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Comparing the developments in power control of CDMA and NOMA using optimization techniques: A review

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Abstract
The concept of power control has received great attention for research since the emergence of code division multiple access (CDMA) for 3G wireless communication in 1990s. The recent adoption of non-orthogonal multiple access scheme (NOMA) for 5G and beyond radio access technology came to be with potential advantages over the orthogonal multiple access (OMA) (which CDMA is inclusive). The increasing demand for more spectral and energy efficiencies for advance wireless system posed huge challenges for power control usage. This means that there still remains a need to further explore more on power control so as to come up with a technology that improves the spectrum efficiency and flexible user resource allocation in the current mobile networks scenario of high traffic demand and higher data rates. This calls for a significant research effort by academia, industries and researchers to dig more on power control area as it has strong bearing in increased spectrum efficiency, combating adverse effects of multiple access interference (MAI). This paper contains a brief survey of numerous power control scheme based on multi-objective optimization (MOO) as the best tool to deal with conflicting objectives and reduced computational complexity in power control problem for CDMA and power domain NOMA technologies. Whilst the paper provides a good treatment of MOO power control, it focused on the applications of scalarization and biologically inspired algorithm techniques for the optimizations. It is envisaged that this review work will be a source of valuable information for wireless communication engineers to keep abreast with the latest progress in this area, as well as for new researchers to get started on MOO power control.

Keywords: CDMA, FDMA, TDMA, 5G, BS, CN, WBAN

Introduction

The radical development of wireless communication over the last four decades gave rise to the evolution of multiple access (MA) technology from the first generation (1G) in the 1980s, the second generation (2G) in 1990's, third generation (3G) in 2000's, fourth generation (4G) in 2010's to the current fifth generation (5G) that was fully deployed in 2020 [1]. Due to the revolution in electronic industry, demand for more system coverage, capacity, spectrum resources scarcity and different wireless standards results to multiple access (MA) transition from one generation to another [2]. Recently, other contributing factors necessitating the evolvement of further generations are; demands for more data rate, spectral efficiency, energy efficiency, emerging technologies etc [3]. Accordingly, multiple access technique can be divided into two major groups; the orthogonal multiple access (OMA) and the non-orthogonal multiple access (NOMA) [4]. OMA comprises; frequency division multiple access (FDMA) [5], time division multiple access (TDMA) [6], code division multiple access (CDMA) [7] and orthogonal frequency multiple access (OFDMA) [8] i.e. 1G to 4G. But NOMA is 5G and beyond technology which is either power domain (PNOMA) or code domain NOMA CNOMA [9]. All these technologies serve multiple users; hence multiple access interference MAI becomes a dominant problem [10].

The idea behind power control is to adjust the mobile transmit power in each mobile station (MS) links [11] so as to solve the near-far problem (NFP) (in CDMA), MAI and power consumption minimization [12]. This is aimed at maintaining mobile transmit quality in the presence of channel interference and noise effects [13]. So, power control mainly deals with the tradeoff between the performance achieved and the power consumption. In a typical multiple access system, large number of users compete for the available resources, this necessitates a tight power control [14], in order to have on optimal radio resource sharing among the users. With the recent advancements in the fifth-generation (5G) mobile communication system, there still remains the need to further explore the idea of power control in order to satisfy the 5G and beyond 5G (B5G) requirements of high spectrum and energy efficiencies. Power control became a popular stuff in CDMA and now becoming an important cardinal objective in NOMA system. In spite the fact that most existing power control techniques focused mainly on single objective (SO) to determine the mobile transmit power, it appears as though multiple conflicting radio resource parameters (objectives) often arise in practical power control systems. For over two decades, power control problem considers multiple objectives rather than the single objective [2] in a methodology termed multi-objective optimization power control (MOPC). It integrates number of conflicting objectives with different weights for resource management through making a compromise between the objective targets [13]. The scheme has an impressive record of deterministic-based technique optimization which always produced high quality solutions in multi-objective (MO) optimization arena that witnessed significant progress in power control problems. The process multi-objective optimization (MOO) involves choosing the best solution from a pool of potential candidate solutions that is better than the rest (solutions) in certain aspects [2]. So, the concept of multi-objective power control for any multiple access system involves making trade-off between conflicting MO targets. Basically, optimal mobile transmit power values are obtained for better energy efficiency and low outage probability to ensure less interference for each link so as to maintain sufficient transmit power quality [15]. Obviously, MOO entails great deal of computational effort than SO optimization (SOO), owing to compromise that is made between the competing attributes. Since power control is very crucial technique to overcome near-far problem (NFP) and MAI in CDMA systems to maintain a satisfactory communication link between the MS and the base station (BS) [14]. In NOMA, PC is very important in achieving better sum rate and enhanced user fairness. It is also essential in improving spectral efficiency, energy efficiency and address issues in the MOMA power allocation [16]. Again in 5G system, it was discovered that PC actually enhanced quality of experience (QoE) through extending battery life for the same date volume consumed [17]. So, one can perform the MOO so as to optimize the overall system performance by selecting the optimal mobile transmit power [18] based on appropriate MOO scheme of choice [19].

