Modeling and Analysis for Effective Capacity of a Cross-Layer Optimized Wireless Networks

Reham A. El-mayet, Hesham M. El-Badawy, Salwa H. Elramly

Abstract—New generation mobile communication networks have the ability of supporting triple play. In order that, Orthogonal Frequency Division Multiplexing (OFDM) access techniques have been chosen to enlarge the system ability for high data rates networks. Many of cross-layer modeling and optimization schemes for Quality of Service (QoS) and capacity of downlink multiuser OFDM system were proposed. In this paper, the Maximum Weighted Capacity (MWC) based resource allocation at the Physical (PHY) layer is used. This resource allocation scheme provides a much better QoS than the previous resource allocation schemes, while maintaining the highest or nearly highest capacity and costing similar complexity. In addition, the Delay Satisfaction (DS) scheduling at the Medium Access Control (MAC) layer, which allows more than one connection to be served in each slot is used. This scheduling technique is more efficient than conventional scheduling to investigate both of the number of users as well as the number of subcarriers against system capacity. The system will be optimized for different operational environments: the outdoor deployment scenarios as well as the indoor deployment scenarios are investigated and also for different channel models. In addition, effective capacity approach [1] is used not only for providing QoS for different mobile users, but also to increase the total wireless network's throughput.

Keywords—Cross-layer, effective capacity, LTE, OFDM, QoS, resource allocation, wireless networks.

I. INTRODUCTION

OFDM is an effective technique to combat frequency-selective channels and to support high data rate services, which have been adopted in Wireless Local Area Networks (WLANs) (IEEE 802.11a & 11g), WiMAX (IEEE 802.16) and 3GPP Long Term Evolution (LTE) downlink systems [2]. The goal of these networks is to provide real time services for delay sensitive applications, e.g., voice-over-IP, interactive video, mobile TV, and interactive gaming. These applications require that the wireless network provide QoS guarantees, e.g., guarantees on data rate, delay bound, and delay bound violation probability.

Different research work has been carried out on dynamic subcarrier and power allocation to different OFDM users, which allows a flexible multiuser access and enhancement of the multiuser diversity.

The layering principle has been long identified as a way to increase the interoperability and to improve the design of telecommunication protocols. Then, each layer offers services to adjacent upper layers and requires functionalities from adjacent lower ones. Layering enables fast development of interoperable systems. But it deteriorates the performance of the overall architecture, due to the lack of coordination among layers.

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With the rapid increase of demands for high speed multi-media services of wireless networks, these are confronted with fading channels, limited bandwidth and competition of limited radio resources among multiple users, a modification of the layering paradigm has been proposed. So, cross-layer design or "cross-layering" is defined to overcome these limitations [3] [4].

In wireless networking, the QoS plays a crucial part in performance assessment. Therefore, to meet the required QoS, cross-layer optimization is considered.

Cross-layer optimization, which contains dynamic behaviors based on integrated adaptive design across different layers, has been proposed to optimize the system performance. So, cross layer optimization is acting as a coordination strategy with virtually strict boundaries to enable the compensation for e.g. overload, latency, or other mismatch of requirements, and resources by any control input to another layer, but that layer directly affected by the detected deficiency [5].

A cross-layer-modeling based on the concept termed "effective capacity" is used to analyze the statistical delay-bound violation and buffer-overflow probabilities, which are critically important for multimedia wireless networks [6]. Also, it can be considered as the maximum throughput under the constraint of QoS exponent θ [7].

In addition, it can be defined as the maximum arrival rate that a given service process can support in order to guarantee QoS requirements, that are specified by a parameter, θ [8]. The effective capacity function, denoted (θ) characterizes the attainable wireless-channel service-rate as a function of the QoS exponent θ. Thus, it can be used as a bridge in cross-layer design modeling between physical layer system infrastructure and data-link-layer's statistical QoS performance. Also, it captures a generalized link-level capacity notion of the fading channel [1] [6].

In this paper, a cross-layer optimization technique is proposed with guaranteed QoS for the downlink multiuser 4G based Orthogonal Frequency Division Multiplexing (OFDM), which includes a Maximum weighted Capacity (MWC) resource allocation and Delay Satisfaction (DS) based scheduling. The current work is different from that had been presented in [2] via the investigation of different deployment parameters and channel characteristics. Both of number of users, as well as, number of subcarriers will be investigated against the system capacity.

