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Suboptimal Radio Resource Management for Full-Duplex enabled Small Cells

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***Abstract*—This paper addresses the radio resource allocation problem for full-duplex (FD) wireless systems in small multi-cell system, assuming FD base stations and half-duplex (HD) user equipments (UEs). Due to the self-interference and interuser interference, the problem is coupled between uplink and downlink channels, and can be formulated as joint uplink and downlink sum-rate maximization. As the problem is non-convex, a distributed joint resource and power allocation method based on iterative approach is presented. The proposed algorithm assigns resource blocks for FD operation when it provides spectral gain by pairing UEs with appropriate power levels to mitigate the mutual interference, but otherwise defaults to HD operation. Simulation results reveal that during FD transmission, intracell interference is the dominant performance limiting factor even in high intercell interference scenario. Furthermore, the results suggest that despite the strong interferences, the FD system with the proposed algorithm achieves significant spectral efficiency gains comparing to HD system.**

***Index Terms*—Full-duplex, medium access control, power allocation, resource allocation, small cell.**

I. INTRODUCTION

Full-duplex (FD) communication enables radio to transmit and receive simultaneously on the same frequency band and time slot. Until recently, the implementation of FD in a wireless network was believed to be infeasible due to the phenomenon called self-interference (SI). SI occurs when the transmitted signal leaks or couples to the collocated receiver. Recent advances in the transceiver design have demonstrated the feasibility of FD communication [1], [2]. The results indicate that the FD communication is approaching performance requirements of practical systems.

Although extensive advances have been made in designing and implementing wireless transceivers with FD capability, but little has been done to understand the impact of such terminals on a wireless network in term of system capacity. Deployment of FD technology in a network needs to address issues beyond link level, e.g. intracell and intercell interference management.

To adopt FD communication, modifications to carrier sense multiple access (CSMA) were presented in [3], [4]. However, it was observed that, FD gain is reduced when it is applied to CSMA based wireless networks due to reduced spatial reuse and asynchronous contention [5]. A system with heuristic greedy resource allocation algorithm for the UE selection in both FD and HD scenarios was proposed in [6]. Furthermore, to tackle interference, a cell partitioning method among users in FD cellular networks is presented in [7]. In both of these research works, the residual SI at BS was ignored. Furthermore, in [8], resource and power allocation is jointly optimized to maximize the sum-rate performance for FD networks with FD enabled BS and HD enabled UEs. This algorithm is maintained by a centralized controller unit. However, LTE-A system has abolished central control unit, because of the stringent time required to exchange information, and relied on coordination among BSs through X-interface.

On the other hand, the interuser channel assumption in most existing studies are not in accordance with 3GPP standard [9]. Prior research also unduly favours the FD communication and ignores the fairness issue while allocating resources to the users. Furthermore, deployment of FD systems in a network however needs to address issues beyond link level, e.g. intracell and intercell in-band interference management. To verify the performance of any large scale deployment of FD nodes in wireless network, system-level evaluation of such systems is necessary. However, such an analysis has received little attention in the literature so far. The main contributions of this paper are as follows:

- A distributed joint downlink and uplink resource allocation algorithm is proposed to mitigate intracell and intercell interferences. The proposed algorithm consists of two steps namely power allocation and UE resource block selection. The power allocation procedure adjusts the power of each UE to an appropriate level and identify all FD pair that maximum the system gain while not violating the maximum power and uplink quality of service (QoS) constraints. UE selection procedure then allocate resource blocks for FD operation when it provides a sum-rate advantage by pairing UEs otherwise defaults to HD operation while maintaining fairness.
- The proposed algorithm is then evaluated and compared to the HD system, FD with round robin and FD with exhaustive search in both single-cell and multi-cell scenario with symmetric and asymmetric traffic.

The rest of the paper is organized as follows: Section II presents the system model including the network architecture, possible FD interference scenarios, SI cancellation and

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fairness model considered. Section III includes the problem formulation for sum-rate maximization and propose distributed resource allocation algorithm in detail. Section IV describes the simulation scenario with the parameters and channel propagation models. Section V highlights the performance evaluation of the proposed algorithm for different system settings. Finally, concluding remarks are drawn in Section VI.

