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Research Article

# DACA: THE SOLUTION FOR FUTURE DEMANDS

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A R T I C L E I N F O

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A B S T R A C T

As of major perspective, Full-duplex communication draws higher attention by enhancing wireless communication capacity. Because of transmitting high power, the existing systems are still imperfect in cancelling the self-interference and hence leadsto the degradation of the performance of the system due to residual interference. Basically for any mobile communication system, proper distribution and signal coverage over all the allocated area is a major task.But the existing algorithms were not efficient as they were succeeded in providing signals up to some extent and in some regions. Complete geographic region was not covered with proper resources (signals) by the existing systems. To overcome the problem of cancellation of self-interference and for efficient management of resources, we propose a new method called Duplexing Aware Cellular Access (DACA). DACA will efficiently manage the signals by assigning appropriate frequencies for uplink and downlink transmissions and it improves the total global coverage and system efficiency.



## INTRODUCTION

Over past few years, many changes were happened and many technologies have developed for providing reliable and faster communication among devices. Usage of internet has become a part of life and it has become necessity. These changes impacts user behaviour and the device mobility level made the activities of internet and telephony to be improved. Prior to this, there were different business plans and revenue markets for internet activities and mobile telephony. But now, the user has unified Quality of Experience (QoE) where the market has unfolded to it. This rapid change in the society look ahead for providing better broadband services. To meet the demand, it is estimated that future 5G networks could provide high capacity. Various solutions have been implemented by mobile operators to handle the high data rates to provide the end user with a complete service structure (in order to handle hotspots)by research communities. For future 5G networks, a promising solution is that to deploy the Heterogeneous Networks (HetNets) which comprises large cells and densely deployed small cells, is suggested. Compared to the massive MIMO systems and Wi-Fi offloading systems, densely deploying small cells overlaid within large macro-cells area has tendency and potential [1].

The operation of both large cells and small cells jointly brings number of fundamental challenges.

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Small cells can be operated in two ways as a separate licensed frequency band to the macro cell or it can be operated in a licensed free band just like of Wi-Fi. For being a part of an operator network, small cells need to be operated over licensed frequency bands. In case of the operation of small cell in a licensed frequency band, when considering the highly dense deployment are infeasible due to limited frequency resources and high cost. Nevertheless, as the density of small-cells increases, these solutions fail to provide reliable interference avoidance. The major challenges regarding to the operation of both small as well as large cells are listed below: [2]

- The co-existence of large and small cells due to the presence of user, who is served by macro cell, in small cells vicinity, is one of the major issue. In such cases, severe interference will be faced by the macro-cell user from the small cells which are near to it and this leads to decrease in the performance of macro cell user significantly. Similarly, the control channel design in OFDMA based systems is not flexible as in case of data channel.
- Since the information present in the control channel serves like a key to unlock reside information which is present inside the data channel, the control channel reliability has a huge and direct impact on the performance measures on data channel. If the information regarding the control channel is not properly decoded at receiver end, the data channel which is associated with that channel also losts the control [3].

- Deploying small cells will increase the overall consumption of energy due to which a significant impact on the overall network capacity. For these devices, their energy efficiency is very poor in off-peak hours of the day**.**

The existing system is a conventional OFDMA based full duplex system which provides continuous transmission for both uplink and downlink communication. There exists two different techniques which enables FD communication. They are (i)OFDMA and (ii)MAC.

***OFDMA:*** It is a popular orthogonal digital modulation scheme in which the multiple access is achieved by assigning all the users with the subsets of sub-carriers. For supporting the Quality of Service which means controlling the data rates and probability of errors for each users individually, different users are assigned with different amount of sub-carriers. It can also be called as a combination of both time domain as well as frequency domain multiple access where the signals are partitioned on the basis of time-frequency slots and these are assigned along with the symbol index of OFDM as well as the sub carrier index of OFDM.

***MAC:*** MAC is responsible for transmitting data packets in between the network and the interface card. While sending the data to a device which is present in the same network, the MAC block encapsulates the higher level frames into the frames which are appropriate for transmission medium and for identifying the transmission errors, it adds a frame check sequence to identify the errors in signal transmission [4].

