Adaptive Soft Frequency Reuse for Inter-Cell Interference Coordination in SC-FDMA Based 3GPP LTE Uplinks

Xuehong Mao, Amine Maaref, Koon Hoo Teo

TR2008-083 December 2008

Abstract

This paper proposes a decentralized adaptive soft frequency reuse scheme for the uplink of a 4G long-term evolution (LTE) system. While universal frequencies reuse (UFR) is being targeted for next generation multi-cellular wireless networks, ongoing efforts supporting the LTE standard have proved that actual implementations of UFR in LTE lead to unacceptable interference levels experienced by user equipments near the cell edge area in a multi-cellular configuration. The herein proposed adaptive soft frequency reuse scheme is a step forward towards effective inter-cell interference coordination (ICIC) in next-generation wireless networks. Our solution to the uplink ICIC problem stands out for its two essential features that consist of physical resources block (PRB) reuse avoidance/minimization and cell-edge bandwidth breathing which can be implemented at the cost of a negligible information exchange over the X2 interference (backbone). The PRB reuse avoidance feature significantly decreases inter-cell interference levels while improving the achievable average throughput per user, especially for those identified as cell-edge ones. The cell-edge bandwidth breathing strategy allows to track and adapt to semi-static changes in traffic loading and user distributions within each cell which drastically reduces the blocking probability of incoming calls under cell-edge bandwidth constrained traffic.

Globecom 2008

Adaptive Soft Frequency Reuse for Inter-cell Interference Coordination in SC-FDMA based 3GPP LTE Uplinks

Xuehong Mao[†], Amine Maaref[‡] and Koon Hoo Teo[‡]
[†]ECE department, University of Utah, Salt Lake City, UT
E-mail: mao@ece.utah.edu
[‡]Mitsubishi Electric Research Laboratories
201 Broadway Cambridge, MA, 02139
E-mail: maaref@merl.com, teo@merl.com

Abstract—**This paper proposes a decentralized adaptive soft frequency reuse scheme for the uplink of 4G long-term evolution (LTE) systems. While universal frequency reuse (UFR) is being targeted for next generation multi-cellular wireless networks, ongoing efforts supporting the LTE standard have proved that actual implementations of UFR in LTE lead to unacceptable interference levels experienced by user equipments near the cell edge area in a multi-cellular configuration. The herein proposed adaptive soft frequency reuse scheme is a step forward towards effective inter-cell interference coordination (ICIC) in next-generation wireless networks. Our solution to the uplink ICIC problem stands out for its two essential features that consist of physical resource block (PRB) reuse avoidance/minimization and cell-edge bandwidth breathing which can be implemented at the cost of a negligible information exchange over the X2 interface (backbone). The PRB reuse avoidance feature significantly decreases inter-cell interference levels while improving the achievable average throughput per user, especially for those identified as cell-edge ones. The cell-edge bandwidth breathing strategy allows to track and adapt to semi-static changes in traffic loading and user distributions within each cell which drastically reduces the blocking probability of incoming calls under cell-edge bandwidth constrained traffic.**

I. INTRODUCTION

SINGLE-carrier frequency division multiple access (SC-FDMA), an Fast Fourier Transform (FFT)-precoded version of orthogonal frequency-division multiple access (OFDMA), aimed at mitigating the peak-to-average-power ratio problems typically encountered by OFDMA on the uplink, has been adopted on the uplink of the 3G Long Term Evolution (LTE) standard. OFDMA on the other hand is being targeted for the downlink scenario in addition to its adoption in both directions (uplink and downlink) in the context of Worldwide Interoperability for Microwave Access (WiMAX). For both OFDMA and SC-FDMA, the available bandwidth is divided into several orthogonal sub-bands each corresponding to a group of orthogonal subcarriers. The orthogonality feature among the subbands assigned to each user is an important aspect of both SC-FDMA and OFDMA since it allows mitigating the intra-cell interference in a multi-cellular wireless network. As a result, the bulk of the interference management problem for the next generation of wireless networks reduces to dealing with the interference into a target cell that originates from neighboring cells, a.k.a inter-cell interference.