Over the years, numerous MOPC techniques have been proposed; this is evident from the growth in number of related papers published in various journals and proceedings. Upon the fact that the methods follow same objectives, they differ in terms of complexity, speed of convergence, effectiveness and flexibility. Again, many researches have been carried out to address the issue of transforming the model to optimization problem so as to determine the optimal mobile transmit power. Ultimately, with emergence of different computing power, new methods based on mimicking algorithms computing techniques received great interest in solving multiple criteria simultaneously and find the Pareto optimal solution.

The emergence of 5G came to be with potential requirements: enhanced mobile broadband (eMBB), ultra-reliable low latency communication (uRLLC) and massive machine type communication (mMTC) [25]. So, it has lot of advantages over the OMA schemes. With all its advantages, stringent power control becomes an integral requirement for improving NOMA performance [26].

In spite of the fact that this paper focused mainly on the review of MOPC of CDMA and NOMA, it is envisaged that some basic information seems helpful to follow through the paper effectively. In consequence, basic types of power control, limitations and advantages are provided. Nevertheless, as the number of papers related to one particular optimization technique for the power control is much, it deemed necessary (with apology) just papers with significant contributions and relevancy will be cited.

a. Multi-objective Power Control Development Stages

The control of mobile transmit power is vital for interference management interference limited system such as CDMA [5]. Other advantages include; capacity increase, overcoming near-far problem, MAI and energy management that results to prolong battery life [19]. This leads to the control of the transmit powers of all active users in such a way that the interference power from each mobile station (MS) to other users sharing same radio resource simultaneously is minimized while preserving sufficient QoS among users [14]. The power control variants based on optimization have been developed to improve the performance of CDMA system. The same way, PC schemes in uplink (UL)/downlink (DL) NOMA systems are very important requirements in order to achieve an appropriate compromise between the NOMA performance and successive interference (SIC) technique computational complexity [26].

When power control using optimization is in its infancy, [24] proposed a rule based technique that optimizes pilot power settings in a CDMA system then tested and compared to uniform pilot settings and those based on ad-hoc approaches; optimization by "hand" and optimization through drive tests. In [27], CDMA radio network power control optimization was evaluated. Also, optimization of power control parameters for direct sequence CDMA (DS-CDMA) cellular systems was envisaged in [28] based on log-linear closed-loop power control (LL-CLPC) model in both uplink and downlink models. Another work on optimal power control of a wireless CDMA with deterministic sequences in fading channels for a finite and arbitrarily number of users and processing gain was proposed by [29].

[30] proposed a multi-objective distributed power control of CDMA based on soft dropping algorithm for the minimization of two objectives; keeping the transmit power close to the minimum power as possible and hold the carrier to interference ratio (CIR) close to the given target [31]. reviewed the concept of power control in multicell CDMA wireless networks as a team optimization problem where each mobile attains minimum individual fixed target (SIR) level, beyond which it optimizes its transmit power. A robust H_∞ power control scheme for CDMA system was proposed [15] to achieve a robust optimal signal to interference plus noise ratio (SINR) tracking. The method achieved better performance in rapid fading environment coupled with round-trip delay and high Doppler velocities.

