Resources Allocation Optimization for Real Time Traffic in LTE Cellular Network

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Abstract **-** Nowadays, a threefold real time traffic system is developing where voice, video and data traffic coexist in cellular networks. Since there are a limited number of resources, some of the traffic cannot be served in the real time. For example when all channels are occupied the remaining user equipments (UEs) requesting the service are blocked. Therefore a resource allocation optimization for real time traffic needs to be studied in this context. Significant studies have been conducted with a common objective of maximizing data rate and adaptive channel borrowing, however they don't mitigate the problem of network coverage at the cell edge and spectrum is not shared efficiently among data and voice traffic. In this paper we propose three resource allocation methods for voice/data integrated in cellular network. In the First case, both voice and data traffic are assigned separate resources and the communication is in a dedicated mode. In the second case, we assign different resources but we allow the reuse of one of the traffic resources either voice or data provided that the interference is well managed. Thirdly we propose the method of borrowing the idle resources depending to the UE transmitting power of new call arrival. Our resource allocation schemes were developed based on blocking probability and weighted cell utilization mathematic model. MATLAB simulation results show that the performance of our proposed schemes in terms of UE blocking probability and cell weighted utility is better compared to cellular alone.

Keywords **-** *Resource Optimization, LTE, Real-Time Traffic, Cell utility.*

I. INTRODUCTION

The increasing demand for higher data rates for local area services and gradually increased spectrum congestion have triggered research activities for improved spectral efficiency and resource allocation management. In order to meet the requirement of the higher data rate transmission in mobile communication, the spectrum allocated to mobile communication systems must be used efficiently. Since; traditional cellular networks are designed mostly according to peak traffic demands in order to guarantee quality-of-service (QoS), even in the worst case, sharing between voice and data traffic need to be envisaged.

In principle, the network is responsible for the resource allocation and can allocate the resources either dynamically or statically. The analysis shows that, dynamic allocation utilizes the radio resources more flexibly at the cost of heavy control overhead while the converse is true for static allocation. In [1], these two methods have been discussed mainly focusing on the use of device to device (D2D) discovery, and static allocation seems appropriate.

According to [2], four methods of resources allocation have been proposed taking in consideration the use of D2D communication. All these methods are focusing on the use of D2D communication, to optimize the network resources which are few and far from the reality when the long distance between users is required. Moreover they never consider the real time traffic, either voice or data streaming. Some of the previous works are proposing different methods of resource allocation. In [3], optimality is discussed under practical constraints such as minimum and maximum spectral efficiency restrictions, and maximum transmit power or energy limitation. Resource Allocation for Heterogeneous Applications is discussed in [4]. They jointly consider resource allocation and power control with heterogeneous QoS requirements from the applications, namely streaming-like and file-sharing-like. Different resource allocation strategies can be applied to allocate the spectrum and to adjust the transmit power to optimize the overall system performance [5]. Significant studies have been conducted with a common objective of maximizing the aggregated data rate and adaptive channel borrowing for quality of service in wireless cellular networks [6], [7].

Our focus is to manage the existing resources in cellular network, by proposing new methods of resources allocation taking in consideration real time traffic either voice or data. The new generations of cellular networks however have long supported heterogeneous applications, which have highly diverse Quality of Service (QoS) specifications. For example, file sharing applications generally demand high data rate but can smoothly adapt to a wide range of data rates. However, maximizing the overall data rate without differentiating the needs of these applications can often lead to under- or over-provisioning. Moreover, since these works are not considering whether the UE is on the cell edge or not, they don't resolve the problem of the network coverage on the cell edge for voice or data traffic. Therefore, our research aims at provisioning of the resources we have and share them among voice and data traffic users, such that the network coverage is improved at the cell edge.

II. RELATED WORK

A lot of works have been done on this topic but most of them did not considered the user is near of far from the base station (BS), neither voice nor data. Many researchers are introducing D2D communication in cellular to improve the data rate. As long as D2D communication is concerned, Resource sharing can be done by either assigning a separate resource to D2D pairs or by reusing the same resource of the cellular users and use some strategies to avoid the interference. There are two kinds of resource allocation schemes, the first one is BS assisted and the second one is BS controlled[8].According to [9], the available resources in cellular networks with D2D links can be allocated in four modes such as Cellular mode, dedicated resource mode, reusing the resource of only one cellular user and reusing the resources of more than one cellular user.

