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IMPACT OF MIMO SCHEMES OVER QOS BASED INDEPENDENT CARRIER SCHEDULING ALGORITHM FOR DOWNLINK 5G LTE-ADVANCED NETWORKS

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ABSTRACT

Carrier Aggregation (CA) and Multi-Input Multi-Output are a promising techniques which invented by 3GPP to support next generation of all IP mobile networks "5G Long Term Evolution-Advanced (LTE-A) network" with extreme virtual bandwidths, for providing unprecedented speed of transmission rate and minimal latency. To the best of our knowledge, an efficient user-level QoS provisioning for multi-services multi-users deployment scenario is of vital importance in 5G LTE-A systems. One of the main challenges to meet the user level Quality-of-Services (QoS) demands for diversified services "Real-Time (RT) and Non-Real-Time (NRT) traffic" is to offer robust and suitable resource scheduling algorithm. However, different MIMO system schemes have various delays in the feedback reporting, resulting lead degradation in QoS performance where accurate feedback is difficult to achieve. In this paper, authors investigate the impact of divers MIMO schemes on the proposed QoS based Independent Carrier Scheduling (QoS-ICS) algorithm in order to find the optimum transmission mode which is exploited for guaranteeing the user QoS performance among different users. Firstly, the QoS-ICS exploits the round robin with service concept which assigns the CCs among users equally based on the user's service. Secondly, for PRBs-Scheduler, the adopted user-level QoS aware packet scheduling relies on different service utility factor was computed in order to achieve QoS performance. Furthermore in this paper, two different MIMO system schemes are considered, Open Loop Spatial Multiplexing (OLSM) and Closed Loop Spatial Multiplexing (CLSM). Simulation results reveal that the proposed QoS-ICS scheme has achieve the QoS requirements for real-time users and meets the user's throughput demands of NRT streaming video, especially in CLSM transmission scheme when compared with conventional ICS algorithm.

Keywords: *Carrier Aggregation (CA), MIMO Schemes, 5G, LTE-Advanced, ICS, QoS-ICS, Service Utility Factor, OLSM, CLSM.*

1. INTRODUCTION

Recently, with the enormous growth of the wireless broadband applications such as, mobile TV, video streaming and social network applications, the number of mobile users has been increased [1]. Based on the application type that accesses by the user, real-time or non-real time, each Mobile User (MU) has diversified QoS constraints [2]. In order to insure the adequate user-level QoS for mobile users which were crucial concern in the preceding generation of wireless mobile network, the demand for extreme spectrum bandwidth to the users is imperative [3]. Therefore, for insuring the outburst of higher peak downlink throughput, the 3GPP has proposed the aggregating frequency band technique, namely, Carrier Aggregation for LTE-A wireless networks. Meanwhile, the CA is exploited as a solution for obtaining 100 MHz (dis-) contiguous bandwidth expansion in order to support high data rate of 1Gbps and 100Mbps for low and high mobility respectively [4]. As a result, the MU can be able programmed to aggregate numerous Component Carriers (CCs) that are in the same or diverse bands to exploit frequency spectrum efficiently.

Furthermore, for achieving the LTE-Advanced network performance, several research works have

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been conducted on the resource scheduling based on CA technique according to the literature survey. The load balancing schemes were introduced by [5, 6] to assign CCs among MUs, while the physical resource blocks of each CC are scheduled based on the packet scheduling algorithm in order to optimize the coverage functionality and radio resource distribution fairness among users. Going by [7], the authors proposed an improved the well-known Proportional Fair scheduler based CA LTE-Advanced system to address the radio scheduling problem for achieving multi-services multi-users performance and pursues to prevent starvation for any MU in the network. As well in [8], the authors proposed the joint radio resource reserved PF strategy with power allocation scheme in order to meet the mobile system capacity. While the study demonstrated in [9] has proposed the joint CC, RB and power allocation (JCRPA) scheme that allocates CCs and PRBs in dynamic manner with fixed power assignment for optimizing the system utility. Moreover, it exploited the multi level water-filling power allocation scheme in order to improve the power of a specified CC and RB assignment for achieving the system fairness. A novel greedy-based algorithm was introduced by [1], which allocates PRBs of each CC with its associated MCSs to users at each transmission time interval for maximizing the system-level QoS. However, for satisfying the fairness among different kinds of users “LTE and LTE-A users”, the authors in [10] proposed the novel Cross-CC proportional fair by introducing a weight factor that is based on the number of CCs assigned to users for RBs scheduler. As well as, it is optimizing the system throughput. Finally, an efficient RB allocation algorithm (ERAA) was proposed in [11] which consider the link adaption jointly with the CC selection and RB assignment. ERAA computes the utility function of all combinations of users, CCs, and MCSs at each TTI, resulting significantly achieves for the system throughput and fairness while computational complexity increases a little bit.

