MULTI-HOP CELLULAR NETWORKS FOR MOBILITY LOAD BALANCING AND INTER-CELL INTERFERENCE COORDINATION USING OFDMA WITH IMPROVED CELL-EDGE SPECTRAL EFFICIENCY

By

P. S. LAKSHMIKANTH * D. LEELA RANI ** P. GEETHA ***

* PG Scholar, Department of Electronics and Communication Engineering, Sree Vidyanikethan Engineering College, Tirupati, India.
** Professor, Department of Electronics and Communication Engineering, Sree Vidyanikethan Engineering College, Tirupati, India.
*** Associate Professor, Department of Electronics and Communication Engineering, Sree Vidyanikethan Engineering College, Tirupati, India.

ABSTRACT

Multi-hop Cellular Networks (MCNs) use different multiple low power transmitters for high throughput and coverage of large area in a cellular network. A quantitative study on resource allocation schemes by jointly considering Interference Coordination (IC) and Load Balancing (LB) in MCNs improves throughput and large coverage. But still it suffers from load unbalance and Inter-Cell Interference (ICI) problems. In this paper, these problems are tackled by jointly considering a novel Mobility Load Balancing (MLB) and Inter-cell Interference Coordination (ICIC) algorithm in MCNs. This algorithm is simulated under fractional Frequency Reuse (FFR), Soft Frequency Reuse (SFR), Reuse-1 and Reuse-3 frequency planning schemes. The simulation is performed with Round-robin, Proportional fair and Best-channel quality indicator (CQI) schedulers. This shows that the proposed algorithm provides significant improvements in the Quality of Service (QoS) provision, cell-edge spectral efficiency and the number of unsatisfied users. The main objective of this paper is to provide higher data rates, improvement in cell-edge spectral efficiency, and reduce the unsatisfied users' in the future wireless cellular networks.

Keywords: Multihop Cellular Networks, Resource Scheduling, OFDMA/TDD, Interference Coordination, Load Balancing, MLB, ICIC, Frequency Planning, Modulation and Coding Scheme, Link Adaptation.

INTRODUCTION

Modern wireless and mobile communication systems are expected to offer higher data rates, to support a large number of subscribers and to ensure fulfilment of Quality of Service (QoS) requirements, given the limited availability of frequency spectrum and time varying channels. The wireless services such as Skype and other multimedia conferencing require high data rate irrespective of user's in the cellular network. Due to the high spectrum efficiency of Orthogonal Frequency Division Multiplexing (OFDM), 3GPP advanced long term evolution [1] networks employ Orthogonal Frequency Division Multiple Access (OFDMA) as the multiple access technology. OFDMA is achieved by assigning different subcarriers to different users. In OFDMA based Long Term Evolution (LTE)/LTE advanced cellular Networks, the intra-cell interference is negligible due to the orthogonality of subcarriers. In single-hop OFDMA networks, cell-edge users may receive high Inter-Cell Interference (ICI) and low signal power [2]. To address this issue, relay becomes a promising technology in future cellular networks, because relay can extend coverage and enhance user's performance in cell-edge area. There are two categories of relay. They are mobile relay and fixed relay [3]. Compared with the mobile relay, a fixed relay can achieve better cell edge coverage and higher data coverage.

According to the worldwide interoperability for microwave access (WiMAX) [4],[5] forum, the frequency reuse pattern can be denoted as $N\times S\times K$, which means the network is divided into clusters of N cells (each cell in the cluster has a different frequency band) with S sectors and K different frequency bands per cell. To mitigate the interference we use frequency reuse core concept. Frequency reuse may simultaneously use the same frequency channel. Frequency reuse drastically increases user capacity and spectrum efficiency. Frequency reuse causes mutual interference. In this regard, Fractional Frequency Reuse (FFR) has an effective ICIC technique in OFDMA based wireless networks. In FFR, the total bandwidth is divided within a cell so that the cell edge users of adjacent cells do not interfere with each other. The use of FFR in cellular networks lead to trade-offs between performance metrics such as coverage for cell-edge users, and spectral efficiency. As reviewed in [6], [7] two common FFR approaches are strict FFR and Soft Frequency Reuse (SFR). While SFR has a higher bandwidth efficiency compared to strict FFR. Due to random distribution of users and the exponentially growing demand for wireless data services, mobile cellular networks face the challenges brought by the uneven load distribution. In order to deal with uneven load distribution, load balancing is widely used to redistribute load among the heavily loaded cell and neighbouring cells.

A dynamic connection based load balancing scheme in fixed relay cellular networks [8] is that RS has dynamic connection with neighbouring BSs according to the neighbouring cell's load. The limitation of this scheme is that the dynamic BS-RS connection might result in a coverage gap since BS needs time to configure and assign spectrum to new connected RS. To tackle these problems, MLB+ICIC algorithm is proposed in each BS in a distributed manner considering load conditions of the cells, which involves N-th tier neighbors of overloaded cell in MLB optimization area and applies HO_{off} adjustment. This algorithm is evaluated under round robin scheduler, best CQI scheduler and proportional fair schedulers, and improvements were observed in terms of the load balance, cell-edge spectral efficiency and number of unsatisfied users.

1. System Model-1

In this system model, the authors consider the MCNs consisting of 19 hexagonal cells with 10 MHz bandwidth [9]. According to IEEE802.16j/m specification [10] Orthogonal Frequency Division Multiple Access (OFDMA) technology was adopted for Multi-hop Cellular Networks (MCNs). Each hexagonal cell is divided into three sectors with relay station deployed in each sector. Each time division duplex mode consists of two frames. One is uplink subframes and another one is downlink subframes. Each frame is divided into two zones. They are Relay Zone (RZ) and Access Zone (AZ). Fixed Relay Stations (RSs) with less functionality than Base Stations (BSs) can be deployed to overcome poor channel conditions while maintaining low infrastructure cost. Nevertheless, MCNs have inherent drawbacks, for example, extra radio resource is required on relay links (BS-RS links).

