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Analysis and optimization of uplink spectral efficiency in massive multiple-input and multiple-output

Delson Therambath Rajanbabu, Iven Jose
Department of Electronics and Communication Engineering, CHRIST (Deemed to be University), Bangalore, India

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ABSTRACT

Fifth Generation (5G) specifications aims for data rate of 1 Gbps in high mobility and 10 Gbps in low mobility conditions, 15-30 bps/Hz of spectral efficiency with less than 1 milli second (ms) latency reduction. Massive multiple-input and multiple-output (Massive MIMO) is one of the promising technologies in 5G standard which offers a high spectral efficiency improvement. This work focus on the uplink scenario spectral efficiency in a Massive MIMO simulation network based on third generation partnership project (3GPP) and long term evolution (LTE) document of 5G. This work analyzes the spectral efficiency metric by simulating the 5G Massive MIMO network. Then, the research identified major constraint parameters; number of user antennas, K, number of base station antennas, M, transmission power, P, channel bandwidth, B, and coherence time, Tau_C and pilot time Tau_P which plays a significant role in varying this metric. The authors focus on improving the spectral efficiency by passing these constraint parameters through different meta-heurestic optimization algorithms, such as, convex optimization solver, White shark optimization (WSO) and Particle swarm optimization (PSO). The results show an overall, 1-10 percent of improvement of the parameter wnen compared with other research articles. The maximum value achieved is 49.84 bps/Hz, which is three times higher as per to the 3GPP and International Telecommunication Unioin (ITU) release document.

Corresponding Author:

Delson Therambath Rajanbabu
Department of Electronics and Communication Engineering, CHRIST (Deemed to be University)
Bangalore, India
Email: delson.r@res.christuniversity.in

1. INTRODUCTION

Fifth genereation (5G) communication standard technology was expected to roll out in the telecom market by the year 2020. However, due to various proposed technologies, test scenarios requirements, hardware trials and deployments amounts the delay. This standard is really different from previous generation in terms of radio access network architecture, such as, standalone and non-standalone long term evolution (LTE). 5G access channels and new radio waveform (NR), beam forming, Massive multiple-input and multiple-output (MIMO), Femtocells and various other technologies being part of this standard. The test cases in various parts of the globe in 5G trials have done in the localized hardware set up environment in a small geographical test area. LTE releases 17 advancement stage shows 5G is all set to roll out in near future, by the end of 2022. In India, 5G roll out is expected in the end of this year, 2022 with the spectral band allotted is 3.4-3.6 GHz. This frequency band and technology deployments varies in different countries. It makes the consortium of 3 GPP, ITU and IMT 2020, developed this 5G standard is currently in standardizing the test scenarios applicable to different regions. In developing countries, the requirement of frequency band may be in Sub 6 GHz, whereas, in developed countries planning for mmWave spectrum above 30 GHz radio spectrum. Spectral efficiency estimation is one of the important performances metric in wireless communication system. However, the mathematical functions need to be formulated for spectral efficiency considering Massive MIMO and Rayleigh channel multipath fading model. Literatures [1]-[3] developed mathematical expressions for spectral efficiency in uplink scenario. This research work utilizes the extensive work done by Bjornson *et al*. [1], described the mathematical analysis of Massive MIMO network. There are different receiver combining schemes, say minimum mean square error (MMSE) (Multi cell MMSE (M-MMSE), single cell MMSE (S-MMSE)), zero-forcing (ZF) and regularized ZF (RZF) and maximal ratio combining (MRC). Here, the expressions of MMSE (multi cell MMSE (M-MMSE) took from the literature is just used as it is with the simulation network.

The current work in this paper run various meta-heurestic optimization algorithms such as convex optimization, white shark optimization (WSO) and particle swarm optimization (PSO) on this simulation network in the University computing lab. By doing so, this research article focused on to different ways of improving spectral efficiency which is not refereed in the research papers [3], [4]. The principle optimization constraints are inter and intra cell interference, number of base station antennas and receiver combining schemes in conventional Massive MIMO network. However, this research article brings out a deeper understanding on other parameters such as pilot time interval and transmission power jointly with the number of users and base station antennas [5]-[10]. This optimization is passed through convex optimization solver and achieved the maximum spectral efficiency value from the research papers till date. The author contribution through this research article is to incorporate meta-heuristic optimization algorithms that greatly influence spectral efficiency with identifying high impact parameters responsible for this quantum improvement. In order to do this, nature inspired WSO and PSO also utilized to understand the influence of B, Tau_C and P in the spectral efficiency parameter improvement.

