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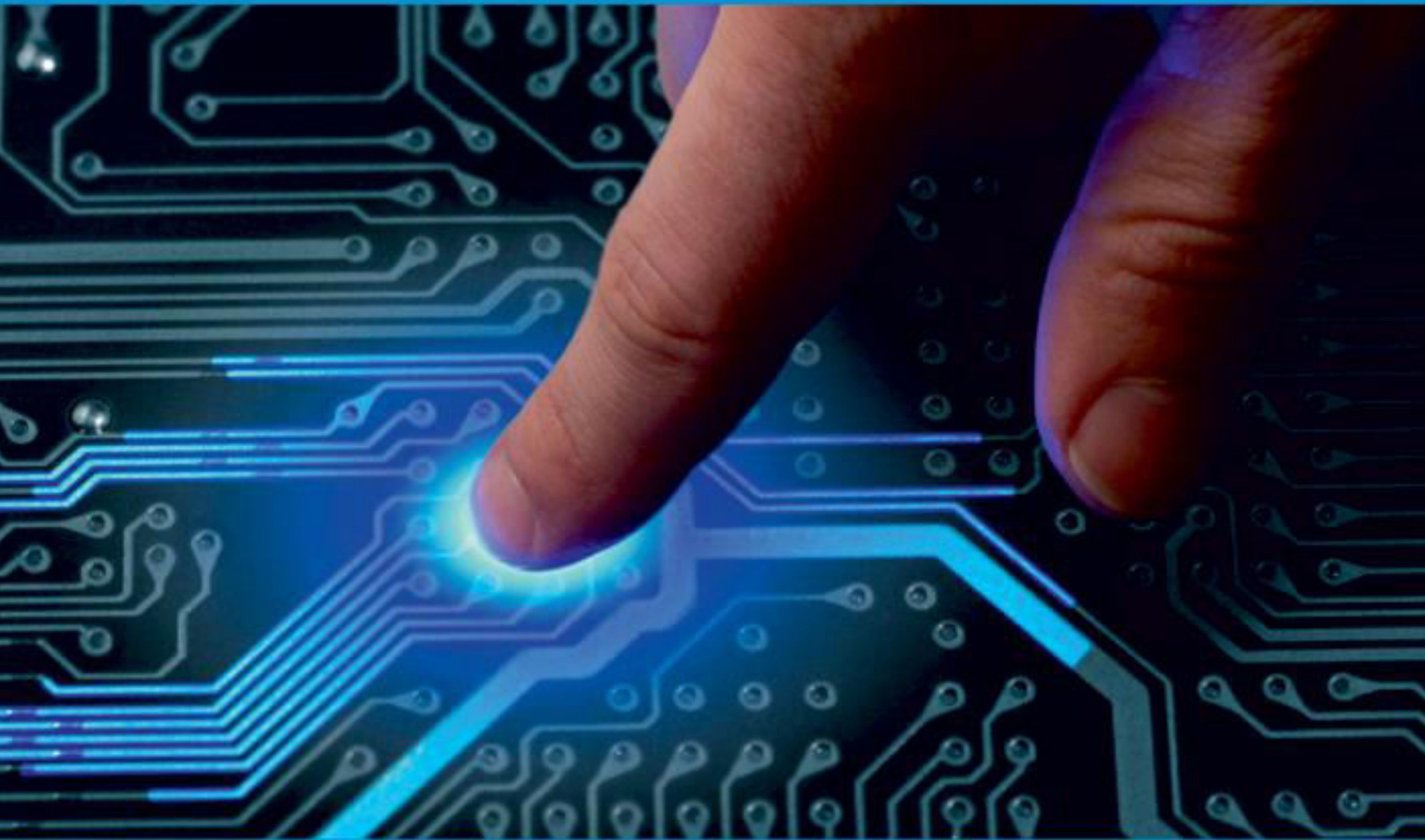

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Performance Improvement of PSO Based Resource Allocation for Secure URLLC