Therefore, well-designed radio resource allocation schemes are crucial for MCNs to effectively exploit the benefit of RSs, while overcoming the disadvantage. Since RSs always utilize the same spectrum as MSs or BSs, Co Channel Interference (CCI) [11] will be closely related to the radio resource allocation schemes in MCNs due to the inter cell and intra cell frequency reuse. Traditional Single-hop Cellular Networks (SCNs) typically employ the frequency reuse pattern with factor of 3 or 7 to reduce CCI, which results in low spectral efficiency [12-15].

Frequency reuse with factor of 1 is likely to be used in LTE-Advanced and IEEE 802.16m systems [16], aiming at improving the spectral efficiency. However, the CCI using this frequency planning causes severe performance degradation at cell boundaries. In [17], Fractional Frequency Reuse (FFR) is extended to MCNs as a compromise solution to reduce CCI while maintaining the sector frequency reuse factor as 1. The main idea of FFR is to adopt frequency reuse $1\times3\times1$ at the cell centre to maximize the network spectral efficiency while harnessing frequency reuse $1\times3\times3$ at the cell edge to alleviate CCI. Too many users accessing one station (BS or RS) yields load imbalance in MCNs. Such an imbalance could severely affect the performance of hot spot areas, which may not meet the users' Quality of Service (QoS) requirements. To guarantee users' QoS, therefore, Load Balancing (LB) [18],[19] should be adopted along with IC for MCNs. In [20] jointly considering IC and LB is designed to improve the weighted sum of data rates in multi cell networks.

2. System Model-2

In this paper, a novel algorithm is presented which operates conjointly with strict FFR and FFR [21]. Frequency reuse-1 or reuse-N where all or fraction of the bandwidth is used in the entire cell. In Figure 1, FFR technique, area of cell is divided into two regions. They are cell-centre and cell-edge region. All available sub carriers are divided into two groups; one is for cell centre region and another one for cell-edge region.

In SFR cell-centre region of a particular cell, cell-edge sub bands of the adjacent cells are allowed to share. The boundary between cell-centre and cell-edge is represented with an inner circle with radius R_{int}. The numbers of users allotted to inner and outer bands are dependent on R_{int}.

The received SINR for user u in band w from base station c is given as in equation (1),

$$SINR_{cu}^{w}=\frac{P_c^W h_{cu}^W G_{cu}}{\sigma^2+\sum_{z\in Q_c^W, z\neq c} P_z^W h_{zu}^W G_{zu}} \quad (1)$$

Where P_z^w and P_z^w are the downlink transmit powers of serving and interfering cells in the sub band w. h_{zu}^w and h_{cu}^w are corresponding channel fading coefficients.

$G_{cu}=||c-u||^{-\alpha}$ is the path loss between the user and the base station, where c and u are coordinates of the base station c and user u and α is the path loss coefficient. Q_c^w is the set of base stations using the same sub band w as user u.

In FFR, a constant transmit power is applied for all users in all sub-bands. In SFR interior region, fixed transmit power is applied for all users in the sub bands. In SFR exterior region, power control factor β is employed to create two different power classes for exterior users. $P_c^{ext}=\beta P$, where β is typically set as 2or 4.

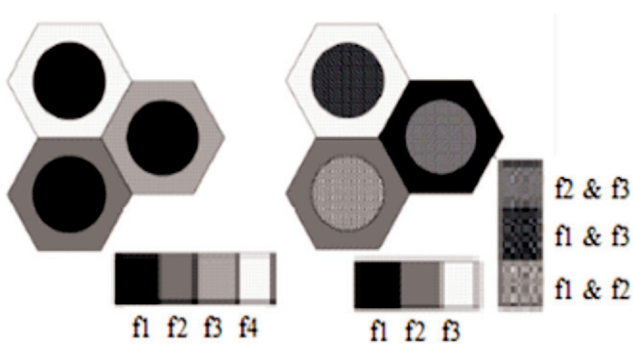

Figure 1. FFR and SFR Deployments

Adaptive modulation and coding scheme have offered an alternative link adaption method that promises to improve the overall system capacity. AMC provides flexibility to match the modulation coding scheme to the average channel conditions for each user. With AMC, the power of the transmitted signal is held constant over a frame interval and the modulation and coding format is changed to match the channel conditions. In a system with AMC [22] , users close to the base station are typically assigned higher order modulation with higher code rates (64-QAM with R=3/4 turbo code), but the modulation order or code rate will decrease as the distance from base station increases. For the best radio conditions, QPSK-3/4, 16-QAM, 64-QAM-2/3, 64-QAM-3/4 modulations schemes are used. For most robust condition at cell boundaries, QPSK modulation is used. Link Adaption (LA) selects different Modulation and Coding Schemes (MCS) based on CQI reports to maximize the spectral efficiency.

2.1 Virtual Load

Load estimation is an essential step for load balancing schemes [23].

$$\text{Cell load} = \frac{\text{Number of carriers used in the cell}}{\text{Total number of carriers available to the cell}} \quad (2)$$

Cell load in equation (2) is in the range of 0% to 100% ($0\% \leq L \leq 100\%$)

Overload: The traffic generated by users is equal to or larger than the cell capacity, namely, all carriers are used in the cell.

Heavy load: A large number of carriers are used in the cell, namely $100\% > L \geq L_{HL}$. L_{HL} is the threshold identified as a heavily loaded cell. In this theses, the value of L_{HL} is 70% [24].

