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Multi-Level Queue based Resource Allocation in Downlink of OFDMA Wireless Cellular Networks

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Abstract

Objectives: Optimizing the resource allocation to improve throughput in the downlink of OFDMA based wireless cellular networks. **Method/Statistical Analysis:** In the proposed method, a multi-level queue based resource allocation is proposed where different classes of users will be assigned different queues and different algorithms can be applied to them. The algorithm is implemented and its performance is analyzed and the results are collected and compared with the existing solutions to evaluate the algorithm behavior under different channel conditions. **Findings:** The algorithm improves the performance and ensures the fairness among the various classes of users based upon the chosen parameters. Also, the algorithm can be configured to either improve the throughput or ensure the fairness depending on the requirements. **Applications/Improvement:** The algorithm improves the performance and provides a way for different classes of users to be assigned different priorities.

Keywords: Channel Quality Information, OFDMA, Resource Allocation, Transfer Rate, Wireless Cellular Networks

1. Introduction

Orthogonal Frequency Division Multiple Access (OFDMA) is the access scheme used in the various wireless networks like Wireless LANs, LTE and WiMAX. In OFDMA based mobile wireless cellular networks, each high frequency carrier is split into smaller subcarriers of smaller frequencies and the subcarriers are assigned to various users. The advantage of such splitting is that only low complexity equalization is needed in the receiver side. The performance of the OFDMA networks will be affected by various factors like user mobility, inter-cell interference, signal to noise (S/N) ratio etc. To optimize the OFDMA network performance, the resource allocation has to be carried out considering all these factors.

There are several types of resource allocation algorithms implemented for OFDMA based networks[1-6]. Margin adaptive resource allocation algorithms try to minimize the transmit power subjected to the transfer rate constraints. The ergodic rate adaptive algorithms try to maximize the transfer rate subjected to the transmit power constraints[7-10]. Often the resource allocation has to be performed with limited feedback data and imperfect channel conditions[11-14]. Channel prediction can be used to predict the inter cell interference during resource allocation[15-18]. Overhead of control signalling has to be taken care in case of inter cell interference coordination[19-22].

In this paper, we propose an algorithm which will optimize the throughput of the network using multi-level

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queues. The users are split into multiple queues depending on the channel conditions. Each queue will be assigned different priorities during resource allocation. To ensure fairness, the lowest priority queue is assigned a minimum bandwidth.

Margin adaptive scheduling algorithm for OFDMA networks[23] provides a linear but suboptimal solution for resource allocation in OFDMA systems.

Rate adaptive algorithm[24] provides scheduling based upon full as well as limited feedback to improve the network performance. While it improves the network performance considerably, the fairness is not achieved.

Proportional Fair scheduling[25-31] algorithms try to allocate resources for all users such that when the network throughput is optimized, fairness for users with poor channel conditions also is ensured.

Maximum throughput schedulers[32,33] try to maximize the throughput of the entire network by allocating the resources to the user with best available channel condition. This increases the overall throughput of the network, but users with poor channel conditions may not get sufficient bandwidth.

Throughput to average scheduler[34] tries to maximize the achievable throughput for the user with respect to the average throughput for the user and hence tries to increase both the network throughput as well as ensure the fairness for all the users.

Blind Average Throughput scheduler attempts to provide equal throughput to all users present in the network. While this ensures fairness across all the users, the overall network throughput is not optimal.

QoS Aware Schedulers[35-38] perform scheduling based upon the QoS guaranteed bandwidth requirements and channel conditions. They consider the Head of Line delay, bit rate parameters and channel conditions for performing resource allocations. They ensure fairness as well as try to optimize the throughput of the network.

This paper is split into several sections. Section 2 describes the proposed algorithm in details. Section 3 provides the results obtained. The future directions are discussed in Section 4.

2. Proposed Method

The proposed method is multi-level queue based resource allocation in the downlink of the OFDMA networks. The algorithm maintains a number of queues to which the users are allotted based upon the channel conditions. Users with good channel conditions are allocated the higher priority queues and users with poor channel conditions are allocated the lower priority queues.

Due to the nature of user mobility in the network, any entry of new users, exit of existing users as well as movement of users from one place to another place with differences in channel condition will cause the internal data structures to be reordered as per the changes in the network environment. The algorithm should try to ensure that the complexity of such reordering is trivial.

The algorithm tries to perform resource allocation to the users in the queue with the highest priority first, followed by next higher priority queue so on. If all the resources are allocated but users/queues are still left unallocated, allocation will happen next time starting from the last unallocated user in the higher priority queue. This will ensure that the fairness will be maintained in the network. By providing users in the higher priority queue higher data rate, the throughput is also optimized.

The number of queues can be configured based upon the no of users in the network. The resource allocation parameters for each group also can be configured based upon the average network throughput. Based upon the average network throughput, the different queues can be allocated different target bit rates.

Let N be the no of users in the network.

Let C be the no of queues in the network.

