robin fashion.

Due to the mobility nature of the network, arrival of new users, exit of existing users as well as movement of users from one place to another place will cause the changes in the channel conditions and network environment. The algorithm tries to ensure that the changes in channel conditions are handled smoothly.

The algorithm maintains different queues: First one is for users with QoS requirements for immediate delivery of packets. Next queue is for QoS requirements for guaranteed bandwidth requirements. Further queues are for nodes with good channel conditions and nodes with poor channel conditions.

During each iteration, the algorithm first looks for users who require immediate delivery of packets first and perform resource allocation for them. If no such users are available, it will try to perform resource allocation for users in other queues trying to ensure fairness. If fairness has already been ensured and bandwidth is still available for allocation, nodes with guaranteed QoS allocation are handled first followed by nodes with good channel conditions.

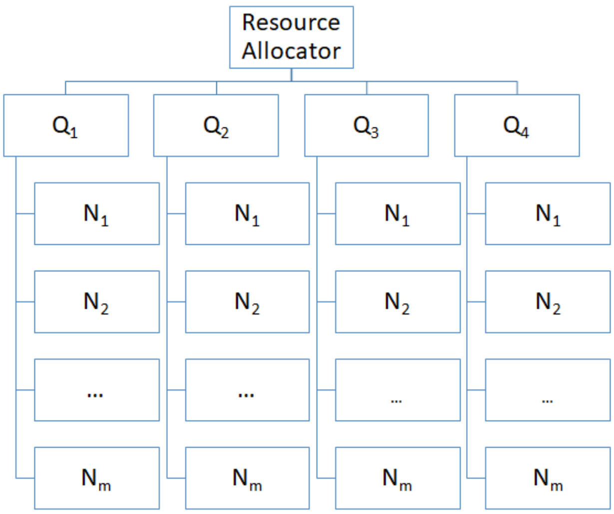


Fig.1. Block diagram for proposed method

Figure 1 shows the block diagram for the proposed solution. In this diagram, there are four queues. The queue Q1 is the queue with immediate QoS requirements. The queue Q2 is the queue with guaranteed QoS requirements. The queue Q3 is the queue for nodes with good channel conditoins and queue Q4 is the queue for the nodes with poor channel conditions. Each of the mentioned queues has nodes named N1, N2, etc. The resource allocator will perform bandwidth allocation first for Q1, followed by Q2, Q3 and then for Q4.

Following is the control flow for the proposed method as shown in Fig.2:

1. The resource allocator checks whether there are any nodes from the queue Q1 with QoS requirements which are yet to be satisfied.
2. If none of the nodes in the queue need resource allocation, it performs step (1) with queue Q2 without QoS requirements.

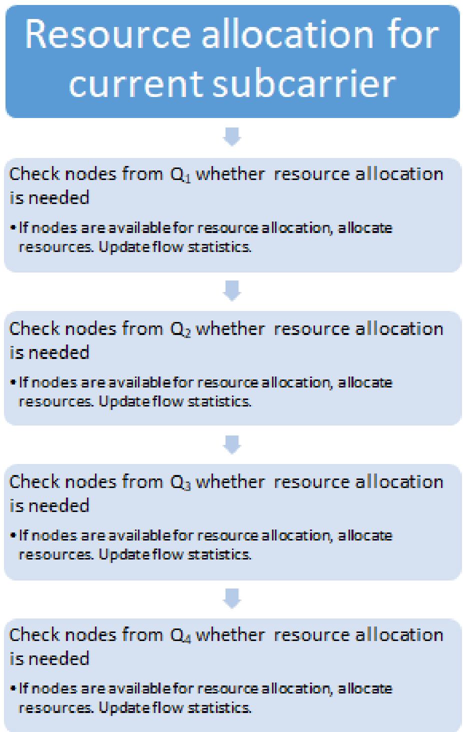


Fig 2. Control flow for the proposed method

3. If no more nodes in the first two queues to be allocated, resource allocation is performed on the queue Q3 with QoS requirements already satisfied.
4. If there are no nodes with need for resource allocation or no subcarriers to be allocated, the algorithm will exit.