This will be done in conjunction with the cross layer interaction between PHY layer and MAC sub-layer. In addition, the system will be optimized for different operational environments namely: outdoor and indoor deployment scenarios. Also, the effective capacity link model is used to characterize wireless channels in terms of functions that can be easily mapped to data link level QoS metrics, such as delay bound violation probability [1].

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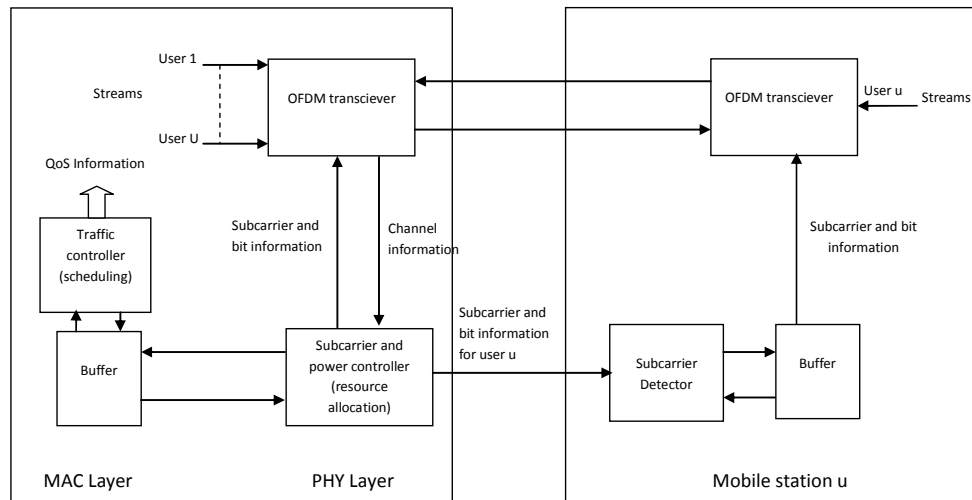International Journal of Electronics and Communication Engineering
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Fig. 1 Multiuser OFDM System Model

In Section II, the system model is presented. Sub-carrier and power allocation are presented in Section III. Delay satisfaction based data scheduling is presented in section IV. Section V. shows the used channel models. Numerical results and analysis are shown Section VI. Section VII concludes this paper.

II. SYSTEM MODEL

The current work considers a downlink OFDM system with U users as shown in Fig.1, to meet the QoS requirements. Without loss of generality, and for simplicity, it's assumed that each subcarrier is occupied by only one user [8]. With cross-layer optimization, the QoS information is transferred from the traffic controller to the subcarrier, and power controller for resource allocation. Then, the resource allocation results are fed back to the traffic controller in the base station for scheduling of the data to be sent out in each slot [3].

In consistence with [2], this paper assumes a total bandwidth of B shared by N subcarriers, and the OFDM signaling is time slotted. Each slot has duration of T_{slot}. Let, Ω_u denotes the index set of subcarriers allocated to user u ($u=1,...,U$). Let $p_{u,n}$ be the power allocated to user u on subcarrier n; ($n \in \Omega_u$). $h_{u,n}$ is the corresponding channel gain which is represented for outdoor and indoor deployment scenarios. Through the current work, the outdoor environment is represented by Rayleigh faded channels. On the other hand, the indoor environment is represented by Rician faded channels.

N_o is the power spectral density of Additive White Gaussian Noise (AWGN). By assuming perfect channel estimation, the achievable data rate of user u on subcarrier n is expressed as [2]:

$$R_{u,n} = \frac{B}{N} log_2(1 + p_{u,n} \varphi_{u,n}) \qquad (1)$$

where,

$$\varphi_{u,n} = \frac{|h_{u,n}|^2}{N_o B/N} \qquad (2)$$

is the channel-to-noise power ratio for user u on subcarrier n.

For outdoor scenario, the signal is Rayleigh distributed. So, the received signal power is exponentially distributed. While, for indoor scenario, the signal is Rician distributed. So, the received signal power is gamma distributed [9].