II. SYSTEM MODEL

This section describes the network architecture, FD interference scenarios, SI cancellation and fairness model under consideration.

A. Network Architecture

The scenario consists of multiple small cells randomly deployed in a large area according to 3GPP standard [9]. Each cell has UEs for downlink and uplink at a random location based on uniform distribution. It is assumed that BSs are capable of operating in both FD and HD, whereas UE can only operate in HD. The frequency band is composed of N resource blocks, each of which is a group of subcarriers. The network is assumed to have up to I_b downlink and J_b uplink users in cell b, where the total number of cells is B. The transmit power of the i_bth downlink user and j_bth uplink user in cell b on the nth resource block is denoted by $P^n_{i_b}$ and $P^n_{j_b}$ respectively, where $i_b \in \mathrm{I_b} = \{1, ..., I_b\}$, $j_b \in \mathrm{J_b} = \{1, ..., J_b\}$, $b \in \mathrm{B} = \{1, ..., B\}$ and $n \in \mathrm{N} = \{1, ..., N\}$.

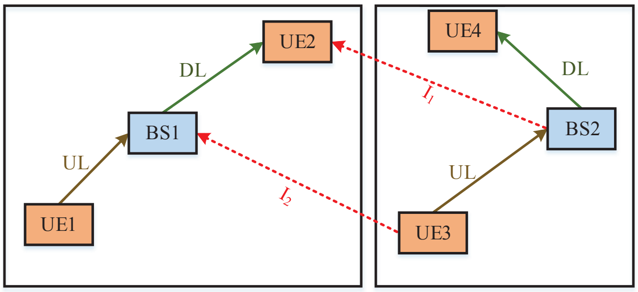
B. Full-duplex interference scenario

Based on the duplexing schemes, there exist two possible transmission modes in a cell with FD enabled BS as follows:

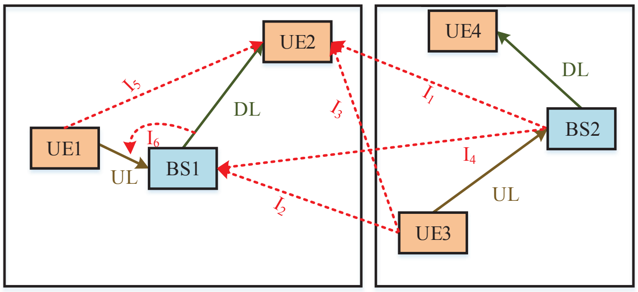
- **HD-HD mode:** A BS is operating in HD and connected with UEs also operating in HD on a radio resources.
- **FD-HD mode:** A BS is in FD operation and is connected with two UEs operating in HD on the same radio resource, one for downlink and one for uplink.

During FD communication, additional interferences deteriorate the system performance and corresponding SINRs. In a multi-cell scenario, the impact of interferences becomes more severe because of the intercell interference. Consider the two-cell scenario, Fig.1a. shows HD scenario in which UE1 and UE3 are in uplink and UE2 and UE4 are in downlink. It can be noted that during HD operation, UE2 receives interference I_1 from BS2 (which is transmitting to UE4 at the same time), and BS1 receives I_2 from the uplink UE3 of the neighbouring cell. In FD scenario as shown in Fig.1b., downlink UE2 not only receives interference I_1 from the BS2, but also I_3 and I_5 from the uplink UE3 and UE1. Similarly, uplink UE1 not only receives interference I_2 from UE3, but also I_4 from the BS2 as well as residual SI I_6 from the collocated transmitter at BS1.