The following are some of the drawbacks that may occur while using the existing system in case of its communication and cell coordination [5].

- In-appropriate cell coordination
- Unable to provide the resources efficiently in hilly terrain regions.
- Increased levels of radiated power for transmission which increases system's cost.
- Spectrum utilization is poor.
- In-appropriate uplink & downlink frequencies.
- Not reliable
- Bit Error Rate is high
- There exists cross talk while communicating.

Full-duplex communication now has emerged to give a solution for the increasing capacity of significant wireless channel, it enables future wireless systems to meet the rapid growing demands. It offers promising solutions to the data services which requires high bandwidth. Here on the same frequency spectrum, a node simultaneously transmits and receives signals. This concept is not so typical and has clear expected benefits. Due to its strong self-interference, it had been so far considered as infeasible. Self-interference means receiving the wireless signals, at higher power levels, transmitted by the node itself rather than that of intended data signal transmitted by another node. Thus, the key realization of FD communication is that of suppression of self-interference below to certain level [6].

***Mobile Communication in Present Days:*** In present days, the correspondence to communication utilizes an essential unit named a cell which comprises of hexagonal region with a base station present in focal point of the hexagonal region. It provides communication throughout the region. To meet the demands of different clients, various techniques like FDMA, TDMA, OFDMA systems are used [7].

***Proposed Method***

***Fundamental Technique:*** When the set-up for the system is said to be done, first the information is conveyed from a versatile station or supporter unit to a settled base station, which it imparts the flipside client. Similarly, portable station comprises of handset, multiplexer alongside reception apparatus mounted on the tower. Likewise, Base stations are connected, for the transmission of correspondence of radio signs, to the power hotspot and is called as settled spine organize. The procedure of maintaining the call in automatic to the correspondence when connected to coverage of one base station to another base station coverage area is called as Handoff. Moreover, the larger coverage areas have their own difficulties in providing signals, those are made into small segments which is called as cell. Those cells, when formed together into a group to assemble together for forming a cluster. Let us consider a node which does the simultaneous action of both transmission and reception of signals on a single channel. The received signal $S_R$ can be obtained as the sum of those signals which are transmitted by itself $\mathbf{S_S}$ and the signal from other network $\mathbf{S_O}$.

$$S_R = S_S + S_O + \sigma \quad \rightarrow \quad (1)$$

where **σ** indicates Gaussian Noise.Because of the presence of this Gaussian noise, errors can be occurred at the receiving signal so that these errors could be easily detectable and can be easily minimized. Due to this transmission, the cellular networks in FD communication will face certain interference scenarios between the users and base stations.

***Intra-Cell Interference:*** The users who are served by the same cell in conventional OFDMA systems, are allocated by the time slots and orthogonal resource blocks so that the chance of existence of interference between them is less. However in full duplex communication networks, intra-cell interference occurs as it is shown in below figure.

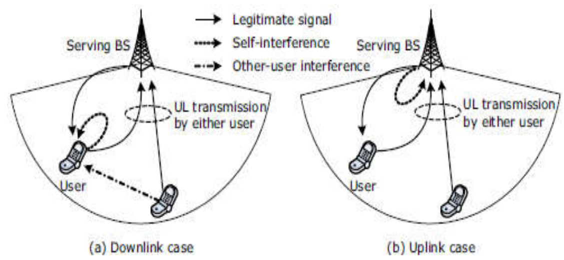


**Fig 1** Interference scenarios for Intra-cell region in full-duplex networks.

When any user receives a signal for downlink transmission from his present serving base station, there is also permission for uplink transmission to him or for any other user. This results in the occurrence of self and other user interference to the downlink communication of the first user. It is shown in figure 1(a). The uplink signal which was assigned to a user may also experiences interference due to the downlink signal of base station, radiated in same resource block. This scenario corresponds to the self-interference of the base station which is shown in figure 1(b).

