Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 192 (2021) 2502–2511

Procedia Computer Science

www.elsevier.com/locate/procedia

25th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems

Call Admission Control Optimization in 5G in Downlink Single-Cell MISO System

Ahmed Slalmi[a*], Hasna Chaibi[b], Rachid Saadane[b], Abdellah Chehri[c]

[a]*Department of Computer science research, Ibn Tofail Universtity, Kenitra, Morocco*
[b]*SIRC/LaGeS-EHTP, EHTP Km 7 Route, El Jadida 20230, Morocco*
[c]*Department of Applied Sciences University of Quebec in Chicoutimi Chicoutimi, QC, Canada*

Abstract

The main goal ofNew Radio 5G (NR) mobile technology is to support three generic service categories, each with very specific requirements. The first category is enhanced Mobile Broadband (eMBB), the second category relates to massive Machine-Type Communications (mMTC), and the third category relates to ultra-Reliable Low Latency Communications (URLLC). The slicing of the radio part of 5G network access network has greatly contributed to the emergence of these three categories of service with different qualities of service. This division therefore enabled the network to reserve the necessary resources for each category of services, orthogonally, and according to the performance required. In this article, we have dealt with the problem of Call Admission Control (CAC) in 5G networks where we have considered the case of the only two categories eMBB and uRLLC, which their users are served by a single cell. We calculated the maximum eMBB users admitted into the system with guaranteed data rate, while allocating power, bandwidth, and beamforming directions to all uRLLC users whose latency requirements and reliability are always guaranteed. We only considered the downlink communication, and we used the case of the multiple-input single-output (MISO) system. This CAC problem is formulated as a minimization problem l_0 which is known as NP-hard problem. We therefore chose to use Sequential Convex Programming (SCP) to find a suboptimal solution to the problem.

Keywords: 5G NR; eMBB; uRLLC; MISO; beamforming; Optimization sequential convex programming

1. Introduction

The New Radio of the Fifth Generation (5G NR) is the successor radio access technology to the Fourth Generation (LTE-Advanced) technology introduced by the Third Generation Partnership Project (3GPP). 5G is introduced to allow users to access increasingly large information and with greater reliability and very low latency and also to share data anytime and anywhere and with any other users or any connected objects [1, 2]. 5G also allows a very high connection density compared to previous generations. It thus enables applications that were until then very difficult to provide or even impossible such as the connection and control of autonomous vehicles, virtual reality and augmented reality, the smart city, factory automation, telemedicine, etc.

* *Corresponding author email address: aslalmi@gmail.com*

10.1016/j.procs.2021.09.019

5G technology introduces three main categories of services. The first category is for enhanced mobile broadband (eMBB), the second category is for ultra-reliable low latency communications (uRLLC), and the third category is for massive machine-type communications (mMTC) [3].

- eMBB provides very high data throughput, high spectral efficiency and wide coverage;
- uRLLC allows applications which are very demanding in terms of reliability and latency;
- mMTC allows very high traffic density and connectivity of a large number of equipment and devices.

There are several circumstances in which users of eMBB and uRLLC share the same limited resources; for example, autonomous vehicles (AV) that use applications which require very short latency for high responsiveness, high transmission reliability to avoid accidents and allow complex maneuvers, high precision and finally high data throughput to process large amounts of data used in these vehicles.

According to 3GPP, uRLLC's quality of service (QoS) requirements are ultra-high reliability (e.g. 99,999% success probability) and low transmission latency of 1ms, while eMBB requires high data rates which can reach 1Gbps [3]. The coexistence of eMBB and uRLLC users in the same resource and in the same cell is a very delicate task. Indeed, simultaneously achieving high rates for eMBB users and ultra reliability and low latency for uRLLC users becomes a difficult planning task as there the challenge is a trade-off between latency, reliability and obtaining high throughputs [4].

On the other hand, the principle of admission control in cellular mobile networks [5] can be defined as the search for capacity, that is to say the maximum volume of traffic or even the maximum number of users that can be admitted simultaneously in the system, while making efficient use of available resources and also meeting quality of service (QoS) requirements. It is this principle that we will adopt in this article. Another principle of admission control, also widely used by researchers in this field, is to decide on the possibility of admission, into the system, of a newly arrived traffic or of a newly arrived user taking into account the constraints of available system resources and incoming traffic QoS requirements.

We also define effective bandwidth as the maximum achievable amount of bandwidth required to meet QoS requirements [6,7]. The reliability and latency requirements of the uRLLC user are guaranteed when the maximum achievable throughput of the uRLLC user is greater than or equal to the effective bandwidth [8].