Let B_t be the overall bandwidth of the network over time t.

We split the overall bandwidth among the queues such that

$$B_{it} = \Sigma a_i Q_i,$$

where the coefficient a_i will be larger for higher priority queues and smaller for lower priority queues. Q_i is the queue with the set of users for which a_i is the coefficient assigned.

Using the following distribution function the coefficients a_i are determined:

$$\Sigma a_i = 1.$$

We use the following function to generate coefficients such that more priority can be provided to higher level queues.

If n is the no of queues,

$$\sum a_i = 1 \text{ for } i = 1..n$$

The coefficient

$$a_i = 2(n-i)/(2n-1)$$

This will provide most bandwidth to the highest priority queue and lesser for next level queues.

If different algorithms are used for different queues, then the bandwidth achievable will vary depending on the capability of the algorithm used. Let us say B_{ti} be the bandwidth which can be achieved by the algorithm for queue Q_i over time t. Then, the maximum overall bandwidth possible is,

$\sum a_i B_{ti} = \text{for } i = 1..n$

The complexity of the algorithm depends on how the resource allocation is made for each queue. For reordering of the queues $O(n \log n)$ will be the complexity. If the algorithm to be used for a particular queue has a complexity of $O(n)$, then the overall complexity of the algorithm for one allocation will be $O(n \log n) + O(n)$.

Figure 1 shows the architecture diagram for the proposed method. In this diagram, each queue Q_i is shown with various mobile nodes named N_i and the resources for them are allocated by resource allocator up to bandwidth a_i. The bandwidth value will be more for higher priority queues than the lower priority queues to improve throughput.

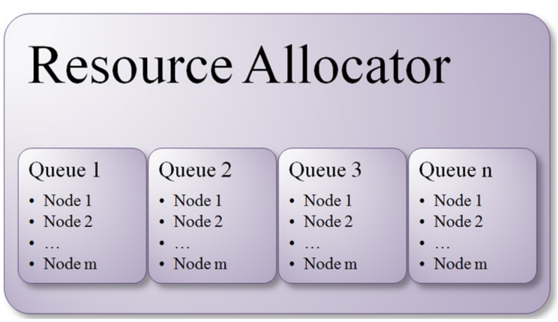

Figure 1. Architecture diagram of the proposed method.

Figure 2 shows the flow diagram for the proposed method. Following is the control flow during the resource allocation scenario:

- The resource allocator checks in queue Q_1, whether there are any nodes which needs resource allocation. If such nodes are there, it picks one among them which has not yet been allocated up to entire allowed bandwidth a_i.
- If none of the nodes in the queue Q_1 need resource allocation or nodes have already been allocated up to bandwidth a_i, it performs step (1) with queue Q_2 and so on.
- For the node chosen in step (1), it performs allocation and updates the allocation statistics. If still there is scope for more allocation, step (1) is continued.
- If there are no nodes with need for resource allocation or no subcarriers to be allocated, the algorithm will exit.

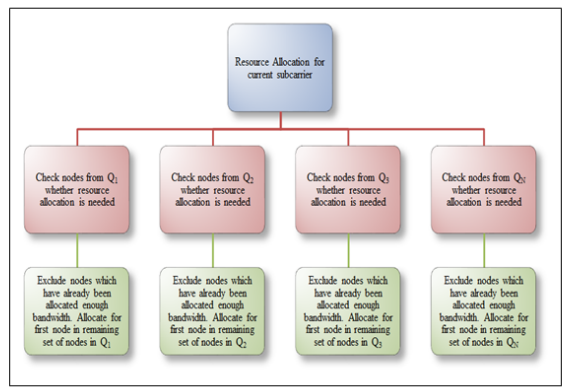

Figure 2. Flow diagram of the proposed method.

Following is the proposed multi-level queue based resource allocation algorithm:

Algorithm 1. Multi-Level Queue based Resource Allocation

Step 1: Whenever a new node enters the network, update the CQI information of the node into the internal data structures.

Step 2: Whenever a node leaves the network, remove the CQI information of the node from the internal data structures.

Step 3: Whenever periodic CQI update information is received for a node, update the CQI information into the internal data structures.

Step 4: During resource allocation in the downlink for a particular sub carrier,
Organize/Reorganize the queues based upon the current channel conditions.
For each queue starting from highest priority to lowest priority,

I. For each node in the queue i.
   i. If the node has resource requirements and has not been already allocated its bandwidth ai,
      a. Perform allocation for the node and update allocation information in the internal data structures.
      b. If more allocation can be done on the subcarrier, go to step (I) for next node.
      c. If no more allocations can be done on the subcarrier, exit.
   ii. Else if the node does not have bandwidth requirements,
      a. Go to step (I) for next node.

II. If none of the nodes can be allocated, report that no nodes are available for scheduling.

3. Simulation Results

The algorithm was implemented using Ns3 and the simulation results obtained are shown below along with results from similar algorithms. As shown below, the algorithm maintains a stable performance comparing to the other two algorithms.