Light load: A small number of carriers are used in the cell, namely $L < L_{HL}$ Load balancing can be triggered when the load of cell is equal to or higher than the heavily loaded threshold L_{HL}. In this thesis, a cell with a load above L_{HL} is defined as a hot-spot cell. Load of a cell is defined as the ratio of allocated Physical Resource Blocks (PRBs) to the total number of PRBs in a given cell. Under the Constant Bit Rate (CBR), the number of PRBs required to serve user u is calculated as in equation (3)

$$\widehat{N_{cu}^{w}} = \frac{D_u}{R[SINR_{cu}^{w}](BW_{PRB})} \quad (3)$$

Where D_u is the CBR requirement of user u. The transmission bandwidth is given by BW_{PRB}. Modulation and Coding Scheme (MCS) link level simulation spectral efficiency is given by $R[SINR_{cu}^{w}]$.

2.2 Mobility Load Balancing

In 3GPP Long Term Evolution (LTE)/LTE advanced [25], Mobility Load Balancing (MLB) is an effective method to address an uneven load distribution. Mobility load balancing aims at shifting edge users to lightly loaded neighbouring cells via adjusting the cell specific handover offset HO_{off} to enforce handover. The adjusted HO_{off} may impact the handover performance e.g, handover failure. In order to achieve high cell capacity, one of the frequency reuse technologies considered in LTE/LTE advanced networks is that all cells share the same spectrum (Frequency Reuse Factor=1) [26],[27]. In OFDMA based LTE/LTE advanced cellular networks, the intra-cell interference is negligible due to the orthogonality of subcarriers. In order to effectively

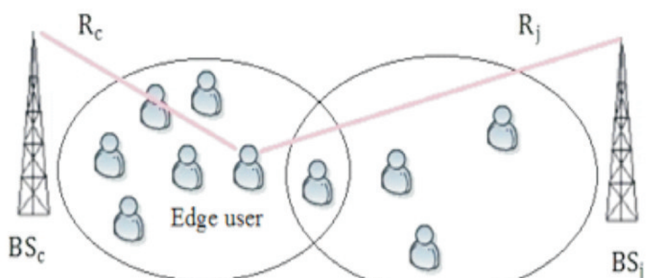

Figure 2. Cell Region

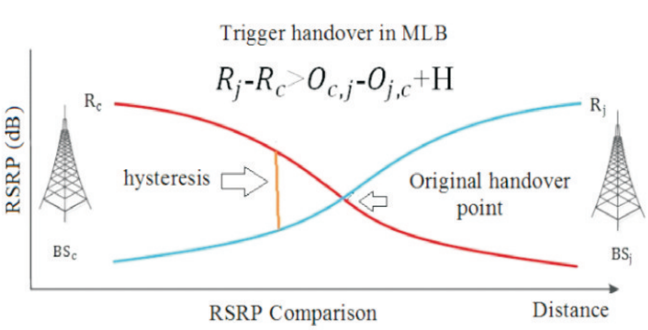

Figure 3. Traffic Shifting Stage in MLB

balance the load in LTE/LTE advanced networks, 3GPP release-8 defines MLB as self-organising networks functionality [28]. Generally, MLB is composed of two stages: partner selection and traffic shifting. In the partner selection stage, the hot spot cell selects less-loaded neighbouring cells as partners, which are also called as target cells or selected neighbouring cells.

In the traffic shifting stage, the hot spot cell calculates the amount of shifting traffic and adjusts HO_{off} towards each partner. The adjusted HO_{off} enlarges the handover area, thus shifting cell edge users to selected partner cells, where $cell_c$ is a hot spot and intends to offload traffic to partner $cell_j$. However, the users R_j from BS_j is weaker than R_c from BS_c, and hence the edge user is unable to trigger handover. In order to shift the edge user, BS_j adjusts its HO_{off} towards BS_c. Once the handover condition event A3 in [29] which is shown in Figure 2 is met, the user will be handed over to BS_j.

The traffic shifting stage in MLB is shown in Figure 3.

$$R_j\text{-}R_c > O_{c,j}\text{-}O_{j,c}+\mathrm{H} \quad (4)$$

Where R_j and R_c are the Reference Signal Received Power (RSRP) values from target cell j and serving source cell c respectively. $O_{c,j}$ is the Cell Individual Offset (CIO) of cell c with respect to j, $O_{j,c}$ is the CIO of a cell j with respect to cell c and H is the hysteresis. $O_{c,j}$ and $O_{j,c}$ are symmetric. The hysteresis is a parameter used within the entering and leaving conditions of an event-triggered reporting condition. Hysteresis can ensure that is R_j-R_c is 2 dB higher than R_c [30], in order to deal with the Ping-Pong handover [31]. That Ping-Pong handover denotes that the user is handed over to $cell_j$ and then it is handed over back to $cell_c$.

3. Joint MLB and ICIC Algorithm

The proposed algorithm 1 is implemented in each base station (called evolved node B (eNB) in LTE) in a distributed manner. Cell edge users of each overloaded cell by adjusting CIO parameter formal neighbourhood cells do not get overloaded. Once an overload occurs in a cell, it becomes a Source eNB (SeNB) and collects all load information for adjacent cells to create a potential Target eNB (TeNB) list. The SeNB chooses the first entry from the list, assumes it as temporary TeNB ($TeNB_{temp}$) decrease CIO value of SeNB with respect to $TeNB_{temp}$. For each user satisfying the condition in equation (4), the load is created in $TeNB_{temp}$.$\tilde{\rho}$ $TeNB_{temp}$ is estimated. If $\rho TeNB_{temp}$ is less than the load threshold then limits HO of users. ρ_{th}, HO, the current $O_{SeNB,TeNB}$ value is updated to the $O_{SeNB,TeNB_{temp}}$ to maintain symmetry.

The adjacent neighbours of SeNB are the first tier neighbours and the neighbours of the first tier are the second tier neighbours. If SeNB is overloaded and Nth tier neighbors and Nth tier neighbours have not sufficient resources, then they are requested to direct some of their load to N+1th tier neighbors and are also included LB optimization area. $R_{int,c}$ is a radius of interior region and $R_{(I}$

is the temporary interior region value. $R_{int,c}$ is updated to $R^{temp}_{int,c}$ and adjacent cell operation is triggered for the users who are need to be change their current band.