The organization of paper follows; In section 2, on mathematical expressions on spectral efficiency is focused; in section 3, shows the concept of optimization parameters identification and meta-heuristic algorithms, onvex optimization, WSO and PSO initiated in this network; section 4 a detailed analysis results and discussions; in section 5, conclusion and future directions in the area of research is discussed.

2. PROBLEM IDENTIFICATION

Massive MIMO uplink spectral efficiency expression used in [1] is (1).

$$\mathrm{SE}_{\mathrm{jk}}^{\mathrm{UL}} = \frac{\mathrm{T_u}}{\mathrm{T_c}} \mathrm{E}\left\{\log_2\left(1 + \mathrm{SINR}_{\mathrm{jk}}^{\mathrm{UL}}\right)\right\} \tag{1}$$

Where Tu is uplink data time and Tc is coherence time considering flat fading Rayleigh multipath fading channel. The spectral efficiency is estimated considering user k in say, in cell j. T_u and T_c are uplink time and coherence time respectively. Coherence time is the time interval assumed where channel is flat. Here, Rayleigh fading channel is assumed. In equation, $T_u=T_c–T_p–T_d$, where T_p is pilot time and T_d is downlink data. If we consider T_u, uplink data time, the objective is to reduce pilot time T_p. This is the reason; optimal pilot time is the constraint parameter for improving the spectral efficiency. Also, the power required, P to send T_p will be reduced if the T_p interval is reduced [11]-[14]. Hence, we got one more constraint parameter, P, transmission power also plays vital role in the improvement of spectral efficiency. Now, let us consider the importance of Signal-to-interference-plus-noise ratio (SINR). This is signal to interference noise ratio. This factor is clearly the increase of signal power and reduction in inter-cell interference noise. Consider, pre-log factor in the equation, T_u/T_c, where, this factor if increased, automatically spectral efficiency increases. It means, the T_u time to be increased. This is done by decreasing the pilot time interval [15]-[20].

$$\mathrm{SINR}_{\mathrm{jk}}^{\mathrm{UL}} = \frac{p_{jk}|V_{jk}^{H}\hat{h}_{jk}^{j}|^2}{\sum_{l=1}^{L}\sum_{\substack{i=1 \\ (l,i)\neq(j,k)}}^{K_l} p_{li}|V_{jk}^{H}\hat{h}_{li}^{j}|^2 + V_{jk}^{H}\left(\sum_{l=-1}^{L}\sum_{i=1}^{K_l} p_{li}C_{li}^{j} + \sigma_{UL}^2 I_{M_j}\right)V_{jk}} \tag{2}$$

Where, p_{jk} is the transmit power and vjk is the receiver combining vector. p_{li} is the inter cell interference power which has to be minimized. These two expressions are used in this discussion. More analysis on each receiver combining vectors based on different receiver combining schemes such as M-MMSE, ZF and MRC is developed with proof in the literature [1], [2].

This work takes this problem critically by first running the Massive MIMO simulator network as such and evaluates the spectral efficiency. Then, the constraint parameters are analyzed by running different optimization algorithms, such as convex optimizer, WSO and PSO to achieve the improvement in the spectral efficiency metric [21].

3. METHOD

Spectral efficiency parameter coud be maximized or improved depends on the constraint parameters. If closely observed, the parameters such as Tau_p (pilot time interval) and transmission power, P are primarily important parameters influencing spectral efficiency. In addition to this, two other contributing parameters such as number of base station antennas, M and number of user equipment, k, channel bandwidth, B and coherence time, Tau_C are also taken into the optimization algirthms in this work. This research paper first analyzed the spectral efficiency parameter using the existing 5G Massive MIMO network simulator [22], [23].

The author's contribution in this paper is to identify and analyse high impact parameters influencing spectral efficiency and then pass through optimization techniques-convex optimization solver, WSO and PSO metaheurestic algorithms to improve spectral efficiency parameter. For this, the direct influencing multi-objective parameters are identified. These are Tau_p, P, K and M in running convex optimization solver. Other parameters such as B and Tau_C are taken in WSO and PSO. The problem formulation focuses on the maximization of spectral efficiency in uplink scenario. Maximization of spectral efficiency from equation 1, means, either increase SINR or Tu (uplink data time). Increasing SINR in turn increase the transmission power, P and increasing Tu in turn increases Tc (channel flat/coherence time) by assuming Tp (uplink pilot time) constant. The requirement of maximizing spectral efficiency is to improve the overall wireless connectivity parameters, such as increased data rate, received signal quality, reduced latency and interference power.

