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Performance Analysis of Paired Heterogeneous Cellular Network by Abolition of Self Interference

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Abstract: In this paper, the abolition of self-interference in a paired heterogeneous cellular network is done by designing a Duplexing Aware Cellular Access (DACA) architecture. The DACA consists of a Resource Block (RB). The intracell scheduler is designed to decide the transmission modes of RB their users and the power levels for both uplink and downlink and then the spectrum to be shared among the users. This is done to resist imperfect self-interference cancellation. The intercell interference co-ordination is made to design the co-ordination with congestion control algorithm to handle the femtocell interference. The transmit powers of femtocell and connected users are adjusted by coordination with congestion control mechanism.

Keywords: Transmission modes, Femtocell, Utility Sum, Heterogeneous cellular network, Intracell.

I. Introduction

Full duplex data transmission is that the data can be transmitted in both direction on signal carrier at the same time. For example, on a local area network with a technology that has full-duplex transmission, one work station can be sending data on a line while another workstation is receiving data. When one node transmits data and the neighbour nodes transmits signal with high power then there occurs some self-interference.

The cancellation of these self-interference is realized in more scenarios. The research done in [1] to improve the performance of SC-FD cellular systems. A analytical model to derive both downlink and uplink throughput for a SC-FD cellular system is designed. The SC-FD generates inter-cell interference is the major disadvantage. In [2] a novel technique of antenna cancellation is presented for self-interference cancellation. The potential MAC and network gains with full-duplex is discussed. In [3] a technique called ContraFlow uses MAC that benefits self-interference cancellation and increases spatial reuse. Through these techniques the hidden terminal problem is decreased and utility is maximised.

FD-PHY and FD-MAC are the real time design and implementation of full duplex physical and MAC layers to optimize the system performance. This technique could lead to Self-interference suppression and push the performance to near perfect full duplex systems [4]. The disadvantage of these techniques is that it can analyse only lower layer protocols of wireless system. Digital cancellation will always help to improve total cancellation. System implementation reveals the benefits of both digital and analog cancellation in an antenna system [6].This technique can be used only in one full-duplex system this is the major disadvantage. A Multi-antenna wideband PHY and MAC design is used to enable a practical full duplex mode in wifi. More benefits gained from including a FD mode in future wifi standards is concluded in [7].

The first MIMO full duplex wireless system MIDU is designed and implemented in [8] with two levels of antenna cancellation and compared their performance with HD-MIMO. The result has significant improvement in both point-to-point and point-to-multipoint schemes. A scheme called RCTC in [9] uses the signatures to allow fast handshaking for co-ordinating transmission in neighbourhood and allows secondary transmission in full duplex system by suppressing self-interference in a wireless system. This RCTC technique is used to identify the transmission modes, exposed terminal identification and picking of exposed and secondary receivers. Compared with native full duplex MAC, this prototype shows as high as 78% throughput gain.

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In [10] two algorithms are designed to update sum-rate, transmit power level and user assignment. The prioritized algorithm does not allow the neighbour BS to change their transmit power level whereas the randomized algorithm allows the neighbour interference BS to change their transmit power level based on the probabilities of transition. The above two algorithms produce the same rate of performance but the randomized algorithm is the most preferred algorithm. In [11] a scheme called Han-Kobayashi achieves the rate pair of any rate in interference channel capacity region. It is used to achieve high SNR with small interference by setting the power of private information of each user is received at the level of the Gaussian noise at other receivers. The major disadvantage of this scheme is that it often gets interfered with other receiver producing interference.

A coverage analysis of multi-tier network based on random spatial models is provided to design a network with no inter-cell interference co-ordination (ICTC). The standard ICTC technique for a macro-pico scenario is developed by applying TDM based ICTC. Cell range and utility sum of users are increased in pico cell network compared to the macro cell network in [12]-[13].A novel femtocell management framework, called CTRL, for OFDMA-based cellular networks is designed in [14] to protect the macrocell's uplink communication, coordinate resource usage of femtocells, and protect the femtocells' uplink communications. CTRL enables spatial reuse of channel resources within femtocells without degrading macrocell users' performance regardless of the number of femtocells operating in a macrocell. CTRL is designed to facilitate its deployment in existing cellular network and it ensures a distributed and self-organizing operation in estimating the global femtocell status.

Two key contributions are designed in [15] to deal full duplex system. First the dynamic algorithms to estimate the distortions introduced by analog circuits and accurately model the actual self-interference being experienced by the received signal. Second analog cancellation circuit using off-the-shelf components that allows us to implement the above algorithm in "analog" and dynamically cancel the self-interference. These analog cancellation does not completely cancel the self-interference. Hence digital cancellation algorithm is used to cancel any remaining self-interference which does not deal with linear and non-linear distortion. Thus a hybrid analog-digital design that successfully models all linear, non-linear distortions and transmitter noise.