In a multi-cellular network employing frequency reuse across different cells, inter-cell interference occurs when neighboring cells assign the same frequency bandwidth to different user equipments (UEs). In such a context, it is only natural that the most severe form of inter-cell interference is the result of frequency collisions that occur on or near the edge of a given cell. Inter-cell interference coordination (ICIC) techniques, whereby UEs in a target cell are allocated orthogonal frequency resources to all or portion of the interfering UEs in the adjacent cells, can effectively reduce inter-cell interference effects especially in the cell-edge area. In this vein, various frequency reuse schemes have been proposed in the literature [1]–[3]. The most straightforward approach is the so-called fixed frequency reuse scheme whereby the whole available bandwidth is divided into three non-overlapping parts which are assigned to three neighboring cells. This frequency planning scheme allows to eliminate frequency collisions at the cost of spectrum efficiency. To overcome this drawback, a soft frequency reuse (SFR) scheme has been introduced in [3]. As depicted in Fig. 1, the SFR scheme divides the available spectrum into two reserved parts: a cell-edge bandwidth and a cell-center bandwidth. UEs within each cell are also divided into two groups, interior cell-center UEs and exterior cell-edge UEs, depending on which type of bandwidth they are assigned or have access to. Cell-edge UEs are restricted to the reserved cell-edge bandwidth while cell-center UEs have exclusive access to the cell-center bandwidth and can also have access to the cell-edge bandwidth but with less priority than cell-edge UEs. Usually, the cell-edge bandwidth in one cell/sector is fixed to one third of the entire available bandwidth with the aim of ensuring that adjacent cells/sectors can allocate non-overlapping frequency bands for their cell-edge traffic.

The SFR scheme outlined in [3] is a bandwidth efficient ICIC mechanism which is typically most effective in static scenarios with evenly distributed traffic across the whole network. However, more often than not, the traffic load changes

---

This work was done while Xuehong Mao was a graduate intern at Mitsubishi Electric Research Laboratories (MERL).

978-1-4244-2324-8/08/$25.00
This full text paper was peer reviewed at the direction of IEEE Communications Society subject matter experts for publication in the IEEE "GLOBECOM" 2008 proceedings.

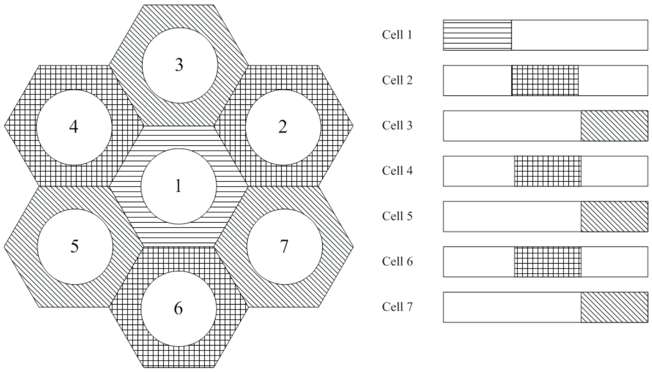

Figure 1. A seven-cell hexagonal system layout and frequency planning for the SFR scheme.

semi-statically and/or is uneven among neighboring cells, then it observed that there is room for improving the performance of the SFR scheme at the cost of a negligible exchange of information between neighboring eNodeBs.[1] In that sense, we refer to our proposed adaptive soft frequency reuse scheme as a semi-distributed one that dynamically adapts to semi-statically changing traffic load and user distributions among neighboring cells, while relying on a per frequency sub-band indicator exchange between adjacent eNodeBs over the X2 interface, indicators that are currently being discussed within the 3GPP community.

The remaining of this paper is organized as follows. The basic assumptions and system model for the inter-cell interference coordination problem in the LTE uplink are presented in Section II. In Section III, an SFR-based ICIC scheme with frequency reuse avoidance is proposed. Combined with the novel indicator-based cell-edge bandwidth breathing strategy, an adaptive SFR scheme is then identified. Simulation results are presented in Section IV highlighting the benefits of the proposed ICIC mechanism and concluding remarks are drawn in Section V.