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ABSTRACT: Fifth-generation (5G) mobile communication technology offers higher data rates, a better user experience, lower power consumption, and shorter latency. Various layers of cellular networks are utilized in such networks, including device-to-device networks, macro-cells, and a variety of small cells to facilitate the customer's desired quality-of-service (QoS). A multi-layer model affects several studies that deal with interference management and resource allocation in 5G networks. In response to a growing need for cellular service, resource distribution has become a challenge due to limited resources. To support a better quality of service, alleviating network jamming is one of the most pressing problems. In order to enhance 5G service quality, this project analyzes resource allocation by classifying the various schemes used in resource allocation. The Particle Swarm Optimization (PSO) method can be used to allocate resources for resource allocation problems and can improve the performance of users based on their channel state.

KEYWORDS: URLLC, secure communications, short packet transmission, energy minimization.

I. INTRODUCTION

The 5th generation (5G) new radio (NR) is the most recent radio access technology, introduced by the 3rd generation partnership project following the fourth generation (4G) long term evolution (LTE) (3GPP). The ambition of 5G is the ability to access information and share data with everybody and everything at any time and from any location. Great peak data rates, low latency, high dependability, higher user mobility, higher connection density, higher throughput, and many other benefits are all possible with 5G. Autonomous vehicle control, smart cities, high-speed trains, virtual and augmented reality, emergency communication, factory automation, huge outdoor events, media applications, remote surgery and examination, and inside retail stores are all areas where 5G NR is critical. There are three key use cases for 5G NR. Enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (URLLC), and massive machine-type communications are the three technologies (mMTC). Enhanced mobile broadband (eMBB) - Offers high data rates, spectral efficiency, low latency, and wide coverage. Ultra-reliable and low-latency communication (URLLC)- Offers ultra-reliability and low latency. Massive machine-type communication (mMTC) offers higher traffic density and scalable connectivity as the number of devices grows. According to 3GPP, the quality of service (QoS) requirements of URLLC are ultra-high reliability (11105) and low transmission latency of 1 ms, whereas eMBB requires high data rates of 1 Gbps. Coexistence of eMBB and URLLC users in the same resource is a difficult task because simultaneously achieving highdata rates for eMBB users and ultra-reliability and low latency for URLLC users becomes a difficult scheduling task because there is a trade-off between latency, reliability, and achieving high data rates.
Admission control in wireless networks can be defined as determining the maximum quantity of traffic or number of users that can be allowed to the system at the same time while utilising available resources efficiently and meeting QoS criteria. Another meaning of admission control is determining whether additional arriving traffic or users can be admitted to the system based on the system's available resources and the entering traffic's QoS needs. The least amount of bandwidth required to meet QoS standards is known as effective bandwidth [4]. If the URLLC user's highest feasible rate is more than or equal to the effective bandwidth calculated using the reliability and latency values, we can state that the URLLC user's reliability and latency requirements are met. The downlink of a multi-user multiple-input single-output (MISO) network is the source of our dilemma. To coexist, we propose orthogonal spectrum sharing between eMBB and URLLC users. The Shannon equation is used to model the maximum data rate that an eMBB user may

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achieve. We used the approximation of Shannon's rate in the short block-length regime to estimate the data rate of a URLLC user because the packet length of a URLLC user is minimal. The concept of effective bandwidth was then used to further simplify and derive a lower bound for the short block length capacity equation. The problem has been framed as a '0 minimization problem. It's an NP-hard (non-deterministic polynomial-time) problem. As a result, in order to discover an ideal solution, we must make some approximations. To solve the problem, we employed sequential convex programming.