II. PROPOSED SYSTEM

A new technique called Duplexing Aware Cellular Access (DACA) for FD communication mainly aims to maximize the user's utility sum. The DACA is designed by the allocation of a transmission mode, users and transmit power levels for frequency resource block (RB) based on the unconsumed self-interference. It also provides co-ordination of femtocells that is surfaced on macrocells using same frequency spectrum.

The transmission modes of RB are selected by the review on the relationship between power resource and the channel capacity by identifying the crossover points between the modes. The utility sum is maximized by the allocation of resource block. The intra-cell scheduler is used to allocate both resources of UL and DL in DACA jointly in FD communication.

New inter-cell interference in paired communication with co-channel femtocells are observed. DACA regulates the UL and DL such that they donot interfere in the macrocell. This process is done with the co-ordination and congestion control algorithm which co-ordinates the co-channels of femtocell and the congestion in those femtocell co-channel is reduced.

In this paper, the abolition of self-interference in a paired heterogeneous cellular network is done by designing a Duplexing Aware Cellular Access (DACA) architecture. Fig 1. Represents the block diagram of DACA Architecture. The DACA consists of a Resource Block (RB). The intracell scheduler is designed to decide the transmission modes of RB their users and the power levels for both uplink and downlink and then the spectrum to be shared among the users. This is done to resist imperfect self-interference cancellation. The intercell interference co-ordination is made to design the co-odination with congestion control algorithm to handle the femtocell interference. The transmit powers of femtocell and connected users are adjusted by coordination with congestion control mechanism.

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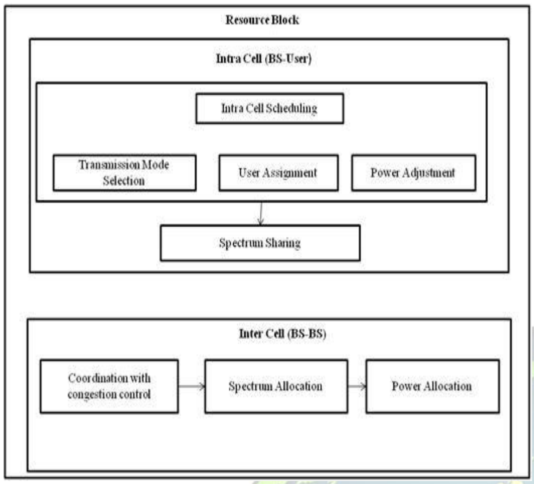

Fig 1.DACA Architecture

2.1 INTRA-CELL SCHEDULING

When the user receives downlink signals from the base station (BS) uplink transmission is also allowed in the same RB to the user then there occurs self-interference or other types of interference. The UL signalfrom the same BS receives the radiated signal from DL then there occurs interference. This interference is known as intracell interference.

An Intra-cell scheduling problem is formulated and an algorithm is used to solve this problem.

2.1.1 Resource Block Allocation

The Resource Block is allocated based on the selection of transmission mode and assignment of users. The transmission mode is selected to increase the capacity and the user assignment is done to increase the utility. This can be done by the following, the transmission mode is selected if any user satisfies ineqn (1) and (2) then FD-FD is the mode of RB and if any pair of users satisfies both the ineqns then it is FD-HD mode.These modes are based on the capacity and doesnot produce utility.

$$\gamma^{UL}_{k,FD-FD(n)} > \frac{p_{n,k}}{\sigma}\left(\frac{1}{h_{n,k}} + \Delta\right)^{-1} - 1$$

$$(1)\ I_k > (-c_0 + \sqrt{c_0^2 - 4c_1}/2$$

$$(2)\ I_k < (-c_0 + \sqrt{c_0^2 - 4c_1}/2$$

(3)

Once the transmission mode is selected then the user or pair of users is assigned utility increase. The utility increase is obtained by

$$\Delta U(\Delta r_n, \Delta s_m) = \frac{\partial}{\partial r_n} U(r,s)\Delta r_n + \frac{\partial}{\partial s_m} U(r,s)\Delta s_m \qquad (4)$$

Where Δr_n and Δs_m are the data rate increase of DL and UL respectively, where user n is for DL and user m for UL is assigned.Gradient U is multiplied with step size and r,s are the rate vectors of DL and UL respectively.

