A RESOURCE ALLOCATION APPROACH TO CONTROL INTERFERENCE IN MULTI -CARRIER –DS-CDMA SYSTEMS

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ABSTRACT

Resource allocation approaches play a very important role in improving the performance of a communication system. Load matrix (LM) [3] is a resource allocation approach used in single carrier mobile communication systems in a multi-cell scenario to reduce the interference (both inter-cell and intra –cell) to increase the system throughput decrease the packet delay. In this paper a resource allocation scheme called Modified Load Matrix (MLM) is proposed for Multi -Carrier –DS-CDMA systems .Simulation results show that using MLM there is a significant improvement in throughput and packet delay of the system compared to bench mark schedulers.

Keywords: load matrix, modified load matrix, resource allocation, interference, packet delay.

1. INTRODUCTION

Resource allocation Schemes find their importance in emerging cellular communication systems in providing better quality of service (QoS) to the users in using wide range of services and applications. To provide required high data rates with less inter symbol interference it is advantageous to use multi –carrier cellular systems rather than single carrier cellular systems.

Different resource allocation strategies are developed in the past mainly for downlink and be obtained from the references [5-10]. In [5] a scenario of users with various traffic classes were taken and resource allocation approach is used to decrease the power consumption or leads to increase the capacity of the system. In [6] a allocation approach method is proposed in total resource is partitioned using a fixed portioning scheme over users of different service classes and independent resource schedulers are used to share the resources between different users in a service class. In [7] an approach is used to maximize the quality of service of the users where partitioning approach is dynamic. In [8-10] the resource allocation approach is based on the utility function ,in [8] for resource allocation utility function used is pricing, in [9], utility function used is QoS and in [10] to dynamic pricing is used as utility function in downlink to increase the summation of all users utility.

In [11], to improve the spectral efficiency on the link level it is proposed to use the adaptive type of transmission and using this in [12] a fast scheduling approach with adaptive modulation and coding is proposed to improve the QoS of the users which takes the channel conditions into consideration. Resource allocation approaches based on the adaptive transmissions is recommended for low mobility user environment only.

Uplink resource allocation methods are classified as centralized and decentralized, in centralized type of approach the scheduler lies in centralized controller and in decentralized approach the scheduler lies in each of the base station. As the transmit power of the user terminals is limited [17], the uplink cell/Base station (BS)/eNodeB capacity of the interference limited system is restricted by the total received power at the base station. It is noted that in single-carrier cellular systems that resources are allocated to the users for every transmission time interval (TTI) in a priority basis up to a moment the parameter called Rise Over thermal noise (RoT) is below a threshold value set by the network. In [2],[24] the performance of centralized scheduling is analyzed and in [2][25] the analysis of decentralized scheduling is presented and also the comparison between two is presented. It is noted that under heavily loaded systems the centralized scheduling is better than decentralized scheduling and this situation arises because the decentralized scheduling are vulnerable to inter-cell interference. Hence the decentralized scheduling algorithms have less performance in terms of interference outage. The inter-cell interference is the interference produced at the given base station by the other base stations. In literature a variety of interference mitigation techniques are available such as multi-user detection (MUD)[19],interference cancellation(IC)[20] and antenna beam forming[21], and succeeded to reduce the intra-cell interference to a large extent and inter-cell interference to a small extent since base station has a little knowledge on it. It is noted from [22] that the combination of MUD with MMSE serves the need and considered to an effective interference suppression technique. From [23] it is noted that MMSE-MUD performs well for single user MC-CDMA system. In [3], the effect of interference is reduced and controlled even in highly loaded conditions using a resource allocation approach called LM and by keeping the RoT under threshold value. RoT is a parameter which takes into account the effect of interference to a base station from the other base stations. LM approach also proposes a global priority function which considers the channel condition in giving priority to the users which are not admitted into the network or which are waiting for resources. It is also noted that LM approach no longer works for multi-carrier systems since the load on subcarriers vary differently.

In [4], [28], [29], a new parameter called Interference over thermal noise (IoT) is used to control the performance of the multi-carrier communication system.