According to the above studies, the system-level QoS performance has been achieved, whereas in multi-services scenario “RT and NRT”, the user-level QoS performance under various MIMO transmission strategies has not been researched in depth, where the user performance has been affected by various several antenna methods. Thus, in this paper, the authors design a novel QoS-IC Scheduling algorithm which achieves the user-level QoS demands. Moreover, the proposed scheme is compared with a classical ICS scheme under impact of different MIMO schemes in order to analyze the performance of QoS-ICS scheme.

The rest of this paper is organized as follows. Section 2 shows the system model. Section 3 explains the concept of Multi-Carrier Radio Resource Management Framework. Section 4 the services classes and their QoS requirements are illustrated. Section 5 demonstrates a brief review of the conventional Independent Carrier Scheduling (ICS) algorithm. Section 6 the analysis of proposed radio resource scheduling scheme is discussed in detail. Section 7 explains the impact of MIMO system Schemes on QoS performance. Section 8 depicts the simulation setup and outcomes. Finally, the conclusion is given in Section 9.

2. SYSTEM MODEL

OFDMA based Carrier Aggregation LTE-A system is considered for downlink transmission, in order to achieve excellent immunity to frequency selective fading and completely omit the chance of inter-symbol interference of the radio channels, where the K mobile users can be served on M CCs of the frequency spectrum by the base station (eNB) [12]. Each MU is capable to receive data from a single or numerous CCs. Regarding the signal computational intricacy and the power saving at MU, it is efficient to have MU jointing to CCs as less as possible [13].

According to the time domain as depicted in Figure 1, 10 consecutive sub-frames with 1 ms long for each form the physical frame structure of each CC. Furthermore, each sub-frame is splitted into equally 2 time slots which are able to convey 6 or 7 OFDM symbols for each slot based on whether the normal or extended cyclic prefix is employed. Whereas in frequency domain, each time slot consists a numerous of PRBs depending on the utilized bandwidth which specified by LTE-A system. The PRB is the smallest unit of resource distribution allocated by a scheduler which spans 12 consecutive subcarriers spacing of 15 KHz for one time slot [14].

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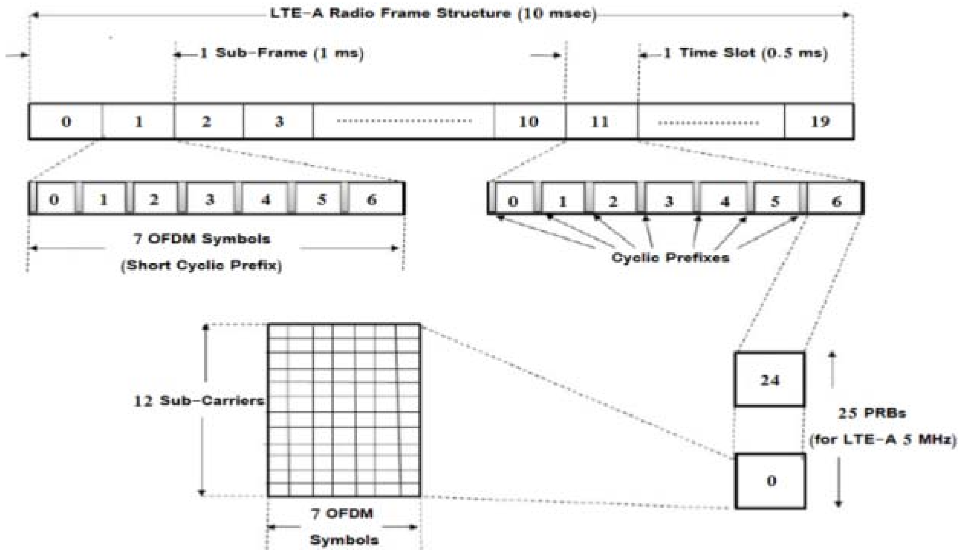

Figure 1: OFDMA Technique in LTE-A System

All PRBs occupied by connected MUs are managed by the resource scheduler (RS) as demonstrated in Figure 2. Each RS has merely one Resource Pool (RP) which composed of PRBs that belong to the CCs handled by this RS. Based on the applied CS scheme, the number of CCs which controlled by each RS can be one or numerous. Specially, the PRB of each component carrier can only be allotted to one of the RSs. For each MU, there is a Serving Queue (SQ) in each RS to accumulate data separately in provisional buffers. Once a new MU is allocated to the RS, the buffer is established, and removed when the transmission is completed. At each Transmission Time Interval (TTI), RS schedules the PRBs in its RP by packet scheduling policy, such as Best CQI, Proportional Fair (PF), and so on [13].