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Algorithm 1: Joint MLB and ICIC Algorithm

1. for t=c to C do
2. N←1 ► Begin from 1-st tier neighbours
3. while $\rho c \geq = \rho_{th}$ do ►Overload condition
4: SeNB ← c
5. L ← sort (create a list of potential TeNBs and sort according to the load status)
6. while $\rho c \geq = \rho_{th} \wedge i <$ size (L) do
7. i ← 1
8. $TeNB_{temp} \leftarrow (I)$
9. $CIO_{temp} \leftarrow O_{SeNB,\,TeNB_{temp}}$
10. while $\rho_{SeNB} \geq = \rho_{th} \wedge I \leq$ size (L) do
11. $CIO_{temp} \leftarrow CIO_{temp} - \Delta$
12. u ← group (estimate and group the users that satisfy A3 event HO for a given CIO_{temp})
13. if $\tilde{\rho}_{TeNB_{temp}} \leq \rho_{th}$, HO then
14. $TeNB \leftarrow TeNB_{temp}$
15. $O_{SeNB,TeNB} \leftarrow CIO_{temp}$
16. $O_{TeNB,SeNB} \leftarrow O_{SeNB,TeNB}$
17. $\rho_{SeNB} \leftarrow \rho_{SeNB} \leftarrow \rho_{SeNB,\,u}$
18. $\rho_{TeNB} \leftarrow \tilde{\rho}_{TeNB_{temp}}$
19. end if
20. end while
21. I ← i+1
22. end while
23. if i>size (L) $\wedge$ $\rho_c >= \rho_{th}$ then
24. N ← N+1 (add (N+1)-Th tier neighbors to the optimization area)
25. end if
26. end while
27. if reuse method is FFR
28. if $\rho_c^{outer} > \rho_c^{inner}$ then
29. $R^{temp}_{int,c} \leftarrow R_{int,c} + \Delta_{intra}$
30. else
31. $R^{temp}_{int,c} \leftarrow R_{int,c} - \Delta_{intra}$
32. end if
33. $R_{int,c} \leftarrow R^{temp}_{int,c}$
34. end if
35. end for

4. Overall Design Simulation Platform

Figure 4 shows the flowchart of the system level simulation platform. This simulation platform uses time-stepping. The function of each module is as follows,

4.1 Cells Initialisation

This module initialises the system parameters, including the network topology, the position of BS and RS, the antenna configuration, and the frequency planning.

4.2 User and Service Update

This module generates both active users and non-active users, and then initialises their physical locations. Since this simulation platform uses time-stepping, users' physical locations are updated at every time step.

4.3 Channel Update

This module updates the path-loss according to users' 'physical locations. This module also updates the shadow fading in cellular networks.

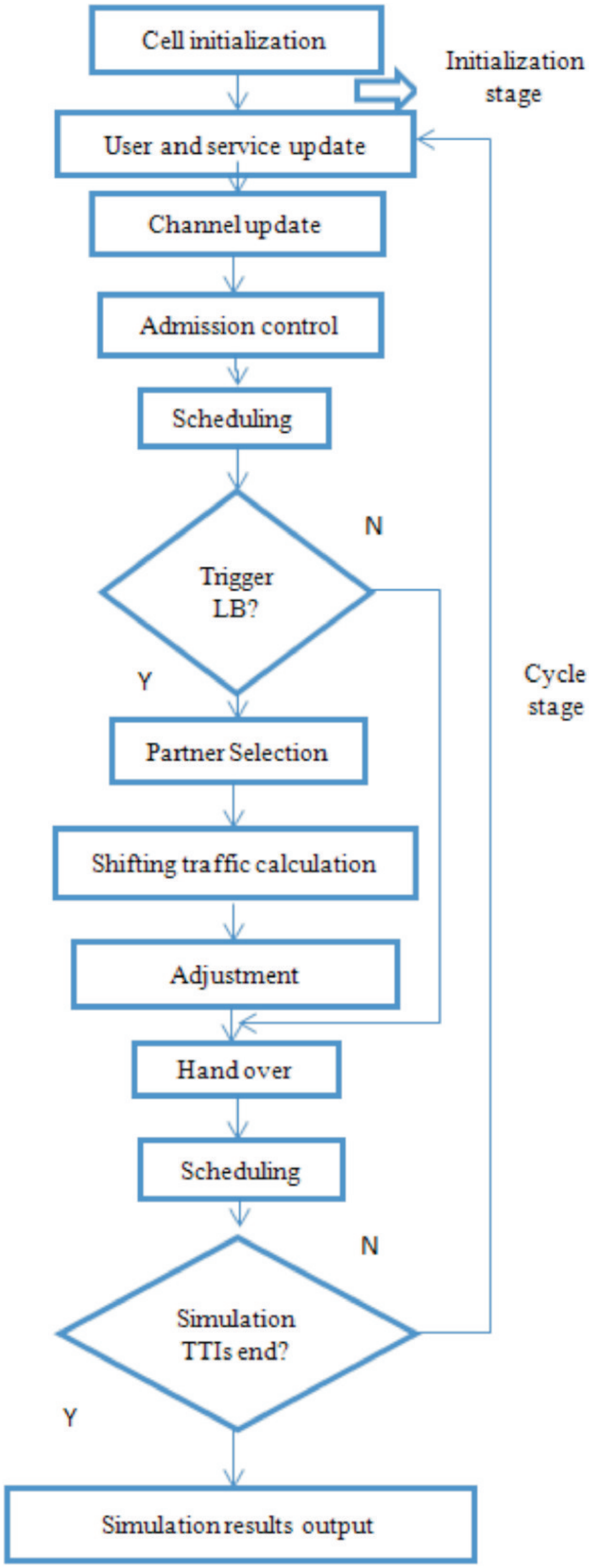

Figure 4. Flowchart of the Simulation Platform

4.4 Admission Control

In this simulation platform, a new call user selects a cell from which the user receives the strongest Reference Signal Received Power (RSRP). When the number of subcarriers is enough to meet the user's service requirement, the user can access [32]. Otherwise, the new call user will be blocked.