II. SYSTEM MODEL AND PROBLEM FORMULATION

Radio resource management in SC-FDMA based LTE uplink involves three dimensions: frequency, time and space. The basic resource element considered in this paper is the physical resource block (PRB) which spans both frequency and time dimensions. The component frequencies of one PRB can be either contiguous or disjoint. The time duration of the PRB is defined by one transmission time interval (TTI). By judiciously coordinating the usage of PRBs in adjacent cells, frequency, time and spatial diversity can be leveraged.

A. Basic Assumptions

We consider the uplink direction (from UEs to eNodeBs) of a seven-cell hexagonal layout as illustrated in Fig. 1 and assume the following throughout the paper:

1) Intra-cell interference is successfully avoided. Indeed, the scheduler of each eNodeB ensures that PRBs will not be simultaneously assigned to more than one UE within each cell. By further assuming that orthogonality among sub-carriers can be adequately maintained then intra-cell interference can be ignored.
2) UEs are categorized as cell-center and cell-edge UEs based on reported measurements of their received signal reference signal (RSRP) [4]. It should be noted that several methods other than the geometry factor can be employed to distinguish between cell-center and cell-edge UEs. Although different methods may lead to different simulation results, we should stress that the ensuing implications fall outside the scope of this paper. A cell-edge UE may be blocked or denied access if there is a shortage of available cell-edge PRBs within the current cell. A cell-center PRB may be blocked if there are no more cell-center PRBs or cell-edge PRBs to be allocated. Since the number of PRBs within each cell is limited, there exists a limit on the number of active UEs within the cell/system.
3) Inter-cell interference is the major problem we try to minimize since adjacent cells are allowed to reuse the same set of PRBs in order to achieve a frequency reuse factor close to one. Owing to its higher bandwidth efficiency, SFR is strongly tipped for use in LTE systems for ICIC purposes. Therefore two UEs in adjacent cells are allowed to transmit on the same PRBs and one objective of the proposed ICIC scheme is to minimize the probability of such events which we refer to as PRB reuse.
4) Taking the uplink scenario into account, two transmission power levels are imposed on cell-center and cell-edge UEs. For cell-edge UEs, in order to guarantee the required SINR, full transmission power P_0 is applied. However, for cell-center UEs, since they are closer to the serving base station, a power reduction is suggested in order to reduce the potential interference on other UEs, without violating the SINR requirement. Hence cell-center users transmit power is set to αP_0, where α is some tunable constant such that $0 \leq \alpha \leq 1$.

B. Resource Usage Modelling

Denote by L the number of cells in the system, e.g. $L = 7$ as per our working assumption in this paper and by N the number of available PRBs that can be used for transmission in each TTI and in each cell. Besides, let M_l be the number of UEs and $\mathfrak{M}_l$ be the set of indexes denoting the UEs belonging to cell l, respectively, where $l = 1, \cdots, L$. Therefore, the total number of UEs in the system is $M_t = \sum_{l=1}^{L} M_l$.

1) Resource Allocation Matrices: Let $\mathbf{Y}_{M_t \times N} = [y_{mn}]$ and $\mathbf{X}_{L \times N} = [x_{ln}]$ be resource allocation matrices from the UEs and eNodeBs perspective, respectively, with elements y_{mn} and x_{ln} defined as follows:

$$y_{mn} = \begin{cases} 1, & \text{if PRB } n \text{ is used by cell-edge UE } m \\ \alpha, & \text{if PRB } n \text{ is used by cell-center UE } m \\ 0, & \text{otherwise,} \end{cases}$$

---

[1] eNodeB commonly refers to a base station in LTE terminology.

and

$$x_{ln} = \begin{cases} 1, & \text{if PRB } n \text{ is used by cell-edge UE at cell } l \\ \alpha, & \text{if PRB } n \text{ is used by cell-center UE at cell } l \\ 0, & \text{otherwise,} \end{cases}$$

respectively. Since for each cell, PRB usage is restricted to one UE at any given TTI, then $x_{ln} = \sum_{m \in \mathfrak{M}_l} y_{mn}$. Therefore $\mathbf{X}$ is uniquely determined by $\mathbf{Y}$.