Both Rayleigh and Rician distributions are special cases from Nakagami distribution:

$$|h_{u,n}|^2 = p^2(x) = \left(\frac{m}{P_r}\right)^m \frac{x^{m-1}}{\Gamma(m)} exp\left(\frac{-mx}{P_r}\right) \qquad (3)$$

where,

$$m = \begin{cases} 1 \; ; & \text{Rayeligh fading distribution} \\ m = \dfrac{(K+1)^2}{2K+1} \; ; & \text{Rician fading distribution} \end{cases} \qquad (4)$$

where, m is the degree of Nakagami-m distribution, P_r is the average received power and K is the Rician fading parameter. Therefore, the total data rate of user u is given by:

$$R_u = \sum_{n \in \Omega_u} R_{u,n} \qquad (5)$$

III. SUBCARRIER AND POWER ALLOCATION

A resource allocation scheme had been proposed in [2], to maximize the weighted sum of all users' capacity J, i.e., to maximize

$$J = \sum_{u=1}^{U} W_u R_u \qquad (6)$$

Subject to: $\quad p_{u,n} \geq 0 \quad , \quad \sum_{u=1}^{U} \sum_{n \in \Omega_u} p_{u,n} \leq P_{total}$

$$\Omega_i \cap \Omega_j = \emptyset \; (i \neq j) \text{ and,}$$

$$\Omega_1 \cup \Omega_2 \cup ... \Omega_U \subseteq \{1,2,...,N\},$$

where, W_u denotes the weight for user u, which is evaluated based on the cross-layer optimization criteria. So it indicates the QoS information for user u, and is obtained from the result

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of data scheduling at the MAC layer as will be investigated in Section IV-B and P_{total} denotes the total power.

The optimization process is divided into two stages namely, subcarrier allocation and power allocation.

A. Optimal MWC based subcarrier allocation

For simplicity, by assuming uniform power allocation across all subcarriers, i.e., each subcarrier is allocated a power $p=Ptotal/N$. Optimal subcarrier allocation leads to the maximum cost function, which is denoted by J_{max}. If an arbitrary subcarrier n allocated to user u ($u=1,...,U$) with optimal subcarrier allocation is now reassigned to user s, let J' denote the resulting cost function. The difference between the two cost functions is given by:

$$J_{max} - J' = W_u R_{u,n} - W_s R_{s,n} \geq o \tag{7}$$

Substituting (1) into (8), we have

$$\frac{W_u}{W_s} \geq \frac{log_2(1 + p\varphi_{s,n})}{log_2(1 + p\varphi_{u,n})} \tag{8}$$

Which implies that, with optimal subcarrier allocation, subcarrier n should be allocated to user u rather than user s if (8) is satisfied. However, it is prohibitively complex to perform optimal subcarrier allocation with a large number of subcarriers. Therefore, a suboptimal scheme is desired.

Also, the effective capacity $\alpha(\theta)$ which is a function of QoS exponent θ, is used to find out the effective capacity for different number of subcarriers (N). This may be found out by [10].

The effective capacity is based on the desired rate for each subcarrier in a certain bandwidth. Furthermore, the effective capacity is function of the channel characteristics and its propagation model. $\alpha(\theta)$ is derived as follows, [10]:

$$\alpha(\theta) = \frac{-\Lambda(-\theta)}{\theta} \qquad , \forall\, \theta > 0, \tag{9}$$

where,

$$\Lambda(-\theta) = \lim_{t\to\infty}\frac{1}{t}log\, E[\, e^{-\theta S(t)}], \tag{10}$$

$$S(t) = \int_o^t r(\tau)d\tau \tag{11}$$

$(-\theta)$ is the asymptotic log-moment generating function of a stochastic process, $S(t)$ is the actual service provided by the channel in bits during the interval [0,t] and $r(t)$ is the instantaneous channel capacity at time t.

To understand the meaning of θ, consider a queuing system with stationary arrival and service processes. Then the queue length process, $q(t)$, can be shown to converge in distribution to random variable, $q(\infty)$ such that [11]:

$$\theta = - \lim_{x\to\infty}\frac{log(Pr\{q(\infty) > x\})}{x} \tag{12}$$

The QoS parameter, θ, is a crucial parameter describing the exponential decaying rate of the probability of QoS violation event. Specifically, large and small values of θ correspond to fast and slow decaying rates, i.e., stringent and loose QoS requirements, respectively.