The area of resource allocation optimization has received significant interest. In [9], the seminal network utility maximization problem is presented. The network utility maximization problem allocates the resources among users optimally based on bandwidth proportional fairness by using Lagrange multiplier methods of optimization theory. An iterative algorithm based on the dual problem has been proposed to solve the resource allocation optimization problem [10]. The applications considered in early research work, as in [8] and [10], are only delay tolerant Internet traffic for wired communication networks. However, for current cellular networks both real-time and delay-tolerant applications are considered. In this work we used the cell splitting into two parts the inner part and the outer part where we assign resources depending to which traffic concerned. Moreover we suggest a new method: "Orthogonal sharing method" in each part and we assign priority to either voice or data depending to whether a UE is located in inner part or the outer part of the cell. This improve the network coverage at cell edges since voice traffic are prioritized in outer part. The blocking probability is reduced since only UEs closer to the BS (Base station) are allowed to use both data and voice traffics

III. SYSTEM & MATHEMATICAL MODEL

A. *System Model*

In our methodology we consider the heterogeneous traffic with the system model in Fig.1 which is compared with the traditional cellular network alone. The UEs in inner part can use either data or voice communication where the data traffic has a higher priority compared to voice traffic. That is, if two UEs are requesting the resources for communication one of them with data traffic will be served at the first place. If there are still enough resources the later can be served as well. For the UEs in outer part, we only allow voice communication. Since they are far from the BS, their network coverage can be improved if we assume they are using only voice traffic with few resources blocks, without competing with the data traffic UEs.

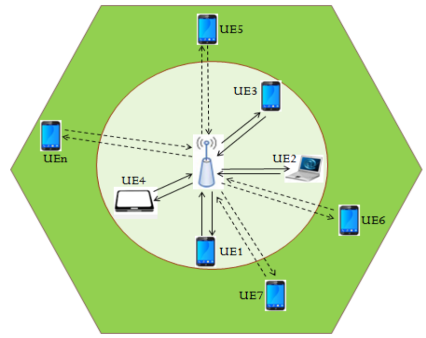

Fig.1: Heterogeneous traffic in cellular network.

As shown in figure 1, traditional cellular users in inner part are from UE1 to UE4 and can use either data of voice communication where the data traffic has a higher priority compared to voice traffic. That is, if two UEs are requesting the resources for communication one of them with data traffic will be served at the first place. If there are still enough resources the later can be served as well. The UEs from UE5 up to UEn are in the outer part and only voice communication is allowed for them.

In order to guarantee that radio resources are sufficiently allocated to data UEs in cell inner region, voice UEs located in cell outer region preferentially use the radio resource which cannot be used by voice UEs located in cell inner region. Figure 2, shows the procedure of how BS allocates the radio resources to data UEs in the proposed scheme.

B. *Mathematical model*

Our purpose in this section is to know how much resources can be assigned to both UEs in outer part and cellular UEs in inner part that minimizes the network congestion. We assume that more data traffics are generated than voice traffics in inner part. A comparative study with the traditional communication is envisaged.

Firstly, we use Erlang formula (1) to calculate the blocking probability in traditional cellular alone case and Engset distribution is used for the cellular inner (2) and outer area (3) since we assume a limited number of UEs.

$$B_C(A) = \frac{\frac{A^C}{C!}}{\sum_{i=0}^{C} \frac{A^i}{i!}}, \quad (1)$$

where C is the number of channels and A is the offered traffic load with parameter $\lambda$and H which represent the call arrival rate and mean holding time respectively ($A = \lambda * H$).Also i describes the number of iterations corresponding to the current number of channels and is varying from $i = 0$ up to $i = C$.

$$B_c(\beta_{inner}) = \frac{\binom{S_c-1}{C_c}\beta_{inner}^{C_c}}{\sum_{i=0}^{C_c}\binom{S_c-1}{i}\beta_{inner}^{i}} \quad (2)$$

$$B_v(\beta_{outer}) = \frac{\binom{S_{vo}-1}{C_{vo}}\beta_{outer}^{C_{vo}}}{\sum_{i=0}^{C_{vo}}\binom{S_{vo}-1}{i}\beta_{outer}^{i}} \quad (3)$$

Where B_c is blocking probability for the cellular inner part and B_v is blocking probability for cellular outer region.