2) Interference Sets: Define $\mathfrak{J} = \{\mathfrak{J}_{mn}\}_{m,n=1}^{M_t,N}$ where for $m = 1, \cdots, M_t$ and $n = 1, \cdots, N$, $\mathfrak{J}_{mn}$ represents the set of UE m's interfering set of eNodeBs on PRB n, where $\mathfrak{J}_{mn}$ denotes any subset of $\{1, 2, ..., L\}$ including the empty set $\emptyset$ which refers to the case where no other UE from neighboring cells is concurrently using the same PRB n.

Careful observation of the above notations reveals that given the resource allocation matrix $\mathbf{Y}$ as well as the serving eNodeBs of UEs within the considered coverage area, the remaining resource allocation variables $\mathbf{X}$ and $\mathfrak{J}$ can be easily deduced. Therefore, the signal-to-interference-and-noise ratio (SINR) for UE m on PRB n can be expressed as:

$$\text{SINR}_{mn} = \frac{y_{mn} P_0 \beta_{0,m}}{N_0 + \sum_{J_{mn} \in \mathfrak{J}_{mn}} P_0 x_{J_{mn},n} \beta_{J_{mn},m}} \tag{1}$$

where $\beta_{0,m}$ denotes the path loss between UE m and its serving eNodeB, $\beta_{J_{mn},m}$ represents the path loss between the interfering UE in eNodeB J_{mn} and UE m's serving eNodeB and N_0 is the eNodeB thermal noise variance.

3) Problem Formulation: PRB scheduling is formulated as an optimization problem with the objective of maximizing the total throughput expressed as

$$\sum_{m=1}^{M_t} T_m \quad [bits/s] \tag{2}$$

where

$$T_m = W_{\text{PRB}} \sum_{n=1}^{N} \log_2 (1 + \text{SINR}_{mn})$$

is the throughput of UE m and W_{PRB} is the PRB bandwidth, subject to the following constraints:

1) Uneven traffic loading such that the traffic load of each cell TL_l is given by

$$\text{TL}_l = \sum_{m \in \mathfrak{M}_l} \sum_{n=1}^{N} \lceil y_{mn} \rceil / N, \quad l = 1, \cdots, L \tag{3}$$

where $\lceil . \rceil$ denotes the ceil operator.

2) No PRB sharing within each cell, i.e. $x_{ln} = \sum_{m \in \mathfrak{M}_l} y_{mn}$.

3) Reserved cell-edge bandwidth in each cell is one third of the available bandwidth, i.e.

$$\sum_{n=1}^{N} \lfloor x_{ln} \rfloor = \sum_{n=1}^{N} \left(\sum_{m \in \mathfrak{M}_l} \lfloor y_{mn} \rfloor \right) \leq \frac{N}{3}, \quad l = 1, \cdots, L$$

where $\lfloor . \rfloor$ denotes the floor operator.

III. ADAPTIVE SOFT FREQUENCY REUSE SCHEME

The proposed adaptive soft frequency reuse (ASFR) scheme whose flow chart diagram is illustrated in Fig. 2, comprises three main parts. First, we randomly assign reserved PRBs to requesting UEs according to their type, i.e. cell-center PRBs to cell-center UEs and cell-edge PRBs to cell-edge UEs. Then, based on the previous random allocation, we redistribute the reserved cell-edge bandwidth according to the traffic load in each cell. Finally, we apply the PRB reuse avoidance algorithm described below to each cell and decide whether to accept the reallocation or not.