2.1.2 Power Adjustment

Once resource block is allocated power adjustment is made based upon the capacity of RB. If k is in FD-FD mode capacity is approximated as

$$\text{w}\log_2\left(\frac{h_{n,k}p_{n,k}}{q_{n,k}/_{\Delta}}\right) + \text{w}\log_2\left(\frac{h_{n,k}q_{n,k}}{p/_{\Delta}}\right)$$

$$= 2\text{w}\log_2 h_{n,k}\Delta \qquad (5)$$

which is constant to power.

Similarly for FD-HD mode capacity is approximated as

$$\text{w}\log_2\left(1 + \frac{h_{n,k}p_{n,k}}{h^k_{m,n}q_{m,k}}\right) W\log_2\left(\frac{h_{m,k}q_{m,k}}{p_{n,k}/_{\Delta}}\right)$$

$$= \text{w}\log_2\frac{(h^k_{m,n} + h_{n,k})h_{m,k}\Delta}{h^k_{m,n}} \qquad (6)$$

which is independent of power. The other HD-HD mode depends on power.

2.2 INTER-CELL CO-ORDINATION

The inter-cell interference in heterogeneous network occurs between small cell to macrocell user and vice versa and between small cell to other small cell user. If two users served by different cells are in close proximity to each other then there occurs handover between them then these interference is called as intercell interference. The other inter-cell interference occurs when one BS is in close proximity with the other BS.

The proposed algorithm for the co-ordination of femtocell to avoid the power resource of macrocell being used by the femtocell which creates femtocell interference. This is done by the identification of interference cap and usingco-ordination with congestion control algorithm.

The interference cap is identified by how much interference is the femtocell is allowed to give.Let I_k^f and J_k^f be the DL and UL interference levels, respectively, experienced by the underlying macrocell due to cochannel femtocells in RB k. We denote the limits of I_k^f and J_k^f for the minimum SINR requirement by,

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$$\tilde{I}_k^f \begin{cases} \frac{h_{n,k} p_{n,k}}{\Gamma} - \frac{q_{n,k}}{\Delta} - I_k - \sigma & FD(n) \\ \frac{h_{n,k} p_{n,k}}{\Gamma} - h_{m,n}^k q_{n,k} - I_k - \sigma & HD(n,m) \end{cases}$$

(10)
$$\tilde{J}_k^f = \frac{h_{m,k} q_{n,k}}{\Gamma} - \frac{p_{n,k}}{\Delta} - I_k - \sigma$$

(11)

2.2.1 Co-ordination Algorithm

The co-ordination algorithm is used when the macrocell experience interference from femtocell in $\tilde{K}$ set of resource block and then $\tilde{F}$ is the set of femtocell users using femtocell base station which are close to the macro base station. To co-ordinate co-channel femtocell the power level of femtocell user for RB's should be minimized. The objective function is given as

$$V(p_f, q_f) = \sum_{k\in\tilde{K}} \sum_{u\in\tilde{F}} (\log p_{u,k} + \varepsilon_u \log q_{u,k})$$

(12)

Where p_f and q_f are DL and UL power vectors of the femtocells serving $\tilde{F}$; ε_u is a balancing constant. The powers can be renovated by these gap between current interference I_k^f and interference cap I_k^{f*}.

2.2.2 Congestion Control Algorithm

Congestion occurs in a mobile communication when more number of users communicate (load) at the same time with the base station. Due to this congestion there occurs delay or degradation in performance. To control this congestion the congestion control algorithm can be used. The main problem of congestion control algorithm is to select the exact congestion signal for link algorithm which is executed in the router that finds a better way to respond in source algorithm which is executed in end system. The congestion feedback can be done by sending special packets or changing fields in the packets as they pass through the router. These explicit congestion feedback performance better than that of implicit congestion feedback. Consider the system of differential equations

$$r_1(t) = \beta_{r1}(t)\left(1 - \frac{(\sum_{p\in i} x_p(t) + q_i(t) - q_o)/T}{c_i}\right)$$

(13)

Where β is a constant parameter, q_o is the expected queue length in steady state, T is the time constant. The term $\sum_{p\in i} x_p(t)$ denotes the whole load on link 1. The term $\left(1 - \frac{(\sum_{p\in i} x_p(t) + q_i(t) - q_o)/T}{c_i}\right)$ is used to represent the normalized available capacity.