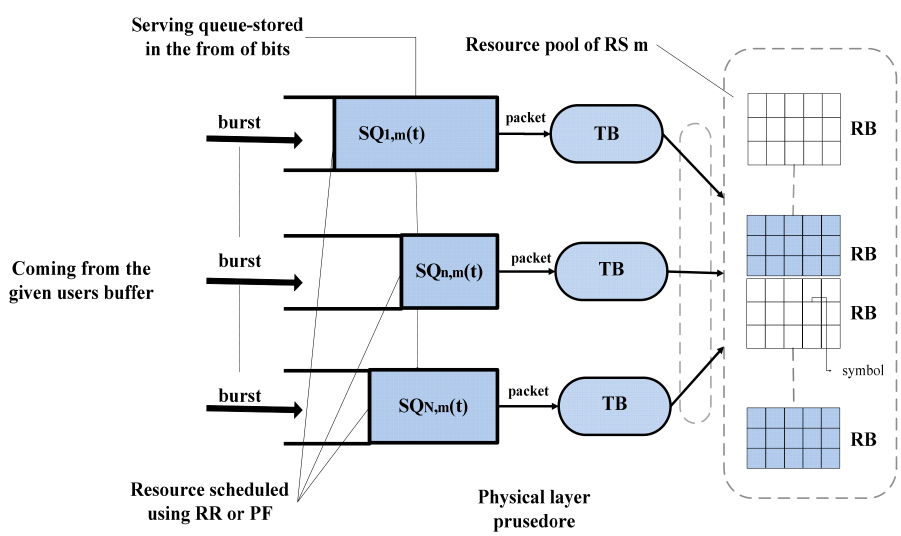

Figure 2: Framework of the Resource Scheduler Based CA

3. MULTI-CARRIER RADIO RESOURCE MANAGEMENT FRAMEWORK

In Carrier Aggregation based LTE-Advanced network, a new functionality referred as CC assignment is introduced in RRM. In order to allocate the available resources over the whole spectrum, the scheduling metric is calculated across the aggregated CCs. The main concept of the RRM procedures is illustrated as follows [15]:

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- Admission Control (AC): according to the user channel state and requirements of QoS, the admission decision is made for each user.
- CC Assignment: each user is able to allocate on one or more CCs based on the user's terminal type.
- Packet Scheduling (PS): once the users are allocated to the CCs, the process of PRBs distribution is performed.
- Link Adaption (LA): in order to satisfy certain requirements of spectral efficiency and Block Error Rate (BER) obligations for each allocated user, a suitable Modulation and Coding Scheme (MCS) is selected.

4. SERVICES CLASSES AND QOS REQUIREMENTS

In 3GPP standard [16], the broadband services that are available in mobile networks have been classified into four classes according to the user experience class and service classes that are similar in terms of required QoS as follows:

- Conversational Class
- Interactive Class
- Streaming Class
- Background Class

As shown in Table 1, each service class consists a group of services which have the same QoS feature. Each service is either delay sensitive that has very strict delay requirement or delay insensitive that permits relatively high delay.

Table 1: Services Classes

User experience class	Service classes
Conversational	Voice telephony, video conference.
Interactive	Internet browsing, e-mail.
Streaming	Buffered video streaming, live video streaming.
Background	Messaging, Video messaging

However, the user-level QoS parameters for different classes are configured in all LTE-Advanced network nodes in order to support a wide range of services. Table 2 gives the QoS parameters of various traffic types defined by 3GPP [17].