In this article, we have considered the case of a downlink of a multi-input single-output (MISO) network. We have assumed that there is orthogonal spectrum sharing between users of the eMBB and uRLLC service categories to avoid interference and thus have them cohabit in the same system and share the same limited resources [9]. The maximum data rate that can be achieved by an eMBB user is modeled using Shannon's formula. Since the packet length of a uRLLC user is very small, to model the data rate of a uRLLC user, we modified Shannon's formula using an adequate approximation of Shannon's capacity valid for block lengths that are short [10,11]. We have formulated the problem as a minimization problem l0. This is a non-deterministic polynomial-time problem considered as NP-hard which requires generally metaheuristic algorithms to resolve it. Therefore, it is necessary to make an approximation to find an optimal solution. To do this, several approximation methods exist. In this article, we have the choice for the sequential convex programming (SCP) method for simplifying the resolution of our problem.

The rest of this article is organiezd as follow, section 2 presents the formulation of the problem and the modeling of the system, it presents the general framework presenting the case where a single multi-antenna cell serves users whose services are different and heterogeneous belonging to the two categories of services eMBB and uRLLC and each user has only one recceiver antenna, this section also introduces the admission control optimization problem and section 3 discusses a proposed method for resolvingthis optimization problem and finally section 4 concludes this article.

2. System modeling and formulation of problem

2.1. General problem framework

We consider the following model in which we consider the downward direction of a single cell of a MISO (Multiple Input and Single Output) type system for which we assume that the 5G base station (gNB) has N transmission antennas and each user has a single receiving antenna [12]. We also consider that gNB only transmits data to its users who are attached to it (Fig.1).

We denote by U the set which includes all users of the eMBB and uRLLC services. All users of the eMBB category is noted as U_B and the set of users in the uRLLC category is denoted by U_R, with $Card(U_B) = K$ and $Card(U_R) = L$, where $Card$denoted the cardinality of a set. We also have $U = U_B \cup U_R$ and $Card(U) = K + L$ (since each user is served by a single category of services).

In this paper we assume that the equipment of each of the K + L users is equipped with a single receiving antenna (MISO type system).

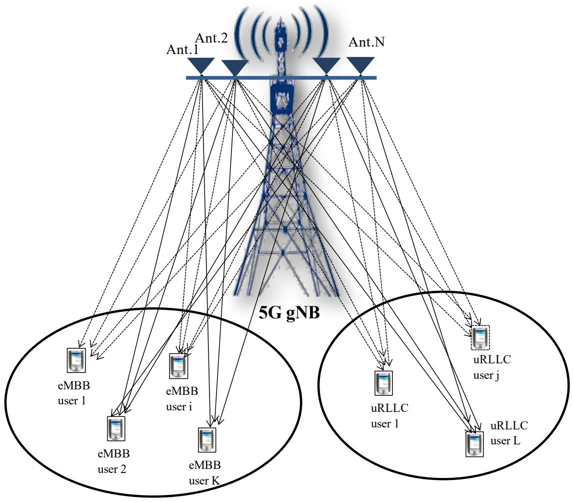

Fig. 1. Downlink transmission with coexistence of eMBB and uRLLC services

We consider in this article that the spectrum sharing between all eMBB and uRLLC users is orthogonal [13,14]. We denote by W the width of the total band and we consider that the sum of the bandwidth for eMBB users (denoted W_B) and that for uRLLC users (denoted W_R) is equal to W:

$$W = W_B + W_R \tag{1}$$

The separation of the two bands made it possible that interference between eMBB and uRLLC users be avoided.In addition, we suggest giving a separate portion of bandwidth for each uRLLC user and we are also considering orthogonal frequency division multiple access (OFDMA) for uRLLC users. This implies that users are assigned orthogonal resources and therefore there is no interference between uRLLC users [15].

2.2. Formulation of the admission control problem

In the following, we will present the admission control problem. The signal transmitted by the base station (gNB) is given by:

$$\mathbf{X} = \sum_{k \in U} \sqrt{p_k}\, d_k \mathbf{u}_k \tag{2}$$

where, $\mathbf{X} = \left(X_1, X_2, \ldots, X_N\right)^T$ and $\mathbf{u}_k = \left(u_{k,1}, u_{k,2}, \ldots, u_{k,N}\right)^T$ and $\left\|\mathbf{u}_k\right\|_2 = 1$

d_k is the data symbol of the kth user.

$\boldsymbol{u}_k$ is a unit vector and p_k is the power of the kth user ($\sqrt{p_k}\mathbf{u}_k$ is the beamforming signal)

It is assumed that the data flows are independent.

On the other hand, the signal received by the kth eMBB user is given by:

$$y_k^B = d_k^B \sqrt{p_k^B} < \mathbf{h}_k^B, \mathbf{u}_k^B > + \sum_{\substack{i=1 \\ i \neq k}} d_i^B \sqrt{p_i^B} < \mathbf{h}_k^B, \mathbf{u}_i^B > + n_k^B \tag{3}$$

$\mathbf{h}_k^B \in C^N$ is the channel vector going (out of) the base station to the kth user,

$\mathbf{u}_k^B \in C^N$ is a unit vector (normalized beamformer)

p_k^B is the power for the kth user of eMBB services

$n_k^B : CN(0;\sigma_{k,B}^2)$ is the additive Gaussian white noise (AWGN) at the level of the kth user, with $\sigma_{k,B}^2 = N_0 W_B$ and N_0 is the spectral density of the noise ($\sigma_{k,B}$ is the standard deviation). CN denoted the complex Gaussian.