Using this parameter IoT a modified load matrix (MLM) approach which is an extension for LM approach but applied for multi-carrier systems.

In section II ,system model and the calculation of IoT in a muti-cell scenario is presented , in section III the resource allocation problem is discussed in detail ,section IV the MLM approach is presented, section V gives the performance of MLM approach for MC-CDMA systems in compliance with 4G standards[1][2],and in section VI conclusion and future scope is presented .

2. SYSTEM MODEL AND IOT

Multi-carrier spread spectrum can be realized using two schemes. The first realization scheme is MC-CDMA which is a referred to as CDMA-OFDM and second is MC-DS-CDMA. In both schemes, by using different spreading codes which are user specific, the different users utilize the same spectrum at the same time and the separation of the user signals is carried out in the code domain. Moreover, to reduce ISI multi-carrier modulation is used by both schemes to condense the symbol rate and amount of ISI per sub-channel. The difference between MC-CDMA and MC-DS-CMDA is the allocation of the chips to the sub-channels and OFDM symbols. In this paper a Multi-carrier –DS-CDMA (MC-DS-CDMA) mobile communication system is considered with N cells and$M$ users in each cell where the radio access technology used in uplink and downlink is MC-DS-CDMA. MC-DS-CDMA refers to the modulation scheme which involves the multi-carrier transmission of DS-CDMA signals.MC-CDMA simultaneously transmits a user's data symbol over a various sub-channels of very narrow band width. The chips of the user-specific spreading code are multiplied by these narrow band sub-channels. OFDM is used to realize the multi-carrier modulation. In MC-DS-CDMA a serial to parallel convertor is used prior to user-specific spreading on each sub-channel with a code spreading. This is done to convert the incoming high rate data into parallel low rate sub-streams in the time direction, which relates to direct sequence spreading on each sub-channel. These systems with narrowband sub-channels use more numbers of sub-carriers and can be implemented by using the OFDM operation. The main reason to use MC-DS-CDMA is it is having advantage of Low peak to average power ratio in uplink than MC-CDMA [27]. In this paper a MC-DS-CDMA mobile communication system in a multi –cell scenario is considered, let M denote the number of cells or base stations or eNodeB in the network each consisting of N active users and$K$ be the number of sub-carriers used in the MC-DS-CDMA. The IoT of a cell$i$at a given TTI 'w' denoted as $IoT_{i,w}$is calculated as follows.

$$IoT_{i,w} = \frac{u + v + N'}{N'} \tag{1}$$

Where

u- The total received power at eNodeB i due to the active users in the given eNodeB i y - the total received power of users in all eNodeB excluding eNodeB .

$$u = \sum_{j=1}^{M} (\sum_{sc} p_{j,sc} * G_{j,sc}) \tag{2}$$

$$v = \sum_{j=1, k \notin eNB_i}^{M} (\sum_{sc} p_{j,sc} * G_{j,sc}) \tag{3}$$

$p_{k,sc}$ -subcarrier power,

$G_{k.sc}$ - The sub carrier channel gain.

N'- Thermal noise power.

The term v is referred to as an inter-cell interference to the given eNodeB $i$in the uplink. The effect of inter-cell interference is observed using a definite simulation scenario .In each cell 5 users with full buffer are waiting for transmission. The IoT characteristic under this scenario is as shown in the Figure-1.

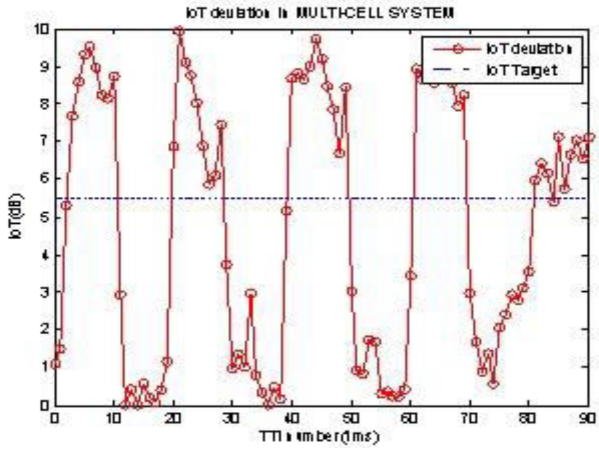

Figure-1. IoT fluctuation in a multi-cell system.