***Inter-Cell Interference:*** In conventional half duplex heterogeneous networks, the inter-cell interference scenarios which observed are

1. small cell ↔ macrocell user
2. macrocell ↔ small cell user
3. small cell ↔ other small cell user.

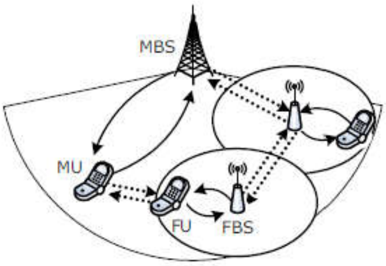


**Fig 2** New inter-cell interference scenarios in full-duplex cellular networks with overlaid co-channel femtocells (solid line: legitimate signal, dotted line: interference)

In addition to the above cases, new scenarios are observed in full duplex heterogeneous networks as illustrated in above figure and described as follows.

***Users in proximity:*** Users in proximity but are connected to different users, avoids the handovers of ping-pong if large value of handover hysteresis is used.

***BSs in proximity***: When two base stations are operated in full-duplex communication and they are very close to each other, then the downlink signal of one Base Station becomes interference to uplink of other Base Station.

Because of the presences of many drawbacks in MAC and OFDMA systems, we are introducing a new method called Duplexing Aware Cellular Access (DACA) to overcome all such problems. The main aim of the proposing method is for maximizing the total utility of sum of users. It also provides co-channel coordination for femtocells which are overlaid by using the same frequency spectrum.

***Procedure of DACA:*** By designing the radio resource management architecture for FD communication, we can identify the transmission modes of RB's and the mode capacities of various cross over points which then enables the transmission mode selection and networking architecture.For compacting the cancellation model of imperfect self-interference, we will design an intra cellular scheduler which then decides proper transmission modes in available resource blocks and the users who are associated with it. This design will schedule uplink and downlink power levels jointly for self-interference cancellation. By designing the co-ordination algorithm, the co-channel femtocells mechanism can handle both conventional as well as the newly occurred inter cell interference scenarios. This system consists of several base stations, many antennas, and gain analyser circuits which made the system to provide wireless signals for a full duplex communication.

***Communication Network:*** Let us consider a two layer femtocell network in which all the cells are overlaid on single macrocell. These set of femtocells and the macrocell are assumed of using an identical radio access OFDMA based technology and also on a single frequency spectrum. The frequency band is composed of multiple RB's.A group of many contiguous subcarriers having the minimum scheduling granularity forms a single resource block. All base stations which are present inside a cell, are capable of providing wireless mobile services for either HD or FD communication. In any resource block, the user may be connected to either femtocell or macrocell.

***Cancellation of interference:*** We may define that the gain of cancellation of self-interference ▲ by which $S_S$i.e. self interference signal will be decreases and the residual interference is $S_S$/▲. By this, we can say that the system having the larger gain value, the stronger the self-interference cancellation technique is. Here the assumption is that▲ is constant in the power range of $\mathbf{S_S}$ as well as across RBs. Since UL and DL transmissions are on same frequency band in the operation of full duplex communication, the reciprocal channel gain is assumed for every resource block.

***Resource Block Allocation:*** One of the major problem in this network is to allocate the resource blocks over the network. For solving this problem,

1. Selecting the mode of transmission for RB so that its capacity will be maximized.
2. Assigning users to the RB so that total utility rate will increases.

According to the channel gain, users are assigned to RB in either FD-FD or HD-HD as there is a proper distribution of power resources among RBs.

***Transmission mode selection of a RB:*** If there exists any user who meets it, the FD-FD mode becomes the candidate mode of the RB. It is then examined and the FD-HD mode is selected if there exists a pair of users who meet both of the conditions. Since the mode is chosen based on capacity only, not depending on the utility function, all users within the FD region operate in either the FD-FD or FD-HD mode while those outside the region use either the FD-HD or HD-HD mode.