In traditional HD system, the problem of intercell interference is solved optimally in the downlink direction [10], where the interferers are the fixed BSs in the neighbouring cells. It is easy to estimate the channel gains for each UE with the neighbouring BSs without knowing the actual resource allocation decision of the neighbouring cells. On the other hand, in uplink, where the interferer is the UE of the neighbouring cell, interference estimation is critical without the resource allocation information from the neighbouring cell. This applies to the FD system, in both downlink and uplink, where interference from the neighbouring cell could be from a UE or BS or both depending on the transmission mode of the neighbouring cell. However, the impact of intercell interference is not significant on FD transmission due to strong intracell interference. But even if intercell interference affect the system, strong interference from neighbouring cell BS's dominate the interferer UEs. Thus, the interference from the neighbouring cell UE during FD operation can be ignored and the problem of intercell interference in FD can be resolved with distributed approach.



Half-duplex multi-cell scenario
(a)



Full-duplex multi-cell scenario
(b)

Fig. 1: Multi-cell interference scenario, where interference is considered only at BS1

However, one might argue that cell-edge UE of a neighbouring cell may generate severe interference. This can be resolved by enhanced intercell interference coordination (eICIC) techniques like in traditional HD system [11].

C. SI cancellation model

This paper considered a SI model in which the cancellation capability does not vary with the transmission power, i.e., for the given transmission power $P^n_{i,b}$ and the SI cancellation value ζ^n_m, the residual SI is given by $\frac{P^n_{i,b}}{\zeta^n_b}$ at BS.

D. Fairness model

To provide fairness among UEs in accessing the channel, so that algorithm should not unduly favour FD opportunities over HD, the proposed algorithm initially allocates resource blocks to the UEs in the same manner as in HD scenario. The algorithm then identifies corresponding UE pair to perform FD operation which maximize sum-rate of the resource block. If FD operation is not possible, that particular resource block will remain in HD operation. Furthermore, a UE can make a FD pair with more than one UE which provides more gain than HD. In this case, the proposed algorithm will provide each FD pair equal opportunity to transmit as its unfair that only the highest FD pair will always get the transmission. This will no doubt reduce the FD gain over HD but there is always a trade-off between spectrum efficiency and fairness.

III. RESOURCE ALLOCATION

Since FD link expands the interference range compared with a HD link and degrade the SINR on each link as explained in Section II-B. Therefore, the SINR of downlink UE i_b of cell b on the nth resource block is given as:

$$x^n_{b,i_b} = \frac{\frac{P^n_{i_b}}{\theta^n_{b,i_b}}}{z_{\text{ue}} + \beta\frac{P^n_{j_b}}{\theta^n_{i_b,j_b}} + \sum\limits_{\substack{k=1\\k\neq b}}^{\text{B}} \gamma\frac{P^n_{i_k}}{\theta^n_{k,i_b}} + \sum\limits_{\substack{k=1\\k\neq b}}^{\text{B}} \delta\frac{P^n_{j_k}}{\theta^n_{i_b,j_k}}} \tag{1}$$

Similarly, SINR of uplink UE j_b of cell b is as follows:

$$x^n_{b,j_b} = \frac{\frac{P^n_{j_b}}{\theta^n_{b,j_b}}}{z_{\text{bs}} + \varrho\frac{P^n_{i_b}}{\zeta^n_b} + \sum\limits_{\substack{k=1\\k\neq b}}^{\text{B}} \gamma\frac{P^n_{i_k}}{\theta^n_{b,k}} + \sum\limits_{\substack{k=1\\k\neq b}}^{\text{B}} \delta\frac{P^n_{j_k}}{\theta^n_{b,j_k}}} \tag{2}$$

where, z_{bs} and z_{ue} are the noise power per resource block at the BS and UE respectively. $\theta^n_{b,k}$ and θ^n_{b,i_k} are the radio signal propagation loss between BS b to neighbouring BS k and between BS b to downlink UE i_k respectively on the nth resource block, where $b, k \in \text{B}, n \in \text{N}$. $\theta^n_{i_b,j_k}$ is the radio signal propagation loss between downlink UE i_b to uplink UE j_k on the nth resource block. $\beta, \gamma, \varrho, \delta \in \{0, 1\}$ and represent different transmission mode in both current b cell and neighbouring cell k as follows:

- if b in HD-HD mode: $\beta = 0, \varrho = 0$
- if b in FD-HD mode: $\beta = 1, \varrho = 1$
- if k in HD-HD mode: $\gamma = 1, \delta = 0$, if in downlink or $\gamma = 0, \delta = 1$, if in uplink
- if k in FD-HD: $\gamma = 1, \delta = 1$

It is clear from (1)–(2) that the co-channel intracell and intercell interference can deteriorate the SINR. The maximum achievable sum-rate of transmission modes at each SINR can be calculated using the Shannon's formula for Gaussian channel, if SINR is known. The sum-rate of the i_bth downlink user, R^n_{b,i_b}, and of j_bth uplink user, R^n_{b,j_b}, of cell b on the nth resource block is given as follows:

$$R^n_{b,i_b} = W\log_2(1 + x^n_{b,i_b}) \quad \forall n\epsilon\text{N}, \forall b\epsilon\text{B}, \forall i_b\epsilon\text{I}_\text{b} \tag{3}$$

$$R^n_{b,j_b} = W\log_2(1 + x^n_{b,j_b}) \quad , \forall n\epsilon\text{N}, \forall b\epsilon\text{B}, \forall j_b\epsilon\text{J}_\text{b} \tag{4}$$

where W is the bandwidth of a resource block. As explained in Section II-B, a distributed algorithm can calculate the rates of each UE in each cell, and make the UE resource allocation decision for each cell optimally. Therefore, with the knowledge of SINR, the resource allocation problem that maximizes the system spectral efficiency can be formulated as follows

$$\sum_{b\epsilon\text{B}} \max_{x^n_{b,j_b}, P^n_{i_b}, P^n_{j_b}} \left\{ \sum_{i_b\epsilon\text{I}_\text{b}} \sum_{n\epsilon\text{N}} R^n_{b,i_b} + \sum_{j_b\epsilon\text{J}_\text{b}} \sum_{n\epsilon\text{N}} R^n_{b,j_b} \right\} \tag{5}$$

subject to

$$P^n_{i_b} \leq P^n_{b\text{max}} \quad \forall n\epsilon\text{N}, \forall i_b\epsilon\text{I}_\text{b} \tag{6}$$

$$P^n_{j_b} \leq P^n_{u\text{max}} \quad \forall n\epsilon\text{N}, \forall j_b\epsilon\text{J}_\text{b} \tag{7}$$

$$x^n_{b,j_b} \geq \gamma^n_{b,j_b} \quad \forall n\epsilon\text{N}, \forall b\epsilon\text{B}, \forall j_b\epsilon\text{J}_\text{b} \tag{8}$$

First two constraints in (6) and (7) are for transmit powers of BSs and UEs in each cell, in which P^n_{bmax} and P^n_{umax} are the maximum downlink and uplink transmission powers that can be used on nth resource block respectively. The third constraint in (8) captures the QoS requirement of uplink UE on nth resource block, where γ^n_{b,j_b} is j_bth uplink user SINR threshold of cell b for specific QoS.

The above problem is a non-linear non-convex combinatorial optimization and computing its globally optimal solution may not be feasible in practice. Although the problem can be optimally solved via exhaustive search, the complexity of this method increases exponentially as the number of cells increase. Therefore, an iterative joint UE resource block and power allocation algorithm is proposed.

A. Proposed resource block and power allocation algorithm

To solve the problem presented in (5)-(8), this paper provides a distributed algorithm that runs by each cell individually as given in Algorithm I. The proposed algorithm operates in two steps as follows:

- **Power allocation:** With an evenly distributed downlink power, this step computes the transmission rate matrix by iterative power control at uplink with a step size of 'λ'. Firstly, the proposed algorithm iteratively computes the transmission rate for HD operation R^n_{b,i_b} and R^n_{b,j_b} for each downlink and uplink UE based on SINRs. The uplink transmission rate are updated iteratively on different uplink power and the maximum transmission rate matrix is obtained. In the next step, algorithm computes a FD transmission rate $R^n_{b,i_b}(j_b)$ and $R^n_{b,j_b}(i_b)$, where $R^n_{b,i_b}(j_b)$ refers to the rate of downlink UE i_b when in FD mode with uplink UE j_b on the nth resource block. Similarly $R^n_{j_b}(i_b)$ refers to the rate of uplink UE j_b when in FD mode with downlink UE i_b. It can be noted that while computing the FD transmission rate, for each downlink UE, the corresponding FD transmission rates are computed iteratively on each uplink power and maximum transmission rate are then obtained in rate