$p_k^B \mathbf{u}_k^B$ is the signal beamforming

$< \mathbf{a}, \mathbf{b} >= \mathbf{a}^H \mathbf{b}$ is the inner product (scalar) between vectors $\mathbf{a}$ and $\mathbf{b}$, $\mathbf{a}^H$ is the Hermetian transpose of $\mathbf{a}$.

$\|\mathbf{u}_k\|_2$ is the l_2-norm of vector $\mathbf{u}_k$.

Since uRLLC users are assigned orthogonal resources, there is no interference between uRLLC users. The signal received from the jth user uRLLC can therefore be written as:

$$y_j^R = d_j^R \sqrt{p_j^R} < \mathbf{h}_j^R, \mathbf{u}_j^R > + n_j^R \tag{4}$$

$\mathbf{h}_j^R \in C^N$ is the channel vector from the base station (gNB) to the jth user uRLLC.

$p_j^R \mathbf{u}_j^R$ is the beamforming vector of the jth user uRLLC.

$n_j^R : CN(0;\sigma_{j,R}^2)$ is the Gaussian additive white noise for the jth user uRLLC, with $\sigma_{j,R}^2 = N_0 W_{j,R}$ and N_0 is the spectral density of the noise and the bandwidth allocated to the jth user uRLLC.

The SINR received from the kth eMBB user can be written as :

$$SINR_k^B = \frac{p_k^B \left| < \mathbf{h}_k^B, \mathbf{u}_k^B > \right|^2}{\sum_{\substack{i=1 \\ i \neq k}}^{K} p_i^B \left| < \mathbf{h}_k^B, \mathbf{u}_i^B > \right|^2 + N_0 W_B} \tag{5}$$

The SINR received from the jth uRLLC user can be written as:

$$SINR_j^R = \frac{p_j^R \left| < \mathbf{h}_j^R, \mathbf{u}_j^R > \right|^2}{N_0 W_{j,R}} \tag{6}$$

By using Shannon formula, the maximum achievable throughput for the kth eMBB user can be expressed as:

$$R_k^B = W_B \log_2(1 + SINR_k^B) \tag{7}$$

Assume that the target rate for an eMBB user is R_T^B. Hence, the target SINR for the kth eMBB user can be written as:

$$SINR_{k,T}^B = 2^{\frac{R_T^B}{W_B}} - 1 \qquad (k = 1,...,K) \tag{8}$$

The target throughput for eMBB users can be achieved if its SINR is greater than or equal to SINR threshold for each user:

$$SINR_k^B \geq SINR_{k,T}^B \quad (k = 1,...,K) \tag{9}$$

The maximum packet delay threshold, Dmax, is considered to be 1ms and the overall reliability requirement, R, is 99,999%.

Overall reliability is the overall probability of a single user's packet loss which is the combination of the transmission error probability (P_e) and the probability of queuing-delay violation (probability of queuing timeout of *k*th user) (P_q).

The overall reliability, *R*, can be given by:

$$R = (1 - P_e) + (1 - P_q) \tag{10}$$

With, P_e is the transmission error probability
and P_q is the probability of queuing timeout of *k*th user.

Additionally, we assume that the downlink and uplink transmissions only require a single frame and that the duration of a frame is L_{bh} (i.e. L_{bh} is the backhaul latency).

So, we can get end-to-end queuing delay as follows:

$$D_q = D_{\max} - 2\, L_{bh} \tag{11}$$

As the packet length of anuRLLC user is small, to model the data rate of a uRLLC user, Shannon's formula cannot be applied without modification, for this we used the approximation of the capacity given by Shannon's formula to take into account the short block length regime. On the other hand, we note that the characteristics of the communication link between gNB and users are known by Channel State Information (CSI). If the CSI is known at the level of the transmitter and the receiver, in quasi-static, without interference, flat fading channel, the maximum throughput that the *j*th user can reach can be given approximately as [16-18]:

$$R_j^B = \tau_f \; W_{j,R} \left[\log_2(1 + SINR_j^R) - \sqrt{\frac{V_j^R}{\tau_f \; W_{j,R}}} \; Q^{-1}(P_e) \right] \qquad (bit / frame) \tag{12}$$

Where τ_f is the duration of data transmission in a frame, $Q^{-1}$is the inverse of the Gaussian Q-function,

where $Q(x) = \frac{1}{2}\left(1 - erf\left(\frac{x}{\sqrt{2}}\right)\right)$and $erf$is error function defined as $erf(x) = \sqrt{1 - \exp\left(\frac{-4x^2}{\pi}\right)}$

$V_j^R$is the channel dispersion of the*j*th user uRLLC (channel dispersion).

where,

$$V_j^R = 1 - \frac{1}{\left(1 - SINR_j^R\right)^2} \qquad (j = 1, \ldots, L) \tag{13}$$

Note that according to [19], if SINR is greater than 10 dB, V_j^Rcan be approximated by the value 1.