Table 2: QoS Parameters for Various Classes

Services	Packet Delay Budget	Packet Error Loss Rate
Voice telephony	100 ms	10^{-2}
Live streaming	150 ms	10^{-3}
Real-time gaming	50 ms	10^{-3}
Video buffered streaming	300 ms	10^{-6}
IMS signaling	100 ms	10^{-6}

5. CONVENTIONAL INDEPENDENT CARRIER SCHEDULING SCHEME

ICS manages each CC autonomously as demonstrated in Figure 3, so each CC in the system should have separate RS to store its own PRBs [18]. Consequently, ICS restrictions the MUs to receive from a single CC. Obviously, ICS demands two-level radio resource scheduling, "CC-level scheduler and PRB-level scheduler". The former scheduler is in charge of the user assignment among CCs, while the later is actually the same as single-carrier PRBs scheduling which controlled by each RS. The CC that allocates to a single MU is chosen randomly and cannot be altered any more until the end of the session.

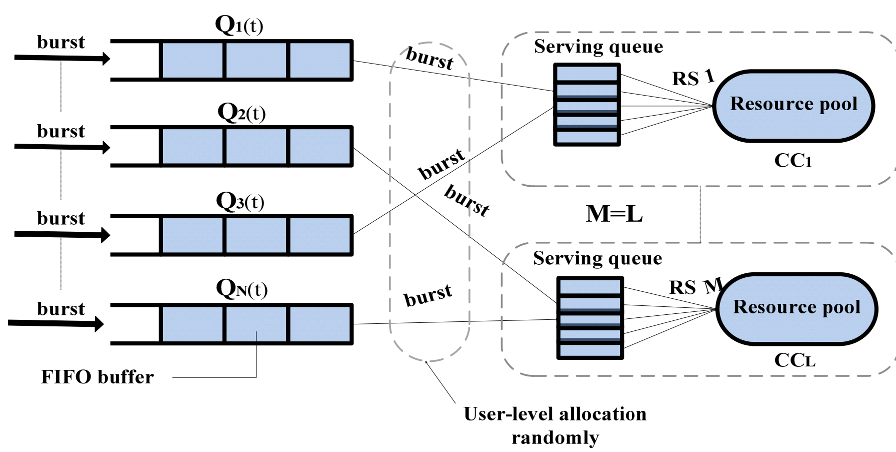

Figure 3: Independent Carrier Scheduling

As demonstrated above, ICS is not likely to growth the signal processing intricacy and consumption of power but with less spectral efficiency. Thus, the authors propose optimizing related technology of ICS termed as QoS-ICS algorithm, to obtain the compromise of performance and complexity. Furthermore, the QoS-ICS is investigated under various MIMO transmission modes which have a major impact on user throughput in order to find the appropriate transmission mode for carrier aggregation based LTE-Advanced network.

6. PROPOSED RADIO RESOURCE SCHEDULING SCHEME

Nowadays, as the number of diverse mobile applications "RT and Non-RT services" is growing, the application of classical ICS scheduling is not a promising for meet the real-time and non-real time QoS demands. To solve this issue, a novel user-level QoS aware packet scheduling based on ICS scheme is proposed. Based on the authors' strategy, it alters the existing ICS scheduling by introducing the service utility factor for each traffic user to priority function.

4.1 Design of Multi-Service Utility Factor

Due to the modern wireless communication technology has emerged a mixture of applications with a diversity of QoS constraints. The authors partitions them into two application classifications, namely, RT-applications and NRT-applications according to its delay-sensitive level and maintain low level of complexity. In view of multi-service QoS requirements, the authors also format the application utility factor for each MU which acquired by calculation through two steps:

Step 1: Calculate the RT-utility factor that each user maintains on the service. The HOL delay of packets *i* in the serving queue for real-time user *k* is defined as:

$$D_{k,i}^{RT}(t) = T_{current} - T_{k,i}^{arrival} \quad (1)$$

In which $T_{current}$ is the current transmission time and $T_{k,i}^{arrival}$ is the arrival time of packets *i* in the user queue, which very crucial to be considered because RT flows is highly delay-sensitive. Then, the RT-utility factor can be expressed as:

$$D_k^{RT}(t) = \frac{D_{k,i}^{RT}(t) * q_k(t) * n_{TS}}{\sqrt{HD_k^{RT} - D_{k,i}^{RT}(t)}} \quad (2)$$

. Where $q_k(t)$ is the queue length of user *k* at time *t*, n_{TS} is the number of time slots per one sub-frame and the delay highest bound HD_k^{RT} is utilized to normalize the HOL packets delay in the user k's queue.