As power control problems with nonlinear objective and constraints appears a vital problem solving tool, MOO becomes very popular in distributed power control of CDMA and now NOMA research work [32]. presented a systematic method of distributed algorithms for power control of wireless CDMA system based on geometric-programming (GP). The scheme shows how to optimize over the transmit powers to create the optimal set of signal to interference ratio (SIR) on wireless links through maximizing the total system throughput and quality of service. Similarly [33], proposed optimization algorithm for power control problem in CDMA system based on particle swarm optimization (PSO). It minimizes three objectives in a more effective through the optimal power vector that satisfies all the objectives. A year later [11], proposes a novel analytic approach for multi-objective optimization of distributed power and rate control. A trade-off was made between power consumption, SINR tracking error deviation and throughput (average rate of successful message delivery over a communication channel). In [34], an adaptive two-loop power tracking control in CDMA systems having outer-loop controller and an inner-loop controller with utility optimization were presented.

[35] proposes a CDMA power control optimization scheme for multiple BS and mobile users over additive Gaussian noise channel. The scheme was based on signal to noise ratio (SNR) at the receiver and the locations of the BSs and mobile users. A very similar work [36] follows same

sequence of work as [35], but shows that the corresponding optimization problem can be transformed into a well-known constrained GP problem. Also, genetic algorithm (GA) optimization technique received great attention in CDMA power control work [37]. proposed a novel MO mechanism to solve the power control problem in CDMA systems based on GA as GA-based PC algorithm (MGPC). A robust two-loop PC scheme for CDMA system was proposed in another study [38] via MOO with inner and outer loop controllers and a fuzzy logic controller to adjust SINR for the required QoS. Also, a similar work by [39] proposed a MOO method for PC in CDMA system based on shadow system and *H-infinity* filter (($(SS - H\infty\ filter)$ scheme, and compensate for the round-trip delay. Another work on MOO PC of CDMA base on bacterial foraging algorithm (BFA) was envisaged [19]. The work also considers three objectives; the minimizations of: power consumption, SINR deviation (tracking error) and system outage. The effects of round-trip delay, different transmission rates, different mobile velocities and outage probability were considered.

After full transition from OMA to NOMA for 5G, the demand for good energy and spectral efficiency becomes obvious. This draws attention of engineers to embark upon power control for effective spectral and energy efficiencies maximization [40]. formulates an uplink PC scheme based on optimization for uplink grant-free uRLLC NOMA. Distributed power control for NOMA was envisaged in [41]. But the work of [42] involves the power control techniques for device-to-device (D2D) communications in 5G mobile network [43]. combine user pairing and power control optimization scheme for multi-input multi-output NOMA (MIMO–NOMA) was envisaged. A similar combination work enhanced by NOMA with addition of mode selection for D2D based cellular network is proposed in [44]. Again, another paper covers joint power control for network of small cells and uplink BS associations [45].

Motivation and Contributions

For both uplink and downlink CDMA and NOMA systems, efficient power control among users is the most fundamental design issues as it is tight to power consumption minimization leading to energy efficient. The optimal power control has strong bearing in overcoming near-far problem in CDMA and great impact on the user grouping and power allocation problems in power domain NOMA. Certainly, most of the review investigations to date have been conducted either for CDMA alone or for NOMA scenario considering uplink or downlink cases. In particular, there is no comprehensive survey that precisely reviewed the impact of power control on CDMA and NOMA systems. In this context, this paper focuses on literature survey of the use of multi-objective optimization power control for OMA class member, the CDMA and power domain NOMA for multi-user uplink and downlink systems. The contributions of this paper are outlined as follows:

- We conduct a brief survey and describe the differences in the working principles of uplink and downlink NOMA.
- For both uplink and downlink NOMA, we formulate a signal to interference plus noise ratio as major performance measure for power control in CDMA and in NOMA.
- Due to the nature of power control, it was formulated here as an optimization problem, where bacterial foraging algorithm (BFA) was employed as the major testing algorithm where optimal mobile transmit power were obtained for both CDMA and the power domain NOMA. This certainly enhanced the energy and spectral efficiency.