III. Simulation Results

The simulation results of self-interference abolition in DACA is compared with using congestion control algorithm and without using congestion control algorithm. The proposed algorithm uses Resource Block allocation which is based on the transmission modes and assignment of users. By the selection of transmission mode capacity is increased and by the assignment of users utility is increased. Both the inter and intracell interference is reduced by using this DACA Architecture. The intercell interference is reduced by using co-ordination with congestion control algorithm. Fig 2. Shows the comparison chart of Uplink Data Rate with and without using congestion control algorithm. The use of congestion control algorithm reduces the congestion in the DACA architecture and increases the UL data rate. The UL data rate of some users tends to have zero mbps. Fig 3. Shows the comparison of Downlink data rate with and without congestion control algorithm. From the above figure it is clear that DL data rate of DACA is greater than that of UL data rate. Fig 4. Shows the utility sum of DACA architecture with congestion and without congestion control algorithm .It shows that the utility is increased by controlling the queue length in congestion control algorithm. Fig 5. Shows the graphical representation of Total Data Rate of DACA with congestion control and without congestion control algorithm. It shows that the overall total data rate is more high when the traffic is controlled. Fig 6. Shows how DACA meets the maximum interference thresholds. The interference room is $\tilde{I}_k^{f*} - \tilde{I}_k^f$ for DL. When DACA is applied, many RBs experience negative interference room, thus performance deterioration is significant. Fig 7. Shows how DACA meets the maximum interference thresholds. The interference room is $J_k^{f*} - J_k^f$ for UL. In UL, quite high rooms are observed in some RBs while very low rooms in some others. This is because some FBSs close to the MBS dominate the interference condition.

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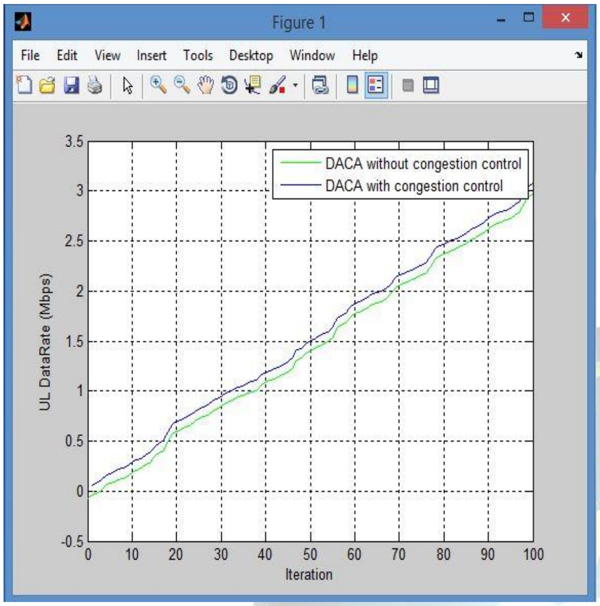