Therefore, the queuing delay requirements (D_q and P_q) can be met when the achievable throughput is greater than or equal to the effective bandwidth.

The effective bandwidth for a Poisson process with the packet arrival rate can be given by:

$$W_{eff} = \frac{\mu\zeta}{D_q \ln\left(1 + \frac{\zeta}{\lambda D_q}\right)} \tag{14}$$

where $\zeta = L_{bh} \ln\left(\frac{1}{R_q}\right)$

and μ is the number of bits existing in each packet.

The target SINR (required) can be obtained to meet the queuing time requirements by considering $R_j^R = W_{eff}$. Hence, we then obtain the threshold of SINR of the jth user uRLLC by:

$$SINR_{j,T}^R = 2^{\nu} - 1 \quad (j = 1, \ldots, L) \tag{15}$$

where the expression of ν is as the following:

$$\nu = \frac{W_{eff}}{\tau_f W_{j,R}} + \sqrt{\frac{V_j^R}{\tau_f W_{j,R}}} \; Q^{-1}(P_e)$$

The latency and reliability requirements of the jth user uRLLC are met if the SINR of the jth user uRLLC ($SINR_j^R$) is greater than threshold SINR ($SINR_{j,T}^R$).

$$SINR_j^R \geq SINR_{j,T}^R \qquad (j = 1, \ldots, L) \tag{16}$$

It is assumed that the power allocated to the users of the two services eMBB and uRLLC is less than or equal to the maximum transmission power at the level of the base station, P_{total}, that is to say:

$$\sum_{k=1}^{K} < \sqrt{p_k^B}\mathbf{u}_k^B, \sqrt{p_k^B}\mathbf{u}_k^B > + \sum_{j=1}^{L} < \sqrt{p_j^R}\mathbf{u}_j^R, \sqrt{p_j^R}\mathbf{u}_j^R > \leq P_{total} \tag{17}$$

This can also be written as:

$$\sum_{k=1}^{K} p_k^B + \sum_{j=1}^{L} p_j^R \le P_{total} \tag{18}$$

In addition, it is assumed that the sum of the bandwidths allocated to all eMBB users and all uRLLC users is less than or equal to the total system bandwidth (W):

$$W_B + \sum_{j=1}^{L} W_{j,R} \le W \tag{19}$$

Most of the scheduling algorithms recommended in the existing literature on the subject, dealing with the coexistence of eMBB and uRLLC users in the same cell [20-22], and to avoid wasting the limited resources in this cell, suggest reducing the bit rates of eMBB users as much as possible, and prioritize uRLLC users and meet their reliability and latency requirements; this is justified by the fact that users of the uRLLC service category must have very strict services in terms of latency and reliability.

Hence, the main aim of this paper is to maximize the number of eMBB users admitted while ensuring that all constraints related to eMBB and uRLLC users are met. Therefore, we need to maximize the sum of cardinalities of U_B.

To formulate this problem as a mathematical optimization problem, we define by ε_k the positive auxiliary variable and with the SINR constraints of the kth user eMBB as follows:

$$SINR_k^B \ge SINR_{k,T}^B - \varepsilon_k \tag{20}$$

We can get the equation (9) for $\varepsilon_k = 0$, that means, when, $\varepsilon_k = 0$ the constraint for SINR regarding the kth user of eMBB is satisfied.

Therefore, and in order to maximize the number of eMBB allowed users for the target rates [23], we need to maximize the number of users who require a strictly positive value of the auxiliary variable ε_k (i.e. $\varepsilon_k \ne 0$).

In other words, we need to increase the number of times when $\varepsilon_k = 0$. This can be done by minimizing the value of $\|\boldsymbol{\varepsilon}\|_0$ of the vector $\boldsymbol{\varepsilon}$ of auxiliary variables.

Hence the problem of optimizing admission control for eMBB in the coexistence of uRLLC and eMBB users can be expressed as follows:

$$Minimize \qquad \|\boldsymbol{\varepsilon}\|_0 = Card\left(\{\, k = 1,\ldots,K / \varepsilon_k \ne 0 \,\}\right) = \sum_{k=1}^{K} \chi_{\{k/\varepsilon_k \ne 0\}}(k) \tag{21}$$

Subject to : Equations (16), (18) , (19) and (20) and considering positive value of W_B, $W_{j,R}$ and ε_k for all j=1, …, L and k=1,…,K and $\boldsymbol{\varepsilon} = (\varepsilon_1,\ldots,\varepsilon_K)^T$.