4.5 Scheduling Algorithm

Scheduler allocates spectrum resources to users. Its aim is to effectively use spectrum resources and improves network performance. In the scheduling model of OFDMA cellular networks, the PRB is the basic allocation unit. In each cell, the scheduling module can allocate PRBs to users at each scheduling period. After the handover module and the admission control module, the cell employs scheduling algorithm to allocate subcarriers to serving users.

4.5.1 Round Robin Scheduler

In this scheduling, users are assigned the shared Resource Blocks (RB) equally to all the users [33]. All users have same channel conditions. The advantage of round robin scheduling guarantee fairness for all users. Furthermore, round robin is easy to implement, since RR does not take the channel quality information into account, which results in low user throughput.

4.5.2 Best CQI Scheduler

The best CQI scheduler assigns a RB to the user that has the highest CQI on that RB [33]. The user's feedback the CQI to the BS and the BS assigned the resources to user with highest CQI. Furthermore the highest CQI, the higher the modulation order and the coding rate.

4.5.3 Proportional Fair Scheduler

The best CQI scheduling algorithm [33], [34] provides high throughput with low fairness and round robin scheduling algorithm provides low throughput with high fairness. Due to this, need of PF algorithm which will have the combination of these two algorithms emerge. In PF algorithm resource blocks are assigned to user with the relative best channel condition. It is based upon maintaining a balance between two competing interests, trying to maximize total throughput while at the same time allowing all users with at least minimum level of service. This is done by assigning each data flow a data rate or a

Parameters	Value/Assumption
Cell layout	Hexagonal-single sector
User distribution	Uniform
Inter-site Distance	1 Km
Cell edge SINR	10dB
System bandwidth	10 MHz (48 PRBs)
Channel model	Rayleigh flat fading
N_{int}	24 PRBs
Traffic model	256 kbps CBR
Initial CIO configuration	0 dB
CIO_{max}	6 dB
CIO_{min}	-6 dB
D	1 dB
D_{intra}	0.01 km
H	3 dB
Transmission time interval	1 ms
r_{th}	95% of total PRBs
rt_{h}, HO	85% of total PRBs
$SINR_{th,min}$	-7.04 dB

Table 1. Simulation Parameters

scheduling priority that is inversely proportional to its anticipated resource consumption.

5. Performance Evaluation

In this section, the proposed schemes are evaluated by using the simulation study.

5.1 Simulation Model and Parameters

The system is simulated with 19 hexagonal cells each operating with 10 MHz bandwidth which corresponds 48 PRBs. The system level simulation parameters are shown in Table 1. The SFR power control factors are 1 and 4 which relates to cell-edge user gains of 0dB and 6dB, respectively.

Number of unsatisfied users can be calculated as in equation (5).

$$Z=\max(|U_c|*(1-\frac{1}{\rho_c}),0) \quad (5)$$

Spectral efficiency parameters are bits/s/Hz. The Empirical Cumulative Distribution Function (ECDF) of cell-edge spectral efficiency gives a clear idea about how MLB improve the performance.

5.2 Results and Discussions

Figure 5 shows the performance comparison of cell spectral efficiency in terms of various scheduling algorithms, considering six frequency reuse patterns. Average spectral efficiency is calculated as the ratio of

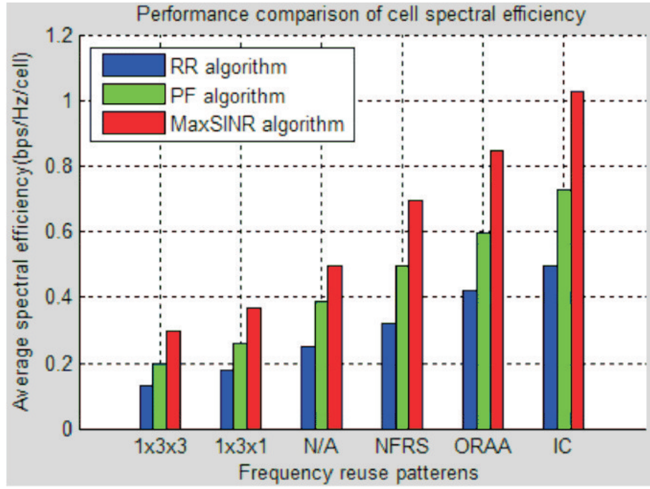

Figure 5. Performance Comparison of Cell Spectral Efficiency

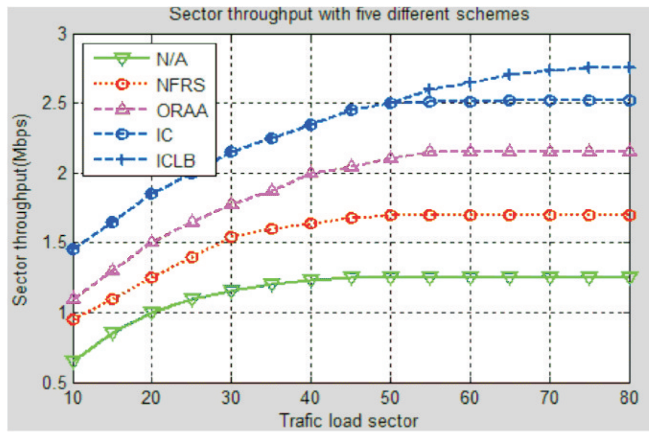

Figure 6. Sector Throughput with Five Different Schemes

cell throughput to the channel bandwidth of a cell [12].