Table 1. Shows the algorithm performance over a period of time in comparison with other algorithms.

Table 1. Algorithm performance

Time (in sec)	Round Robin(Bytes)	Proportional Fair(Bytes)	Multilevel Queue(Bytes)
1.290	1434	1620	1532
1.291	1280	2196	1260
1.292	1526	2196	1444
1.293	1382	1620	1416
1.294	1562	903	1346
1.295	1326	2196	1756
1.296	1532	2196	1342
1.297	1362	1383	1562
1.298	1550	1383	1324
1.299	1434	775	1664

Figure 3 provides the comparison of algorithm performance to other algorithms. While the round robin algorithm maintains a stable performance, the proportional fair algorithm oscillates between lower and higher values considerably. Our algorithm performance is neither too low, nor too high. The algorithm can be easily tuned to either increase the performance or increase the fairness with minimal effort by altering the a_i values.

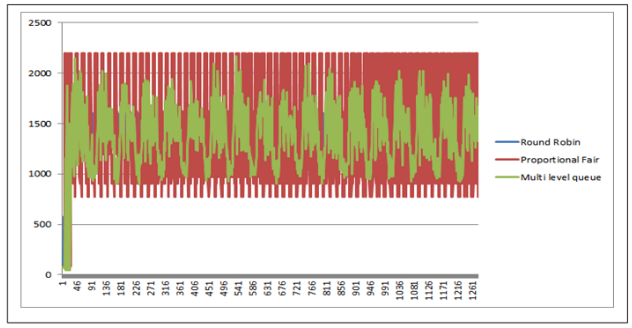

Figure 3. Comparison of throughput of different algorithms over time.

Figure 4 depicts the resource allocations for different users over time for the algorithm. Users with good channel conditions have better bandwidth allocated compared to users with poor channel conditions. Also as shown in the chart, the fairness has been ensured for the users with poor channel conditions since they are always allocated a reasonable amount of network bandwidth. Here all queues are using round robin algorithm.

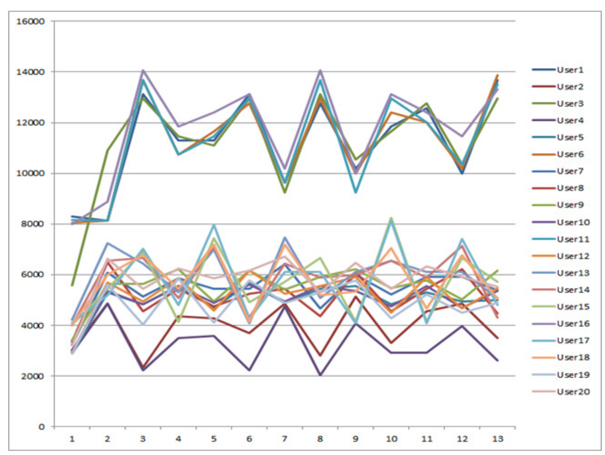

Figure 4. Comparison of throughput of different users over time.

Figure 5 depicts the resource allocations for different users with one of the queues using a maximum throughput scheduler algorithm and other queues using round robin algorithm. Due to this, it can be observed that one of the nodes with good channel condition in that queue has maximum throughput comparing to all other nodes belonging to various queues.

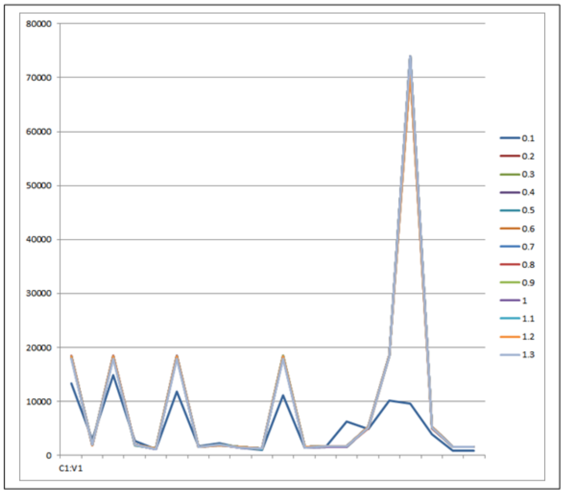

Figure 5. Comparison of throughput with using different algorithms for different queues.

4. Future Directions

While the proposed method has been implemented to improve the throughput while maintaining the fairness, it does not take into account the QoS requirements. So, we can further enhance the algorithm by taking into account the QoS constraints to improve the system throughput.

5. Conclusion

The multi-level queue based resource allocation has been implemented and the performance of the algorithm has been compared with existing algorithms. Each queue has been applied different algorithm to analyze the performance at queue level. Also the algorithm behavior has been analyzed under different channel conditions. The algorithm provides a reasonable bandwidth for the users with good channel conditions as well as users with poor channel conditions. The algorithm also can be easily tuned to improve the throughput or fairness.

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