a. The Power Control in Multiple Access

Currently, the available spectrum resource in current wireless communication arena is becoming increasingly crowded due to the increased traffic demand [46], while significant amount of the allocated frequency resource is largely underutilized [47]. Hence, improving network capacity is highly needed and became necessary. Equally, the rapid evolution of information and communication technology (ICT) and the emergence of new wireless equipment, power consumption certainly grow at an astounding rate coupled with security challenges [46]. So, power control research received much greater attention over the last few decades to increase spectral efficiency and minimize energy consumption [16].

Power control is a critical aspect of wireless system design and is applied to systems where users interfere with each other [48]. So, it manages interference, connectivity and energy. The main idea of power control strategy is to adjust the transmit power (minimization of power consumption) in each MS-BS link so as to mitigate the near–far effect and MAI [49] under maintaining sufficient transmission quality constraint in the presence of external interference and channel fading [15]. These makes it essential in an interference-limited capacity communication systems to regulate user's transmit power as close to optimum as possible, maintains the battery life of the mobile terminals [50] while at the same time achieving sufficient quality of service (QoS). Also, the task of conventional power control is to keep the transmit power level of transmitter at the minimum power required to achieve the desired QoS [51]. However, these advantages and many more peculiar to the system may be hindered if tight power control scheme was not implemented. This however calls for a significant research effort to dig more the field of power control, so as to reduce the effect of the interference as it has strong bearing in increased spectrum efficiency.

Ultimately, power control schemes can be divided into two:

1. **Centralized power control (CPC):** This scheme needs to know the information of all users and decides the control actions at the BS. But this method has the main drawback where enormous amount of computation and communication is needed at the base station [39].

2. **Distributed power control (DPC):** This scheme only needs the local information about the users at the BS. It has number of advantages over CPC scheme in that; it is easy to implement without extensive signaling in the network and that the scheme is more feasible [39].

DPC has been approached from two different perspectives: multivariable optimization and control theory. The advantage of using a control theory framework is that stability and reference tracking can be jointly studied for each multi-user (MU).

Also, the PC mechanism can be classified based on information feedback and the nature of control action involved; we have the closed-loop PC (CLPC), open-loop PC (OLPC) or combination of both as closed loop-open loop PC (CLPC-OLPC). In OLPC, the MS measures link quality based on the predetermined equations and measure the uplink transmit power level in a distributed fashion [5][11][52]. Figures 1 shows the schematic of OLPC. In CLPC, the power control action is centralized at the BS. The MS provides feedback on link quality, and the BS computes the uplink transmit power level for the MS and directs it using control command signal [5][18][19]. Figure 2 shows the schematic of CLPC scheme.

b. The Power Control Model and Analysis

Consider an uplink (communication from mobile to base station) CDMA/NOMA wireless system where the BS, *B* support *N* number of active mobile users (user equipment, *UE*) as in [16]. This is illustrated in Figure 1.

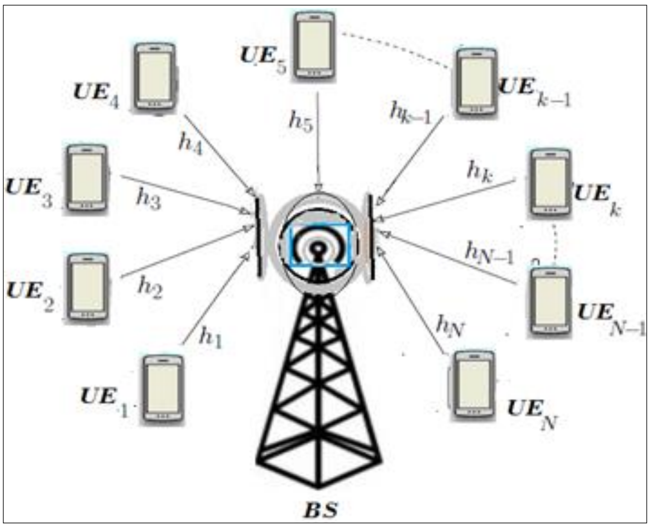

Fig 1: Uplink Communication in Multiple Access System

The received SINR, $\Im_N(k)$ of the *N*-th mobile user in the desired cell [11][1] is given by;

$$\therefore \quad \Im_N(k) \, \frac{P_N(k)G_N}{\sum_{j\neq 1}^{Q} P_M(k)G_M(k) + \delta_N^2} \quad \textbf{...} \ (1)$$