Following is the algorithm implemented for the proposed QoS aware allocation:

Algorithm 1. QoS aware resource allocation

1. Create four queues, one with set of nodes with immediate QoS requirements Q1, other for set of nodes with guaranteed QoS requirements Q2, and other for set of nodes with good channel conditions Q3 and other for the set of nodes with poor channel conditions Q4.
2. Sort the queues as follows:
3. Q1 will be managed such that nodes will be allocated the resources in round robin fashion. Once node is allocated, it will go to the rear of the queue.
4. Q2,Q3 and Q4 will be sorted such that the nodes with poor allocation ratio will be at the front of queue. As nodes are allocated the resources, the ratio will change and the nodes will move back.
5. During each iteration,

a. Check Q1 for outstanding requests

if there are, pick the front item in the queue and perform allocations. Update the allocation ratio and reorder the queue

else
check Q3, Q4 for any nodes with with allocation less than expected fairness value
if there are, pick them and allocate.

else if there are nodes in Q2 available,
allocate for the front node in Q2 and update allocation ratio and reorder the queue

else if there are nodes in Q3 available
allocate for the front node in Q3 and update allocation ratio and reorder the queue

else if there are nodes in Q4 available
allocate for the front node in Q4 and update allocation ratio and reorder the queue

else If none of the nodes can be allocated, report that no nodes are available for scheduling and exit

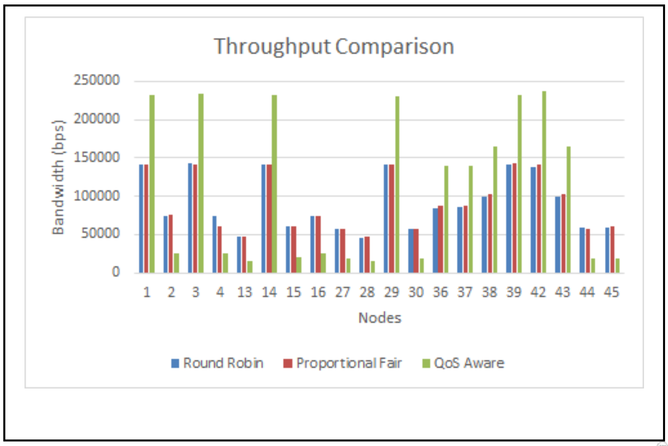
IV. Results

The algorithm was implemented and the results obtained are provided below along with results from similar algorithms.

Table I shows the algorithm performance in comparison with other algorithms in specific time period. As shown below, the algorithm maintains a reasonably consistent performance when compared to the other two algorithms.

TABLE I. ALGORITHM PERFORMANCE

Time (in sec)	Round Robin (Bytes)	Proportional Fair (Bytes)	QoS aware (Bytes)
1.001	1562	1191	1738
1.002	1310	967	1756
1.003	1584	967	1760
1.004	1274	967	1796
1.005	1604	903	1760
1.006	1486	2196	1738
1.007	1462	1191	1756
1.008	1434	1620	1760
1.009	1280	775	1796
1.010	1526	903	1760
1.011	1382	2196	1738
1.012	1562	1620	1756
1.013	1326	903	1760
1.014	1532	2196	1796



The Figure.3 shows the comparison of algorithm performance to other algorithms. Our algorithm performs better than the proportional fair and round robin algorithms since it tries to maintain the QoS awareness.

V. FUTURE DIRECTIONS

While the current algorithm has been implemented to improve the throughput while maintaining the fairness as per the QoS requirements, it can be improved further by having separate flows assigned for different kind of QoS requirements. So, we can further enhance the algorithm by taking additional types of QoS flows into consideration to further improve the system throughput.

VI. CONCLUSION

The QoS aware resource allocation algorithm has been implemented in the OFDMA based mobile wireless cellular network and the performance has been analysed and compared with other existing algorithms. The algorithm provides good bandwidth improvement and reasonable fairness among the users in the network under different channel conditions.

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