The authors have studied the universal frequency reuse scheme for the cluster size N=1 (N/A) [35], the Novel Frequency Reuse Scheme (NFRS) [36], and Orthogonal Resource Allocation Algorithm (ORAA) [37].

Max SINR algorithm has better spectral efficiency than Round Robin (RR) and Proportional fair (PF) algorithm. In Figure 6, universal frequency reuse N=1, the sector throughput gets minimum value compared to other schemes.

When traffic load of a sector is 70, the sector throughput of IC is 2.5 Mbps and ICLB is 2.8 Mbps. Compared to other schemes, the sector throughput has improved drastically. Power gain (R) is the ratio of transmission power of inner region to the outer region. The power gain (r) varies from 0 to 1. The result shows the comparative performances of

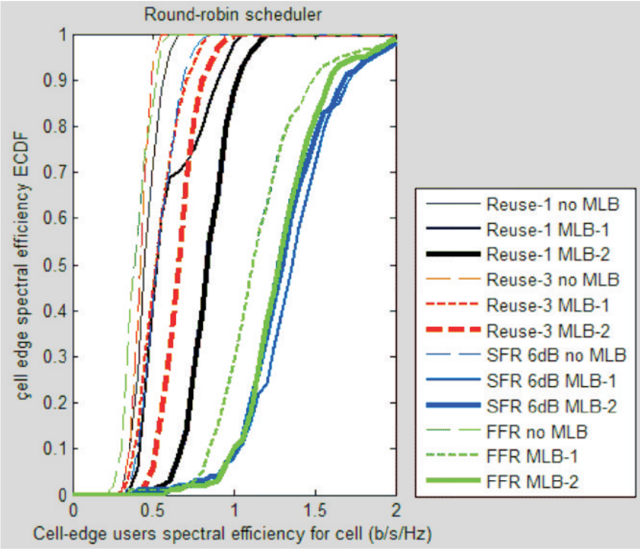

Figure 7. Round Robin Scheduler

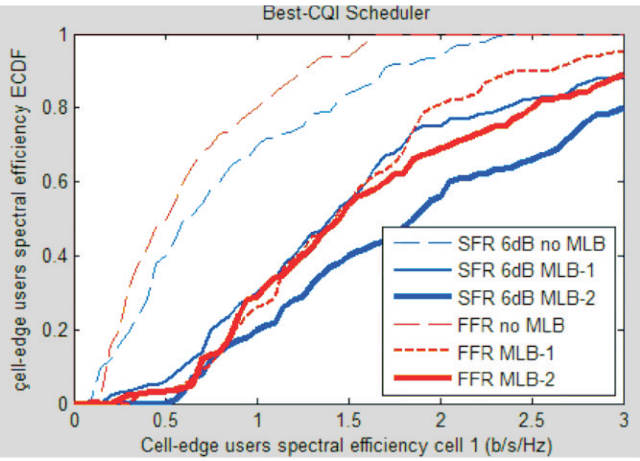

Figure 8. Best-CQI Scheduler

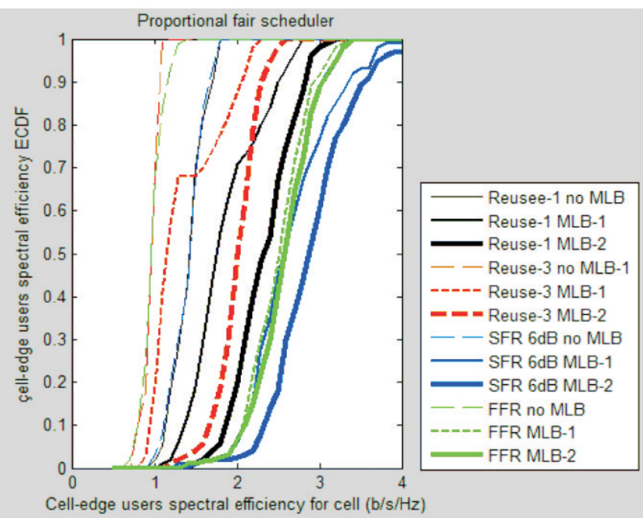

Figure 9. Proportional Fair Scheduler

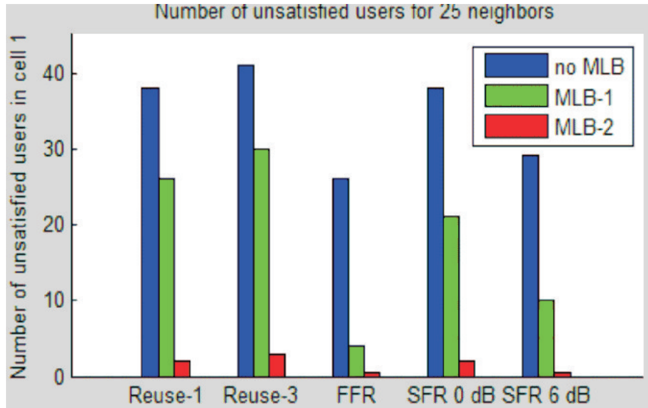

Figure 10. Number of unsatisfied users for 25 Neighbours

joint ICIC+MLB algorithm. The simulations are performed with three schedulers. They are round robin, proportional fair and best-CQI scheduler.

Figures 7, 8, and 9 show simulations with round robin, proportional fair and best-CQI schedulers respectively. This is an algorithm for different schedulers considering ECDF plots of cell edge spectral efficiency for cell with 25 first tier neighbors. For round robin scheduler with MLB-1 and MLB-2 are 1.3 and 1.35 b/s/Hz respectively, while in case of no MLB spectral efficiency between 0.25-0.5 b/s/Hz.