Fig 2.UL Data Rate in mbps

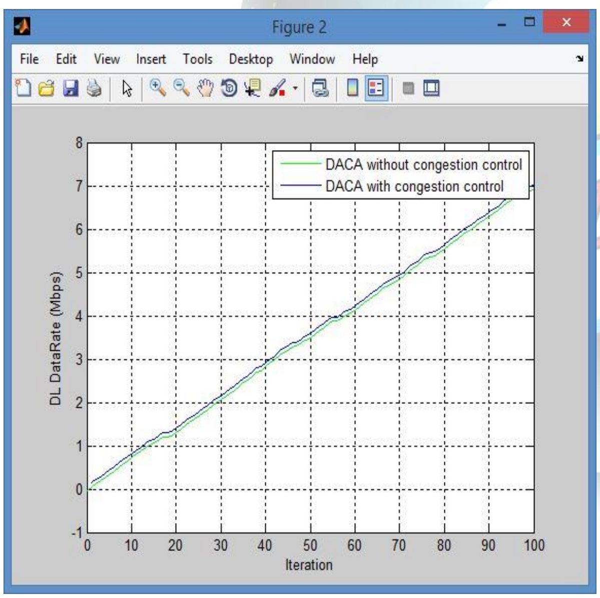

Fig 3. DL Data Rate in mbps

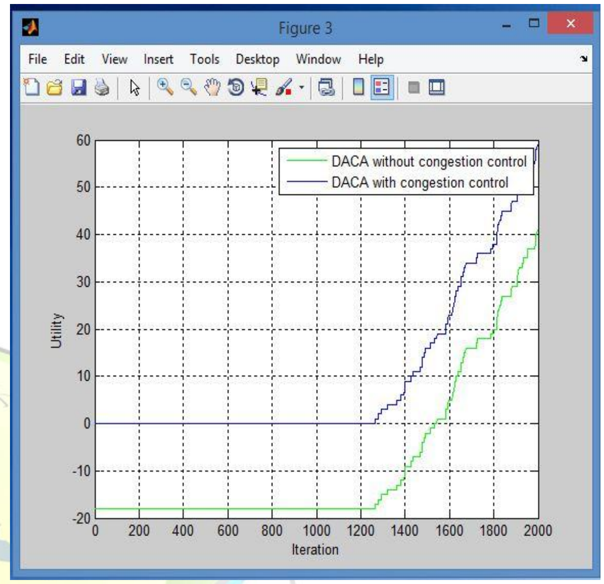

Fig 4. Utility

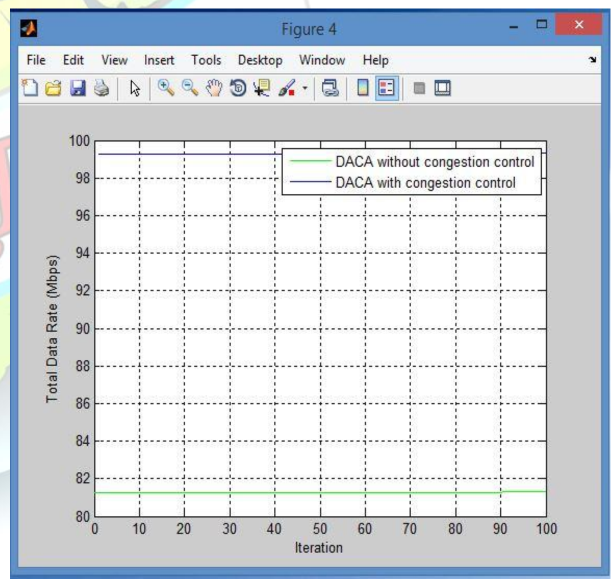

Fig 5. Total Data Rate in mbps

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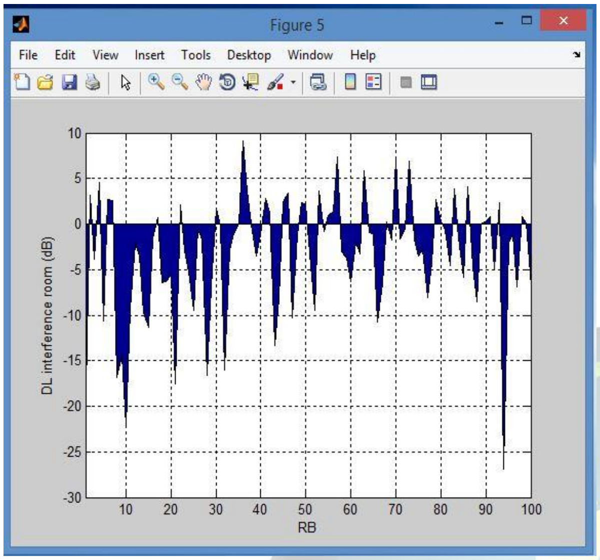

Fig 6. DL interference room in Db

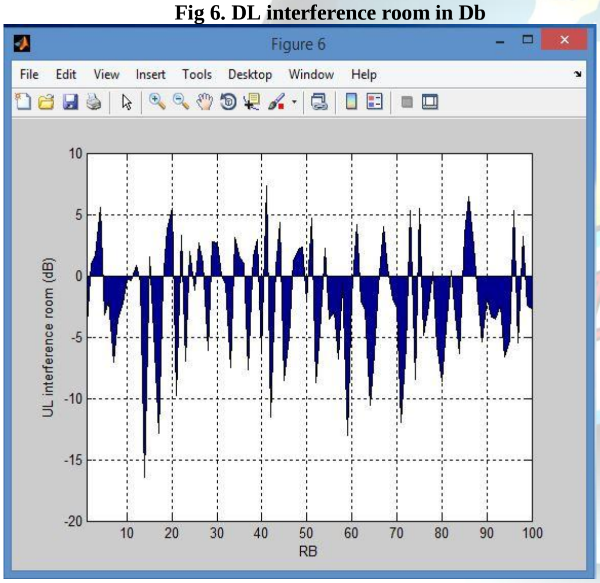

Fig 7. UL interference room in Db

IV. CONCLUSION

In this paper a DACA architecture is designed by the allocation of Resource Block (RB). The intracell scheduler decides the transmission modes, users and power levels of UL and DL .The intercell interference co-ordination is made to design co-ordination with congestion control algorithm to handle femtocell interference. The above simulation results shows the results both with and without using congestion control algorithm and from the result it is clear that the performance of DACA architecture with using congestion control algorithm is better than that without using congestion control algorithm.

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