Delivering Individualised QoS on Spectrum-Sharing OFDMA Networks

Yue Liu, Laurie Cuthbert
Electronic Engineering and Computer Science
Queen Mary University of London
London, UK
{yueliu}{laurie.cuthbert}@eecs.qmul.ac.uk

Xu Yang, Yapeng Wang
Information Systems Research Centre
Macao Polytechnic Institute
Macao, China
{xuy}{yapeng}@mpi-qmul.org

Abstract—**This paper describes an improved QoS-aware and user-priority-aware subcarrier allocation algorithm to maximize the number of low priority users meeting their QoS requirements subject to the condition that the high priority users all meet theirs. Under overload, it does macro control of the system performance by automatically triggering a compromise mechanism that allows the system to serve more users. Simulation results show the fast convergence of the algorithm and its robustness to overloaded network.**

Keywords—Quality of Service; OFDMA; user priority; resource allocation

I. INTRODUCTION

A lot of research has been done on SubCarrier (SC) allocation algorithm for Orthogonal Frequency Division Multiple Access (OFDMA) networks with different goals, e.g. to maximize the system throughput [1]-[5]. However, in the current literature all users are treated as having the same requriement but here we match the Quality of Service (QoS) to the mix of services chosen by the user in the SC allocation.

In our approach, a user has two attributes: the priority and requried QoS with a group of users having the same attributes forming a *user class*. We consider a scenario derived from cognitive radio with two classes:

- User class A whose expected QoS is delivered with absolute priority; for simplicity we call these *Primary Users* (PU).
- User class B (the *Secondary Users* – SU) who the operator wishes to serve, provided the QoS of the PUs is guaranteed so PUs have absolute priority. These SUs are served with one of two levels of QoS: desired and minimum.

We define a *qualified user* as one able to receive service at an acceptable level: the expected QoS for PUs; and at least the minimum QoS for SUs.

TABLE I. THE ATTRIBUTES OF USER CLASSES

	Priority	Expected QoS	Min QoS
Class A (PU)	High	✓	
Class B (SU)	Low	✓	✓

This research follows on from the SC allocation algorithm in [6], but adds the concept of generality of user classes and macro-control when dealing with overloaded networks.

II. SYSTEM MODEL & GAME FORMULATION

We use a standard model derived from cognitive radio with a 7-cell wrap-around model, with a cell radius of 1 km and 3 sectors per cell. PUs require 1Mbps; 50% of the SUs require 1Mbps and the others 500kbps. The frequency band used is 2GHz with 960 SCs (bandwidth 10 kHz) available in each cell.

Every cell aims to decide the best SC allocation scheme to maximize its number of qualified SUs subject to the condition that 100% of PUs are qualified; it does this by competing against other cells which have the same purpose. The BS knows the interference map for its cell and takes its own decisions on SC allocation but these decisions will affect the interference map of the other cells: this is the basis of the game. By analyzing the other's decision from round to round (but without the need to co-operate), the cells change their decisions accordingly until all the cells choose to maintain their current decisions. At that point, they have reached an agreement called the Nash Equilibrium. Game formulation and the basic SC allocation algorithm can be found in details in [6].

In the basic algorithm, PUs are always guaranteed to get their desired QoS provided sufficient resources are available overall. However, that might not always be the case for SUs. When the system becomes heavily loaded, some SUs with poor channel conditions will not be served. The danger to the operator is that user satisfaction is severely damaged.

We demonstrate a QoS compromise mechanism which reduces the QoS given to SUs from the desired to the minimum in order to serve more SUs. The PUs will not be affected by the QoS compromise. Moreover, the compromise will be triggered only when the qualified user ratio drops below a predefined threshold set according to the operator's requirement.

Figure 1. shows the mechanism. Initially, all served users are allocated their desired QoS; unqualified SUs are allocated nothing. If the qualified user ratio is below the threshold and the compromised SU ratio is not 100%, more SUs are compromised and the algorithm is run again. This is carried out

iteratively until the qualified user ratio reaches the threshold or there are no more SUs that can be compromised.

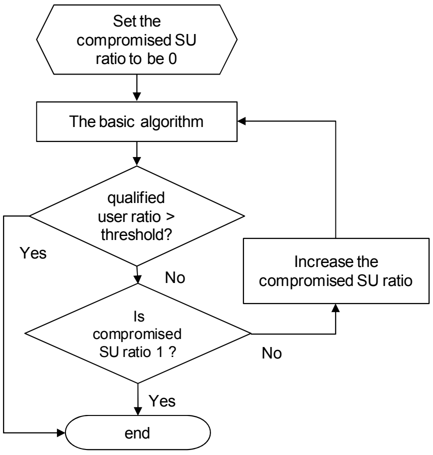

Figure 1. QoS compromise mechanism

III. SIMULATION RESULTS

Figure 2. and Figure 3. show the total number of qualified users and system throughput as the total number of users increases. The basic algorithm without QoS compromise (BA-NC) and with QoS compromise (BA-C) is tested. 80% and 95% are used in the QoS compromise mechanism as the thresholds of qualified user ratio and the range of total number of users in the system is 70-1050 (3.18-47.7 users/km^2).