In best-CQI scheduler, cell-edge users cannot be scheduled for reuse-N. Because in this case SFR and FFR, the users in the inner and outer bands are scheduled separately. In this scheduler, MLB spectral efficiency is up to 3 b/s/Hz. For proportional fair scheduler with no MLB, the cell-edge spectral efficiency is between 0.9-1.4 b/s/Hz, with MLB-1 and MLB-2, it is more than 2.5 b/s/Hz and maximum up to 5 b/s/Hz. PF scheduler is the best scheduler among these schedulers.

Figure 10 shows the number of unsatisfied users in cell-1 for no MLB, MLB-1 and MLB-2. Number of unsatisfied users can be calculated from equation (5). FFR and SFR-6dB with MLB-2 outperforms the other planning schemes. LTE can support up to 20 MHz spectrum allocation. Significantly improved spectral efficiency is 2-4 times better than in 3GPP release-6. Mobility across the cellular network shall be maintained at speeds from 120 km/hr to 350 km/hr (or even up to 500 km/hr depending on the frequency band). Down Link (DL) data rate is of 100 Mbps within 20 MHz DL spectrum allocation (5bps/Hz).

Conclusion

In this paper, the authors have carried out a quantitative study on resource allocation schemes based on IC and LB on MCNs. This resource allocation algorithm improves the network performance compared to previous schemes. But still, it suffers from load imbalance and ICI problems. To overcome these problems, a novel joint MLB+ICIC algorithm is proposed to improve the system performance and provide more balanced load distributions among inner and outer regions. The system performance is measured in terms of cell-edge spectral efficiency and a number of unsatisfied users with round robin, proportional fair and best-CQI schedulers with MLB-1 and MLB-2.

References

[1]. S.W. Peters, A.Y. Panah, K.T. Truong, and R.W.Heath Jr., (2009). "Relay Architectures for 3GPP LTE-Advanced". *EURASIP J. Wireless comm. and Networking,* Article 618787.

[2]. Lin Xiao, (2010). "Radio resource allocation in relay based OFDMA cellular networks". (Doctoral Dissertation, Queen Mary University of London).

[3]. Lei Guan, Jianhua Zhang, Jianing Li, Guangyi Liu, and Ping Zhang, (2007). "Spectral efficient frequency allocation scheme in multihop cellular network". *IEEE 66th Vehicular Technology Conference,* pp.1446-1450.

[4]. WiMAX Forum, (2006). *Mobile WiMAX - Part I: A Technical Overview and Performance Evaluation.*

[5]. WiMAX Forum, (2008). *WiMAX System Evaluation Methodology.* Version 2.1.

[6]. T. Novlan, J. G. Andrews, I. Sohn, R. K. Ganti and A. Ghosh, (2010). "Comparison ofFractional Frequency Reuse Approaches in OFDMA Cellular Downlink". *IEEE Globecom*, Miami, USA, pp. 1-5.

[7]. A. Gok and M. Koca, (2014). "Performance evaluation of frequency planning and scheduling schemes in OFDMA Networks," *IEEE Black Sea Comm 2014*, Chisinau, Moldova, pp. 149-153.

[8]. K. Son, S. Chong and G. Veciana, (2009). "Dynamic association for load balancing and interference avoidance in multi-cell networks". *IEEE Trans. on Wireless Com.*, Vol. 8, No. 7, pp. 3566-3576.

[9]. Y. Zhao, X. Fang, R. Huang, and Yuguang Fang, (2014). "Joint Interference Coordination and Load Balancing for OFDMA Multihop Cellular Networks". *IEEE Trans. Mobile Computing*, Vol. 13, No. 1, pp. 89-101.

[10]. IEEE 802.16m-08/003r7, IEEE 802.16m System Description Document (SDD), *IEEE,* Feb. 2009.

[11]. L. Wang, Y. Ji, F. Liu, and J. Li, (2008). "Performance Improvement through Relay-Channel Partitioning and Reuse in OFDMA Multihop Cellular Networks". *Proc. IEEE Int'l Wireless Comm. and Mobile Computing Conf.*, pp. 177-182.

[12]. IEEE 802.16m-08/004r3, IEEE 802.16m Evaluation Methodology Document (EMD), *IEEE,* Oct. 2008.

[13]. G. Boudreau, J. Panicker, N. Guo, R. Chang, N. Wang, and S. Vrzic, (2009). "Interference Coordination and Cancellation for 4G Networks". *IEEE Comm. Magazine*, Vol. 47, No. 4, pp. 74-81.

[14]. Third Generation Partnership Project, (2008). *Technical Specification Group Radio Access Network; Requirements for Further Advancements for E-UTRA (LTE-Advanced) (Release 8).* 3GPP Technical Report 36.913 V8.0.0.

[15]. Y. Wang, S. Kumar, L. Garcia, K.I. Pedersen, I.Z. Kovcs, S. Frattasi, N. Marchetti, and P.E. Mogensen, (2009). "Fixed Frequency Reuse for LTE-Advanced Systems in Local Area Scenarios". *Proc. IEEE 69th Vehicular Technology Conf.*, pp. 1-5.

[16]. IEEE P802.16m/D6, Draft Amendment to IEEE Standard for Local and Metropolitan Area Networks Part 16, *Air Interface for Fixed and Mobile Broadband Wireless Access Systems, IEEE,* and May 2010.

[17]. Y. Zhao, X. Fang, X. Hu, Z. Zhao, and Y. Long, (2009). "Fractional Frequency Reuse Schemes and Performance Evaluation for OFDMA Multi-Hop Cellular Networks". *Proc. IEEE Fifth Test beds and Research Infrastructures for the Development of Networks and Communities and Workshops*, pp. 1-5.

[18]. A. Sang, X. Wang, M. Madihian, and R.D. Gitlin,

(2004). "Coordinated Load Balancing, Handoff/Cell-Site Selection, and Scheduling in Multi-Cell Packet Data Systems". *Proc. 10th Ann. Int'l Conf. Mobile Computing and Networking*, pp. 302-314.