Step 2: According to the NRT packet size, denoted by *M;* and the required minimum throughput for NRT service, denoted by *R*. The arrival time of packets *i* will be calculated virtually, denoted by $T_{k,i}^{virtual}$.

$$T_{k,i}^{virtual} = \begin{cases} 0, & if\, q_k(t) = 0 \\ T_{k,i}^{arrival} + M/R, & if\, q_k(t) \neq 0 \end{cases} \quad (3)$$

Then, the HOL delay of packets *i* in the serving queue for NRT user *k* is defined as:

$$D_{k,i}^{NRT}(t) = \max(T_{current} - T_{k,i}^{virtual}, 0) \quad (4)$$

Consequently, the NRT-Utility factor can be expressed as:

$$D_k^{NRT}(t) = \frac{D_{k,i}^{NRT}(t) * q_k(t)}{HD_k^{NRT}} \quad (5)$$

4.2 QoS-ICS Scheme

Firstly, according to the above for optimum load balancing, the authors design adopting carrier scheduling scheme, where the number of RT-MUs and NRT-MUs which are assigned to each carrier reveals the metric that evaluates the load of each CC.

Secondly, for PRB-Scheduler among MUs, the multi-carrier Proportional Fair communication system relies on traffic QoS is deployed in order to achieve the overall resource allocation than classical PF.

Based on the priority function of the scheduling scheme which optimized by emerged the application utility factor for each traffic user, the resource scheduler assigns the PRBs to the users with the highest priority on all CCs:

$$k_{i,n} = arg_{k=1,2,\dots,K} \max\{P_{k,i,n}\} \quad (6)$$

Where $k_{i,n}$ is the selected user k at i^{th} CC of the n^{th} PRBs.K is the total number of users.

At time *t*, all radio resources are allocated based on the following priority function:

$$P_{k,i,n}(t) = \log\left(\frac{R_{k,i,n}(t) * D_k(t)}{(T_{PF} - 1)\overline{R_{k,total}(t)} + \sum_{n=1}^{N} \rho_{k,n} * R_{k,i,n}(t)}\right) \quad (7)$$

$R_{k,i,n}(t)$ is estimated transmittable data rate for user k at the n^{th}PRB group of the i^{th}CC at time slot t; $D_k(t)$ is sum of HOL packets delay for user k; $\sum_{n=1}^{N} \rho_{k,n} * R_{k,i,n}(t)$ is the overall throughput of user k at time slot t;$\rho_{k,n}$ is the assignment indicator variable for user *k* and subcarrier *n* that is equal to 1 when the subcarrier n is allocated to the user k , while 0 otherwise; $\overline{R_{k,total}(t)}$ is user k throughput divided by the total of CCs; T_{PF} is the average proportional window length.

The average user throughput for all *CCs*, $\overline{\mathrm{R}_{\mathrm{k,total}}(\mathrm{t})}$ is defined by:

$$\overline{R_{k,total}(t)} = \begin{cases} \overline{R_{k,i}(t)}, & k \in RT \\ \overline{R_{k,i}(t)} - \delta, & k \in NRT \end{cases} \quad (8)$$

Where $\overline{R_{k,\iota}(t)}$ is the average throughput for user k on the i^{th}CC; δ is the minimum throughput for NRT traffic "240kbps".

Hence an updated version can be expressed as;

$$\overline{R_{k,\iota}(t+1)} = \begin{cases} \left(1 - \frac{1}{T_P}\right)\overline{R_{k,\iota}(t)} + \frac{1}{T_P}\overline{R_{k,\iota}(t)}, & k = k^* \\ \left(1 - \frac{1}{T_P}\right)\overline{R_{k,\iota}(t)}, & k \neq k^* \end{cases} \quad (9)$$

Repeat the priority function until all N radio resources (PRBs) allocated to users, and then update$\overline{R_{k,total}(t)}$.

7. MIMO SCHEMES

MIMO technique has been employed in wireless mobile network in order to optimize the spectral efficiency and system capacity. For scheduling the resources among users, each MU sends Channel State Information (CSI) as a feedback to eNB periodically. CSI compromises of three parts: (i) Channel Quality Indicator (CQI), (ii) Pre-Coding Matrix Indicator, and (iii) Rank Indicator (RI). Where the CQI is obtained by measuring Signal to Noise Ratio (SNR) on reference signals that transmitted by eNB in downlink. Based on the measured reference signals, each MU selects the PMI and RI index from corresponding codebook [19].

