A Radio Resource Allocation Algorithm in Future Wireless Communication Systems

Zirarushya Pierre Celestin[1], Mupenzi Jean de la Paix[1,2], Ngamije Jean[1], Habiyaremye Gabriel[1]

1. Independent Institute of Lay Adventists of Kigali (INILAK), P O Box 6392 Kigali-Rwanda
2. State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Science, 818 Beijing Road south, Urumqi, Xinjiang, 830011, China.

(z_pc_@yahoo.com/ jeandelapaixmup@yahoo.fr / jeanngamije@yahoo.com , gabrielhaby@yahoo.fr)

Abstract: This research project investigated the Radio Resource Allocation Algorithm in Future Wireless Communication Systems. The traditional resources that have been used to add capacity to wireless systems are radio bandwidth and transmitter power (1G). These two resources are simply not growing or improving at rates that can support anticipated demands for wireless capacity. From an engineering point of view, the best possible solutions to effectively deal with challenges of providing higher QoS (BER & Bit Rate) through supporting increased mobility and throughput of multimedia services and keeping in mind the scarcity of spectrum resources can only be achieved when, on top of efficient modulation and multiple access mode, elements of the radio network are properly configured and suitable radio resource management approaches/algorithms applied. The purpose of resource allocation at the base station is to intelligently allocate the limited resources; it has been proved that the system spectral efficiency can be significantly enhanced by adjusting the allocation of s/carrier, power and constellation sizes (modulation) in accordance with the user's channel conditions and traffic requirements. The current paper is concerned with adaptive subcarrier allocation to users with their rate requirements put into consideration. Given that the complexity reduction is of big concern for practical implementation and that a fixed power allocation leads to a negligible throughput penalty if only the power is poured on sub channels with good channel gains, only subcarriers are adaptively allocated to users placed randomly in a cell and the constellation size is according to user's channel condition and traffic

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1. Introduction

The development of novel signal transmission techniques and advanced receiver signal processing methods that allow for significant rise in wireless capacity without attendant increases in bandwidth or power requirements and hence the deployment of intelligent radio resource management algorithms in both the physical and the media access control (MAC) layers are essentially the key of success (Sanam et al. 2007). These techniques include AMC and Radio resource management (RRM) techniques (such as admission control, scheduling, sub-carrier allocation, channel assignment, power allocation, and rate control) essential for maximizing the resource utilization and providing quality of service (QoS) in wireless networks.

In what follows much attention is put in dynamic channel allocation as an intelligent method for allocating radio resources as required for wireless communication between a terminal and a base station. Dynamic channel allocation produces higher capacity, which in turn enables a larger number of communications relationships to be implemented simultaneously in the available frequency ranges. Efficient use of the radio resources is a very challenging task for future wireless communication systems due to the scarcity of the former, time-varying channel conditions, and heterogeneous classes of traffics and very diverse QoS requirements of users.

Adaptive resource allocation involving adaptive modulation and coding (AMC), adaptive power distribution and hybrid multiple access has been identified as one of the key technologies for providing efficient utilization of the limited power and spectrum with better QoS guarantees in future wireless systems (Berzdivin et al. 2002).

2. Methodology

Static Allocations & Dynamic Allocations

Radio resources under consideration are mainly subcarriers (Gautam,et al, 2005; Sanam et al., 2007) and power (Brian L. et al., 2003) .The objectives of different works range from minimizing power and maximizing throughput to minimizing bit error rate. The works can also be classified through optimization techniques by system parameters in single (Zukang et al., 2005, Wong, et al. 1999) or multi-cell, models for downlink or uplink (Pietrzyk and Janssen, 2002).

Resource allocation in OFDM/OFDMA systems has been under extensive study in the past few years. The general approach is to set the system model targets subjected to some set of QoS constraints (rate requirement, etc) against which the performance metrics are measured.

In TDMA (Time Division Multiple Access) or FDMA (frequency Division Multiple Access) systems with non-adaptive fixed resource allocation, an independent dimension such as time slot or frequency band is assigned to each user regardless of channel responses. In these systems each user effectively becomes a single user, independent of all other users and, the water-filling power spectrum is optimal (Wonjong and John , 2000). However a set of users suffers from poor channel gains of assigned dimensions and the throughput is far below the rate that can be achieved by assigning the dimension to users whose channel gains are good for it. The latter case is all about dynamic allocation.