For BA-NC, there are two obvious phases: when the system is not heavy loaded, all the users can get their desired QoS and are qualified (the slope is 1). When there are no longer sufficient resources to satisfy all the users (from A), those SUs with worse channel conditions will be dropped first. The system will serve all the PUs and the SUs with better channel conditions to maximize the number of qualified users The slight increase after A is because as more SUs appear, some of the extra load will be near the centre of the cell: those SUs with worse channel conditions (e.g. edge users) will then be dropped and their SCs reallocated to SUs with better channel conditions so more SUs will be served for the given number of SCs.

For BA-C, the qualified user ratio is the criterion to trigger the SU compromise mechanism. By setting the threshold higher, the SU compromise will be triggered earlier as the total number of users increases and the SUs that can compromise will be used up ealier. For the 80% case, C is the trigger point and D is the point where the compromised SU ratio reaches 1. For the 95% case these are A and B respectively.

The number of qualified users goes up immediately after the compromise is triggered. But, as serving more users with worse channel conditions will introduce more inter-cell interference, the SC utilization will be lower and the system throughput will suffer. Also with a higher threshold, the overall system throughput is reduced more between the points A-D since more SUs are compromised earlier, although conversely more users are qualified. Once all the SUs are compromised (D in the 80% case, B in the 95% case), the qualified user number and system throughput follow the same trends as BA-NC. However, as the total number of SUs served is greater the system throughput is lower because of the larger number served with poor channel conditions. There is a slight increase in the number of qualified users as the overall number of users goes up – again because some of the extra ones will have better channel conditions.

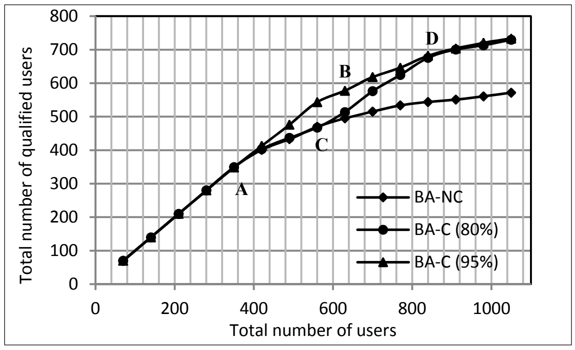

Figure 2. Qualified user number vs. total number of users

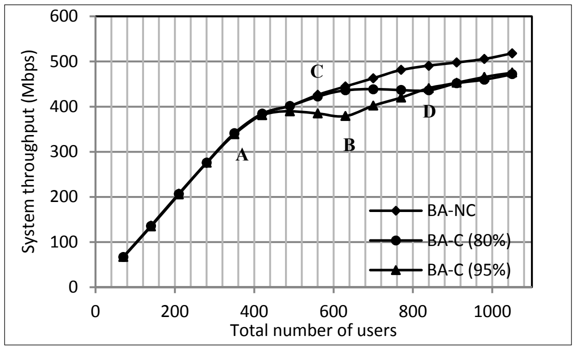

Figure 3. System throuhgput vs. total number of users

IV. CONCLUSION

In this paper, we proposed an improved algorithm based on [6] which is enhanced in terms of maximizing the number of qualified users in overloaded network. This overall approach can be used as a tool in satisfying the business demand of the operators by providing a user priority mechanism.

REFERENCES

[1] H. Kwon, B. Lee, "Distributed Resource Allocation through Non-cooperative Game Approach in Multi-cell OFDMA Systems", IEEE International Conf. Comms., pp4345-4350, Jun. 2006

[2] M. Kaneko and P. Popovski, "Radio Resource Allocation Algorithm for Relay–aided Cellular OFDMA System", IEEE Int'l Conf. on Comms., pp4831-4836, Jun. 2007

[3] H. Kwon and B. Lee, "Distributed Resource Allocation through Noncooperative Game Approach in Multi-cell OFDMA Systems", IEEE Int'l Conf. on Comms., pp4345-4350, Jun 2006

[4] G. Li and H. Liu, "Downlink Radio Resource Allocation for Multi-Cell OFDMA System", IEEE Trans. On Wireless Comms, vol.12, issue.5, pp3451-3459, Dec. 2006

[5] C. Koutsimanis and G. Fodor, "A Dynamic Resource Allocation Scheme for Guaranteed Bit Rate Services in OFDMA Networks", IEEE Int'l Conf. on Comms., pp2524-2530, May 2008

[6] Y. Liu, L.Cuthbert, X. Yang and Y. Wang, "QoS-aware Resource Allocation for Multimedia Users in a Multi-cell Spectrum Sharing Radio Network", 15th ACM Int'l Conf. on Modelling, Analysis and Simualtion of Wireless and Mobile Systems, Aug. 2012.