χ_A denoted the characteristic (or indicator) function of a set A

3. Approximation method for optimization problem

The optimization problem (21) is known as NP-Hard problem. It can be resolved by using some metaheuristic algorithms [24,25]. However, it can be approximated by using a concave function arc tangent (atan) as a penalty function such as:

$$Minimize \quad \sum_{k=1}^{K} \operatorname{atan}\left(\frac{\varepsilon_k}{\theta}\right) \quad , \varepsilon_k \ge 0 \,, k = 1\ldots, K; \theta > 0 \tag{21}$$

The equation (16) can be replaced by (16)' according to equations (6) and (15) as the following:

$$\frac{p_j^R \left| < \mathbf{h}_j^R, \mathbf{u}_j^R > \right|^2}{N_0 W_{j,R}} \ge 2^{\nu} - 1 \qquad , j = 1,\ldots,L \tag{16)'$$

where ν is expressed in equation (15).

The equation (20) can be replaced by (20)' according to equations (5) and (8) as the following:

$$\frac{p_k^B\left|<\mathbf{h}_k^B,\mathbf{u}_k^B>\right|^2}{\sum_{\substack{i=1\\i\neq k}}^{K}p_i^B\left|<\mathbf{h}_k^B,\mathbf{u}_i^B>\right|^2+N_0W_B}\geq 2^{\frac{R_T^B}{W_B}}-\varepsilon_k-1 \qquad ,k=1,\ldots,K \tag{20'}$$

We can finally obtain an accurate approximation of the optimization problem (21) by the optimization problem (21)' as follows:

$$Minimize \quad \sum_{k=1}^{K}\operatorname{atan}\left(\frac{\varepsilon_k}{\theta}\right) \quad ,\varepsilon_k\geq 0\,,k=1\ldots,K;\theta>0 \tag{21'}$$

Subject to: (16)', (20)' and (19) and also considering constraints such as positive value of $W_B, W_{j,R}$ and ε_k for all j=1,…,L and k=1,…,K.

To find an optimal solution to the optimization problem (21) ', we have chosen to apply the sequential convex programming method (SCP) [26].For this purpose, we consider the objective function *f* of the optimization problem defined by:

$$f(\boldsymbol{\varepsilon})=\sum_{k=1}^{K}\operatorname{atan}\left(\frac{\varepsilon_k}{\theta}\right) \quad ,\varepsilon_k\geq 0\,,k=1\ldots,K;\theta>0 \tag{22}$$

where, $\boldsymbol{\varepsilon}=(\varepsilon_1,\varepsilon_2,\ldots,\varepsilon_K)^T$

f is a concave function, because it is a sum of concave functions [27].This function can be approximated by Brook Taylor's formula [26,27], using the quadratic model, so we have the following second-order model:

$$\widetilde{f}(\boldsymbol{\varepsilon})=f(\widetilde{\boldsymbol{\varepsilon}})+\nabla f(\widetilde{\varepsilon}_k)^T(\boldsymbol{\varepsilon}-\widetilde{\boldsymbol{\varepsilon}})+\frac{1}{2}(\boldsymbol{\varepsilon}-\widetilde{\boldsymbol{\varepsilon}})^T\nabla^2 f(\widetilde{\boldsymbol{\varepsilon}}_k)\,(\boldsymbol{\varepsilon}-\widetilde{\boldsymbol{\varepsilon}}) \tag{23}$$

where, $\widetilde{f}$ and $\widetilde{\boldsymbol{\varepsilon}}$ are an approximation of *f* and $\boldsymbol{\varepsilon}$ respectively and $\widetilde{\boldsymbol{\varepsilon}}=(\widetilde{\varepsilon}_1,\widetilde{\varepsilon}_2,\ldots,\widetilde{\varepsilon}_K)^T$

∇ and ∇^2 are the gradient and the Hessian respectively.

On the other hand, since $\nabla f(\varepsilon)^T=\left(\frac{\partial f}{\partial\varepsilon_1}(\boldsymbol{\varepsilon}),\frac{\partial f}{\partial\varepsilon_2}(\boldsymbol{\varepsilon}),\ldots,\frac{\partial f}{\partial\varepsilon_K}(\boldsymbol{\varepsilon})\right)$

and $\frac{\partial f}{\partial\widetilde{\varepsilon}_k}(\boldsymbol{\varepsilon})=\frac{\theta}{\widetilde{\varepsilon}_k^2+\theta^2}$ and $\frac{\partial^2 f}{\partial\widetilde{\varepsilon}_k^2}(\boldsymbol{\varepsilon})=\frac{-2\,\theta\,\varepsilon_k^2}{(\widetilde{\varepsilon}_k^2+\theta^2)^2}$ for all k=1,…,K