In wireless multi-user OFDM systems, there is a need for a multiple access scheme to allocate the subcarriers to the users and dynamic resource allocation improves the performance by exploiting the multi-user diversity, i.e. the fading parameters for different users are mutually independent, the probability that a subcarrier is in deep fade for all the users is very low (Wong, et al. 1999).

Many dynamic resource allocation algorithms and optimization techniques have been proposed for the downlink of a multi-user OFDM system. They can be classified into two broad categories: Aim to reach the highest throughput with the minimum transmit power , either (a) with the users' data rates as the constraint and the total transmit power as the objective (power adaptive) or (b) with the constraint on the power and the total throughput of the system as the objective (rate adaptive) Wong, et al. 1999; Rhee and.Cioffi, 2000; Jang and Lee, 2003; Kivanc et al., 2004)

- ❖ Aim to maximize the throughput within the power budget while maintaining the proportionality between the users' rates according to proportional constraints rather than reaching a specific requested data rate.

Dynamic resource allocation algorithms can also be classified, depending on control element allocation: Centrally Controlled Allocation or Distributed Control Allocation.

3. Results and Discussions

Reduced Complexity Adaptive Subcarrier and Bit Allocation for Multi-user OFDM networks

Support for a large number of subscribers and the fulfillment of quality-of-service (QoS) requirements in a limited resource environment are challenging tasks and the top priorities for next generation wireless systems. Ubiquitous OFDM, mostly for its ability to mitigate ISI with high data rates support is chosen to be in the heart of future wireless systems' design. The evidence is that even the CDMA pioneers' camp has recently shifted to OFDM in their newest standard of UMB.

RRM, responsible for the efficient distribution of radio resources (subcarriers and transmit power) within a cellular system, involves two key aspects:

- Handling the co-channel interference (CCI) caused by the RF bandwidth reuse
- Providing the required QoS (bit rate and bit error rate).

Traditionally, cellular systems use frequency reuse concept to enhance the efficiency of spectral utilization, which introduces co-channel interference mainly from adjacent co-channel cells and hence the major sources of performance degradation.

The second major impairment considered is frequency selective fading due to inter-symbol-interference (ISI) induced by wireless multi-path fading channels while supporting high data rate transmission over wireless radio channels (Junqiang et al., 2003). The latter is mitigated when OFDM modulation is used and a right gap length applied.

With multi-user diversity capability of OFDM (A) the statistics of fading and interference over links between BS and MS are mutually independent and hence unlikely to concurrently deeply fade or experience high CCI altogether for all users (Wong, et al. 1999).

In OFDMA system, multi-user adaptive resource allocation of downlink in a cell is showed in figure 1. At the base station side, all the packets of downlink queue in the base station. According to the dynamic information of the system, users and channels, with the allocation schemes of subcarrier, power and bit, which formed from adaptive scheduling algorithm, the base station allocates the sub-carrier to the user, and determines the transmitting bits per symbol of every subcarrier and the suitable transmitting power.

It is assumed that the instantaneous CSI is known to BS as the information is got on access of the MT to the BS through reverse link.

The present and core section of this thesis has some relative works existing in literature but targets and emphasis are different. The number of performance metrics is increased and we study the convergence of the proposed algorithm, the outage performance and spectrum efficiency comparing the current work and other proposals.

It is shown that the present proposal converges far faster than others with nearly the same outage probability and spectrum efficiency.

Problem Formulation and System Model

With complexity reduction as ultimate target (speed of convergence), the prime objective is to allocate radio resources (subcarriers particularly) to users taking into account the QoS constraints (bit rate requirement and bit error rate reduction).