Because of its ability to indicate the level of statistical QoS guarantee, θ is referred to as the QoS exponent [11].

Nakagami fading can model Rayleigh and Rician fading [9]. So, in this paper the calculation of the effective capacity is in consistence with the assumed Nakagami-*m* fading channel which had been given in [10].

By considering a Gaussian random vector y_b has zero mean and correlation coefficient matrix $\sum$, which has dimension $N{\times}N$. By knowing the correlation coefficient $\rho_{i,j}$, the $\sum$ matrix is defined by the following relation [10]:

$$\Sigma_{i,j} = \begin{cases} 1; & i = j \\ \rho_{i,j;} & i \neq j, \ 0 \leq \rho_{i,j} \leq 1 \end{cases} \tag{13}$$

Then, the expectation for the moment generating function can be evaluated via [10] as follows:

$$E\left[e^{-\theta S(t)}\right] = E\left[e^{-\theta \int_0^t r(\tau)d\tau}\right]$$
$$= \sum_{i_1=0}^{N}\sum_{i_2=0}^{N}\cdots\sum_{i_{N-1}=0}^{N}\frac{A}{2^N}\ C(i_1, i_2, \ldots, i_{N-1}).$$
$$\prod_{j=1}^{N}\left\{\left(\theta\delta + \frac{\omega_{j,j}}{2}\right)^{-(m+i_{j-1}+i_j)}\Gamma\left(m + i_{j-1} + i_j\right)\right\} \tag{14}$$

where,

$$A = \frac{[det(\Sigma^{-1})]^m}{2^{m-1}(m)} \tag{15}$$

$$C(i_1, \ldots, i_{N-1}) = \prod_{x=1}^{N-1}\frac{\omega_{x,x+1}^{2i_x}}{B_{i_x}} \tag{16}$$

$$B_i = 2^{m-1+2i}(m+i)i! \tag{17}$$

δ: is the sampling rate.

$\omega_{i,j}$: are elements of matrix $\sum^{-1}$, i, e., $\sum^{-1} = [\omega_{i,j}]$

Equation (14) can be approximated according to mathematical manipulation in [10]:

$$\alpha(\theta)$$
$$\cong \frac{-1}{\theta N\delta}log\left(\begin{aligned}&\sum_{i_1=0}^{N}\sum_{i_2=0}^{N}\cdots\sum_{i_{N_t-1}=0}^{N}\frac{A}{2^N}C(i_1,i_2,\ldots,i_{N_t-1}).\\ &\prod_{j=1}^{N}\left\{\begin{aligned}&\left(\theta\delta + \frac{\omega_{i,j}}{2}\right)^{-(m+i_{j-1}+i_j)}.\\ &\Gamma(m + i_{j-1} + i_j)\end{aligned}\right\}\end{aligned}\right) \tag{18}$$

$$\alpha(\theta) = \frac{-1}{\theta N\delta}log\left(\begin{aligned}&\frac{A}{2^N}C(i_1 = 0,\ldots,i_{N_t-1} = 0).\\ &\prod_{j=1}^{N}\left\{\left(\theta\delta + \frac{\omega_{i,j}}{2}\right)^{-m}\Gamma(m)\right\}\end{aligned}\right) \tag{19}$$

To get the relation between the total arrival rate and the effective capacity:

For a given source rate μ, $\gamma(\mu) = Pr\{Q(t){\geq}0\}$ is the probability that the buffer is non-empty at a randomly chosen time t, while the QoS exponent $\theta(\mu)$ is defined as in [1].

$$\theta(\mu) = \mu\alpha^{-1}(\mu) \tag{20}$$

Let, Q is the system total arrival rate.

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So, when using a link that modeled by the pair $\{\gamma(\mu), \theta(\mu)\}$, a source that requires a communication delay bound of D_{max}, and can tolerate a delay-bound violation probability of at most ϵ, needs to limit its data rate to maximum of μ, where μ is the solution for $\epsilon = \gamma(\mu)e^{-\theta(\mu)D_{max}}$.
If $\epsilon = 10^{-n}$:

$$\alpha(\mu) = \frac{D_{max}}{U * n * ln\,10} Q \qquad (21)$$

- *Suboptimal MWC based subcarrier allocation*
  Intuitively, to maximize the cost function in (6), a larger weight demands a higher data rate. Let R_u/W_u denote the Rate-to-Weight Ratio (RWR) and assuming uniform power allocation across all subcarriers. Then, the following suboptimal subcarrier allocation scheme is employed, where the user with the lowest RWR is allowed to pick subcarriers in each iteration:
  1) Initialization:
     a) Set $R_u = 0$, $\Omega_u = \emptyset$ for all u ($u=1,...,U$), sort W_u in the descending order, and let $L=\{1,2,...,N\}$ denote the set of unallocated subcarriers.
     For $u=1$ to U:
     b) If $\varphi_{u,m} \geq \varphi_{u,n}$ ($m,n \in L$; $m \neq n$), assign subcarrier m to user u, i.e., add subcarrier m to Ω_u. Remove subcarrier m from L. Update R_u according to (5).
  2) Find the minimum R_u/W_u ($k=1,..., U$), and repeat 1-b) for the corresponding user u.
  3) Repeat 2) until $L = \emptyset$.

B. Optimal MWC based power allocation

Following subcarrier allocation, the optimal power allocation for each user can be obtained by using the Lagrange multiplier, i.e., (6) can be rewritten as:

$$J = \sum_{u=1}^{U} W_u R_u + \lambda \left(\sum_{u=1}^{U} \sum_{n \in \Omega_u} p_{u,n} - P_{Total} \right) \qquad (22)$$

Subject to $\sum_{u=1}^{U} \sum_{n \in \Omega_u} p_{u,n} = P_{Total}$ and $p_{u,n} \geq 0$. Letting $\partial J/\partial p_{u,n} = 0$, the optimal solution for $p_{u,n}$ is given by:

$$p_{u,n} = max \left\{ \frac{W_{u,n}}{\sum_{u=1}^{U}(W_i \, size \, of \, (\Omega_i))} \left[P_{Total} \right. \right.$$
$$\left. \left. + \sum_{i=1}^{U} \sum_{q \in \Omega_j} \frac{1}{\varphi_{i,q}} \right] - \frac{1}{\varphi_{u,n}}, \quad 0 \right\} \qquad (23)$$

Consider users j and u ($j,u \in \{1, \ldots, U\}$, and subcarrier $m \in \Omega_j$ and $n \in \Omega_u$ are two arbitrary subcarriers allocated to users j and u, respectively. By $\partial J/\partial p_{u,n} = \partial J/\partial p_{j,m} = 0$, we can drive:

$$\frac{W_i}{W_j} = \frac{\varphi_{u,n}(1 + p_{j,m}\varphi_{j,m})}{\varphi_{j,m}(1 + p_{u,n}\varphi_{u,n})} \qquad (24)$$

1) If $W_j/W_u = 1$, from (24) it can be derived that:

$$p_{j,m} - p_{u,n} = \frac{\varphi_{j,m} - \varphi_{u,n}}{\varphi_{j,m}\varphi_{u,n}} \qquad (25)$$

Equation (25) implies that with equal weight, the subcarrier with a better channel gain is allocated more power, which is the same result as water-filling [12].

2) If $W_j/W_u > 1$, we have:

$$p_{j,m} - p_{u,n} > \frac{\varphi_{j,m} - \varphi_{u,n}}{\varphi_{j,m}\varphi_{u,n}} \qquad (26)$$

Equation (26) implies that the subcarrier corresponding to the user with a higher weight is allocated more power than the case using water-filling.

IV. DELAY SATISFACTION BASED DATA SCHEDULING

A. DS Based Data Scheduling

After receiving the resource allocation results from the PHY layer, which indicates the amount of data allowed for each user, the MAC layer performs scheduling for each batch of data to be sent out. A scheduling scheme is proposed, which assigns a higher weight to the batch of data packets with a less DS, i.e., the data with the least DS should be sent out first.

This paper defines a DS indicator $C_{u,i,l}$ for the batch of packets for connection i of user u, which arrive in slot ($l \in [L_c - L_r, L_c]$), where L_c denotes the current slot, and L_r is the delay bound for the ith connection, which is the class-r QoS traffic, in terms of slot. Also let G_r be the guard slot of the class-r QoS traffic, and $S_{u,i,l}$ be the waiting time for connection i of user u, which is the duration between slot l and the current slot. The DS indicator $C_{u,i,l}$ is expressed as:

$$C_{u,i,l} = L_r - G_r - S_{u,i,l} \qquad (27)$$

Which implies that the longer the data's waiting time is, the less the DS is.