3. RESOURCE ALLOCATION PROBLEM

The resource allocation strategies are developed to improve the performance of the system in terms of throughput and packet delay whilst providing promised QoS to the users. The resource allocation problem in mobile communication system is formulated as a NP-hard problem [15]. A basic scenario in which assigning of rate and time to users is considered which aims at throughput maximization. Initially the resource allocation problem is formulated and analyzed in a single cell-scenario and then the multi-cell case. Consider a candidate rate set of a user j labeled as $s_j$from which the user can choose one of the required rate at that scheduling instant. For M active users in a cell consider a set S which is union of all the candidate rate sets of all users. It is taken that the rates in different CRSs are independent to each other even if they have the same value. A binary variable $z_t = 1$ indicateswhether an element is chosen from set S and if

$z_t = 0$ the element is not chosen from set S.If chosen let it leads to a generated throughput and consumed capacity p_t and c_t respectively for the cell. If element t is chosen from set S then p_t equals the transmission rate itself and c_t interpreted differently represents the amount of base station power has consumed to produce this capacity or equivalently the Load factor [14] based on the type of the system. Under these assumptions the single -cell resource allocation problem (SCRAP) can be mathematically formulated as follows

Given a condition of the system described by traffic, user location, cell capacity SCRAP deals with how to choose elements for active users from their CRSs so as to maximize the throughput subjected to the following constraints C_1 and C_2. C_1 and C_2 indicates the available cell capacity and only one element to be chosen from every CRS.

$$maximize: p = \sum_{t \in S} p_t x_t \quad (4)$$

Where p indicates the aggregate throughput
Subject to:

$$\sum_{t \in S} c_t x_t \leq C_1 \quad (5)$$

$$\sum_{t \in S} x_t = 1 \quad (6)$$

SCRAP is a NP-hard problem and can be solved using solving procedure of classical Multiple choice Knapsack problem (MCKP)[15].MCKP can be expressed as follows given an item set which in turn divided into a finite subsets , how to choose items from the subsets so as to maximize the aggregate weight of the Knapsack without exceeding the holding capacity of Knapsack and also choosing only one item from each subset. Considering the available capacity of cell as Knapsack capacity and the items chosen to be the transmission rates the SCRAP can be viewed as MCKP. In MC-DS-CDMA mobile communication systems the resource allocation problem relates to the allocation of finite number of subcarriers to the users which in turn forms the CRS.For a multi-cell case, let the interested area is covered by N cells , $i \in \{1,2 \dots N\}$ and let the number of active users in every cell is indicated by m_i and the total no of users is $M = \sum_{i=1}^{N} m_i$and the multi-cell resource allocation problem (MCRAP) can be described as follows

$$maximize: p = \sum_{t \in S_i} p_t x_t \quad (7)$$

Subject to:

$$\sum_{t \in S_i} c_{t,i} x_t \leq C_{1,i} \quad (8)$$

$$\sum_{t \in S_i} x_t = 1 \quad (9)$$

Where $C_{1,i}$ represents the available cell capacity for cell i.

4. MODIFIED LOAD MATRIX

Modified load matrix (MLM) resource allocation strategy is considered as an improvement to the resource allocation strategy Load matrix (LM) which is proposed for single-carrier systems under multi-cell case .It is noted that LM is based upon a parameter called RoT in controlling the interference (both intra and inter cell) in distributing the available radio resources and also has proposed a global priority function for scheduling the users waiting in queue in the next scheduling instant or TTI . It is also noted that RoT averaged is not a appropriate parameter to analyze the interference effect in multi-carrier systems where the load in subcarriers vary differently. It is noted that inter-cell interference is predominant in uplink since a base station has no knowledge of the inter-cell interference. For multi-carrier systems a parameter called interference over thermal noise (IoT)[4][28][29] is considered to analyze the effect of inter-cell interference in uplink .In this paper ,allocation of resources (rate and power)to the active users in a cell at a given TTI or scheduling instant is done so as to satisfy the specific constraints on power, SINR and calculated IoT in the cell. As the resources are allocated using the MLM the IoT do not exceed the target value and consequently the inter-cell interference is controlled. The MLM resource allocation approach can be describes as follows.