***User assignment.*** Once the mode of a RB is determined, a user (for the FD-FD and HD-HD modes) or a pair of users (for the FD-HD mode) is assigned such that the increase of the utility resulting from this assignment is maximized. Let $\Delta r_n$and$\Delta s_m$ be the data rate increases of DL and UL, respectively, when user n is assigned for DL and user m for UL (n = m if the FD-FD mode is considered). Then, the increased utility is obtained as

$$\Delta \mathbf{U}(\Delta \mathbf{r_n}, \Delta \mathbf{s_m}) = \mathbf{U}(\mathbf{r,s})\, \Delta \mathbf{r_n} + \mathbf{U}(\mathbf{r,s})\, \Delta \mathbf{s_m}$$

which is the gradient of U multiplied by the step size(we assume that u is differentiable). Here, r and sare DL and UL rate vectors before this assignment.User(s) to use a RB is selecteddepending on the RB'stransmission mode as below

$$\text{FD-HD:} \quad (n^*, m^*) = \arg\max_{(n,m)} \Delta U(\Delta r_n, \Delta s_m),$$
$$\text{FD-FD:} \quad n^* = \arg\max_{n} \Delta U(\Delta r_n, \Delta s_n),$$
$$\text{HD-HD:} \quad n^* = \arg\max_{n} \Delta U(\Delta r_n, 0).$$

The FD-FD(n) mode achieves larger channel capacity than the HD-HD(n) mode if

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

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

**Algorithm:** Intra-cell RB allocation algorithm

Initialize $a_{n,k} = b_{n,k} = 0$ for □$_{n,\ k}$
**for all** n ЄM **do**
$k^* = \arg\max_k h_{n,k}$
**if** n satisfies larger channel capacity equations **then**
/* FD-FD mode */
Set $a_{n,k^*} = 1$ and $b_{n,k^*\_} = 1$
$r_n \leftarrow r_n + \Delta r_n$, $s_n \leftarrow s_n + \Delta s_n$
**else**
/* HD-HD mode */
Set $a_{n,k^*} = 1$
$r_n \leftarrow r_n + \Delta r_n$
**end if**
$K \leftarrow K - \{k^*\}$
**end for**
**for all** k ЄK **do**
**for all** n ЄM **do**
**if** n is FD-capable AND satisfies larger channel capacity equations **then**
$\hat{}M$ = {m|m ЄM satisfies channel capacity equation}
**if** $\hat{}M$ is empty **then**
$\Delta U_{n,k} = \Delta U(\Delta r_n, \Delta s_n)$, $USER_{UL}(n, k) = n$
**end if**
**else**
$\hat{}M$ = {m|m ЄM satisfies larger channel capacity equation}
**if** $\hat{}M$ is empty **then**
$\Delta U_{n,k} = \Delta U(\Delta r_n, 0)$, $USER_{UL}(n, k)$ = null
**end if**
**end if**
**if** $\hat{}M$ is not empty **then**
Find m* Є $\hat{}M$ satisfying Eq. (32) with fixed n
$\Delta Un,k = \Delta U(\Delta r_n, \Delta s_{m^*})$, $USER_{UL}(n, k) = m^*$
**end if**
**end for**
Find $n^* = \arg\max_n \Delta Un,k$
$a_{n^*},k = 1$ and $r_n \leftarrow r_n + \Delta r_n$
**if** $m = USER_{UL}(n, k)$ is not null **then**
$b_{m,k} = 1$ and $s_m \leftarrow s_m + \Delta s_m$
**end if**
**end for**

***Femto-Cell Co-ordination:*** For protecting the macrocell data services from the interference of overlaid femtocells, the coordination of these femto cells restricts the usage of its power resources. This can be happened in two ways

1. In terms of capacity, the mode selection for transmission of microcell remains optimal.
2. Minimum SINR requirement of MUs must be met.

***DACA Performance:*** For evaluating the efficiency and the effectiveness of the proposed method, consider a macro-cellular network which has multiple deployed femtocells. For simulating purposes, we are following 3GPP for the models with no path loss. There are 30 randomly placed Mus in each macro cell, the distance of each of these Mus to the MBS are to be chosen randomly with uniform probability distribution. Both of these MBS and FBS will operate at same band of 2GHz whereas the system bandwidth is 20MHz and 100 RBs. All these FBs are distributed randomly across the macrocell and FU is placed with in the shorter distance of 30m from each cell. An algorithm is implemented with utility function to the Rayleighfading for considering of small scale fading.