In convex optimization solver, the optimization problem developed primarily minimizes power to get optimal spectral efficiency by varying costraint parameters such as Tau_p, M and K. This reduction in power but at the same time reducing pilot time and adjusting M and K values will retain the spectral efficiency value to a considerable amount. This is run in a convex optimization solver initially. The general optimization problem can be formulated by focusing on the spectral efficiency expression.

Optimization problem:

Minimize p

$$\text{Subject to } \frac{p_{jk}|V_{jk}^{H}\hat{h}_{jk}^{j}|^{2}}{\sum_{l=1}^{L}\sum_{\substack{i=1\\(l,i)\neq(j,k)}}^{K_l} p_{li}|V_{jk}^{H}\hat{h}_{li}^{j}|^{2}+V_{jk}^{H}\left(\sum_{l=-1}^{L}\sum_{i=1}^{K_l} p_{li}C_{li}^{j}+\sigma_{UL}^{2}I_{M_j}\right)V_{jk}} \tag{4}$$

$\tau_P > O.5$,

$M > 100$; $K < 10$

$p_{jk}>0$; $p_{li>0}$;

WSO is a meta-heuristic algorithm which includes like other intelligent based optimization the characteristic of exploration, inspired by White shark, behavior of navigation and foraging, searching and tracking for preys using their exceptional senses of smell and hearing. Mathematical formulation of this algorithm depends on the velocity of wavy motion of white shark hunting and tracking prey [24]. Initial velocity depends on the wavelength and frequency of the motion of shark. Constant acceleration at each position of the shark tracking towards prey is updated. It uses an undulating motion to navigate to prey using its hearing and smell senses. A population of n sharks (search agents) is initiated in a 2D space where, it depends on d decision variables and the location of the shark in its d dimension space. The optimization starts with the initialization with a random position in nature with an upper and lower bound values of the position and location dimensional space. The movement speed towards prey is optimally computed includes the total number of sharks population, its relative motion and the location in the space and finds the best possible optimal solution in running different iterations. This optimization is now used in our spectral efficiency expression by creating constraint parameter variable with lower and upper bound values in B, Tau_C and p.

PSO is a traditional and intelligent optimization method to use the global best values determination in the problem identified. PSO algorithm is a traditional optimization algorithm. PSO uses a number of agents, i.e., particles that constitute a swarm flying in the search space looking for the best solution. The random nature of intelligent swarm optimization such as group of birds flying direction to achieve the global best optimization value by using parameters-position, velocity and previous best position [25], [26]. This nature inspired Meta-heuristic algorithm uses lower and upper bound variables for B, P and Tau_C.

4. RESULTS AND DISCUSSIONS

The Massive MIMO network simulation is taken from the literature [1], [2] is provided in Table 1. This simulation network takes the important parameter under test such as bandwidth, B, transmission power, P, number of base station antennas, M and number of user antennas, K and coherence time, Tau_C. This simulation framework utilizes multipath small scale and large scale fading parameters such as pathloss exponent and median channel gain. This network test the spectral efficiency estimation considering uplink scenario in a Massive MIMO network.

Table 1. Massive MIMO Simulation network [1]

Simulation Parameter	Chosen Value
Number of Cells	16
Channel Bandwidth	20 MHz
Median channel gain	-148 dBm
Path loss exponent, alpha	3.76
Number of base station antennas, M	100
Number of User equipment, K	10
Coherence Time, Tau_C	200
Transmission Power	20 dBm
Receiver Schemes	M-MMSE, S-MMSE, ZF, R-ZF, MR

4.1. Optimization using convex optimization solver

The authors in this work use this network simulator [1] and run in the university computing lab to obtain the spectral efficiency. This spectral efficiency is benchmarked as the maximum value achieved in the existing research papers of 5G Massive MIMO simulation networks till date as per our knowledge. Now, this simulator passes through convex optimization solver to check the possibility of improved result. Different trials are done by varying transmission power, P, number of base station antennas, M, number of user antennas, K in accordance with pilot time, Tau_P initially and Tau_p reduced to half as provided in Table 2.