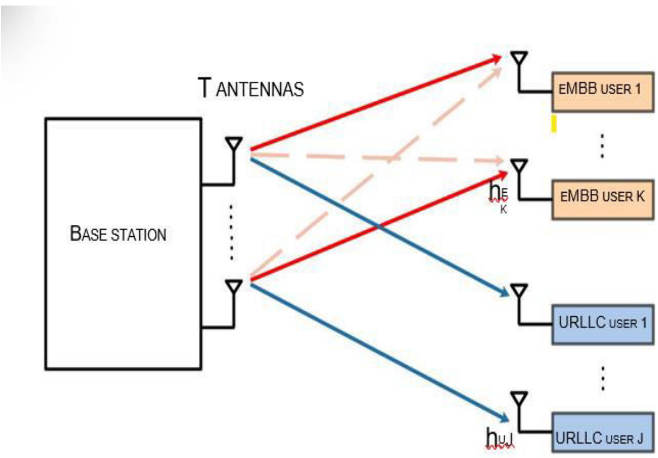
Many studies have been published on scheduling algorithms for the coexistence of eMBB and URLLC applications [3], [6] - [8]. Furthermore, there is literature available that aims to solve the admission control problem in wireless networks [9] – [12]. The majority of the scheduling algorithms in the literature for the coexistence of eMBB and URLLC recommend puncturing eMBB users in order to give URLLC users priority and meet their reliability and latency criteria. However, no research on the admission control problem in a wireless network where eMBB and URLLC users coexist has been found. As a result, finding a solution to the challenge of admission control in 5G networks where eMBB and URLLC users coexist inspires us. It is necessary to develop an optimization problem based on [13] in order to discover the best beamformer that meets user-specific SINR targets.

Section II provides our solution for the problem of admission control for eMBB users in the coexistence of eMBB and URLLCin 5G network. In this section, we describe our system model and problem formulation. Furthermore, this section includes the derivation of the algorithm of our solution for the problem of admission control for eMBB users in 5G networks in which eMBB users and URLLC users coexist. At the end of this section, we introduce the algorithm of our solution. Section III discusses about the simulations carry on to prove the correctness of our solution for the problem of admission control for eMBB users in 5G networks in which eMBB users and URLLC users coexist. It also provides the numerical results which we obtain to illustrate the performance and effectiveness of our solution. Section IV includes a conclusion for this project. Moreover, it provides potential future research directions.

II. SYSTEM MODEL

In this section, we formulate the problem of admission control for eMBB users in the coexistence of eMBB and URLLC in a 5G network. Also, in this section we present the solution approach and an algorithm to find a suboptimal solution. We consider the downlink of a single-cell MISO system. We assume that the base station has T transmit antennas. The set of users are denoted by U. The set of all eMBB users denoted by $U_e \subset U$ and they are labelled with the integer values $k = 1, \ldots, K$. We use the notation $U_u \subset U$ to denote the set of all URLLC users and they are labelled with the integer values $j = 1, \ldots, J$. We assume that all users have only one receive antenna. Figure1 shows an illustration of the system model. We propose orthogonal spectrum sharing between eMBB and URLLC users to coexist them. Let the total bandwidth of the system is B_{total}, total bandwidth for eMBB users is b^e and total bandwidth for URLLC users is b^u. Thus, the expression for bandwidth sharing can be written as

$$B_{total} = b^e + b^u \qquad \text{eq. (1)}$$



There is no interference between eMBB and URLLC users because they each have their own bandwidth allocation. Furthermore, we recommend allocating a specific amount of bandwidth to each URLLC user. For URLLC users, we

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also examine orthogonal frequency divisionmultiple access(OFDMA). As a result, URLLC users are given orthogonal resources, and there is no interference between them.

A. *Problem Formulation*

In this section we present the problem of admission control. The signal vector transmitted by the base station is given by

$$\mathrm{X} = \sum_{k\in \mathrm{U}} \mathbf{m}_k \mathrm{d}_k \quad \text{eq. (2)}$$

where d_k is the normalized data symbol of the kth user, and we assume that the data streams are independent. The beamforming vector $\mathbf{m}_k \in \mathbf{C}^T$ can be written as

$$\mathbf{m}_k = \sqrt{p_k}\mathbf{u}_k \quad \text{eq. (3)}$$

where $\mathbf{u}_k$ $\mathbf{C}^T$is the normalized beamformer, $\mathbf{m}_k \in \mathbf{C}T$ is the beamforming vector of the kth user and $p_k$is the power of kth user. Received signal vector of the kth eMBB user is given by