Where P_N is the power that *N*-th user consumes for packet transmission, G_N denotes the link gain on the path between the candidate mobile user *N* and the BS, *B*. $P_M(k)$ is the *M*-th co-channel user power. G_M represents the channel gain between *B*-th base station and *M*-th subscriber. δ_N^2 is the power of the background thermal noise contained in the spread spectrum [14][53]. In cellular systems (e.g. CDMA or NOMA), the SINR depends inversely on the power assigned to the other users in the system, thereby creating a nonlinear control problem [6].

As in [41], the downlink is the communication from BS to the mobile terminals. This is illustrated in Figure 2.

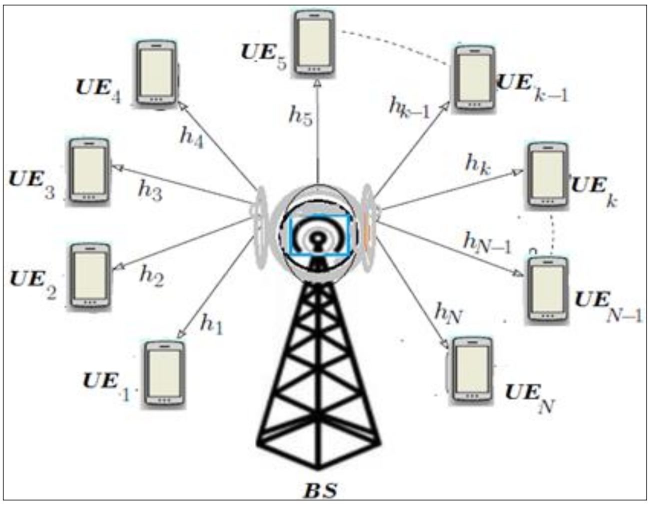

Fig 2: Downlink Communication in Multiple Access System

As in [19], the outage probability, P_o was used as a performance measure in the power control problem. It is the probability for the system failing to achieve the required SINR level (threshold SINR), $SINR_{Th}$. The outage is a QoS requirement in a typical wireless communication system. It is defined by equation (2).

Outage probability, $P_o = P_d\,(SINR < SINR_{Th})$ **...** (2)

$SINR_{Th}$ is the minimum SINR value of the received signal for a successful communication link quality. P_d is the probability density function of the SINR which is defined according to [2] as;

$$P_o(SINR_{th}) = P_d\,(SINR < SINR_{Th}) = \int_0^{SINR_{Th}} \emptyset(x)\; dx \quad \dots (3)$$

$$P_o(SINR_{th}) = P_d\,(SINR < SINR_{Th}) = \frac{1}{\sqrt{2\pi}} \int_0^{SINR_{Th}} \frac{1}{\sigma_{SINR}} \exp\left[\frac{-(x-\mu_{SINR})^2}{2\sigma_{SINR}^2}\right] dx \quad \dots (4)$$

where μ_{SINR} is the mean SINR value, and σ^2_{SINR} the standard deviation of SINR.

The outage probability P_o largely depends on the channel fading $f(k)$ effect and the mobile velocity [19].

c. Characteristics of Multi-Objective Optimization

Certainly, many real-world practical problems are often characterized by a set of criteria against which a solution should be mathematically assessed. This scenario was what drew the concept of mathematics of finding the possible optimal solution from the pool of potential candidate solutions. Multi-objective optimization is formally defined as the task of finding a feasible vector, *x**, that simultaneously optimizes certain number of components of an objective or criteria vector that are usually conflicting. Hence, the term "optimize" refers to finding a particular solution which gives the values of all the objective functions acceptable to the decision maker and such problems are known as multi-objective optimization or pareto optimization problems [54]. The MOO has two major research fields, these are; the deterministic (scalarization) or classical technique and the Meta-heuristic or population based (mimic) scheme.