In contrast to the resource allocation strategy described in [1], the proposed ASFR scheme is more decentralized in the sense that it does not require a radio network controller (RNC). When a cell detects that it faces a shortage of cell-edge PRBs, it will send out a borrowing request for cell-edge PRBs reserved for its adjacent cells. If any cell-edge PRBs in adjacent cells are not currently occupied, the overloaded cell can benefit from it thereby being able to accommodate more cell-edge traffic.

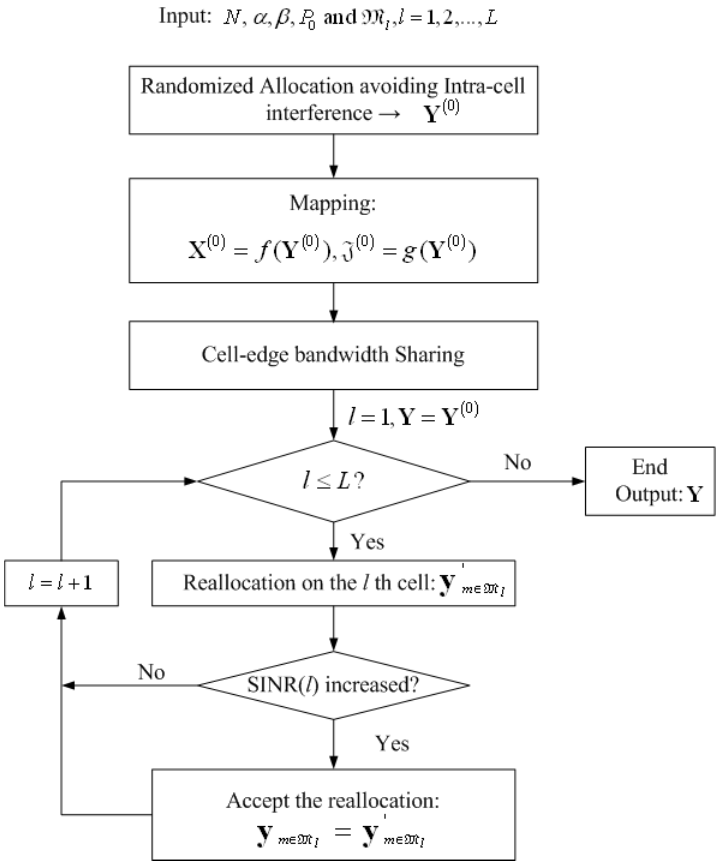

Figure 2. Flow chart for the adaptive SFR scheme.

A. PRB Allocation Step

This first step ensures that no PRB is assigned to two different UEs within one cell. The total bandwidth is divided into two parts: cell-edge bandwidth and cell-center bandwidth. The cell-center UEs are allowed to access the cell-edge bandwidth if it is not occupied. For each UE, the eNodeB randomly assigns one available PRB according to the UE's category (cell-edge or cell-center). Since the cell-edge bandwidth assigned for adjacent cells is non-overlapping (as shown in Fig. 1), two cell-edge UEs from adjacent cells will be prevented from using the same PRB. However, PRBs taken by cell-edge UEs from one cell might be assigned to other UEs at cell-center in a neighboring cell. In a downlink scenario, this might not cause a serious problem. However, in the uplink scenario, cell-edge UEs might be a non-negligible source of interference to cell-center UEs, so more so as the cell-edge UEs usually have a higher transmission power. When two UEs from different cells use the same PRB, we refer to such an event as PRB reuse. The third step of ASFR aims at reducing the probability of PRB reuse in as much as possible in order to improve the achievable throughput. After performing the randomized PRB allocation, the resource allocation matrix $\mathbf{Y}^{(0)}$ is obtained. As a result, the two resource allocation variables $\mathbf{X}^{(0)}$, $\mathfrak{J}^{(0)}$ can be generated by the mapping functions $f(\cdot)$ and $g(\cdot)$, respectively.