Table 2. Spectral efficiency analysis for different trials of optimization in convex optimization solver

Case 1	Receiver Schemes	Spectral efficiency (Taup=0.5 f*K)	Spectral Efficiency (Taup=f*K)
(Parameters (P=10:10:100, K=10, M=90, F=1)	M-MMSE	49.84	45.08
	S-MMSE	45.02	40.78
	ZF	42.86	41.54
	RZF	41.37	38.8
	MR	22.43	25.32
Case 2	Receiver Schemes	Spectral Efficiency (Taup=0.5 f*K)	Spectral Efficiency (Taup=f*K)
(Parameters (K=1:1:10, P=100, M=90, F=1)	M-MMSE	49.32	49.53
	S-MMSE	44.56	45.27
	ZF	44.84	44.3
	RZF	42.81	41.57
	MR	23.58	25.28
Case 3	Receiver Schemes	Spectral Efficiency (Taup=0.5 f*K)	Spectral Efficiency (Taup=f*K)
(Parameters (P=1:1:5, P=10, M=40, F=1)	M-MMSE	28.71	27.78
	S-MMSE	29.23	28.15
	ZF	26.64	29.66
	RZF	25.79	24.38
	MR	18.72	18.47
Case 4	Receiver Schemes	Spectral Efficiency (Taup=0.5 f*K)	Spectral Efficiency (Taup=f*K)
(Parameters (M=10:10:100, P=100, K=10, F=1)	M-MMSE	49.53	50.33
	S-MMSE	41.37	44.73
	ZF	40.28	37.52
	RZF	42.79	43.47
	MR	24.27	23.83
Case 5	Receiver Schemes	Spectral Efficiency (Taup=0.5 f*K)	Spectral Efficiency (Taup=f*K)
(Parameters (P=10:10:50, K=10, M=40, F=1)	M-MMSE	33.39	37.28
	S-MMSE	32.78	35.37
	ZF	28.22	29.3
	RZF	28.48	32.15
	MR	17.96	18.47

- Results acheived: The authors conclude the Table 2 results to note the spectral efficiency is maximum in M-MMSE, which is 49.84 bps/Hz.
- Observations and discussions: The first reason is as such, MMSE algorithm by its principle mathematical functions can greatly reduce the mean squared error from all the inter and intra

interferences compared to other schemes. The second reason is the importance of reducing pilot time and therefore channel could provide more time for uplink data bits and thereby improves the overall spectral efficiency.

- Comparson of the research with other technical papers: To understand this better, the authors benchmarked the work by correlating other research papers provided in Table 3.

Table 3. Comparison of the proposed optimization method with existing literatures

SL NO	Research papers details	Technique used	Achieved Spectral efficiency
1	Lu, Songtao, and Zhengdao Wang. "Training optimization and performance of single cell uplink system with massive-antennas base station." *IEEE Transactions on Communications* 67, no. 2 (2018): 1570-1585.	Pilot time and power optimization. Used MRC and ZF schemes	MRC-24 bps/Hz and ZF-33 bps/Hz
2	Björnson, Emil, Erik G. Larsson, and Merouane Debbah. "Massive MIMO for maximal spectral efficiency: How many users and pilots should be allocated?." *IEEE Transactions on Wireless Communications* 15, no. 2 (2015): 1293-1308.	M/K ratio >10; Receiver combining schmes – ZF and MRC. Optimizing pilot length. Also used pilot reuse and power control	MRC-24 bps/Hz and ZF-35 bps/Hz
3	Sanguinetti, Luca, Emil Björnson, and Jakob Hoydis. "Toward massive MIMO 2.0: Understanding spatial correlation, interference suppression, and pilot contamination." IEEE Transactions on Communications 68, no. 1 (2021): 232-257.	Revisited spatial correlation and Massive MIMO network. Defined structure of network. Used MMSE, ZF and MRC used.	MMSE-48.71, MRC-18.94, ZF-39.26 bps/Hz
4	Proposed optimization method used in the work	Used ZF, MRC, MMSE schemes. Optimization of M, K, Tau_p and Transmission power	MMSE – 49.84 bps/Hz MRC-25.32 bps/Hz and ZF-42.86 bps/Hz (Taking Frequency reuse=1)

- Conclusion and Inferences: A sample spectral efficiency waveform taking case of MMSE receiver combining scheme as is shown in Figure 1. The barchart plot of the spectral efficiency when compared with Tau_P= f* K and 0.5 f*K considering base staion antennas, M running in iterations is shown in Figure 2.