Algorithm I: Resource block and power allocation

```
Initialization: $P^n_{i_b} = P^n_{\text{bmax}}, P^n_{j_b} = P^n_{\text{initial}}$
for $i_b \in I_b$ do
    Compute $R^n_{b,i_b}$ with $P^n_{i_b}$
    for $j_b \in J_b$ do
        for $P^n_{j_b} \in P^n_{umax}$ do
            Compute $R^{tmp}_{b,j_b}$, $R^{tmp}_{b,i_b}(j_b)$ and $R^{tmp}_{b,j_b}(i_b)$ as in (1)–(2)
        end for
        $R^n_{b,j_b} \leftarrow argmax(R^{tmp}_{b,j_b})$
        $R^n_{b,i_b}(j_b) \leftarrow argmax(R^{tmp}_{b,i_b}(j_b))$
        $R^n_{b,j_b}(i_b) \leftarrow argmax(R^{tmp}_{b,j_b}(i_b))$
    end for
end for
Initialize resource allocation vectors:
$\boldsymbol{u}^n = [u^1, ..., u^{N/2}]^{\mathrm{T}}$: where $\boldsymbol{u}^n \in \mathrm{I_b}$
$\boldsymbol{v}^n = [v^1, ..., v^{N/2}]^{\mathrm{T}}$: where $\boldsymbol{v}^n \in \mathrm{J_b}$
for $n \in N$ do
    if $n < N/2$ then
        $j_{b\text{max}} = \arg\max_{j_b} R^n_{b,u^n}(j_b)$
        if $R^n_{b,u^n}(j_{b\text{max}}) > R^n_{b,u^n}$ then
            FD-HD mode
        else
            HD-HD mode
        end if
    else
        $i_{b\text{max}} = \arg\max_{i_b} R^n_{b,v^n}(i_b)$
        if $R^n_{b,v^n}(i_{b\text{max}}) > R^n_{b,v^n}$ then
            FD-HD mode
        else
            HD-HD mode
        end if
    end if
end for
```

matrix and the complexity of algorithm depends on 'λ' and number of users in the cells.

- **UE resource block allocation:** given FD transmission rate matrix, this step assign the resource blocks in an iterative manner, one-by-one, to a user with the largest sum-rate. This step also ensures fairness and if more than one FD pair exists, resource assignment take that into account by allocating both pairs rather than selecting the largest sum-rate pair in all resource block. In this step, algorithm initializes the resource allocation vectors for downlink $\boldsymbol{u} = [u^1, ..., u^{N/2}]^{\mathrm{T}}$ and uplink $\boldsymbol{v} = [v^1, ..., v^{N/2}]^{\mathrm{T}}$ in which first half resource blocks allocated for downlink users and the second half for uplink users as in HD scenario. The index in $\boldsymbol{u}$ and $\boldsymbol{v}$ contains the downlink and uplink UE assigned on the nth resource block, where $\boldsymbol{u}^n \in \mathrm{I_b}$ and $\boldsymbol{v}^n \in \mathrm{J_b}$. This step ensures the first objective of fairness model that the algorithm does not unduly favour FD over HD.

  The algorithm then finds the corresponding UE FD pair with the pre-allocated downlink and uplink UEs from $R^n_{b,i_b}(j_b)$ and $R^n_{b,j_b}(i_b)$ for each resource block. If FD transmission rate provides sum-rate gain over HD, the algorithm assign the resource block to the corresponding FD UE pair otherwise remains in HD operation.