d. Power control as an optimization problem

Owing to the fact that power control scheme is aimed at minimizing the power usage in a CDMA network, the problem is often formulated as an optimization problem, where a mathematical optimization problem consists of optimization variables, objective functions, constraint functions. So, the MO power control problem considers the MO targets of a candidate user (user *i*) [5]. Also, it is obvious that the transmit power vector $P = [P_1 P_2 P_3, \dots, P_N]^T$ is the optimization variable. There may also be other optimization variables depending on network requirements, such as the SINR vector $\Im = [\Im_1 \Im_2 \Im_3, \dots, \Im_N]^T$, base station assignment, bandwidth allocation, time schedules and so on [57], usually analogous to decision variable vector, x = $\{x_1, \dots, x_n\}$.

According to [57], objective functions in power control problems are usually of two types: QoS-based utility objective and resource cost objective. The utility objectives functions represent the degree of user satisfaction with the service and are relatively complex. They are often modeled as monotonic, smooth and concave functions, although in some applications they are sometimes required not to be smooth or concave. While cost function objectives on the other hand are often increasing, convex functions of the resource, e.g., linear function of transmit power. They are also often combined to form a single objective function for each user, either additively as in utility minus power, or multiplicatively as in throughput over power.

Research Activities

Early power control analysis of CDMA [1] of non-continuous transmission systems was based on the assumption of very large number of users. In such case, using the central limit theorem, the interference can be approximated as a white Gaussian noise, and the system performance is identical to that of continuous transmission CDMA system with the same average transmission powers. Later publications [12], [13] had shown that this is not the usual case, and demonstrated power control scheme via optimization to achieve an optimal SINR tracking design.

Table I Presents the Chronology of Optimization Schemes for Solving Distributed Power Control in CDMA and NOMA Systems.

Table 1: Chronology of Power Control Techniques for CDMA System

Year	Summary of work performed	Reference
1999	Proposed a pilot optimization technique for CDMA cellular systems	[24]
2000	Worked on CDMA radio network power management optimization	[27]
2004	Used an iterative water-filling algorithm for optimum transmit powers of all mobile users and maximize the sum capacity of the CDMA system with arbitrary signature sequences in a fading channel.	[29]
2006	Proposed a robust state feedback l_1 optimal prediction power control of CDMA via pole placement.	[15]
2007	Proposes a power control problem based on multi-objective optimization of two objectives, the minimization of: (1) transmit power, (2) tracking error	[18]
2008	Achieved a power control problem based on multi-objective optimization of three objectives, minimization of: (1) transmit power, (2) tracking error, and (3) rate	[11
2008	Designed an adaptive two-loop (inner and outer) power control algorithm to achieve the net utility optimization and target SINR tracking simultaneously	[34]
2011	Exploits a CDMA power control based on cerebella model articulation controller (CMAC) with time delays.	[35]
2012	Envisaged a fuzzy logic controller for inner loop to compensate for SINR and Shadow system with H_∞ filter as inner-loop to outer-loop as power controller using multi-objective optimization	[38]
2016	In the work, a bacterial foraging algorithm optimized fuzzy logic control-based power control for CDMA systems was envisaged.	[12]
2018	Proposed 5G optimization power control for uplink grant-free ultra-reliable low latency communication (URLLC)	[40]
2019	Formulates a multi-objective optimization power control of CDMA to minimize: power consumption, tracking error and system outage.	[5]
2019	Came with different Formulation of multi-objective optimization power control of CDMA and minimized only power consumption and tracking error.	[19]
2019	Proposed a joint user pairing, power control and mode selection for device to device (D2D) capable cellular networks enhanced by NOMA.	[44]
2020	A joint user patterning and optimization power control for MIMO–NOMA systems was presented.	[43]
2021	Proposed a mean-field power control with emphasis on CDMA and NOMA systems.	[14]

Comparative Numerical Simulations

This section shows the effectiveness of the multi-objective distributed power control method. A conventional power control with fixed step size and a multi-objective optimization power control scheme based on swarm-based optimization algorithm, a bacterial foraging algorithm (BFA). The power control schemes follow same practical settings.