Given multi-cell MC-DS-CDMA system with N cells and a total of M users in the network with each cell im_i, for allocation of radio resources to a user j in cell i the constraints to be satisfied are

Constraint 1: For each active user j in the network the transmit power p_j should less than P_{max} represented as follows

$$0 \leq p_j \leq P_{max} \quad (10)$$

and in MC-DS-CDMA system ,if a finite no of subcarriers are assumed to be allocated then the power p_j will be equally distributed over the various subcarriers.

Constraint 2:The calculated $IoT_{i,w}$ at every cell i by allocating powers to various users in all the cells should not exceed the IoT_{target} and can be represented as follows

$$IoT_{i,w} \leq IoT_{target} \tag{11}$$

Specifically IoT_{target} is set by the network operator in this paper the assumed value for simulation is 5.3 dB.

Constraint 3: For every active user depending on the channel condition, rate chosen there will be $SINR_{target}$ required and the SINR attained by the approach should be greater than $SINR_{target}$
and can be represented as follows ,for a user j in cell i

$$SINR_{j,i} \geq SINR_{target} \tag{12}$$

Specifically $SINR_{target}$ depends on the user mobility (Doppler effect),Load factor, Block error rate(BLER),Modulation and coding scheme chosen for transmission. Load factor indicates the available cell capacity of a cell and is related to SINR as follows

$$Load\ factor = {SINR}/{1+SINR} \tag{13}$$

Modified Load matrix is viewed as a matrix which is of order M by N and contains load factors of all the users. MLM approach can be implemented both in centralized and decentralized manner. In this paper centralized scheduling is considered as it is best to control interference in heavily loaded systems.
The Load factor [14] contribution of a user j in cell i is expressed as follows

$$MLM_{j,i} = \frac{\sum_{sc} p_{j,sc} * G_{j,sc}}{N' + \sum_{j=1}^{m_j}(\sum_{sc} p_{j,sc} * G_{j,sc})} \tag{14}$$

Using Equation. (14) the IoT of cell i at TTI w denoted by $IoT_{i,w}$ is calculated as follows

$$IoT_{i,w} = \frac{1}{1 - \sum_{j=1}^{m_i} MLM_{j,i}} \tag{15}$$

Where m_i are the total no of users in cell i.

$$\text{Also } SINR_{j,i} = \frac{\sum_{sc} p_{j,sc} * G_{j,sc}}{N' IoT_{i,w} - \sum_{sc} p_{j,sc} * G_{j,sc}} \tag{16}$$

In, MLM resource allocation let $p_{j,k}$ be the power to be allocated to a user j for attaining a k transmission rate. Starting with the maximum rate (k=K), power constraint specified in (10) must be satisfied and for the given rate the $SINR_{j,i}$ can be replaced by $SINR_{target,k}$ so as to satisfy the SINR constraint specified in (12) and recall that MLM aims to keep the IoT in a cell i close to IoT_{target} . Hence rearranging the (14) by replacing $SINR_{j,i}$ and $IoT_{i,w}$ with $SINR_{target,k}$ and IoT_{target} respectively (16) becomes

$$p_{j,k} = \frac{N' IoT_{target,k} SINR_{target,k}}{\sum_{sc} G_{j,sc}\ [1 + SINR_{target,k}]} \tag{17}$$