$$\mathrm{y}_k^e = (\mathbf{h}_k^e)^H \mathbf{m}_i^e d_i^e + \mathrm{w}_k^e \quad \text{eq. (4)}$$

where $\mathbf{h}_k^e \in \mathbf{C}^T$ is the channel vector from base station to eMBB user k, $\mathbf{m}_k^e \in \mathbf{C}^T$ is the beamforming vector of the kth eMBB user and $w_k^e \sim CN(0, \sigma_e^2)$ is the additive white Gaussian noise (AWGN) at eMBB user k. We take the noise variance as$\sigma_e^2 = \mathrm{N}_o \mathrm{b}^e$, where N_0 is single-sided noise spectral density. Since the eMBB users and URLLC users are in two portions of bandwidth there is no interference between URLLC users and eMBB users.

In general, URLLC has an end-to-end delay less than 1 ms. Therefore, the channel coherence time is greater than the end-to-end delay. This means URLLC users have a quasi-static channel and the rate of URLLC users can take as a constant for a given resource allocation policy [5],[19] – [21]. Received signal of the jth URLLC user can be written as

$$\mathrm{y}_j^u = (\mathbf{h}_j^u)^H \mathbf{m}_j^u d_j^u + \mathrm{w}_j^u \quad \text{eq. (5)}$$

where $\mathbf{h}_j^u \in \mathbf{C}^T$ is the channel vector from base station to URLLC user j, $\mathbf{m}_j^u \in \mathbf{C}^T$ is the beamforming vector of the jth URLLC user and $\mathrm{w}_j^u \sim CN(0,\sigma_{j,u}^2)$is the additive white Gaussian noise (AWGN) at URLLC user j. We take the noise variance as $\sigma_{j,u}^2 = \mathrm{N}_0 \mathrm{b}_j^u$, where$\mathrm{b}_j^u$is the bandwidth allocated to the jth URLLC user. Since the URLLC users are allocated orthogonal resources, there is no interference between URLLC users.

The received SINR of kth eMBB user can be expressed as

$$\gamma_k^e = \frac{|(\mathbf{h}_k^e)^H \mathbf{m}_k^e|^2}{\sum_{i=1, i\neq k}^{K} |(\mathbf{h}_k^e)^H \boldsymbol{m}_i^e|^2 + N_0 \mathrm{b}^e} \quad \text{eq. (6)}$$

The received SINR of jth URLLC user can be expressed as

$$\gamma_j^u = \frac{|(\mathbf{h}_j^u)^H \mathbf{m}_j^u|^2}{N_0 \mathrm{b}_j^u} \quad \text{eq. (7)}$$

The maximum achievablerate for kth eMBB user can be written as

$$R_k^e = b^e \log_2(1 + \gamma_k^e) \quad \text{eq. (8)}$$

We assume that the target rate for an eMBB user is R_{target}. Thus, the target SINRfor the kth eMBB user can be expressed as

$$\gamma_k^{e,th} = 2^{\frac{R_{target}}{b^e}} - 1 \quad \text{eq. (9)}$$

The target rate for eMBB users can be achieved if its SINR is greater than the SINRthreshold,$\gamma_k^{e,th}$, i.e.,

$$\gamma_k^e \geq \gamma_k^{e,th} \quad \text{eq. (10)}$$

We consider that the maximum packet delay threshold, $Dmax$is 1 ms and overall reliability requirement, $\epsilon$is 1×10^{-5}. The overall reliability is the overall packet lossprobability of a single user which is the combination of transmission error probabilityand queuing-delay violation probability. The overall reliability, ϵcan be expressed as

$$\epsilon = \epsilon_c + \epsilon_q \quad \text{eq. (11)}$$

where ϵ_c is the transmission-error probability and $\epsilon_q$is the queuing-delay violation probability.