***Single-Macro-cell Network:*** We compare different transmission strategies in various aspects, utility, total data rate as well as link data rate in FD-FD mode. For single network, we are comparing various transmission techniques in different aspects like total utility, total data rates and link data rates in FD-FD mode. There is a significant improvement provided by DACA over HD as it allocates modes of transmission for various resource blocks and it maximizes the cell capacity.

***Multi- Macro-cell Network:*** For having a realistic environment to provide FD communication, consider a two-tier hexagonal cellular network which comprises of 7 macro cells each of having an individual sector. For corresponding to urban and rural case scenarios, consider two cases of cell radius one as 300 meters and other with 1000 meters. When the cell radius is increased to 1,000 meters, this interference gets weaker, but performance is degraded further since users' path loss gets larger. When the radius of cell site increased to 1000 meters, the interference present may get weaker but the overall system performance is degraded and path loss gets increases. Whenever such degradations in system performance occurred, power adjustments are applied significantly to increase systems overall performance. But in this situation, the users who are having high data rates, are assigned with lower power levels, for assigning the other users with more power resources. But the modes of FD-FD and FD-HD capacity is less sensitive with assigned power.

Thus when this power adjustment is applied, there is no such degradation experienced by the top 10 percent of the users while as the bottom 10 percent users gain improvement in the system performance. Within a single coverage area of macrocell, we may deploy 20 to 30 FBSs into it for evaluating the capability of macrocell protection of the proposed femto cell coordination. For having the clear comparison between the two cases of with and without coordination, consider the former version as DACA+ whereas the latter version is simply called as DACA. In the existence of co-channel femtocells, there is a significant decrease in the data rates of all MU's when compared to the case having no femto cells. The performance of FU's decreases even though the usage of power resources of FU's is restricted by DACA+ in both uplink and downlink transmission. But as the matter of fact that the degree of deterioration in the system performance is not more than the performance of MU's because they already have their serving FBS's with high channel gain and the power restriction level is done up to some extent.

Finally, DACA+ meets the maximum threshold levels of interference. When DACA is applied, the negative interference room will be experienced by many resource blocks such that there is much significance in performance deterioration. During uplink transmission, some resource blocks have observed with high rooms where as some resource blocks have observed with low rooms. The main reason behind this is that some FBS's which are close to MBS will dominate the interference condition. When DACA+ is applied, most resource blocks successfully have positive or zero rooms. Since the requirements of both uplink and down link should meet at same time, the rooms in many resource blocks have become larger than zero.

***Cellco-Ordination Results***

After the selection and arrangement of all the cells and their UL and DL frequencies, their coordination need to be analysed. The improved performance of the uncoded BER, uplink and downlink data rates, total utility rates are shown in the below figures.

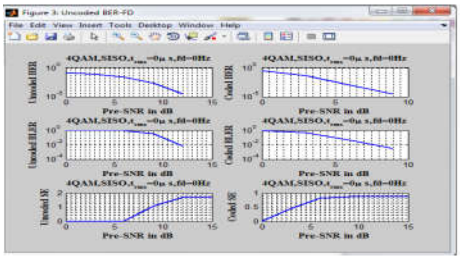


**Fig 3 (a)** Un-coded BER-FD

The comparison of the un-coded BER with the coded BER in Full-Duplex communication is shown in fig 3(a). By assuming the 4QAM SISO system, the Pre-SNR for coded BER decreases by twenty percent than the un-coded BER.