IV. SIMULATION PARAMETERS AND CHANNEL MODEL

Table I shows the simulation parameter under consideration derived from 3GPP standard [9]. The pathloss model for pico-cell environment as given in [9] are used. At 2 GHz frequency, the line-of-sight (LoS) and non-line-of-sight (nLoS) pathloss for BS to UE is given as follows:

TABLE I: Simulation Parameters

Parameter	Value
Bandwidth	10 MHz
Cell size	500 m
Number of small cells	[1, 16]
Number of UEs per small cell	[5, 20]
Min. distance small cell BS to UE	10 m
Number of resource blocks	50
Max. transmit power at BS	15 dBm
Max. transmit power at UE	10 dBm
SI cancellation at BS	[80, 110] dB
SI cancellation at UE	[80, 110] dB
Noise figure at BS	13 dB
Noise figure at UE	9 dB
Noise power spectral density	-174 dBm/Hz

$$\begin{aligned} L^{\text{LoS}}_{\text{b2ue}}[dB] &= 41.1 + 20.9\log_{10}(d) \\ L^{\text{nLoS}}_{\text{b2ue}}[dB] &= 32.9 + 37.5\log_{10}(d) \end{aligned} \tag{9}$$

The LoS and nLoS pathloss for BS to BS is given as follows:

$$\begin{aligned} L^{\text{LoS}}_{\text{b2b}}[dB] &= 38.4 + 20\log_{10}(d), d < 2/3 \\ L^{\text{LoS}}_{\text{b2b}}[dB] &= 40\log_{10}(d) - 18.1, d \geq 2/3 \\ L^{\text{nLoS}}_{\text{b2b}}[dB] &= 49.36 + 40\log_{10}(d) \end{aligned} \tag{10}$$

Similarly, the LoS and nLoS pathloss for UE to UE is given as:

$$\begin{aligned} L_{\text{u2u}}[dB] &= 38.45 + 20\log_{10}(d), d \leq 50 \\ L_{\text{u2u}}[dB] &= 55.78 + 40\log_{10}(d), d > 50 \end{aligned} \tag{11}$$

where d is the distance in metre. Furthermore the probability of LoS P_{r} is given as:

$$P_{\text{r}} = 0.5 - \min(0.5, 5e^{(-156/d)}) + \min(0.5, 5e^{(-d/30)}) \tag{12}$$

It is assumed that shadowing occurs in all channels, which follows a log-normal distribution with a standard deviation of 10 dB between BS to UE, 6 dB between BS to BS and 12 dB for interuser channel.

V. PERFORMANCE MEASURE

In this section, the performance of the proposed resource allocation algorithm is evaluated and the respective interpretations are discussed in detail.

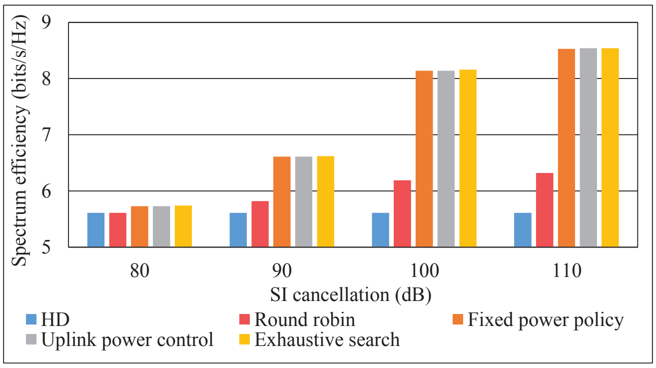


Fig. 2: Spectrum efficiency comparison for HD and FD system with symmetric traffic at different SI cancellation level.

A. Full-duplex performance evaluation in single-cell scenario

In this subsection, the performance of proposed algorithms are evaluated with 10 UE's in a single-cell scenario. The results are first generated for round robin resource allocation with fixed transmission powers, that is, maximum allowed power in both directions. For the HD system, in each direction, BS selects UEs in the round robin manner for all the resource block in downlink and uplink. For the FD round robin system, in each resource block, same UE as in the HD system is considered with a randomly selected UE for the other direction to make a FD pair. The performance of the FD is then compared with traditional HD system, FD round robin and FD exhaustive search algorithm.