Let $Z_{u,i,l}$ denotes the weight of the batch corresponding to connection i of user u arriving in slot l, which is given by:

$$Z_{u,i,l}$$
$$= \begin{cases} [\beta_r/(C_{u,i,l} + 1)]\,log(D_{u,i,l} + 1); & (C_{u,i,l} > 0) \\ \beta_r\,log(D_{i,u,l} + 1); & (-G_r \leq C_{u,i,l} \leq 0) \end{cases} \qquad (28)$$

where, β_r is the class-r QoS coefficient, and $D_{u,i,l}$ is the amount of data of connection i arriving in slot l.
To get the effect of the QoS exponent θ on the QoS coefficient β_r. Thus, β_r can be calculated as a normalized QoS coefficient [7]:

$$\beta_r \triangleq \frac{\theta T_f B}{log2} \qquad (29)$$

where, T_f is the frame duration for LTE based networks.

1) If $C_{u,i,l} > 0$, i.e., $S_{u,i,l} < L_r\text{-}G_r$, from (29) it can be deduced that the weight $Z_{u,i,l}$ increases with the decrease of the DS indicator (i.e., with the increase of the data's waiting time). In particular, if $C_{u,i,l} > 0$ we have,

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$$\frac{\partial Z_{u,i,l}}{\partial C_{u,i,l}} = \left[-\beta_r / (C_{u,i,l} + 1)^2 \right] log(D_{u,i,l} + 1) \qquad (30)$$

Which implies that the smaller the DS indicator becomes, the faster the weight $Z_{u,i,l}$ increases.

2) If $-G_r \leq C_{u,i,l} \leq 0$, i.e., $L_r\text{-}G_r \leq S_{u,i,l} \leq L_r$, $Z_{u,i,l}$ in (29) reaches the maximum value, which implies that the packet batch of class-m arriving in slot l should be sent out with no further delay, since it will be time out very soon.

The proposed DS based scheme performs scheduling by descending order of the weights obtained in (29), which implies that the batches of all connections which will become time out very soon are given a higher priority to be sent out. In conventional scheduling [2], where only one connection is served in each slot until either all the PHY layer resources are consumed or the buffer is empty. However, this is not efficient if the data of other connections are more urgent than the currently served data. Therefore, the DS based scheduling is more efficient, which allows the most urgent data to be sent out first.

B. Weight Calculation for MWC based Resource Allocation

To guarantee the QoS, it is desirable that the resource allocation at the PHY layer acquires the channel information for each user and employs the QoS information obtained at the MAC layer, including the queue length, the QoS class of queues, and the waiting time of queues. As the weight given by (28) contains the above QoS information, the weights in (6) for the MWC based resource allocation are determined by adding the weights of all valid batches of connections for each user:

$$W_u = \sum_i \sum_{l=L_{i,s}}^{L_{i,e}} Z_{u,i,l} \qquad (31)$$

where, $L_{i,s}$ and $L_{i,e}$ denote the arrival and time out slots for connection i, respectively.

By substituting (28) into (31), the QoS weights used in PHY layer ($Z_{u,i,l}$) are used to calculate QoS weights used in MAC layer (W_u), which gives the real meaning of cross-layer design.

V. CHANNEL MODELING

In Rician fading analysis, we study the total arrival rate against system capacity using Stanford University Interim (SUI) channel models as in table (I)[13]:

TABLE I
TERRAIN TYPE AND DOPPLER SPREAD FOR SUI CHANNEL MODELS

Channel	Terrain Type	Doppler Spread	Spread	LOS
SUI-1	C	Low	Low	High
SUI-2	C	Low	Low	High
SUI-3	B	Low	Low	Low
SUI-4	B	High	Moderate	Low
SUI-5	A	Low	High	Low
SUI-6	A	High	High	Low

The Rician distribution is often described in terms of fading parameter K, for $K=0$ we have Rayleigh fading, and for $K=\infty$

we have no fading, i.e. a channel with no multipath and only a LOS component [9].

VI. NUMERICAL RESULTS AND ANALYSIS

In order to investigate the proposed cross-layer optimization scheme, numerical results will be deduced in terms of the system bandwidth efficiency.