In LTE-Advanced network, there are nine various MIMO schemes which differ in terms of the antenna mapping and the type of CSI feedback they rely on. In this study, two main MIMO schemes as shown in Figures 4 and 5 are considered, namely Open Loop Spatial Multiplexing (OLSM) and Closed Loop Spatial Multiplexing (CLSM). The former is more suitable in high mobility scenarios due to not rely on PMI reports which have high latency in reporting, while the later performs optimally at low mobility users which based on precoding matrix.

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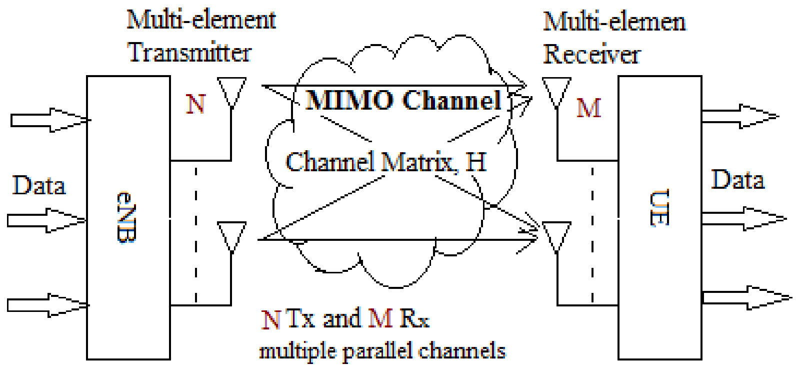

Figure 4: Open Loop Spatial Multiplexing

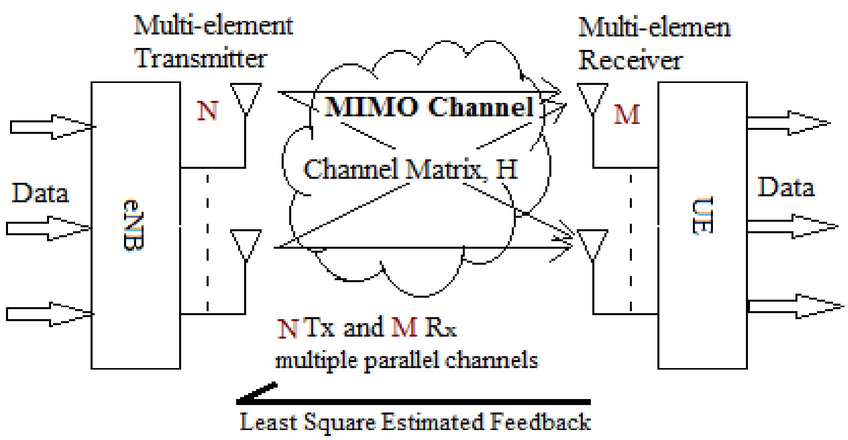

Figure 5: Closed Loop Spatial Multiplexing

8. SIMULATION RESULTS AND PERFORMANCE EVALUATION

The novel QoS-ICS scheduling algorithm's performance with various MIMO schemes configurations for LTE-A will be investigated in this section.

7.1 Simulation Model

The OFDMA downlink transmission system based on the ICS carrier scheduling algorithm is considered. Three CCs are configured with frequency of each carrier is 2.14GHz, 2.4GHz and 2.6GHz in this simulation. All component carriers possess uniformly transmitting power. As to PF scheduling algorithm, the window length average is$T_{PF} = 25$. In order to attain high data transmission rate, the adaptive Modulation and Coding is very important. The total number of RT users is assumed to be equal to total number of NRT users. The delay upper bound for both RT traffic and NRT traffic is considered to be equally which is taken 20 msec. Other simulation parameters are listed in Table 3.

Table 3: LTE-A System Level Simulation Parameters

Parameter	Setting and Value
System Structure	7 cell, 3 sectors per cell
Site-to-Site Distance	500m
MIMO Schemes	2×2 CLSM, OLSM
Pathloss Model	Hata Model
Shadow Fading Model	Lognormal Fading
Modulation and Coding Scheme	QPSK, 16QAM, 64QAM
CC Bandwidth	10 MHz
Sub-Frame Configuration	1 ms
Granularity of Scheduling	1 TTI
Feedback Delay	1 ms
Traffic Model	Full Buffer
Traffic Types	RT and NRT
Number of Users per Sector	70, 78, 86, 94,102

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7.2 Performance Evaluation

In this section, the performance of the classical ICS algorithm and the proposed scheduling algorithm QoS-ICS are analyzed in terms of user level QoS metrics under the influence of different MIMO schemes. Packet Drop Ratio (PDR) represents the major performance indicator when dealing with QoS provisioning for real-time users.