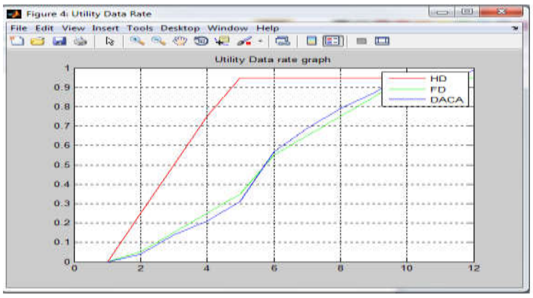


**Fig 3 (b)** Utility Data rate Graph

The comparison of the utility data rate in HD, FD and DACA systems is shown in fig 3(b). From the analysis, the utility rate in DACA system increases to maximum extent than the remaining two systems.

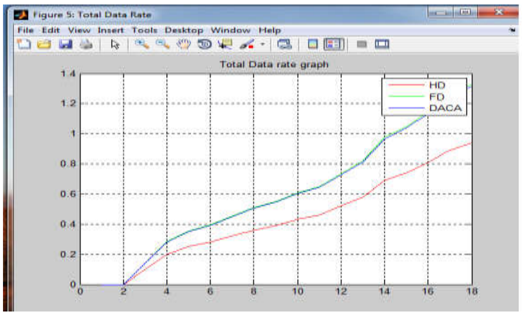


**Fig 3(c)** Total Data rate Graph

The comparison of the total data rate in HD, FD and DACA systems is shown in fig 3(c). From the analysis, the data rate for DACA system increases marginally than the FD system.

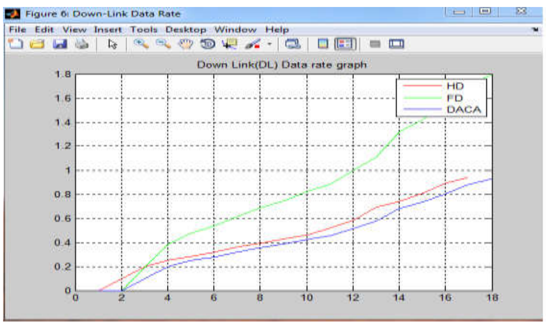


**Fig 3 (d)** Downlink Data rate Graph

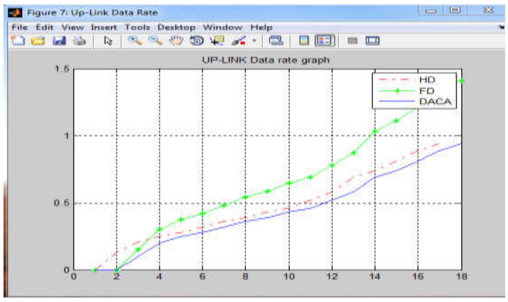


**Fig3(e)** Uplink Data rate Graph

The comparison of the downlink and uplink data rates in HD, FD and DACA systems is shown in fig 3(d) and fig 3(e). From the analysis, the services can be provided efficiently by using lesser data rates which are used in FD system.

This shows that the cost of the proposed system is less than the existing system. Hence proved thatthis method increases the system's overall performance.

## CONCLUSION

In this paper, the proposed method was implemented which manages the signals efficiently as well as capable of managing its network structure for providing the uninterrupted full duplex communication for both intra and inter cell regions. Also, Duplexing Aware Cellular Access (DACA) is perfectly applicable to OFDMA-based networks. While exploiting the full capacity benefit of full-duplex communication, the proposed method aimed to maximize total users utility rate.

The merits for the proposed method are

- Appropriate cell coordination and better signal management
- Can provide signals in both Hilly and Flat terrain regions, thus increases system's efficiency
- Good spectrum utilization
- Has appropriate downlink and uplink frequencies.
- Reduces system cost and equipment cost
- Enhances communication speed
- Reduction in Bit Error Rate
- Highly immune to cross talk

The proposed architecture can be extended for 4G LTE FD communication by designing a giant class FD system for both intra and inter cell users. This extended version may consists of many number of base stations BTS, antennas for transmission of signals, gain analysers to analyse the gain, path loss analysers to analyse the path loss of the signal and channel models which all could make up a giant sized complete system for full duplex communication. For the extended version, the proposed technique can be used as a sub-technique for its implementation. The giant sized extended version of this paper can provide high speed communication with uninterrupted services for both intra and inter-cell users and also provides adequate hand-off capabilities to the users.

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