This paper employs the proposed MWC based resource allocation at the PHY layer and the DS based scheduling at the MAC layer for consistency. It considers a LTE system with $U=100$ users, a total transmit power of $P_{total}=1W$, maximum latency of $D_{max}=10ms$, a total bandwidth of $B=10MHz$, subcarrier width of 15KHz, physical source block code of 180KHz bandwidth and 50 available Physical Resource Block (PRB) and the system slot is set to be 0.5 ms [14]. The channel has six independent Rayleigh fading paths with an exponentially delay profile. The power spectral density of AWGN is N_0=-80dBW/Hz.

In our analysis, each user has two types of streams of the conversational class (real time) with a QoS-class coefficient or normalized QoS exponent β_{rmax} and the interactive class (non real time) with β_{rmin}, respectively, and they are determined by (29) for both of θ_{max} and θ_{min} respectively [10]. The maximum transfer delays for the conversational and interactive classes are 10ms and 100ms, respectively [15]. It is assumed that the arrival process of the conversational class stream is Poisson distributed, and the interactive class streams are always available, which is a reasonable assumption for applications such as File Transfer Protocol (FTP). The maximum total data arrival rate is 25Mbps, the packet arrival rates of voice and best effort traffic are constantly 64kbps and 500kbps respectively [16].

In our analysis we assume omni antenna with 90% coverage is used, with K values as in table (II).

So, the parameter m, which is the degree of Nakagami-m distribution, will be determined based on (4). As a validation of the proposed cross layer model, Fig. 2 illustrates a comparative study for different systems. Namely, previously published work in [2] and the current model with LTE parameters as listed in [13].

TABLE II
FADING FACTOR-K FOR EACH CHANNEL MODEL [13]

Channel model	K –factor
SUI-1	3.3
SUI-2	1.6
SUI-3	0.5
SUI-4	0.2
SUI-5	0.3
SUI-6	0.1

As shown in Fig. 2, the concurrent system is giving higher capacity than that had been represented in [2].

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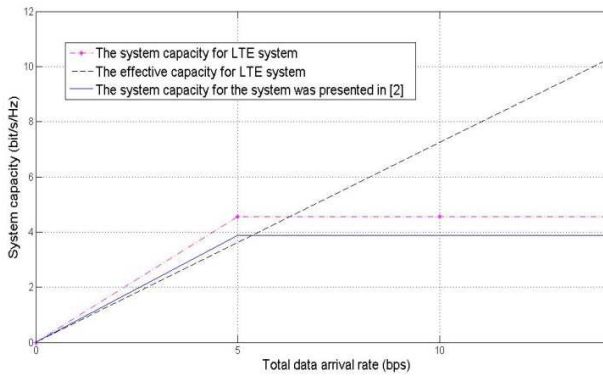Vol:6, No:10, 2012

Fig. 2 Total data arrival rate against system capacity for the proposed LTE system and results of [2]. Also, the effective capacity for LTE system is presented

Fig. 3 Total data arrival rate against system capacity for LTE system using different channel models.

It's noticed that the obtained system capacity for the regular system of [2] is limited by 4 bits/sec/Hz. Whereas, the concurrent system with LTE parameters will give higher capacity more than of [2] system's capacity. So, LTE will improve the overall system capacity by considering more user data rates.

In addition, the effective capacity is giving the upper bound of the obtained system capacity inspite of the LTE operational limitations.

Fig. 3 shows the obtained system capacity for different SUI-models. It shows that, as the arrival data rate is becoming lower than 5Mbps, the system may accommodate more incoming traffic, whereas, the high arrival rates (more than 5Mbps) will drive the system to be fully occupied as a result of using all of the available PRB. It's shown that the SUI-channels are affecting the overall system capacity (as result of cross layer) to enhance the obtained system capacity (approximately) inspite of the channel model. So, cross layer is working as an adaptive controller to get the same performance (approximately).

Fig. 4 shows the obtained system capacity as a function of the used number of subcarriers for different number of users.

It's shown that, by increasing both of the number of subcarriers (available PRB) and the number of users, the obtained system capacity is improved. It's explained as the more the user usage of subcarriers, the more system resource utilization.