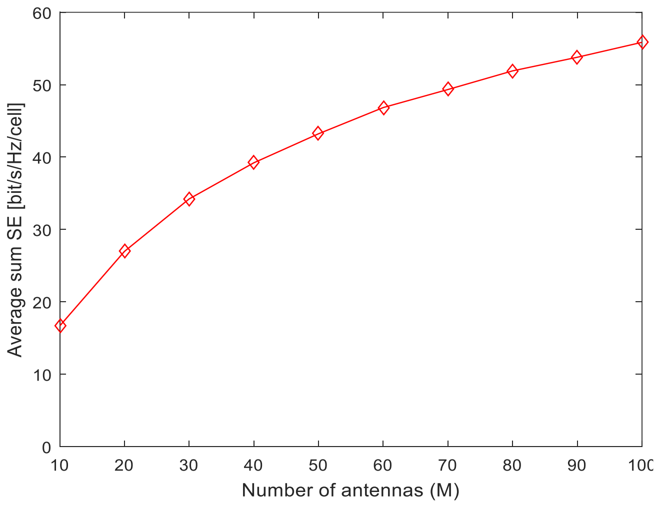

Figure 1. Spectral efficiency Vs number of antennas in MMSE receiver combining scheme

In Figure 1, A sample result waveform of spectral efficiency versus number of base station antenaas, taking example of MMSE receiver combing scheme, is plotted. All other results waveform results indicated in the Table 3. In Figure 2, bar chart when compared spectral efficiency in two cases is taken, Tau_P equals f*K and 0.5*f*K and M, base station antennas run in convex optimizer solver in two cases, M=100 and 50.

This work opens a research investigation requirement that spectral efficiency can be improved by first identifying the constraint parameters and then passes through proper optimization methods. In this section, we use a simple convex optimizer tool that coud increase a quantum jump of overall 1-10 percent increase in spectral efficiency values. In 3GPP, LTE document, the spectral efficiency in uplink aims for 15 bps /Hz in real time deployment. The simulation results obtain the spectral efficiency of 49.84 bps/Hz value which is 3.5 times greater than the expectation.

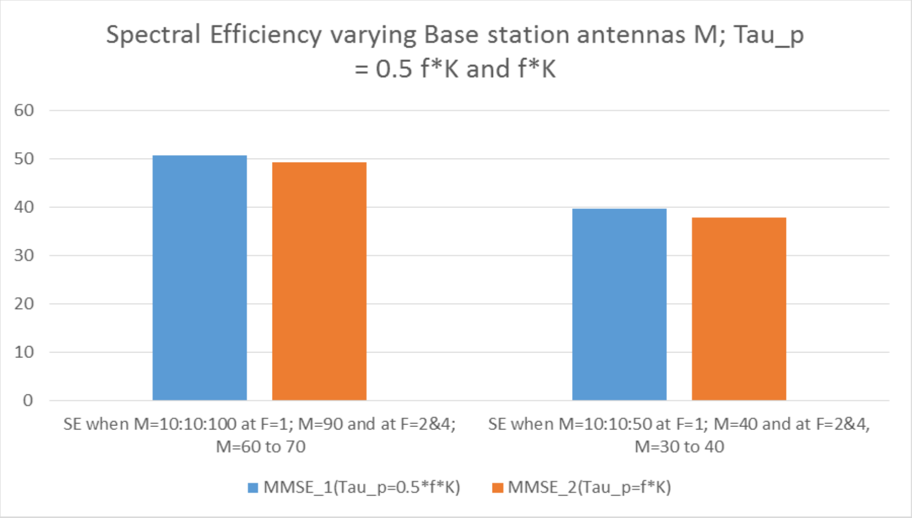

Figure 2. Spectral efficiency estimation using convex optimization solver

4.2. Optimization using WSO and PSO

This work further used metaheurestic algorithms, WSO and PSO optimization algorithms on this simulation environment to run different iterations, to obtain the global best parameters varying M, K, P, B and Tau_C for different receiver combining schemes in WSO and PSO algorithms respectively. As an illustration the simulation narrows down to a single cell out of 16 cells. First introspect in a single user and single base station antenna, that is K=M=1 and later to K=1, M=10. After identifying global best (gbest values) of B, P and Tau_C, spectral efficiency is estimated by incorporating these gbest values. These values are shown in Tables 4 and 5 as Cases 1 and 2 respectively.