In this article, we only consider the first order model, and therefore we have the following approximation, as shown in figure 2:

$$\widetilde{f}(\boldsymbol{\varepsilon})=f(\widetilde{\boldsymbol{\varepsilon}})+\nabla f(\widetilde{\varepsilon}_k)^T(\boldsymbol{\varepsilon}-\widetilde{\boldsymbol{\varepsilon}}) \tag{24}$$

Hence,

$$\widetilde{f}(\boldsymbol{\varepsilon})=\theta\sum_{k=1}^{K}\frac{\varepsilon_k}{\widetilde{\varepsilon}_k^2+\theta^2}+\eta \qquad \text{where,}\quad \eta=f(\widetilde{\varepsilon})-\theta\sum_{k=1}^{K}\frac{\widetilde{\varepsilon}_k}{\widetilde{\varepsilon}_k^2+\theta^2} \tag{25}$$

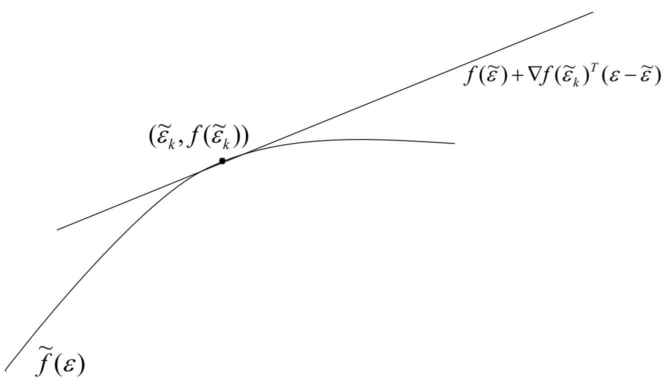

Fig. 2. First order approximation of concave function *f*

where, $\eta = f(\widetilde{\varepsilon}) - \theta \sum_{k=1}^{K} \frac{\widetilde{\varepsilon}_k}{\widetilde{\varepsilon}_k^2 + \theta^2}$

Note that in equation (25), η is considered as constant and therefore, in order to simplify the objective function, we can neglect this constant. Indeed, this constant will have no influence and no effect on the result of the optimization. We finally obtain the following optimization problem:

$$Minimize \quad \widetilde{f}(\boldsymbol{\varepsilon}) = \sum_{k=1}^{K} \frac{\theta\, \varepsilon_k}{\widetilde{\varepsilon}_k^2 + \theta^2} \tag{26}$$

Subject to: (16)', (20)' and (19) and also considering positive value of W_B, $W_{j,R}$ and ε_k for all j=1,…,L and k=1,…,K.

In equation (20)' we pose:

$$\gamma_k = \sum_{\substack{i=1 \\ i \neq k}} p_i^B \left| < \mathbf{h}_k^B, \mathbf{u}_i^B > \right|^2 + N_0 W_B \qquad k = 1,\dots,K \tag{27}$$

Let φ_k the function defined as:

$$\varphi_k(\mathbf{u}_k^B, \gamma_k) = \frac{p_k^B \left| < \mathbf{h}_k^B, \mathbf{u}_k^B > \right|^2}{\gamma_k} \qquad k = 1,\dots,K \tag{28}$$

The approximation of convex function $\varphi_k(\mathbf{u}_k^B, \gamma_k)$ by Taylor first order is as follows:

$$\widetilde{\varphi}_k(\mathbf{u}_k^B, \gamma_k) = \varphi_k(\widetilde{\mathbf{u}}_k^B, \widetilde{\gamma}_k) + \nabla \varphi_k(\widetilde{\mathbf{u}}_k^B, \widetilde{\gamma}_k)^T \left\lfloor \sqrt{p_k^B}(\mathbf{u}_k^B - \widetilde{\mathbf{u}}_k^B, \gamma_k - \widetilde{\gamma}_k) \right\rfloor \tag{29}$$

where,

$$\nabla \varphi_k(\widetilde{\mathbf{u}}_k^B, \widetilde{\gamma}_k)^T = \left(\frac{2\sqrt{p_k}}{\gamma_k} (\mathbf{h}_k^B (\mathbf{h}_k^B)^H \widetilde{\mathbf{u}}_k^B); - \frac{p_k^B}{\gamma_k^2} \left| < \mathbf{h}_k^B, \widetilde{\mathbf{u}}_k^B > \right|^2 \right) \tag{30}$$

Likewise, we define the function ψ_k as:

$$\psi_j(\mathbf{u}_j^R, W_{j,R}) = \frac{p_j^R \left| < \mathbf{h}_j^R, \mathbf{u}_j^R > \right|^2}{N_0 W_{j,R}} \qquad j = 1,\dots,L \tag{31}$$