Furthermore, we assume that downlink transmissions only requires one frame and duration of one frame is $T_f$and the latency of the backhaul is T_f.Thus, we can obtain end to end queuing delay as follows [14]:

$$D_q = D_{max} - 2T_f \quad \text{eq. (12)}$$

If channel state information (CSI) is known at the transmitter and receiver, in quasistatic, interference-free, flat fading channel, the maximum achievable rate of the jth user can be approximated as [14]

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$$R_j^u = \frac{\tau b_j^u}{ln2}\left[\left(1+\gamma_j^u\right) - \sqrt{\frac{V_j^u}{\tau b_j^u}}Q^{-1}(\epsilon_c)\right] bits/frame \quad \text{eq. (13)}$$

where τ is duration for data transmission in one frame, Q^{-1} is the inverse Q function and V_j^u is channel dispersion of URLLC user j, which is given by [14]

$$V_j^u = 1 - \frac{1}{\left(1+\gamma_j^u\right)^2} \quad \text{eq. (14)}$$

Therefore, the queuing delay requirements (D_q and ϵ_q) can be satisfied when theachievable rate is greater than or equal to the effective bandwidth[5], [14] – [16].The effectivebandwidth for a Poisson process with arrival packet rate, can be expressed as [5]

$$E^B = \frac{\mu T_f \ln\frac{1}{\epsilon_q}}{D_q ln\left(\frac{T_f \ln\frac{1}{\epsilon_q}}{\lambda D_q}+1\right)} bits/frame \quad \text{eq. (15)}$$

where μ is the number of bits contained in each packet. We can obtain the SNR required to satisfy queuing delay requirements by taking $R_j^u = E^B$ and by substituting $V_j^u \approx 1$ to achieve the lower bound. Thus, the threshold for SNR of URLLC user j is given by

$$\gamma_j^{u,th} = \exp[\frac{E^B \ln 2}{\tau\, b_j^u} + \sqrt{\frac{1}{\tau b_j^u}}Q^{-1}(\epsilon_c)] - 1 \quad \text{eq. (16)}$$

Latency and reliability requirements of jth URLLC user is satisfied if SNR of the jth URLLC user is greater than the SINR threshold $\gamma_j^{u,th}$, i.e.,

$$\gamma_j^u \geq \gamma_j^{u,th} \quad \text{eq. (17)}$$

We assume that the power allocation for both eMBB and URLLC users is less than orequal to maximum transmit power at the base station P_{total}, i.e.,

$$\sum_{k=1}^{K} ||m_k^e||_2^2 + \sum_{j=1}^{J} ||m_j^u||_2^2 \leq P_{total} \quad \text{eq. (18)}$$

Furthermore, we assume that bandwidth allocation for all eMBB users and for eachURLLC user is less than or equal to the total bandwidth of the system B_{total}, i.e.,

$$b^e + \sum_j^J = 1\, b_j^u \leq P_{total} \quad \text{eq. (19)}$$

We consider the admission of eMBB users who have satisfied the target rate while allocating power, bandwidth and beamforming directions to all URLLC users who have satisfied the latency and reliability requirements under the power and bandwidth constraints.

B. *Algorithm*

There has been a brief overview of particle swarm optimization for MIMO channel estimation. The algorithms' achievable performance is evaluated using Monte Carlo simulations, and general applicable methods for MIMO channel estimation are offered. In addition, a complexity analysis based on the distribution of required iterations until convergence is included. Because missing parameters can be recreated via interpolation, the suggested method allows for the calculation of a maximum number of repetitions with the least amount of simulation overhead. It has been demonstrated that cooperative PSO can approach the best MMSE estimator. As a result, the needed number of iterations is critical for a prospective implementation. The provided MSE and BER data further show that PSO can quickly converge to a "acceptable" MSE, allowing an iterative receiver to reach the same performance as an MMSE-based initialization with only a few iterations. PSO has an advantage over MMSE in that it allows for a variable tradeoff between complexity per iteration and the required number of iterations, making it excellent for parallelization.Furthermore, empirical measures are not required to calibrate the parameters for PSO, which is an advantage of PSO because the technique may be used immediately for MIMO channel estimation.Although the expansion to multiple objectives in PSO/CPSO can be utilised to estimate time-varying channels, the power of Base Work / PSO rests in the estimation of time-invariant channels.