B. Cell-edge Bandwidth Breathing

Although the breathing mechanism for cell-edge bandwidth is intuitively very appealing, realizing it in practice is no trivial task. In the proposed scheme, a high interference indicator (HII) currently in the process of being standardized within LTE, is used. HII is the message whereby a cell informs its neighbors about its decision on ICIC. The neighboring cells can then respond by avoiding to schedule their cell-edge UEs on the PRB(s) indicated by the received HII(s). After sending out a HII to its neighbors, the source cell can monitor via available measurements if the interference levels on the indicated PRB(s) has been reduced or not.

The format and content of the HII message has yet to be agreed upon in the LTE standard. However, the current consensus seems to be that HII employs one bit per PRB [5]. We abide by this agreement and propose the so-called cell-edge bandwidth sharing (CEBS) algorithm which allocates the cell-edge bandwidth dynamically according to the traffic load of the network. In our algorithm, each cell maintains an available cell-edge PRB set and an available cell center PRB set. When a cell is overloaded at cell edge (borrowing cell), it observes the HII(s) sent by its neighbors. Since the frequency bandwidth reserved for each cell is known as the reserved PRB set at the initialization stage, we can compare the PRBs indicated by HII and the reserved PRB set to determine for each cell the 'free' or borrowable cell-edge PRB(s). In order to optimize the cell-edge bandwidth breathing procedure, the borrowing cell first asks for 'free' PRB(s) from the cell that has most borrowable PRBs. Also, to avoid intra-cell interference, the borrowed PRB(s) should be excluded from the borrowing cell's set of available cell-center PRBs. After executing the CEBS algorithm, the available cell-center and cell-edge PRB sets are reallocated according to the traffic load within each cell.

C. PRB Reuse Avoidance

Inter-cell interference arises as a result of PRB reuse by UEs located in neighboring cells. In the context of soft frequency reuse, since cell-edge to cell-edge PRB collisions are inherently taken care of, those suffering the most from inter-cell interference are cell-center UEs that reuse the same PRBs as cell-edge UEs. Such PRB reuse cases can also be detected via HII exchange. Therefore, whenever such PRB reuse cases are detected, we employ our PRB reuse avoidance (RA) algorithm to try to prevent them by allocating another cell-center PRB (subject to availability) to the cell-center UE in question.

Each eNodeB updates the available cell-center PRB set when receiving the HII from the neighboring cells and then chooses a PRB from the updated cell-center PRB set that is reused multiple times. After reallocation, the resource allocation matrix corresponding to cell l is captured by $\boldsymbol{y}'_{m\in\mathfrak{M}_l}$. Then, the total SINR in cell l is evaluated using (1) as

$$\mathrm{SINR}(l) = \sum_{m\in\mathfrak{M}_l} \sum_{n=1}^{N} \mathrm{SINR}_{mn}, \quad l = 1, \cdots, L \tag{4}$$

The re-allocation will be accepted if SINR(l) is increased and rejected otherwise. Simulation results provided below show that the proposed RA algorithm significantly reduces the reuse probability especially at mid-load traffic scenarios.

IV. SIMULATIONS AND RESULTS

In order to evaluate the merits of the proposed ICIC schemes, we focus on the uplink of a 7-cell hexagonal layout with omnidirectional antennas at the center of each cell. In case of a sectorized network, the SFR-based ICIC schemes proposed herein may apply to a cluster of adjacent sectors belonging to three different sites. We assume delay sensitive traffic model for UEs, hence UEs which cannot be serviced due to a shortage on the available PRBs (according to the adopted ICIC scheme) are accounted for as contributing to the blocking probability.

A number of UEs are uniformly dropped within each cell. The cell edge area in each cell is assumed to be the outer one third of the cell area. We further assume that the traffic load is unevenly partitioned between the seven cells; i.e., only the central cell is assumed to be overloaded at cell edge whereas the remaining cells are under-loaded. Only one PRB can be assigned to each active UE per TTI. The main simulation parameters are summarized in Tab. 1.