In Fig. 2 the average spectrum efficiency of all the schemes with symmetric traffic at different SI cancellation levels is illustrated. It can be seen that, there is no significant FD gain with FD round robin compared to HD system, this highlights the need for an intelligent resource allocation algorithm to improve performance during FD operation, which can benefit both downlink and uplink.

Moreover, it can be seen from results that FD fixed power and FD uplink power control achieve almost the same spectrum efficiency as of FD exhaustive search. It is observed that power optimization during FD operation does not significantly improve the combined downlink and uplink gain in FD compared to HD. This is because the SI and interuser interference level in the FD receiver is a function of its own transmit power. The dependency of SINR on the transmit power at both link ends creates the opportunity to adjust the SINR on each node according to the traffic demand, and thereby the transmission rate, at both ends. From a link perspective, power control can be seen as a mean to control SINR of both downlink and uplink jointly and to compensate for channel variations. But the cumulative downlink and uplink gain will remain constant compared to HD system [12].

On the other hand, when traffic is asymmetric, Fig. 3 presents the sum-rate of the HD and FD transmission at various levels of SI cancellation. These results show that the maximum gains achieved by the FD transmission with asymmetric traffic is significantly higher than the HD link, but the gain is less compared to the FD transmission with symmetric traffic. This is because during the asymmetric traffic, UE might not have traffic in both directions and results in less probability for FD pairing. Table II presents the achievable gains in FD with symmetric and asymmetric traffic in single-cell scenario.

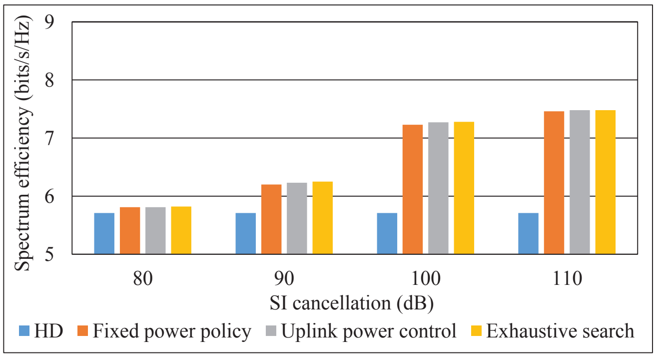


Fig. 3: Spectrum efficiency comparison for HD and FD system with asymmetric traffic at different SI cancellation level.

TABLE II: Average spectrum gain of FD over HD system with proposed algorithm in single-cell scenario

SI cancellation [dB]	80	90	100	110
Symmetric Traffic	2.14%	17.82 %	45.09 %	52.12 %
Asymmetric Traffic	1.75%	9.10 %	27.3 %	31.19 %

B. Full-duplex performance evaluation in multi-cell scenario

In this subsection, the performance of proposed algorithm is evaluated in a multi-cell scenario with 16 small cells and 10 UE's per cell. In Fig. 4 and Fig. 5 the performance of the proposed algorithms are evaluated at different SI cancellation levels in the presence of symmetric and asymmetric traffic respectively. The results reveal that when the SI cancellation is below 100 dB, the intracell interference is the dominant performance limiting factor even in high intercell interference scenario. On the other hand, when an SI cancellation as high as 110 dB can be achieved, the intercell interference is the

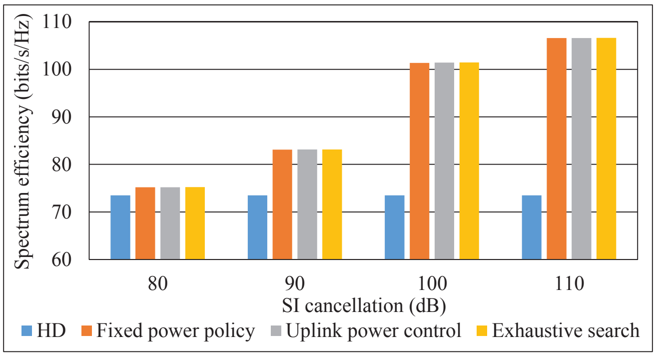


Fig. 4: Spectrum efficiency comparison for HD and FD system with symmetric traffic at different SI cancellation level.