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PSO Algorithm

Initialize swarm
Locate leader
i=1
while $i < i_{max}$ or convergence **do**
  for each particle **do**
Update position
    Evaluation
    Update pBest
end for
Update leader
i++
end while

III. SIMULATION AND NUMERICAL RESULTS

We simulate the proposed algorithm in order to prove the correctness and effectiveness of our algorithm.

A. *Simulation Setup*

In our simulations, the downlink of a single-cell MISO system is considered. We assume that the base station is equipped with four transmit antennas. There are eight eMBB users and eight URLLC users in the system. To model the channel gains, we have used the exponential path loss model which is given by

$$\mathbf{h}_k = \left(\frac{r_k}{r_0}\right)^{-\alpha} \boldsymbol{c}_k \quad \text{eq. (20)}$$

where $\mathbf{h}_k \in C^T$ is the channel vector from base station to kth user, r_k is the distance from base station to kth user, r_0 is the far-field reference distance, α is the path loss exponent and $\boldsymbol{c}_k$ is small scale fading which is arbitrary chosen from circularly symmetric complex Gaussian vector distribution with mean zero and identity covariance matrix.We have done the simulations using MATLAB. We have solved the admission control problem using CVX with MOSEK solver. Furthermore, the simulation parameters mentioned in Table 1 are assumed.

Far field distance r_0	1 m
Path loss exponent α	2
Overall reliability requirement ∈	1 x 10^{-5}
Transmission error probability $\in_c = \in/2$	5 x 10^{-6}
Queueing-delay violation probability $\in_q = \in/2$	5 x 10^{-6}
E2E delay requirement D_{max}	1 ms
Maximum queueing delay D_q	0.8 ms
Duration of each frame T_f	0.1 ms
Duration of data transmission in one frame T	0.05 ms
Packet size μ	20 bytes
Maximum transmit power P_{total}	33 dBm
Arrival packet rate λ	0.2 packets/frame
Single-sided noise spectral density N_0	-83.98 dBm/Hz [8]
Total bandwidth of the system B_{total}	200 MHz
Target rate for an eMBB user R_{target}	200 Mbps

Table 1: Simulation Parameters

B. *Results*

The MSE improves significantly in the first 20, 60, and 120 iterations for PSO depending on the SNR. The subsequent iterations are needed for convergence to the optimumperformance. Interestingly, PSO converges earlier to the optimum performance in case of an SNR of 20 dB. PSO exhibits an inferior performance compared to PSO and/or Base work estimation with increasing SNR and dimensions as illustrated in Figure 2.

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Then, we illustrated the convergence behaviour of the BCD algorithm and PSO approach for various number of devices. It is observed from this figure that the PSO algorithm converges rapidly for all considered values of K, and roughly ten iterations are sufficient for the convergence of the BCD algorithm. Figure 3 also shows that larger number of devices leads to slower convergence speed. The reason is that larger number of devices corresponds to more optimization variables to be optimized and require more iterations.