The universal frequency reuse (UFR) whereby PRBs are randomly assigned to the different users in each cell irrespective of their category (cell-edge or cell-center UEs) is taken as a reference scheme. Another reference scenario that we consider is the conventional SFR scheme which assigns a fixed non-overlapping cell edge bandwidth (usually one-third of the total bandwidth per cell) to a cluster of three adjacent cells. Enhanced SFR (ESFR) is an enhanced version of SFR that applies the RA algorithm. As we mentioned earlier, the proposed ICIC scheme is denoted as ASFR.

Table I
MAIN SIMULATION PARAMETERS.

Parameter	Value
Bandwidth	10 MHz
Carrier frequency	2 GHz
# of cells	7
Cell radius	750 m
Ratio of cell edge area	1/3
Distance-dependent path loss	L=128.1 + 37.6 log10(R/1000), R in m
Shadowing standard deviation	8 dB
Thermal noise	-174dBm/Hz
# of PRBs per UE	1
Total # of PRBs	48 PRBs (PUSCH), 2 PRBs (PUCCH)
# of reserved cell-edge PRBs	16

Fig. 3 shows the average SINR per UE located at cell edge for the different ICIC schemes considered in this paper. It is observed that ESFR yields a significant improvement compared to SFR in terms of achievable SINR owing to the RA algorithm. One can also observe that ESFR slightly outperforms ASFR in terms of average SINR. However, ASFR yields higher throughput and lower blocking probability as is shown in Fig. 4 and Fig. 5, respectively, which makes it the better alternative particularly under stringent resource constraints.

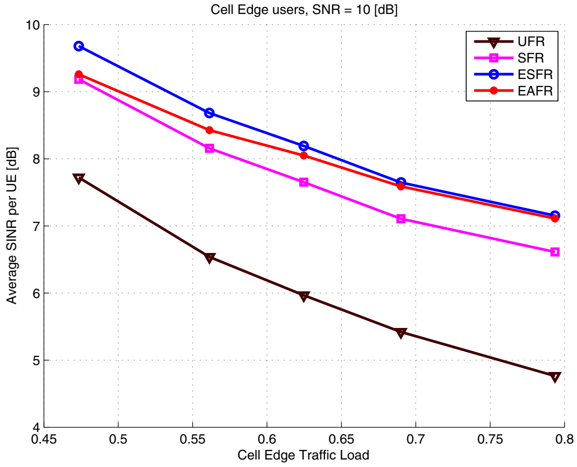

Figure 3. SINR comparison for different allocation scheme.

Fig. 4 shows the normalized spectral efficiency (SE) as function of the cell-edge traffic load. The SE is defined as

$$\mathrm{SE} = \frac{3}{NL\log_2(1+\mathrm{SNR})}\sum_{m=1}^{Mt}\delta_m T_m \tag{5}$$

where $\delta_m = 1$ if UE m is located at cell edge, and $\delta_m = 0$ otherwise. In eq. (5), the total throughput at cell-edge is normalized by an upper bound on the achievable throughput at cell-edge. Simulation results show that the proposed ASFR scheme achieves the best results among the ICIC schemes under consideration in terms of cell-edge throughput. As can be seen from this figure, the two proposed ICIC schemes well outperform SFR especially in mid-load traffic conditions, i.e., when the traffic load is between 40% and 70%.

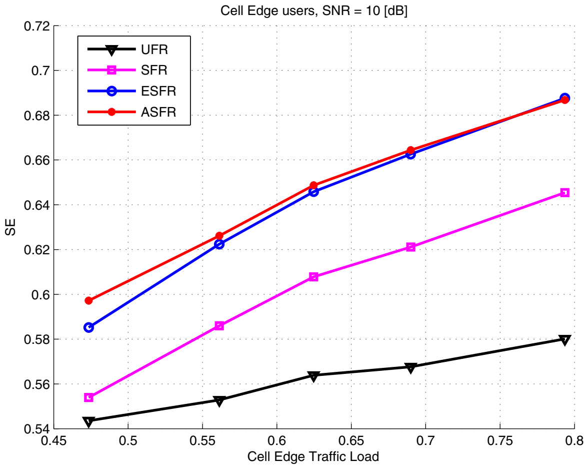

Figure 4. BW efficiency comparison for different allocation scheme.