Table 4. Global best parameter values estimation using WSO algorithm for K=1, M=1

Case 1: K=1, M=1 (M-MMSE) with WSO		
Iteration 1: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	200
gbest (Global Best Value)	B= 11.7084, P = 87.9874, Tau_C = 157.4391	
Iteration 2: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	30
Transmission Power, P	50	150
Coherence Time, Tau_C	100	250
gbest (Global Best Value)	B= 17.0462, P = 99.1620, Tau_C = 208.6545	
Iteration 3: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	300
gbest (Global Best Value)	B= 13.9074, P = 77.8727, Tau_C = 238.3196	
Iteration 4: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	20	100
Transmission Power, P	50	100
Coherence Time, Tau_C	200	400
gbest (Global Best Value)	B= 41.6194, P = 78.8727, Tau_C = 238.3196	

- Results acheived: In iterations 1 to 4, minimum values of gbest values, B=11.7084 (iteration1), P=77.872 (iteration3) and Tau_C=157.439 (iteration 1).
- Observations and discussions: In Table 4, includes Iterations 1 to 4. Lower bound and upper bound values set for each constraint parameters; B, P and Tau_C. It is observed that, when both M=1, K=1, it forms a Single user antenna to Single base station antenna case (SISO). Hence, in all the iterations 1 to 4, we could see the global best parameter values of bandwidth are near to lower bound values. In the case of P, values are almost reaching towards upper bound value. Same the case happens to Tau_C approaching towards upper bound value. This tendency is theoretically correct. When numbers of user antennas are less in the network, obviously, data transmission is less and therefore requirement of bandwidth is minimal. Whereas, transmission power is related to the signal strength and SNR. Therefore, in most of the cases, power transmission will be tending towards high value. Tau_C is the coherence time, where the channel is flat or having significantly low fluctuations or effects due to multipath fading. Therefore, this value is better to be in the upper bound of the allocated time slot.
- Comparson of the research with other technical papers: The authors in best of the knowledge confirm that this optimizer is not used to pass Massive MIMO network structure till date. It is an innovative authors approach to incorporate this newly developed optimization algorithm to be used to see the improvement in spectral efficiency.
- Conclusion and Inferences: The results observed are B and P values are nearing to lower bound values and Tau_C towards higher value.

Table 5. Global best parameter values estimation using WSO algorithm for K=1, M=10

Case 2: K=1, M=10 (M-MMSE) with WSO		
Iteration 5: Parameters under test	Lower bound Value	Upper bound value
Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	200
gbest (Global Best Value)	B= 12.3959, P = 94.0704, Tau_C = 190.7584	
Iteration 6: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	30
Transmission Power, P	50	150
Coherence Time, Tau_C	100	250
gbest (Global Best Value)	B= 20.6828, P = 98.8266, Tau_C = 173.8505	
Iteration 7: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	10	20
Transmission Power, P	50	100
Coherence Time, Tau_C	100	300
gbest (Global Best Value)	B= 12.7781, P = 100, Tau_C = 291.5888	
Iteration 8: Parameters Under Test	Lower bound Value	Upper bound value
Bandwidth, B	20	100
Transmission Power, P	50	100
Coherence Time, Tau_C	200	400
gbest (Global Best Value)	B= 20.8450, P = 78.7003, Tau_C = 250.5172	

- Results acheived: In iterations 5 to 8, minimum values of gbest values, B=12.3959 (iteration5), P=78.7003 (iteration 8) and Tau_C=173.8505(iteration 6).
- Observations and discussions: Bandwidth is tending towards lower bound and transmission power and coherence time, Tau_C is approaching towards upper bound values set for the simulation. This concretes the idea that the transmission power needs to be optimized and is possible with best value for Tau_C time slot. Assuming the channel correlations of multipath fading impact very less and the channel is stable for a longer time. The channel modeling needs to be revisited and the signal processing techniques need to be implemented.
- Conclusion and Inferences: Transmission power, P, could see going to higher bound values. It is a clear indication of the requirement of optimization mechanism for this parameter.