[19]. D. Amzallag, R. Bar-Yehuda, D. Raz, and G. Scalosub, (2008). "Cell Selection in 4G Cellular Networks". *Proc. IEEE 27th Conf. Computer Comm.*, pp. 700-708.

[20]. H. Zhang and S. Rangarajan, (2009). "Joint Load Balancing, Scheduling, and Interference Mitigation in Multi-Cell and Multi-Carrier Wireless Data Systems". *Proc. IEEE Seventh Int'l Symp. Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks*, pp. 1-10.

[21]. Nur Oyku Tuncel and Mutlu Koca, (2015). "Joint Mobility Load Balancing and Inter-cell Interference Coordination for Self-Organising OFDMA Networks". 978-1-4799-8088-8/15/$31.00©2015 IEEE.

[22]. J.M. Ku, P.K. Kim, S.J. Lee, S. Shin, and C.G. Kang, (2006). "On the Performance of Broadband Mobile Internet Access System". *Proc. IEEE First Int'l Symp. Wireless Pervasive Computing*, pp. 1-6.

[23]. 3GPP TS 36.423 V10.0.0, "X2 application protocol (X2AP) (Release 10)". December 2010.

[24]. INFSO-ICT216284 FP7 SOCRATES, "Final report on self-organisation and its implications in wireless access networks". D5.9, v1.0, December 2010. Retrieved from http://www.fp7-socrates.org/files/Publications

[25]. 3GPP TR 36.902 V9.3.1, "Self-configuring and self-optimizing network (SON) use cases and solutions (Release 9)". March 2011.

[26]. 3GPP TS36.300 V9.5.0, "Evolved universal terrestrial radio access (E-UTRA) and evolved universal terrestrial radio access network (E-UTRAN) overall description (Release 9)". September 2010.

[27]. Mahmudur Rahmanand Halim Yanikomeroglu, (2010). "Enhancing cell-edge performance a downlink dynamic interference avoidance scheme with inter-cell coordination". *IEEE Transactions on Wireless Communications*, Vol. 9, No. 4, pp.1414-1425.

[28]. 3GPP TR 36.902 V1.0.0, "Self-configuring and self-optimising network use cases and solutions (Release 8)". December 2008.

[29]. 3GPP TS 36.331 V11.1.0, "Radio resource control (RRC) protocol specification (Release 11)". September 2012.

[30]. Doo-Won Lee, Gye-Tae Gil, and Dong-Hoi Kim, (2010). "A cost-based adaptive handover hysteresis scheme to minimize the handover failure rate in 3GPP LTE system". *Eurasip Journal on Wireless Communications and Networking*, Article ID 750173.

[31]. Thomas Jansen, Irina Balan, John Turk, Ingrid Moerman, and Thomas Kurner, (2010). "Handover parameter optimization in LTE self-organizing networks". *IEEE Vehicular Technology Conference-Fall (VTC-Fall)*, pp.1–5.

[32]. Raymond Kwan, Rob Arnott, and Mitsuhiro Kubota, (2010). "On radio admission control for LTE systems," *IEEE Vehicular Technology Conference-Fall (VTC-Fall)*, pp.1-5.

[33]. Mahnaz Sotoudeh Bahreyni, and Vahid Sattari-Naeini, (2014). "Fairness Aware Downlink Scheduling Algorithm for LTE networks". *Journal of Mathematics and Computer Science*, Vol. 11, pp. 53-63.

[34]. Ronak D. Trivedi, and M.C. Patel, (2014). "Comparison of different scheduling algorithm for LTE". *International Journal of Emerging Technology and Advanced Engineering*, Vol. 4, No. 5.

[35]. H. Hu, H. Yanikomeroglu, D.D. Falconer, and S. Periyalwar, (2004). "Range Extension without Capacity Penalty in Cellular Networks with Digital Fixed Relays". *Proc. IEEE Global Telecomm. Conf.*, pp. 3053-3057.

[36]. M. Liang, F. Liu, Z. Chen, Y. Wang, and D. Yang, (2009). "A Novel Frequency Reuse Scheme for OFDMA Based Relay Enhanced Cellular Networks". *Proc. IEEE 69th Vehicular Technology Conf.*, pp. 1-5.

[37]. W. Lee, M. Nguyen, and J. Jeong, (2008). "An Orthogonal Resource Allocation Algorithm to Improve the Performance of OFDMA Based Cellular Wireless Systems Using Relays". *Proc. IEEE Fifth Consumer Comm. and Networking Conf.*, pp. 917-921.

ABOUT THE AUTHORS

P. S. Lakshmikanth completed his B.Tech in Electronics and Communication Engineering from Kuppam Engineering College, Kuppam, Chittoor, Andhra Pradesh, India. He is now pursuing his Master of Technology (M.Tech) in Digital Electronics and Communication Systems at Sree Vidyanikethan Engineering College, Tirupati, Andhra Pradesh, India.

Dr. D. Leela Rani is currently working as a Professor in the Department of Electronics and Communication Engineering at Sree Vidyanikethan Engineering College, Tirupati, India. She has completed her Ph.D in Atmospheric Radar Signal Processing from SV University, Tirupati. She has an academic experience of 13 years from various institutions of engineering. Her research areas include NEMS, Atmospheric Radar, Image and VLSI Signal Processing.

Dr. P. Geetha is currently working as an Associate Professor in the Department of Electronics and Communication Engineering at Sree Vidyanikethan Engineering College, Tirupati, India. She has completed her B.E in Electronics and Communication Engineering and M.E in Applied Electronics from University of Madras. She did her Ph.D in Anna University under Nano Electronics. She has an academic experience of 18 years from various institutions of engineering. Her areas of interest include Nano Electronics, Signal & Image Processing.