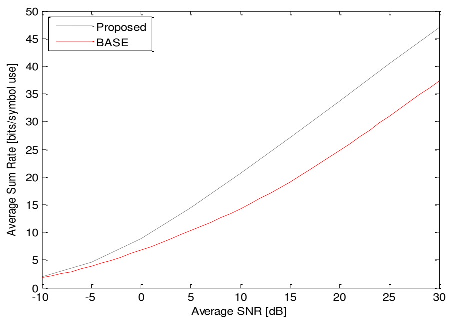

Fig 2: Average Sum Rate vs SNR

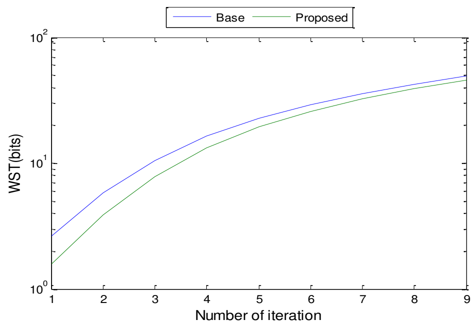

Fig 3: WST vs Number of Iteration

Fig. 3 shows the WST versus the total power limit for various decoding error probabilities _ at the devices. As expected, the WST of each algorithm increases with an increase of the maximum available transmit power as higher transmit power will bring higher value of SNR. The proposed PSO algorithm is observed to outperform the conventional long packet transmission scheme, and the performance gap increases as the transmit power limit becomes larger. This may be due to the fact that largertransmit power corresponds to a higher value of SNR, and thus V x k will approach one.

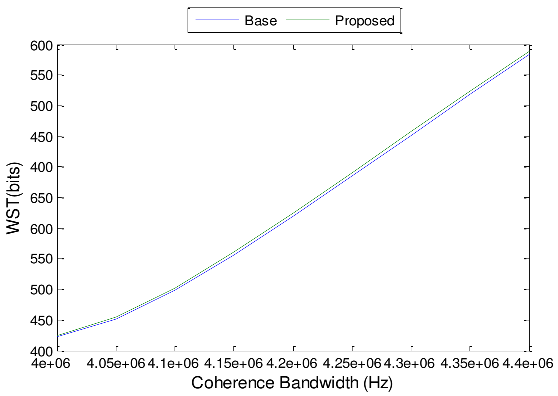

Fig 3: WST vs Coherence Bandwidth

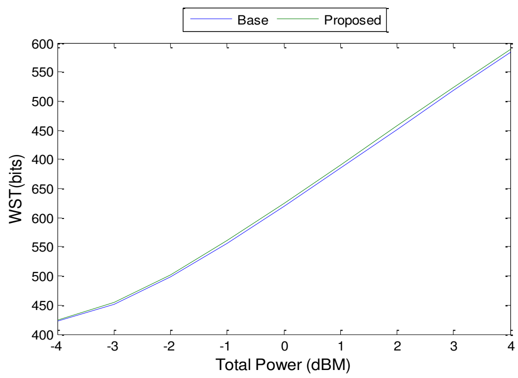

Fig 4: WST vs Total Power

The proposed BCD algorithm is observed to outperform the conventional long packet The complexity of PSO/Base work is determined by the number of particles, subswarms, dimensions, and the required number of iterations for convergence. In each iteration all particles Np of all subswarms Ns have to evaluate their current position and compare their current fitness value with their personal best as well as the global best, which results in a complexity of order.

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IV. CONCLUSION

There has been a brief overview of particle swarm optimization for MIMO channel estimation. The algorithms' achievable performance is evaluated using Monte Carlo simulations, and general applicable methods for MIMO channel estimation are offered. In addition, a complexity analysis based on the distribution of required iterations until convergence is included. Because missing parameters can be recreated using an interpolation, the proposed method allows for the calculation of amaximum number of repetitions with the least amount of simulation overhead.

It has been demonstrated that cooperative PSO can approach the best MMSE estimator. As a result, the needed number of iterations is critical for a prospective implementation. The provided MSE and BER data further show that PSO can quickly converge to a "acceptable" MSE, allowing an iterative receiver to reach the same performance as an MMSE-based initialization with only a few iterations. PSO has an advantage over MMSE in that it allows for a variable trade-off between complexity per iteration and the required number of iterations, making it excellent for parallelization. Furthermore, empirical measures are not required to calibrate the parameters for PSO, which is an advantage of PSO because the technique may be used immediately for MIMO channel estimation. Although the expansion to multiple objectives in PSO/CPSO can be utilised to estimate time-varying channels, the strength of Base Work / PSO is in the estimation of time-invariant channels.

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