PSO algorithm is used in this 5G Massive MIMO simulation network to identify the best values of B, P and Tau_C. As a sample case runs on case 2 with K=1 and M=10 for a single cell in 16 cell network in ZF receiver combining scheme. The results when used PSO on different lower and upper bound values of test parameters are provided in Table 4. The global best value of three constraint parameters, B, P and Tau_C are obtained. As a sample, one test case, Case 3, runs using the PSO algorithm provided in Table 6.

Table 6. Global best parameter values estimation using PSO algorithm

Case 3: K=1, M=10 (ZF) with PSO			
Iteration 9: Parameters Under Test	Lower bound Value	Upper bound value	Global Best value
Bandwidth, B	20	100	27.9897
Transmission Power, P	50	100	40.7383
Coherence Time, Tau_C	200	400	32.2827

- Results acheived: Here, ZF receiver combing scheme is used and only one illustration iterations are shown in the Table 6. Here, Transmission Power is the only parameter moving towards upper bound value.
- Observations and discussions: The interesting point to note is the value obtained in transmission power and Tau_C. Both are nearing towards lower bound value and Tau_C is lesser this value. This shows that the optimization algorithm finds the best convergence and tried to optimize the variables input in the simulator network. This shows that ZF, when used as receiver combing scheme requires less values in P and Tau_C. ZF offers less spectral efficiency as it zero down the intereference factor but, not having a robust mechanism like MMSE scheme to increase the spectral efficiency factor. This could be realized by revising the equations provided in the mathematical analysis in section 2.
- Comparison of the research with other technical papers: The comparison papers of PSO lies in energy optimization methods in the literature. Hence, a direct comparison paper is not available. So, this optimization scheme is a novel idea of incorporation by the authors to the research community.
- Conclusion and Inferences: The attention required parameter is Transmission power, P, which tends to higher bound values. This shows a much other fading coefficiencts can be taken to the optimization loop, so to make this P towards lower bound value.

Using the values of cases 1, 2 and 3 provided in Tables 4, 5 and 6, gbest values of iterations 1-9, are selected and run the specrral efficiency simulation network and obtain the values in Table 7. This is to identify the convergence of the optimization in spectral efficiency, and to bring the releavance of constraint parameters.

Table 7. Spectral efficiency values when running these global parameters

Case 1: K=1, M=1 (M-MMSE) with WSO		
Iteration No.	gbest (Global Best Value)	Spectral Efficiency (bits/s/Hz)
Iteration 1	B= 11.7084, P = 87.9874, Tau_C = 157.4391	1.26
Iteration 2	B= 17.0462, P = 99.1620, Tau_C = 208.6545	0.9661
Iteration 3	B= 13.9074, P = 77.8727, Tau_C = 238.3196	1.478
Iteration 4	B= 41.6194, P = 78.8727, Tau_C = 238.3196	1.3693
Case 2: K=1, M=10 (M-MMSE) with WSO		
Iteration No.	gbest (Global Best Value)	Spectral Efficiency (bits/s/Hz)
Iteration 5	B= 12.3959, P = 94.0704, Tau_C = 190.7584	4.4216
Iteration 6	B= 20.6828, P = 98.8266, Tau_C = 173.8505	2.9744
Iteration 7	B= 12.7781, P = 100, Tau_C = 291.5888	5.2028
Iteration 8	B= 20.8450, P = 78.7003, Tau_C = 250.5172	4.9300
Case 3: K=1, M=10 (ZF) with PSO		
Iteration No.	gbest (Global Best Value)	Spectral Efficiency (bits/s/Hz)
Iteration 9	B= 27.9897, P = 40.7383, Tau_C = 32.2827	3.9898

- Results achieved: The best result of spectral efficicney is obtained in Iteration 7.
- Observations and discussions: In Table 7, the very interesting result of spectral efficiency improvement is observed in the case where used best Tau_C values, then second choice is increase of transmission power, P and finally on Bandwidth, B. In our example simulation network, it is run in 16 cell K=10 and M=100. If taken a single cell, K=1 and M=10, will get the first acceptable spectral efficiency seen in case 2. This supports the theory of equipping more number of antennas in base stations, which is the concept of Massive MIMO. In case 1 both K=M=1 and not able to receive an acceptable spectral efficiency values.
- Conclusion and Inferences: In this case, Iteration 7 when used WSO in M-MMSE offers highest spectral efficiency. The reason is the use of MMSE algorithm and also the global best parameters of P and Tau_C approaches to upperbound value. The results shows different iterations run taking lower bound and upper bound values to select best global optimization parameter values. In both WSO and PSO, Tau_C is one of the design parameter provides best lower bound value, when compared with B and P. So, the channel needs to be flat and not ever changing that is the reason; this value is close to the upper bound.