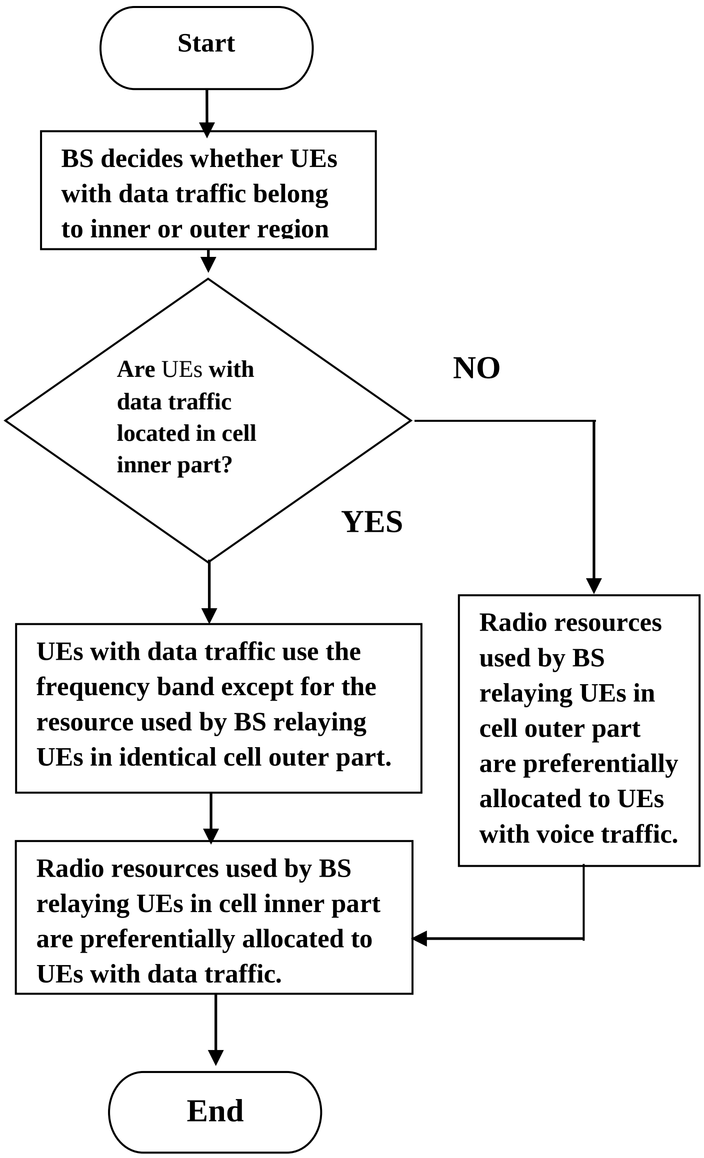

Fig.2: Resource allocation procedure for data traffic UEs

In Eq. (2) and Eq. (3), β_{inner} and β_{outer} represent the offered traffic per idle sources in the inner part and outer part of the cell respectively and according to [11, pp.139], are calculated as follow :

$$\beta_{inner} = \frac{A_{inner}}{(S_c - A_{inner})} \quad (4)$$

$$\beta_{outer} = \frac{A_{outer}}{(S_{vo} - A_{outer})} \quad (5)$$

Where, A_{inner} and A_{outer} are the offered traffic in inner part and in outer part of the cell respectively and their values are obtained from Eq. (6) and (7) below.

$$A_{inner} = (1-\alpha)A_{voice} + (\alpha)A_{data} \quad (6)$$

$$A_{outer} = \alpha A_{voice}\ , \quad (7)$$

Where, $A_{inner}+A_{outer} = A$ which is represented in Eq. (1) as total offered traffic in the whole cell. From Eq. (6) and (7) $\alpha \in [0\ 1]$ and denotes the percentage coefficient.