The first order Taylor approximation of $\psi_j(\mathbf{u}_j^R, W_{j,R})$ is follows:

$$\widetilde{\psi}_j(\mathbf{u}_j^R, W_{j,R}) = \psi_j(\widetilde{\mathbf{u}}_j^R, \widetilde{W}_{j,R}) + \nabla \psi_j(\widetilde{\mathbf{u}}_j^R, \widetilde{W}_{j,R})^T \left\lfloor \sqrt{p_j^R}(\mathbf{u}_j^R - \widetilde{\mathbf{u}}_j^R, W_{j,R} - \widetilde{W}_{j,R}) \right\rfloor \tag{32}$$

where,

$$\nabla \psi_j(\widetilde{\mathbf{u}}_j^R, \widetilde{W}_{j,R})^T = \left(\frac{2\sqrt{p_j^R}}{N_0 \widetilde{W}_{j,R}} (\mathbf{h}_j^R (\mathbf{h}_j^R)^H \widetilde{\mathbf{u}}_j^R); - \frac{p_j^R}{N_0 (\widetilde{W}_{j,R})^2} \left| < \mathbf{h}_j^R, \widetilde{\mathbf{u}}_j^R > \right|^2 \right) \tag{33}$$

Finlly, we obtain the approximation of optimization problem as follows:

$$Minimize \qquad \sum_{k=1}^{K} \frac{\varepsilon_k}{\widetilde{\varepsilon}_k^2 + \theta^2} \tag{34}$$

Subject to:

$$2^{\frac{R_T^B}{W_B}} - \varepsilon_k - 1 - \widetilde{\varphi}_k(\mathbf{u}_k^B, \gamma_k) \leq 0 \quad ; k = 1,\dots,K \tag{35}$$

$$\sum_{\substack{i=1 \\ i \neq k}}^{K} p_i^B \left| < \mathbf{h}_k^B, \mathbf{u}_k^B > \right|^2 + N_0 W_B - \gamma_k \leq 0; \quad k = 1,\dots,K \tag{36}$$

$$2^{\upsilon}-1-\widetilde{\psi}_j(\mathbf{u}_j^R,W_{j,R})\le 0 \quad ; j=1,\ldots,L \qquad \text{where, } \nu=\frac{W_{eff}}{\tau_f W_{j,R}}+\sqrt{\frac{V_j^R}{\tau_f W_{j,R}}}\,Q^{-1}(P_e) \quad (37)$$

$$W_B\ge 0;\quad W_{j,R}\ge 0;\quad \varepsilon_k\ge 0\ (k=1,\ldots,K) \quad (38)$$

$$\sum_{k=1}^{K}p_k^B+\sum_{j=1}^{L}p_j^R\le P_{total} \quad (39)$$

where, $\boldsymbol{\varepsilon}=(\varepsilon_1,\ldots,\varepsilon_K)$ and the optimization variables are $\varepsilon_k, p_k^B, u_k\ (k=1,\ldots,K)$ and $W_B, p_j^R, W_{j,R}\ (j=1,\ldots,L)$

4. Conclusion

In this article, we have considered the case of serving users of two categories of 5G technology services to optimize the consumption of resources which are very limited. To this end, we have proposed an orthogonal spectrum sharing between the eMBB and uRLLC users to make them coexist without interference. We were interested in discussing a simplification of the problem of admission control of eMBB users in 5G networks in which they coexist with uRLLC users, which require very low latency and very high reliability. This coexistence must be done without reducing the quality of service required by eMBB users. Our goal in this article is to admit the largest possible number of eMBB users into the cell with a suitable data rate, while also guaranteeing power, bandwidth and beamforming directions to every single uRLLC user with latency and reliability requirements which must always be guaranteed.Finally in this article we have considered the case of the system using the MISO network, but we can generalize it by considering the case of the systems using the MIMO network. In addition we can also consider the case where the three categories of service coexist in the same cell by also adding the users of category mMTC.

References

[1] A. Osseiran, J.F. Monserrat and P. Marsch. (2016)"5G Mobile and Wireless Communication Technology", Cambridge University Press.

[2] E. Dahlman, S. Parkvall and J. Skold (2018) "5G NR The Next Generation Wireless Access Technology", Academic Press Publications.

[3] Z. Sheng, H.D. Tuan, Q. Duong and H.V. Poor (2018) "Beamforming Optimization for Physical Layer Security in MISO Wireless Networks", *IEEE Transactions on Signal Processing, 66 (14), pp.3710-3723.*

[4] S. Schiessl, J. Gross and H. A. Zubaidy (2005) "Delay Analysis for wireless fading channels with finite blocklength channel coding", *in Proc. ACM MSWiM.*

[5] S. Boyd and L. Vandenberghe (2009) "Convex Optimization", Chapter 3, Convex functions, Cambridge University Press.

[6] A.A. Esswie and K. Pedersen (2018) "Opportunitistic Spatial Preemptive Scheduling for uRLLC and eMBB Coexitense in Mult-User 5G Networks", *in IEEE Access.*

[7] E.J. Candès, M. B. Wakin and S. P. Boyd (2007) "Ehancing Sparsity by Reweighted *l1*Minimization", *in Journal of Fourier Analysis and Applications*.