5. CONCLUSION

This technical paper is focused on identifying the spectral efficiency as the key performance evaluation metric in designing and optimizing transceiver system using Massive MIMO. This research paper shows that the spectral efficiency of 49.84 bps/Z is achieved when used convex optimizer solver, which is nearly three times the spectral efficiency specification requirement by ITU, IMT-2020, 3GPP consortium LTE release document of 5G specifications. However, this result is in network simulator. The research work in future needs to be ported to a hardware testbed to analyze the achieved spectral efficiency. The results show the relevance of running optimization algorithms on the spectral efficiency of Massive MIMO network. This research also runs optimization algorithms, WSO and PSO and obtains the convergence of global best parameters obtained from three constraint parameters, B, P and Tau_C. If check the simulation iterations, the influence happened mainly in the Tau_C value. The other two parameters, such as B and P also tend to increase. But, the increment in B and P is not too high when compared with Tau_C. This is better in one way as the network needs to minimize the bandwidth and transmission power in the best possible way. The reason for this is that, the bandwidth is concerned with economical expense or cost factor in spectrum auctions and also the scarcity in the lower gigahertz band in RF microwave spectrum. Transmission power, P on other hand, is not encouraged to increase as this parameter amounts to the radiation issues in the environment and to a larger extend in the user equipment side. Hence, in this research work, using this WSO and PSO optimization is the novel idea in this research to identify global best parameter values in setting values for B, P, and Tau_C for a said M and K. Further, this work can be extended with the 5G simulation network to other large- and small-scale fading parameters. The future work needs to be focussed work on other random based optimization algorithms and do a comparative study on all the relevant parameters in the network. This ensures better channel modelling and the simulation parameters selection for the future deployment of 5G services.

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BIOGRAPHIES OF AUTHORS

Delson Therambath Rajanbabu received B.E in Electronics and communication Engineering from Visveswaraiah Technological University, Belgaum, India in the year 2005. He completed his Master Degree, MSc. Engineering from FH Giessen Friedberg, University of Applied Sciences, Germany in 2008. His specialization includes information and communication engineering with core area of study IP Based networks, IP protocols, Wireless access technology and optical communication. He owns IEEE papers in different domain such as 5G specifications and testbed overview, Fingerprint biometric and cryptography area. His research interest includes 5G Technology, Massive MIO networks, channel modeling and architecture. He is currently pursuing PhD degree in the area of Massive MIMO technology in 5G Communication Standard. He can be contacted at email: delson.r@res.christuniversity.in.

Iven Jose serves as the Dean, School of Engineering and Technology, CHRIST (Deemed to be University), Bangalore since 2011. He was conferred PhD from reputed Institution IIT-Bombay. His Masters is from Manipal University, Karnataka. He also served as at Siemens Medical Division and institutions like PCCE-Goa, BITS Pilani-Goa Campus. He has to his credit a US patent 'granted' on "Conjugates of Estradiol and Applications thereof". He was awarded the "Microsoft Research India outstanding young faculty award, 2008", for the project titled "Optical Imaging for detection of Cancer". Dr. Iven was honoured as the "Distinguished Engineer" by the Rocheston Accreditation Institute, New York for his contributions in holistic education. He is a recipient of United Board Fellowship, 2015-2016. He has authored and presented many scientific papers in varied international platforms and was a delegate at Global Leadership institute, Boston College, Boston-USA and Harvard University, Cambridge, Massachusetts, USA. He has travelled extensively and visited several universities globally at various capacities like delivering invites talks, research exchange programme, Leadership and short term teaching assignments at universities like, Melbourne University, Melbourne, Australia, UNSW-Sydney, Australia, University of Sydney-Australia, University of Pennsylvania, Philadelphia, USA, Johns Hopkins, Baltimore-USA, University of Calgary, Canada, Wurtzburg-Germany, Stuttgart-Germany Hangzhou-China, Minsk-Belarus, NUS-Singapore to name a few. He is a member of the Institute of Electrical and Electronics Engineers (IEEE) and Indian Society of Technical Engineers. He can be contacted at email: iven@christuniversity.in.