The payoff for this small increase in the interference level seen by each UE under the ASFR compared to the ESFR is a huge improvement in the blocking probability as can be observed from Fig. 5. ESFR yields the same blocking probability as SFR when the system is overloaded in terms of cell-edge traffic. It is worthwhile to mention that the three schemes perform worse than UFR in terms of blocking probability since our basic assumption consists of considering an under-loaded system in each cell whereas each cell has access to the full bandwidth in the UFR scheme.

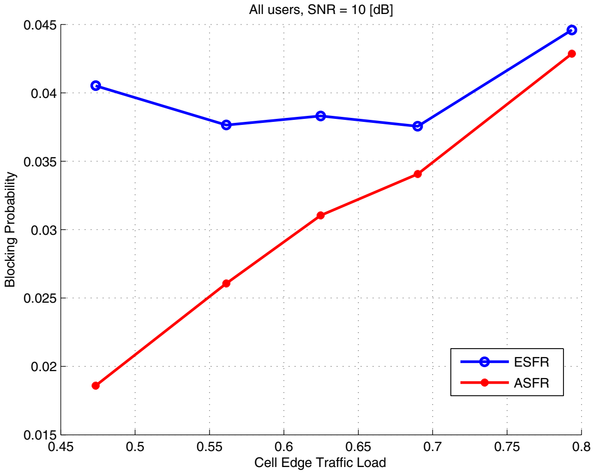

Figure 5. Blocking probability versus traffic load of the system.

V. CONCLUSION

In this paper, we show the benefits of applying an adaptive soft frequency reuse scheme in the 3GPP LTE systems, both in terms of throughput enhancement and QoS guaranty through the reduction of service outage probability. We recommend that the SFR-based ICIC scheme with PRB reuse avoidance and cell-edge breathing, as proposed in the paper, be implemented in LTE systems as we show it can substantially impact LTE performance.

Our simulation results for the uplink scenario show that the proposed methods can dramatically reduce the dropping probability when traffic load is uneven among sectors/cells, e.g. when some sectors/cells experience relatively heavier traffic load on their cell-edge bandwidth. It is noteworthy that, in line with previous contributions pertaining to uplink ICIC [6], [7], more gain is observed for the proposed ICIC scheme when the network is mid-loaded (traffic load averaged over all cells). Intuitively, this is due to the fact that mid-load traffic conditions allow for some "room" to maneuver that can be leveraged by ICIC.

REFERENCES

[1] G. Li, H. Liu, "Downlink Radio Resource Allocation for Multi-Cell OFDMA System," *IEEE Tran. Wireless Commun.*, vol. 5, no. 12, pp 3451-3459, Dec. 2006

[2] Y. Xiang, J. Luo, C. Hartmann, "Inter-cell Interference Mitigation through Flexible Resource Reuse in OFDMA based Communication Networks", European Wireless 2007.

[3] R1-050507, 'Soft Frequency Reuse Scheme for UTRAN LTE', Huawei. 3GPP TSG RAN WG1 Meeting #41, Athens, Greece, May 2005.

[4] R1-080361, 'Additional RSRP reporting trigger for ICIC', Ericsson. 3GPP TSG RAN WG1 Meeting #51b, Sevilla, Spain, January 2008.

[5] R1-080361, 'Summary of email discussion on UL and DL ICIC', Telecom Italia. 3GPP TSG RAN WG1 Meeting #52, Sorrento, Italy, February 2008.

[6] R1-080950, "Performance of proactive uplink ICIC under fractional load", Nokia Siemens Networks, Nokia. 3GPP TSG RAN WG1 #52, Sorrento (Italy), February, 2008.

[7] R1-074444, "On Inter-Cell Interference Coordination Schemes without/with Traffic load Indication", Ericsson. 3GPP TSG RAN WG1 #50b, Shangai (China), October, 2007.

978-1-4244-2324-8/08/$25.00 © 2008 IEEE.