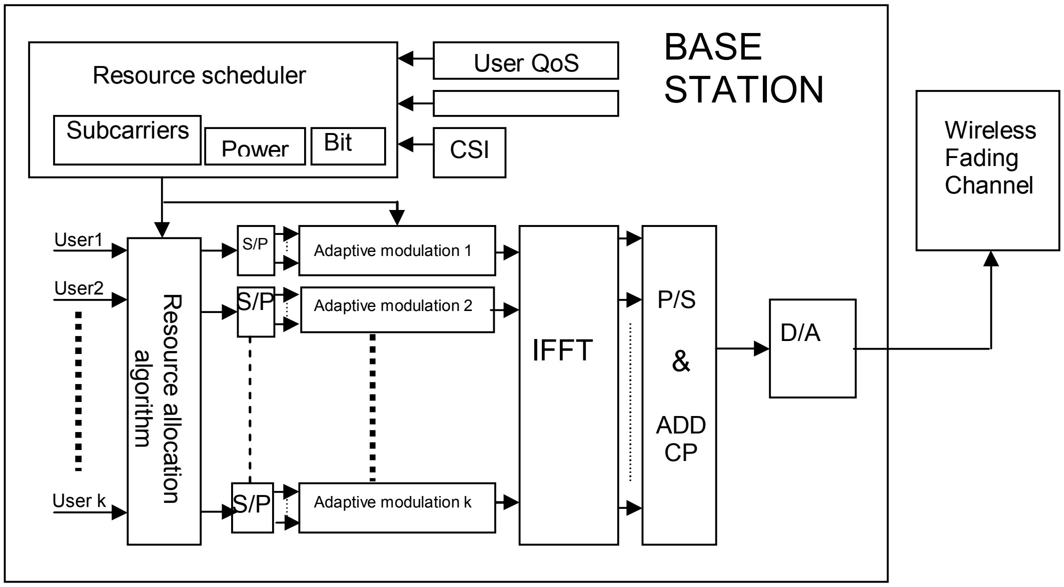

Figure 1Generic OFDMA System _transmitter side

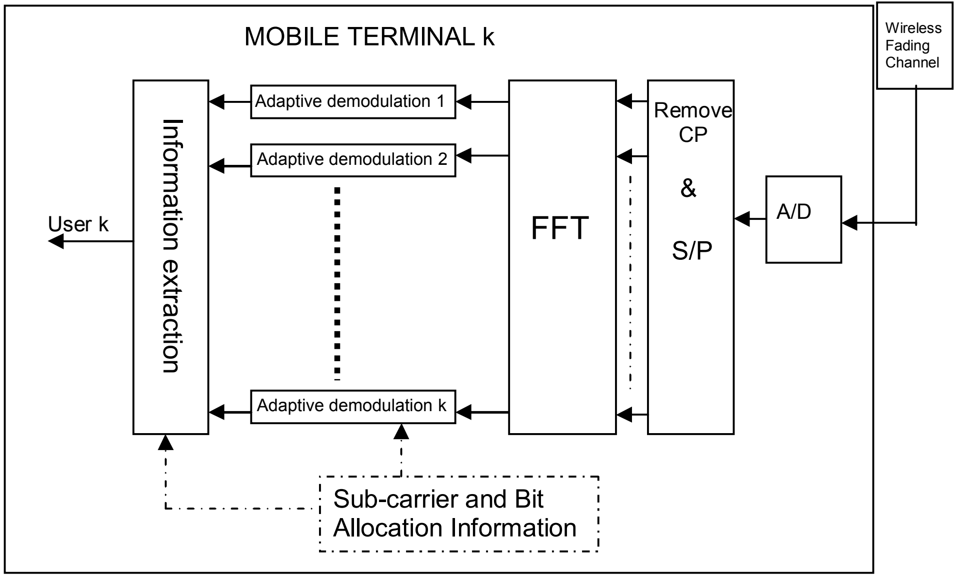

Figure 2 OFDMA SYSTEM Model_ Receiver side

OFDMA system bases its performance on OFDM modulation, described earlier in above pages. Besides the advantages of OFDM, the flexibility of the system in allocating resources to users is an added advantage. It was shown in (Berzdivin, , 2002.) that the system spectral efficiency can be significantly enhanced by adjusting the allocation of subcarrier, power, and constellation sizes in accordance with the user's channel state conditions.

Allocation of resources (subcarriers and bits)

In the BS, the serial data from the K users are fed into the subcarrier and bit allocation block, which is responsible for allocating resource to users.

We assume that the BS knows the instantaneous channel gains of all the users. Using the channel information, the BS applies the resource allocation algorithm (which may combine subcarrier, power and bit allocation algorithms) to assign different subcarriers to different users and the number of bits/OFDM symbol to be transmitted on each subcarrier.