The main difference between Fig. 4 and Fig. 5 is the Rician fading will give the system more propagation problems than that may be happen in case of Rayleigh fading channel in Fig. 4. So, the obtained system capacity is shrinked in case of Rician fading channel much more than that of the Rayleigh fading one. This effect has been reduced as a result of deploying the cross layer technique.
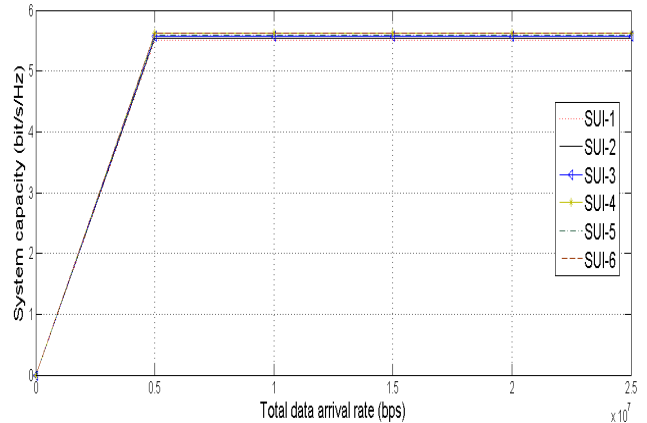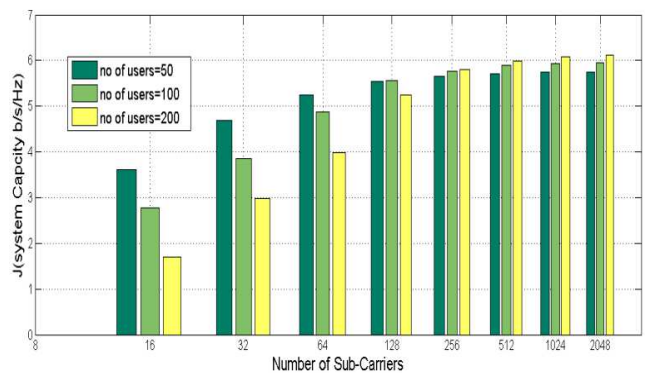

Fig. 4 Total number of subcarriers against system capacity for different number of users in case of Rayleigh fading channel
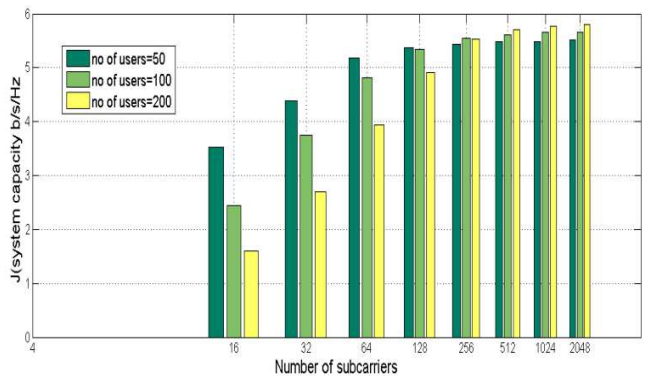

Fig. 5 Total number of subcarriers against system capacity for different number of users in case of Rician fading channel

VII. CONCLUSION

Cross-layer modeling and optimization schemes for Quality of Service QoS and capacity of downlink multiuser OFDM system were presented. In this paper, MWC based resource allocation at the physical layer is used. In addition, the DS scheduling at the MAC layer, which allows more than one connection to be served in each slot was used. The system is optimized for different operational environments: the outdoor deployment scenarios as well as the indoor deployment scenarios were investigated and also for different channel models.

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In this paper, we have modeled a wireless channel from the perspective of the communication link layer. This is in contrast to existing channel models, which characterize the wireless channel at the physical layer. Specifically, we modeled the wireless link in terms of the QoS exponent. Furthermore, we developed a simple and efficient algorithm to estimate the system performance for different operational scenarios.

It was shown that the SUI-channels are affecting the overall system capacity (as a result of cross-layering to enhance the obtained system capacity approximately inspite of the channel model. Also, Rician fading gave the system more propagation problems than that might be happened in case of Rayleigh fading channel. So, the obtained system capacity was shrinked in case of Rician fading channel much more than that of the Rayleigh fading one. This effect has been reduced as a result of deploying the cross layer technique.

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