Secondly, the performance analysis of the proposed schemes was examined based on weighted cell utilization. The data rate is calculated within cellular network based on Shannon capacity, transformed with respect to OFDM techniques as shown in equation (8).

$$R_{lte} = B*(1-CP)*\log_2\left(1+\frac{SNR}{SNR*f+1}\right) \quad (8)$$

Where B is the bandwidth, CP is the cyclic prefix and f is representing the ratio of other-cell signal to own-cell signal [12]. SNR is the signal to noise ratio.

$$R_{inner} = (1-a)*B*(1-CP)*\log_2\left(1+\frac{SNR_{lte}}{SNR_{lte}*f-1}\right)+$$

$$M*a*B*\log_2\left(1\ \frac{SNR_{voice}}{SNR_{voice}*f+1}\right) \quad (9)$$

$$R_{outer} = (1-CP)*B*\log_2\left(1+\frac{SNR_{voice}}{SNR_{voice}*f+1}\right) \quad (10)$$

The formula of data rate is based on [4] and [13]. three kinds of data rate are Calculated. The first is the data rate when all users use LTE, Eq. (8). In this case, the cell is not split using our model, and there is no priority neither for data nor voice. The second data rate is when the cell is split in two part and users in inner part uses LTE for both voice and data, Eq. (9). The third data rate is represented in Eq. (10) which is the one in outer part where voice is the only prioritized traffic.

On these equations, SNR_{lte} is the SNR of LTE users, SNR_{voice} is the SNR of users generating voice traffic.

Our target is then to identify the optimal strategy to allocate the resources and to adjust the transmit power of the BS and UEs to maximize the weighted cell utility. The QoS-aware resource allocation problem can be formulated as follows:

$$WCU = (1-\lambda) * U_d.* R_{inner} + \lambda U_v.* R_{outer})$$

Subject to $P_i \leq P_{max}, \forall i \in \{1, 2, 3\}$,

$$P_B \leq P_{max}^B ,$$

Given U_d, U_v $\{U_1, \ . \ . \ . \ , U_K\}$, as the utility functions of the cellular data in inner and voice traffic in outer part. Here λ (0 < λ < 1) is the weight assigned to the cellular utility in inner part.

Given the file size of a specific task, the utility function thus depends on the data rate. Let R_{max}be the maximum achievable data rate and R be the used data rate, we have the utility function as

$$U = \frac{R}{R_{max}} \qquad (11)$$

IV. SIMULATION RESULT AND DISCUSSION

A. Blocking probability simulation result

In this work, we consider a single cell scenario split into inner and out part (see Figure 1).

Table 1 Simulation Parameters

Parameters &Symbols	Value
System bandwidth, B	10 MHz
Cell radius, R	1 Km
Range of f	0.5, 1
Percentage of dedicated BW for voice, a	0.4
Cyclic prefix percentage, CP	0.2
SNR of LTE users, SNR_{lte}	5 to 10
SNR of voice users, SNR_{voice}	10 to 20
Total number of all UEs in a Cell, S	200
Number of UEs in inner part, S_c	148
Number of voice UEs in outer part, S_{vo}	52
Total Offered traffic, A	1 to 60
Total number of Channels, C	60 RBs
Number of channels in outer part,C_{outer}	30RBs
Number of channels in inner part,C_{inner}	30 RBs
Reuse factor	3

The experiments were done taking in consideration two factors, blocking probability and weighted cell utility (WCU). Table 1 shows the simulation parameters to be used in three resource allocation methods envisaged: the dedicated mode, the reuse mode and the channel borrowing mode.

i. Result for Blocking Probability for Heterogeneous Traffics

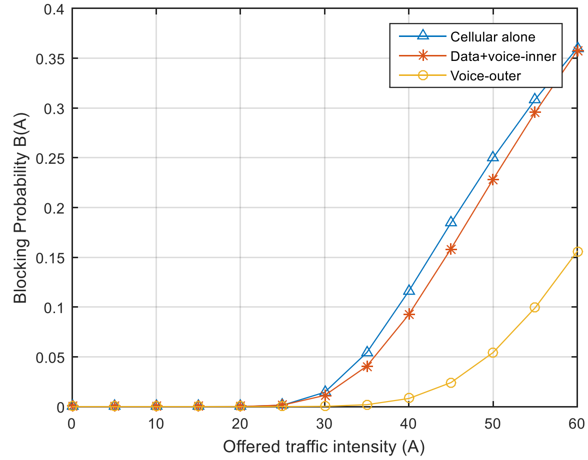

Fig.: Blocking probability for heterogeneous traffic 40RBs in inner part and 20RBs in outer party.