Figure 6 explains the average PDR of real-time service under various system loads with different MIMO schemes in order to differentiate the profit of proposed QoS-ICS algorithm on the user-level QoS performance.

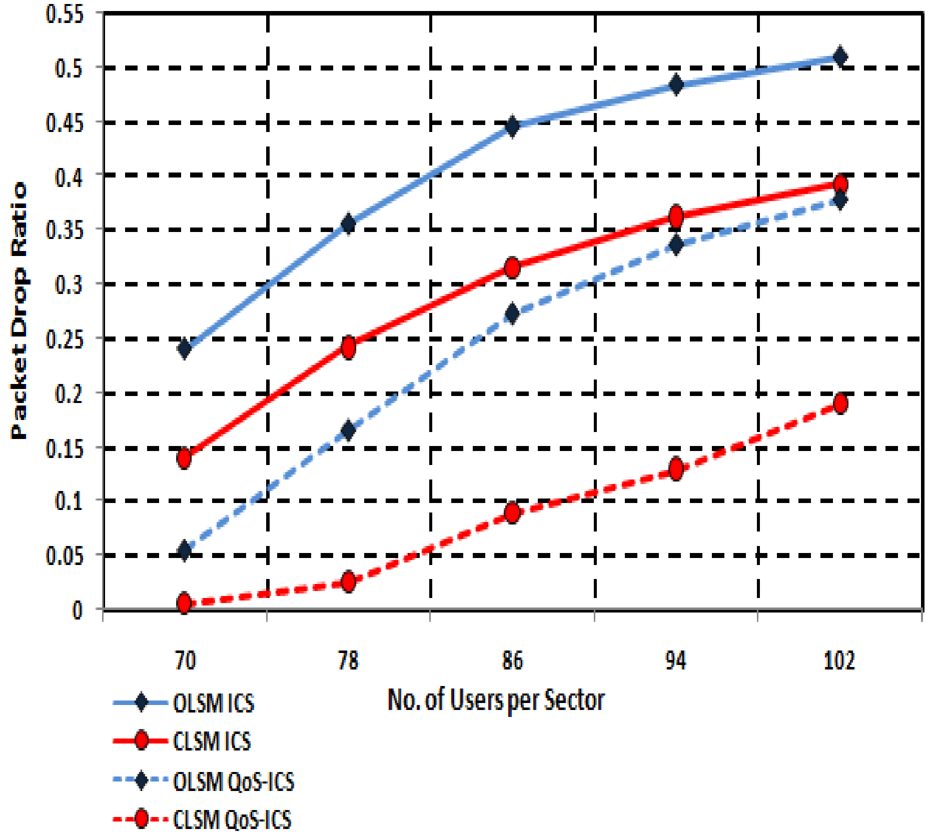

Figure 6: Packet Drop Ratio for RT-Users

The proposed QoS-ICS algorithm outperformed of the conventional ICS algorithm under different MIMO schemes in all various system loads by an approximate average gain of 69.83% for CLSM scheme and 40.51% for OLSM. Where, the QoS-ICS selects the users which have higher packet delay and longer queues length, leading to minimize average PDR.

Figure 7 shows the normalized average delay of real-time service with respect to the system load under various MIMO schemes, where the average packet delay is normalized by the real-time user's delay budget.

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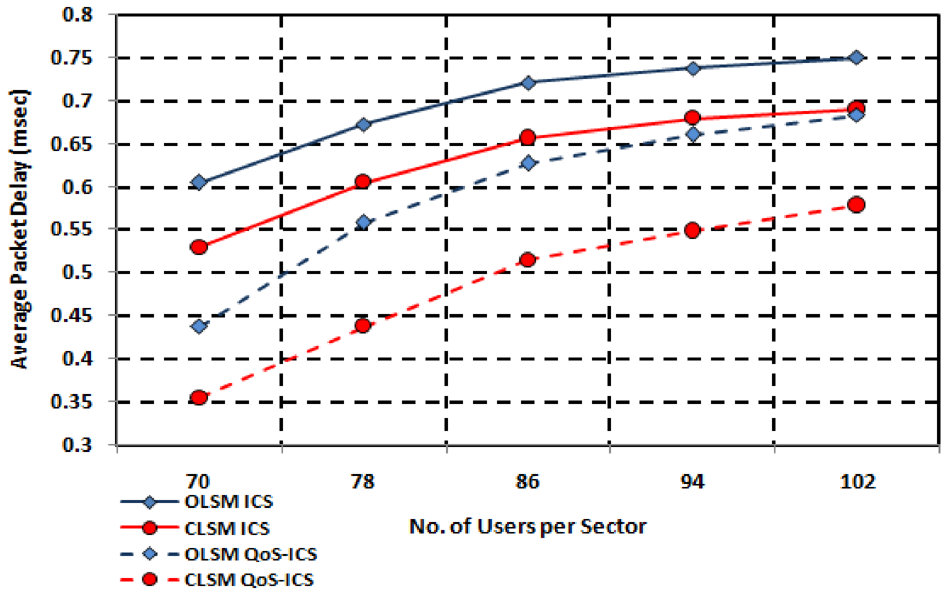