The multi-objective optimization power control problem is based on Pareto optimality theory for solving the MO problems. This is because there does not exist a single solution that satisfies the objective functions simultaneously [2]. So, the objectives are mutually contradictory [4].

Twelve active mobile users are assumed to be in the range of BS. The system operating frequency is 2 GHz; the channel bandwidth (W) is approximately 3.6864 MHz [25].

In this section, a comparison is made for the multi-objective distributed power control optimization algorithm (MODPC) and the conventional power control algorithm (FSS) in terms of power consumption and outage probability.

The plot of average mobile transmit power against number of users is plot in Figure 3. It is clear that the average transmit power for the mobile units based on BFA reached solutions with much smaller values for the same number of active users (12). So, the average mobile transmit power for the MODPC algorithm are considerably lesser than those of the conventional power control scheme.

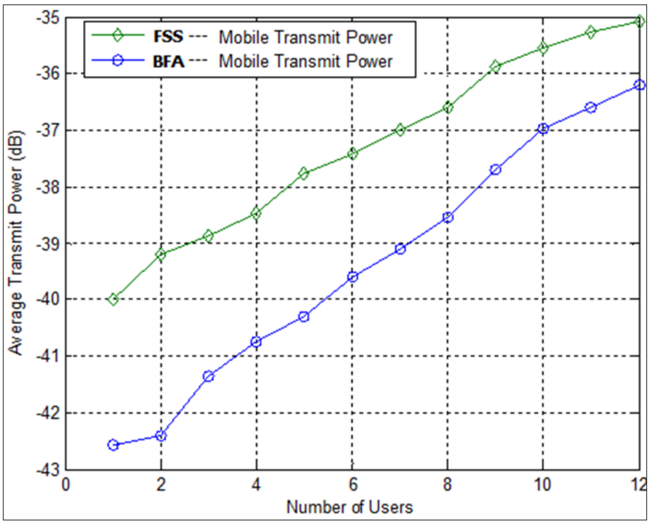

Fig 3: Illustration of the Superiority of Multi-objective optimization over Conventional Power Control Scheme for Average Mobile Transmit Power against Users. The detailed parameter settings are found in [5].

From Figure 3, “FSS” refers to fixed step size power control method; “BFA” refers to Bacterial foraging optimization algorithm.

Regarding the outage probability performance, it is well known that for increased number of users, the outage probability appears to increase also. From Figure 4, the BFA optimization has lesser values of outage probability for the same number of users as the conventional power control scheme. This signifies that the optimization power control scheme achieved better performance in comparison with the conventional power control scheme.

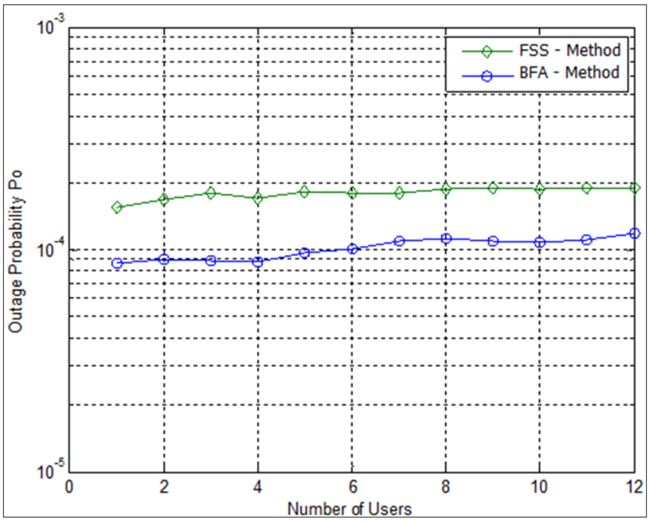

Fig 4: Outage probability versus Number of users for a CDMA system with 12 wireless links

Now, for the uplink power domain NOMA, the performance of two meta-heuristic algorithms namely: BFA and Whale optimization algorithm (WOA) proposed in [26] for the optimal power control where evaluated. As was assumed in the simulation in [26], both users' channel and location are randomly allocated, such that the range between a user and BS are uniformly distributed. Also, Gaussian distribution is considered as the channel response. The parameters used in [26] are assumed in this illustration. It was shown that as the computational overheads increase with increase in the number of users using exhaustive-search algorithm as compared to WOA. In [26] again, the PC approach used in [101] was provided as the main benchmark and the spectral efficiency nears optimal value.