The Figure 3 represents blocking probability when we assign $40RBs$ in inner part and 20RBs in outer part, where α=0.8 in both cases. Recall that assumed more data traffic than voice traffic in inner party are considered as shown in Table 1 and 1RB per UE for voice is used for transmission whereas for data we use 2RBs per UE for transmission. The result shows that our method is more beneficial than in cellular alone. For instance, when the offered traffic intensity is equal to 40 we can experience a blocking probability less than 0.1. In general, these simulation results show that the number of RBs can be optimized so that the blocking probability may be kept at a minimum value which is more reasonable.

ii. Blocking Probability for Heterogeneous Traffics in reuse mode.

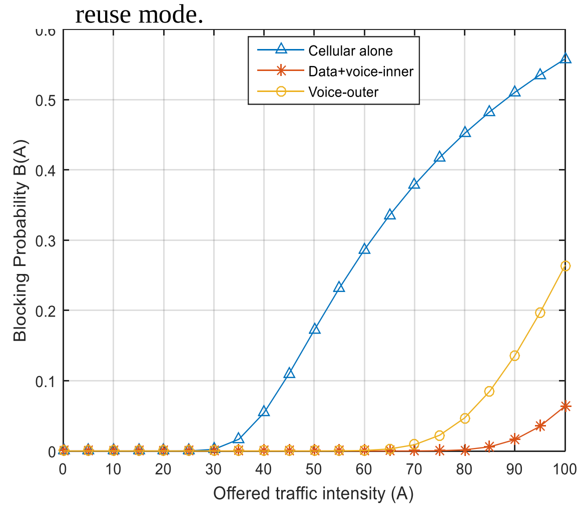

Fig.4: Blocking probability for heterogeneous traffic with reuse mode.

The simulation results shown in Figure 4 comparing the variation curves for cellular alone and when the cell is divided into the inner part with data and voice traffic, whereas the outer part is prioritized to voice traffic in reuse mode with reuse factor of 3.

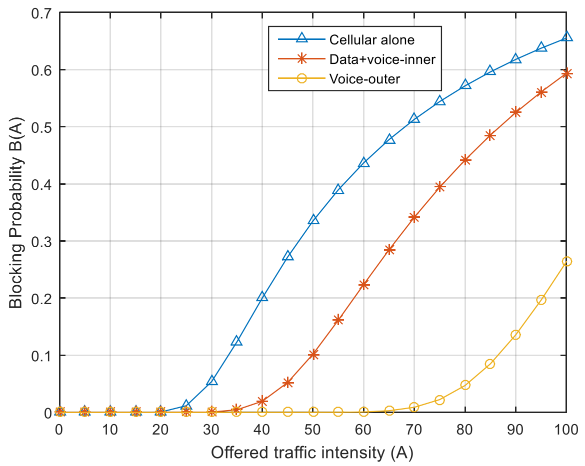

Fig.5: Blocking probability with borrowing

The curve shows that the UEs in inner part will communicate with minimum blocking probability compared to other. This is an improvement since the UEs in inner part are mostly using data traffic and this will ensure the proper and fair delivery of the routed packets or files transferred. On the other side the voice traffic in outer part is improved, which resolves the problem of cell edge network coverage.

iii. Blocking Probability for Heterogeneous Traffics in Borrowing Mode

In our simulation in borrowing mode, we assume that the voice traffic in outer can borrow a half of the resource in inner part. This will more improve the communication in outer part. In this case more resources are assigned to UEs in inner part which can results in many unoccupied channels which can be borrowed. The results in Figure 5 shows that the blocking probability is reduced compared to cellular alone.

B. Cell Weighted Utility for Heterogeneous Traffics simulation result

i. Optimal resource allocation and Data rate calculation with OFDM-based.