The power allocated to the user for rate k is given in (17) and additionally it should satisfy constraints specified in (11)(12) once it is allocated to the user and then $MLM_{j,i}$ is to be updated . If above $p_{j,k}$ do not satisfy the constraints then MLM works the same procedure with next highest rate possible. This process is done in a network controller for all the active users in all the cells and MLM matrix is updated. If for some active users, the network controller cannot allocate power in the given scheduling instant then they are kept waiting in a queue and given priority in the next instant according to a Global priority function which sets highest priority to the users with best channel condition, doing so the throughput can be increased with the analogous concept of water filling bucket algorithm. The MLM can also be used with different benchmark schedulers like Round Robin, Proportional fair, Max C/I etc.,. The Global priority function proposed in MLM approach is expressed as follows

$$priority_{j,i} = \frac{\sum_{sc} G_{j,sc,i}}{\sum_{n=1,n+i}^{N} \sum_{sc} G_{j,sc,i}}, \tag{18}$$

(18) represents priority assigned to user j in cell i.

MLM uses marginal concept for constraint 2 ,that is a user is allocated resources if IoT_{target} of serving node lies in $\pm\gamma$ % with respect to intra -cell interference i.e., considering it is single cell case and$\pm\mu$ % with respect to multi-cell case considering inter-cell interference. The step by step procedure of MLM algorithm is given in Table-1.

5. SIMULATION RESULTS

The MLM approach for MC-DS-CDMA systems is simulated in compliance with 4G LTE standards .The simulation parameters used are given in Table-2, the total simulation of this approach was done using MATLAB incorporating the library functions of communication system tool box and signal processing tool box and LTE system tool box as required for the algorithm. The MLM scheduler uses marginal concept i.e., checking for a region around the $IoT_{\ target}$rather than checking for fixed $IoT_{\ target}$. Two marginal variables are used in the algorithm called as intra-cell margin amd inter-cell margin where for every round of power, data rate (number of subcarriers/RB) to a user the scheduler checks whether the IoT is below the specified intra-cell margin and inter-cell

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margin. The Variation of IoT in MC-DS-CDMA mobile communication system in a multi-cell scenario with MLM by considering intra-cell and inter-cell margin combinations of [-0.5%, 1.5%], [-0.5%, 0.5%] and [0.5%, 1.5%] is plotted in figure 2, 3, and 4 respectively with MLM and without MLM. It is observed that in all the combinations the probability of IoT is more with MLM in and around the set margin of intra-cell and inter-cell which indicates that using MLM the interference outage performance is more with MLM.The aggregate throughput performance of the MC-DS-CDMA mobile communication system is observed with the each of the above combinations of intra-cell and inter-cell margin and compared with the benchmark schedulers used in LTE such as round-robin(RR),first maximum expansion(FME), minimum area difference (MAD) and plotted in Figures-5, 6 and 7. The comparison of packet delay performance of the MLM scheduler is with the standard schedulers is plotted in Figure-8.It can be noted that from the plot of packet delay that using MLM there is a more probability of getting less delay i.e., less than <10TTIS more frequently in heavily loaded conditions than the other bench mark schedulers.

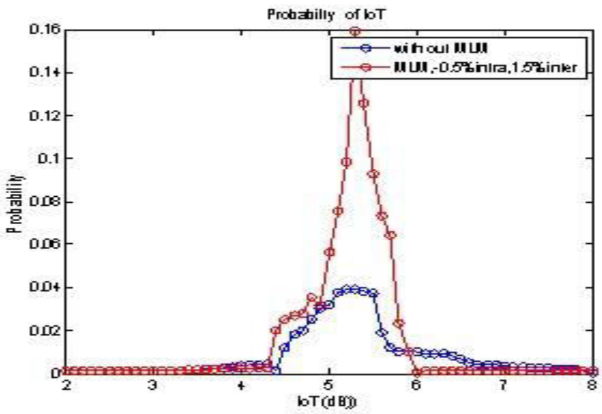

Figure-2. Probability density function of IoT.