[8] M.Z. Chowdhury, Y. M. Jang and Z. J. Haas (2013) " Call Admission Control based on Adaptive Bandwidth Allocation for Wireless Networks", *in Journal of Communications and Networks.*

[9] C.S.Chang and J.A. Thomas (1995) "Effective bandwidth in high-speed digital networks", IEEE Journal on Selected Areas in Communications 13, pp. 1091-1100.

[10] P. Popovski, K.F. Trillingsgaard, O. Simeone and G. Durisi (2018) "5G Wireless Network Slicing for eMBB and mMTC: A communication-Theoric View", *IEEE Access (Volume: 6) pp.55765 – 55779.*

[11] E. Matskani, N.D.Sidiropoulos, Z.Q. Luo and L. Tassiulas (2008) "Convex Approximation Techniques for Joint Multiuser Downlink Beamforming and Admission Control", *IEEE Transactions on Wireless Communications Volume 7, pp. 2682-2693.*

[12] C.Sun, C.She, C.Yang, T.Q.S. Quek, Y.Li and B. Vucetic (2018) "Optimizing Resource Allocation in the Short Blocklength Regime for Ultra-Reliable and Low-Latency Communications", *in IEEE Transactions in Wireless Communications*.

[13] Y. Polyanskiy, V. Poor and S. Verdu (2010) "Channel Coding Rate in the Finite Blocklength Regime", *in IEEE Transactions on Information theory, Vol. 56, NO. 5.*

[14] C.S. Chang and J.A.Thomas (1995) "Effective Bandwidth in High-Speed Digital Networks", i*n IEEE Journal on Selected Areas in Communications (Volume: 13 , Issue: 6).*

[15] W.Yang, G. Durisi, T.Koch and Y. Polyanskiy (2014) "Quasi-Static Multiple-Antenna Fading Channels at Finite Blocklength", *in IEEE Transactions on Information Theory (Volume: 60 , Issue: 7).*

[16] A. Avranas, M. Kountouris and P. Ciblat (2019) "Throughput Optimization in Ultra-Reliable Low-Latency Communication with Short Packet", *IEEE International Conference on Communications (ICC).*

[17] S. R. Pandey, M.Alsenwi, Y.K.Tun and C.S.Hong (2019) "A Downlink Resource Scheduling Strategy for uRLLC Traffic", *inIEEE International Conference on Big Data and Smart Computing (BigComp)*

[18] J.Tang, B.Shim, T.H.Chang and T.Q.S. Quek (2019) "Incorporating uRLLC and Multicast eMBB in Sliced Cloud Radio Access Network", in *IEEE International Conference on Communications (ICC)*.
[19] M.Alsenwi, N.H. Tran, M.Bennis, S. R. Pandey, A. K.Bairagi and C.S.Hong (2020) "Intelligent Resource Slicing for eMBB and uRLLC Coexitence in 5G and Beyond : A Deep Reinforcement Learning Based Approach", in *IEEE Transactions on Wireless Communications.*
[20] C. Zillober (1993) "Sequential Convex Programming in Theory and Praxis", *in Structural Optimization, , pp. 79-86*.
[21] J. Zhang, X. Xu, K. Zhang, B. Zhang, X. Tao and P. Zhang (2019) "Machine Learning Based Flexible Transmission Time Interval Scheduling for eMBB and uRLLC Coexitence Scenario", *in IEEE Access.*
[22] M. Alsenwi, S.R. Pandey, Y.K. Tun, K.T. Kim and C.S. Hong (2019) "A chance Constrained Based Formulation for Dynamic Muliplexing of eMBB-uRLLC Traffics in 5G New Radio", In 2019 International Conference on Information Networkin (ICOIN), pp. 108-113.
[23] J. Duchi (2018) "Sequential Convex Programming", *Notes for EE3646, Stanford University.*
[24] C. Sun, C. She and C. Yang (2017) "Exploiting Multi-user Diversity for Ultra-Reliable and Low-Latency Communications", *IEEE Globecom Workshops (GC Wkshps)*.
[25] A. Karimi, K. Pederson, N. H. Mahmood and P. Mogensen (2019) "Efficient Low Complexity Packet Scheduling Algorithm for Mixed uRLLC and eMBB Traffic", in *IEEE 89th Vehicular Technology Conference.*
[26] C.She, C.Yang and T.Q.S. Quek (2018) "Cross-Layer Optimization for Ultra-Reliable and Low- Latency Radio Access Networks", IEEE Transactions on Wireless Communications 17, pp. 127-141.
[27] D.H.N. Nguyen, L. Bao Le and T. Le-NGOC (2015) « Multiuser Admission Control and Beamforming Optimization Algorithms for MISO Heterogeneous Networks », *IEEE Access, Volume 3, pp. 759-773.*