Figure 5 shows the performance evaluation of BFA and WOA algorithms in-terms of spectral-efficiency and the transmit power-to-noise ratio (dB). An uplink power domain NOMA system is considered. Clearly, from the work in [26], the spectral-efficiency of NOMA scheme outperform OMA scheme with varying transmit power-to-noise ratio (dB). The power control schemes for NOMA uplink system in [26] and [101] are used as benchmark. It has been observed that the spectral-efficiency of both BFA and WOA algorithms shows better results than power control in [101] and OMA schemes with BFA the best. It has been proved that the spectral-efficiency of NOMA using BFA scheme is considerably better and higher than those obtained using WOA in [26] and the result in [101].

Moreover, as the value of the transmit power-to-noise ratio (dB) above 30 dB, the optimal BFA and WOA performs wonderfully well in-terms of the spectral-efficiency as compare to the work in [101] with BFA showing better spectral efficiency.

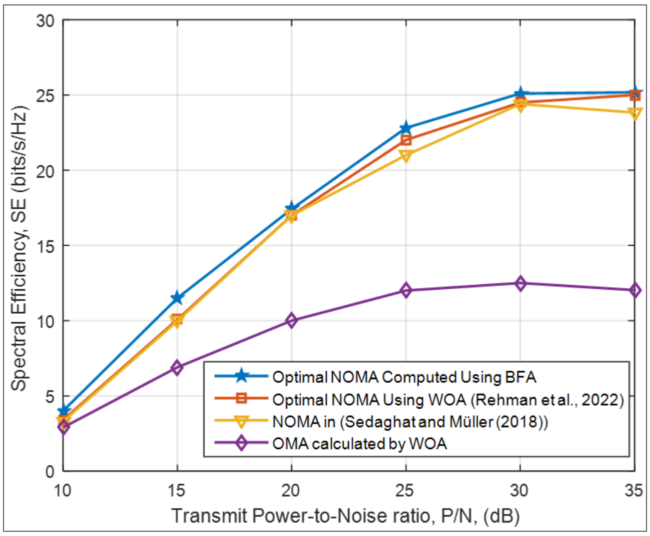

Fig 5: Illustration of spectral efficiency of WOA with increasing

Conclusion

This paper performs a survey to compares the developments of the different distributed multi-objective power control schemes adopted in CDMA and in NOMA systems coupled with the mechanisms involved. This is with the intention to identify the technology's trends and gap. Capacity enhancement, spectral efficiency and outage probability reduction in a CDMA system is achieved through the MOOP, while NOMA also shows appreciable enhancement in the spectral efficiency too. The MOPC concerns with coming up with the optimal power for all users with a goal of maximizing the number of users in the system. The recent 5G and beyond technology evolves with high data rate mobile applications, internet services, massive broadband, ultra reliable low latency, energy efficiency, to mention a few. So, maximizing the data throughput coupled with low latency requirement fulfillments instead of just the number of users found in the literature might be more interesting from the operators' point of view. So, interesting future power control studies could potentially include the further usage of multi-objective optimization schemes. It would certainly be interesting as well to adopt power control strategy in a typical CDMA based coordinator node (CN) of real-time wireless body-area networks (WBANs) for the continuous monitoring of patients in hospitals. If properly studied, PC based on multi-objective optimization scheme could effectively address the issues that might arise in low density signature CDMA (LDS-CDMA) a successful candidate for the futuristic 6G air interfaces. The recent interest garnered from researchers in industry and academia for 5G and beyond systems makes it a necessity to revisit more on power control as basic tool to enhance energy and spectral efficiencies.

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