With combination of -0.5%intra cell and 1.5%inter-cell margin

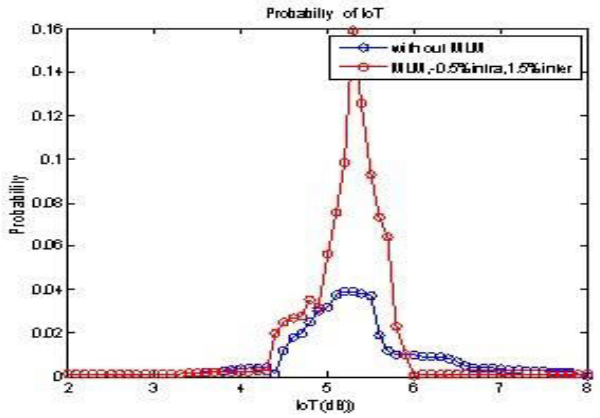

Figure-3. Probability density function of IoT.

with combination of -0.5%intra cell and 1.5%inter-cell margin

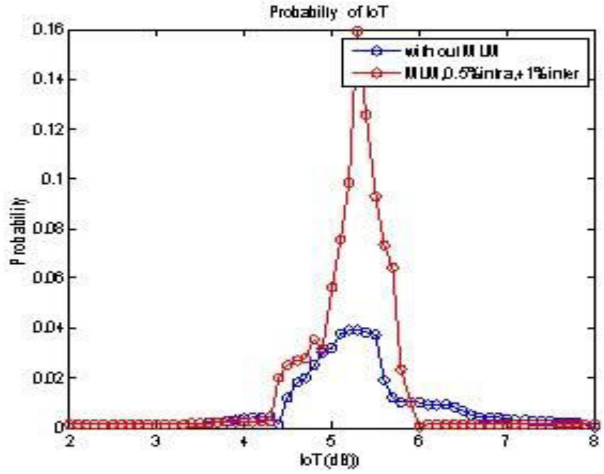

Figure-4. Probability density function of IoT.

with combination of 0.5%intra cell and 1.5%inter-cell margin

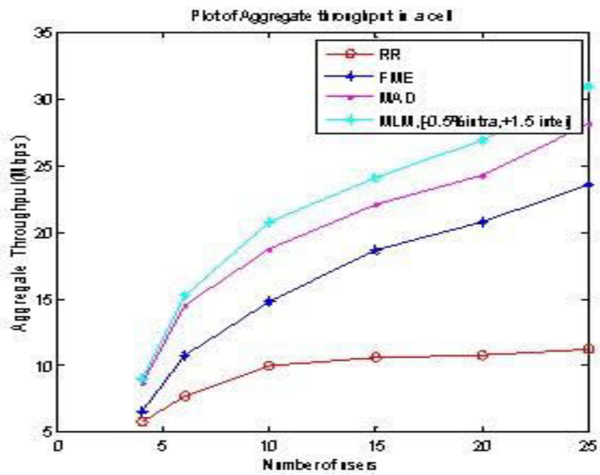

Figure-5. Comparison Aggregate throughput in a cell with MLM (-.5%intra,1.5%inter) and bench mark schedulers used in LTE.

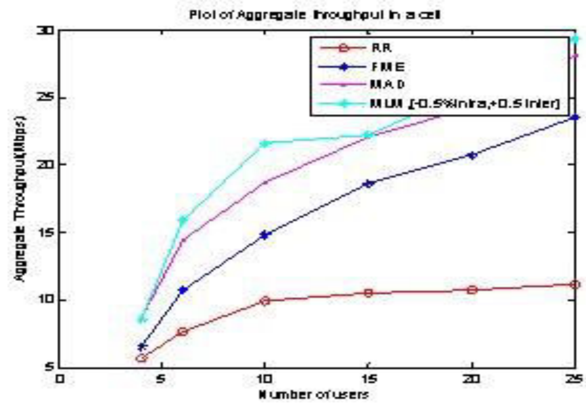

Figure-6. Comparison Aggregate throughput in a cell with MLM (-.5%intra,1.5%inter) and bench mark schedulers used in LTE.