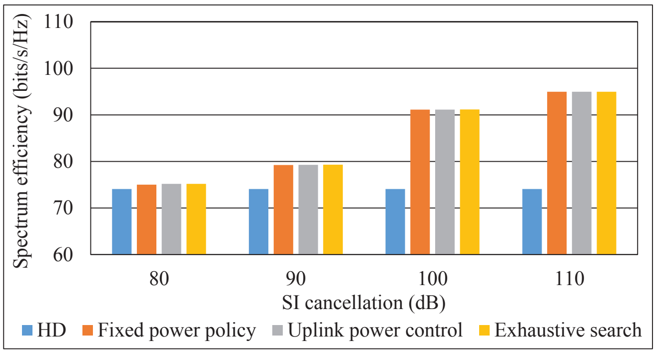


Fig. 5: Spectrum efficiency comparison for HD and FD system with asymmetric traffic at different SI cancellation level.

dominant interferer. But as the small cells have low power and deployed on random locations, the impact of intercell interference is not significant. Table III presents the achievable gains in FD with symmetric and asymmetric traffic in multi-cell scenario. It can be seen that the maximum gain of 45% is achieved in symmetric traffic with FD over HD system.

TABLE III: Average spectrum gain of FD over HD system with proposed algorithm in multi-cell scenario

SI cancellation [dB]	80	90	100	110
Symmetric Traffic	2.32%	13.10 %	37.97 %	45.01 %
Asymmetric Traffic	1.47%	6.97 %	23.03 %	29.21 %

C. Fairness Analysis

Fig. 6 shows the comparison of jain's fairness index as in [13] for proposed algorithm with and without fairness model for fixed power policy algorithm. It is observed that as the number of UEs in the cell increases, the value of the index decrease. This is because the fairness model only include the number of resource blocks allocated to the UEs, it would be much better if rate of each UE is considered in fairness model. But as whole, the proposed fairness model significantly improves the fairness among the UE's.

D. Complexity Analysis

To compute the FD transmission rates, the proposed FD fixed power has a computational complexity of $\mathcal{O}(I_b J_b)$, where I_b and J_b are the total number of users in downlink and uplink in cell b. Whereas, the complexity with FD uplink power control and FD exhaustive search are given by $\mathcal{O}((I_b J_b)\delta)$ and $\mathcal{O}((I_b J_b)\delta\lambda)$ respectively. Where δ and λ are the transmission power step-size for BS and UE. It is evident that FD exhaustive search has a very high complexity and is not feasible to solve in a practical system. On the other hand, proposed algorithms has minimal complexity and provides approximately the same gains as optimal scheme.

VI. CONCLUSION

In this paper, a distributed resource allocation algorithm for FD wireless network is proposed to enhance the overall spectrum efficiency. The results reveal that the intracell interference i.e., SI and interuser interference is the dominant performance limiting factor even in high intercell interference scenario. It is also observed that during the FD transmission most of the gain is coming from UE pairing. Power optimization does not impact the performance gain significantly, because of the coupling of downlink and uplink transmission. Furthermore, the results suggest that despite the strong intracell and intercell interferences, the FD with proposed algorithm achieves considerable spectral efficiency gains comparing to HD system.

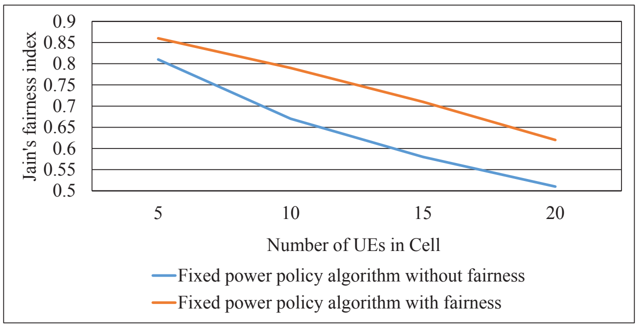


Fig. 6: Fairness comparison

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