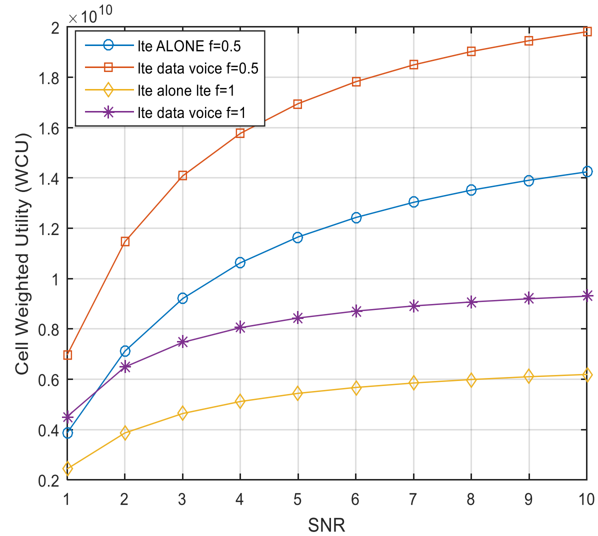

Fig.6: Cell Weighted utility (WCU) versus the SNR

The simulation results are shown in Figure 6 the two curves comparing the WCU for traditional cellular network and when the cell is split into two parts, for either f is 0.5 or 1, the data rate increases as the target SNR increases

ii. Result for Utilization and Resource Allocation with reuse mode.

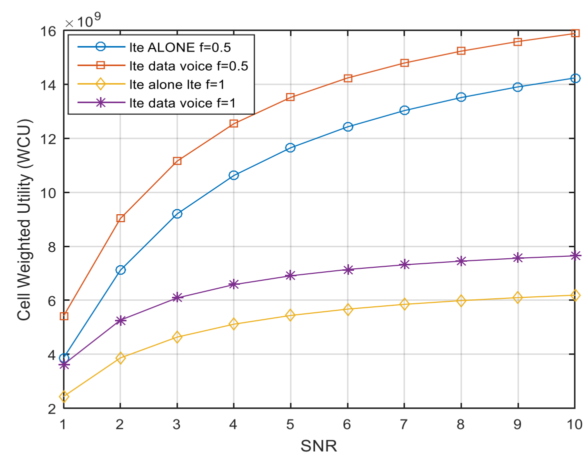

Fig.7: Cell Weighted utility (WCU) versus the SNR with reuse mode

As the curves show in Figure 7, the WCU with reuse mode, our scheme is more efficient compared to cellular alone. There are more benefits and the data rate is improved which results in higher weighted cell utilization when the cell is split into two part and we adopt the frequency reuse

iii. Utilization and Resource Allocation with borrowing mode

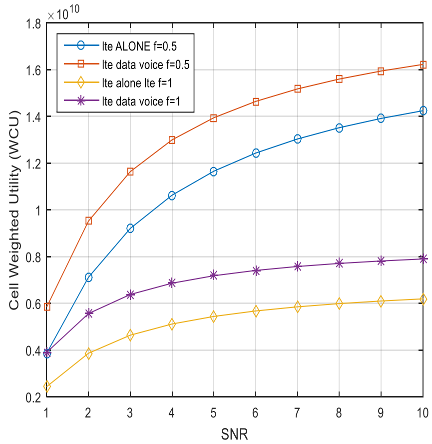

Fig.8: The voice traffic in outer part borrows the idle data resource from inner part

For the borrowing channel mode we use the assumption that one type of traffic either data or voice can borrow the idle resource of the other type. In Figure.8 we assume, that the voice traffic in outer part borrows the idle resource from inner part. For both curves with f equals 0.5 and 1, our proposed method has a WCU compared to cellular alone.

V. CONCLUSION

In this paper, it is presented that resource allocation optimization schemes for real time traffic in LTE network. We split the cell in inner part and outer part. Three resource allocation methods were envisaged. In the First case, both voice and data traffic is assigned separate resources and the communication is in a dedicated mode. In the second case, we assigned different resources but we allow the reuse of one of the traffic resources either voice or data. Lastly we propose the method of borrowing the idle resources depending to the UE transmitted power of new call arrival. The MATLAB simulation results showed that the performance of our proposed schemes is higher comparing to the existing one. In our future work, we will explore heterogeneous traffic more in order to know whether other techniques such as micro and femtocells can be more efficient if used for data or voice transmission.

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