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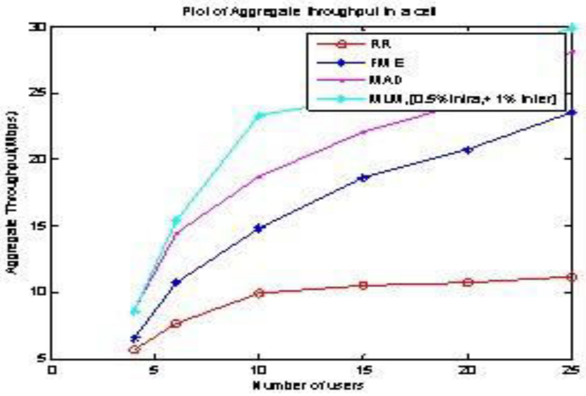

Figure-7. Comparison aggregate throughput in a cell with MLM (0.5%intra, 1%inter) and bench mark schedulers used in LTE.

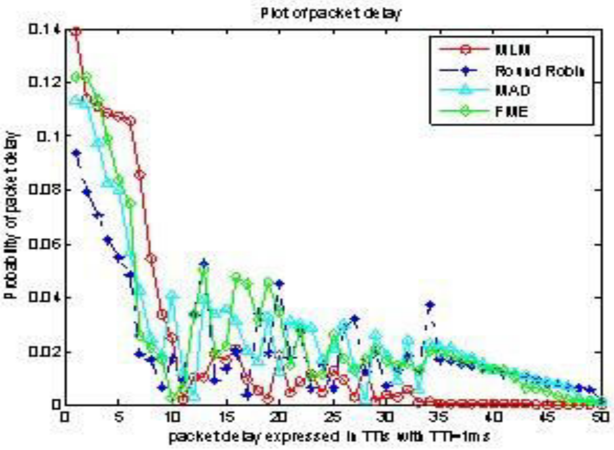

Figure-8. Comparison aggregate throughput in a cell with MLM (0.5%intra, 1%inter) and bench mark schedulers used in LTE.

Table-1. MLM algorithm.

```
Initialize MLM[i,j] to zero
for cell j=1:N
   for user[i] in cell[j]
      set priority[i,j] as in (18);
   end
set all users in cell[j] according to priority[i,j]
end
for assignment round=1:Number of users per cell
   for cell j=1:N
     for the highest priority user[i] in cell[j] if
MLM[i,j]=0
      for data rate of user k, r_k=Max possible: Min
possible
        get p_k using (21);
           (constraint 3 is already satisfied)
          Next data rate cnst3 is not satisfied)
         Check IoT[j] with "intra-cell margin";
         Next rate if constraint 2 is not satisfied;
   Check for all other IoT[:]with "inter-cell margin"
          Next rate if constraint 2 is not satisfied
                Update MLM[i,j];
end;
end;
remove user[i] from sorted users of cell[j]
end ;end;
```

Table-2. Simulation parameters.

Parameter	Value/Description
Number of eNodeBs	5
Number of users per cell	25
Channel Band width	5 MHz
Carrier frequency	2GHz
No. of primary resource blocks	25
No. of subcarriers in RB	12
Spreading sequence	Walsh-Hadamard
Spreading Factor	8
Sub carrier spacing	15kHz
Path loss model	128.1 + 37.6 log10 d, d: distance from the eNodeB (km)
Modulation and Coding Schemes	QPSK 1/2, 16-QAM 1/2, and 64- QAM ¾
Maximum UE transmission power	23 dBm
Minimum UE transmission power	-43 dBm
Fading	Rayleigh
IoT target	5.3 dB

6. CONCLUSIONS

The MLM resource allocation strategy is proposed for MC-DS-CDMA systems in compliance with 4G LTE standards. The interference outage performance of the system is reduced by using MLM and the aggregate throughput and packet delay is signiccantly improved using MLM strategy compared with the other bench mark schedulers used in LTE.

The proposed strategy performance can be enhanced by constraining the quality of service (QoS) of the active users. The performance analysis of QoS-constrained MLM (QoSMLM). In MC-DS-CDMA mobile communication systems remains as future study.

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