Figure 7: Average Packet Delay for RT-Users

The proposed QoS-ICS has better performance than classical ICS algorithm in terms of average packet delay in all different MIMO schemes; which are CLSM and OLSM by an approximate average gain of 22.97% and 14.93% respectively.

Figure 8 depicts the minimal throughput among all NRT users versus different system loads under diverse MIMO schemes.

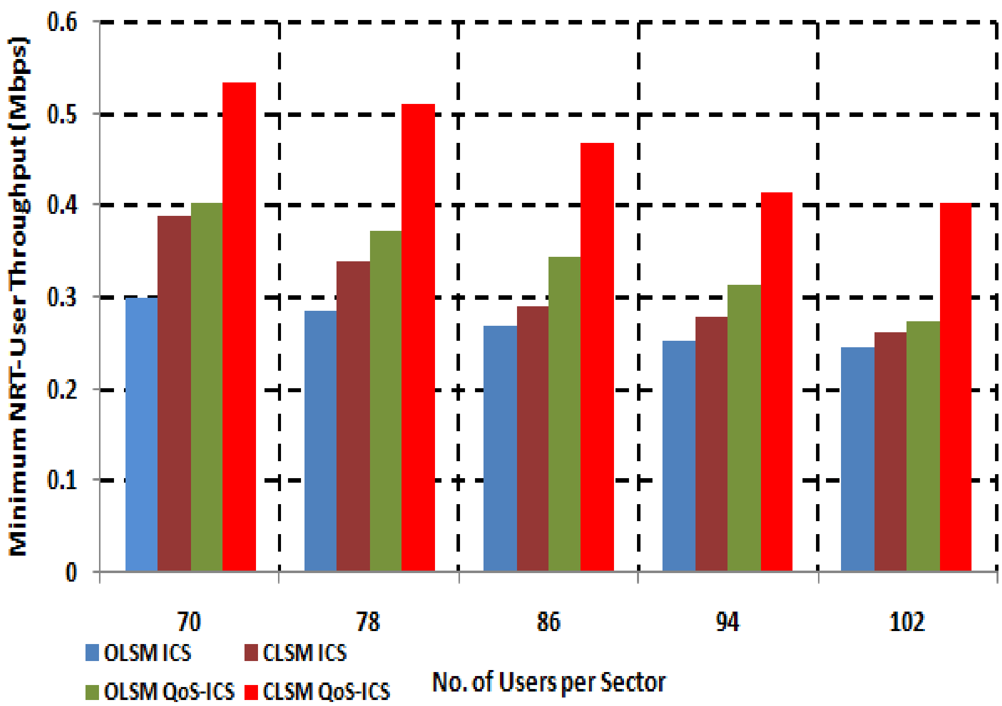

Figure 8: Minimal Long-Term Throughput for Non-Real time users

Both scheduling algorithms, proposed QoS-ICS and classical ICS are able to guarantee the long-term minimal data rate "higher than 240kbps" of NRT users in all system loads with various MIMO schemes.

9. CONCLUSION

In this paper, the scheduling scheme that is based on the application utility factor for multi-services multi-users scenario is performed. Two MIMO transmission techniques, OLSM and CLSM are considered to investigate the performance of user-level QoS for the proposed QoS-ICS in terms of, Packet Delay, Packet Drop Ratio, and Fairness for real-time users and Minimum Throughput demands of non-real time users. The proposed QoS-ICS was compared against the conventional ICS algorithm for different schemes of MIMO transmission. According to the simulation outcome, the proposed QoS-ICS scheduling method appears to be the optimal one for OLSM and CLSM, where it achieves the PDR, PD and the minimum required throughput in terms of user-level QoS provision.

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