As seen in the wireless link adaptation section, depending on the number of bits assigned to a subcarrier, the adaptive modulation level will be used accordingly.

In our multi-user system, no subcarrier is allowed to be allocated to more than one user in the same cell; i.e.

$i_{k,n} = 1$ (Assignment case) and $i_{k',n} = 0$ (no assignment) for $\forall k' \neq k$

Where, $i_{k,n}$ represents assignment indicator for allocation of n^th^ subcarrier to k^th^ user.

We can define $c_{k,n} \in D$ as the number of bits to be assigned to n^th^ subcarrier for the k^th^ user and this is according to the user's channel condition and the adaptive modulator level allowed.

$D = \{1, 2, \ldots, L\}$ With L, the highest modulation level.

The adaptive modulator task is to map the $c_{k,n}$ bits into a QAM symbol and the latter is transmitted on subcarrier n with $p_{k,n}$ transmit power. At the receiver, after removing the cyclic prefix and applying FFT, the user data symbols are extracted from the assigned subcarriers according to the subcarrier allocation information and the modulated symbols are mapped to bits according to the bit and power loading information.

For user k with a requirement on BER, $c_{k,n}$ should be chosen according to the target BER and the received power level of user on subcarrier.

$$c_{k,n} = f(BER, p_{k,n}, g_{k,n}) \qquad (1)$$

Where, $g_{k,n}$ is the magnitude of the channel gain seen by the k^th^ user on the n^th^ subcarrier.

With an overall throughput of $T = \sum_{k=1}^{K} R_k$ (2)

Where, bits per OFDM symbol and the number of bits transmitted by user k are linked

by $R_k = \sum_{n=1}^{N} i_{k,n} c_{k,n}$, (3)

The problem of optimization at hand is to maximize the throughput for a given minimum transmission rate and can be formulated as

$$\max \sum_{k=1}^{K} R_k = \max_{c_{k,n}, i_{k,n}} \sum_{k=1}^{K} \sum_{n=1}^{N} i_{k,n} c_{k,n} \qquad (4)$$

Subject to $\sum_{n=1}^{N} i_{k,n} c_{k,n} \geq r_k \quad \forall k$ (5)

With $i_{k,n} = 1 \Rightarrow i_{k',n} = 0$ (6), whenever $k' \neq k$

We can circumvent the nonlinearity of equation (1) with respect to power by adopting the idea that a fixed power allocation leads to a negligible throughput penalty if only the power is poured on subchannels with good channel gains (Andrea et al., 2001; Andrea and Greene, 1997). With power equally distributed to the subcarriers, the problem complexity is reduced.

$$\therefore \quad p_{k,n} = \frac{P_{tot}}{N}, \qquad \forall i_{k,n} = 1 \qquad (7)$$

We can note that $T = I_{k \times n} \times C_{k \times n}$

Where, the second member is the outer product of assignment matrix and a matrix of number of bits assigned to subcarriers respectively.

With equation (7) in consideration, the objective is to design an algorithm to allocate subcarriers to users, guaranteeing QoS (bit rate) with minimum BER.

The scheme's algorithms

Two cases are investigated: In case (a), the algorithm starts by finding the best user whose allocated subcarrier carries most large number of bits. This is double index process and brings in more processing overhead compared to case (b) though the efficiency and convergence are still better, see fig. 2 and corresponding result figures 3.

Case (b) furthers simplification of the algorithm with reduce processing overheads, the step of calculating the list of best subcarriers carrying more bits is eliminated and subcarriers are allocated one by one. This brings in the simplicity and faster convergence with the cost of very small reduction in efficiency, see figure 4.

Table 1 Simulation Parameters

Parameter	**Values or description**
W	Set of subcarriers
U (number of users)	15
N (Number of subcarriers)	512
Size of the cell(m)	500
Central frequency(GHz)	2GHz
Minimum Rate requirements (bits/OFDM symbol)	1,30,80,90,60,90,60,60,60,100,60,60, 60,80,60
Target BER	10^{-4}
Path loss exponent	4
Number of blocks	100

$W = \{1, 2, ...n, ..., N\}$

$U = \{1, 2, ...k, ..., K\}$

$While$

$W \neq \phi \ \& \ U \neq \phi$

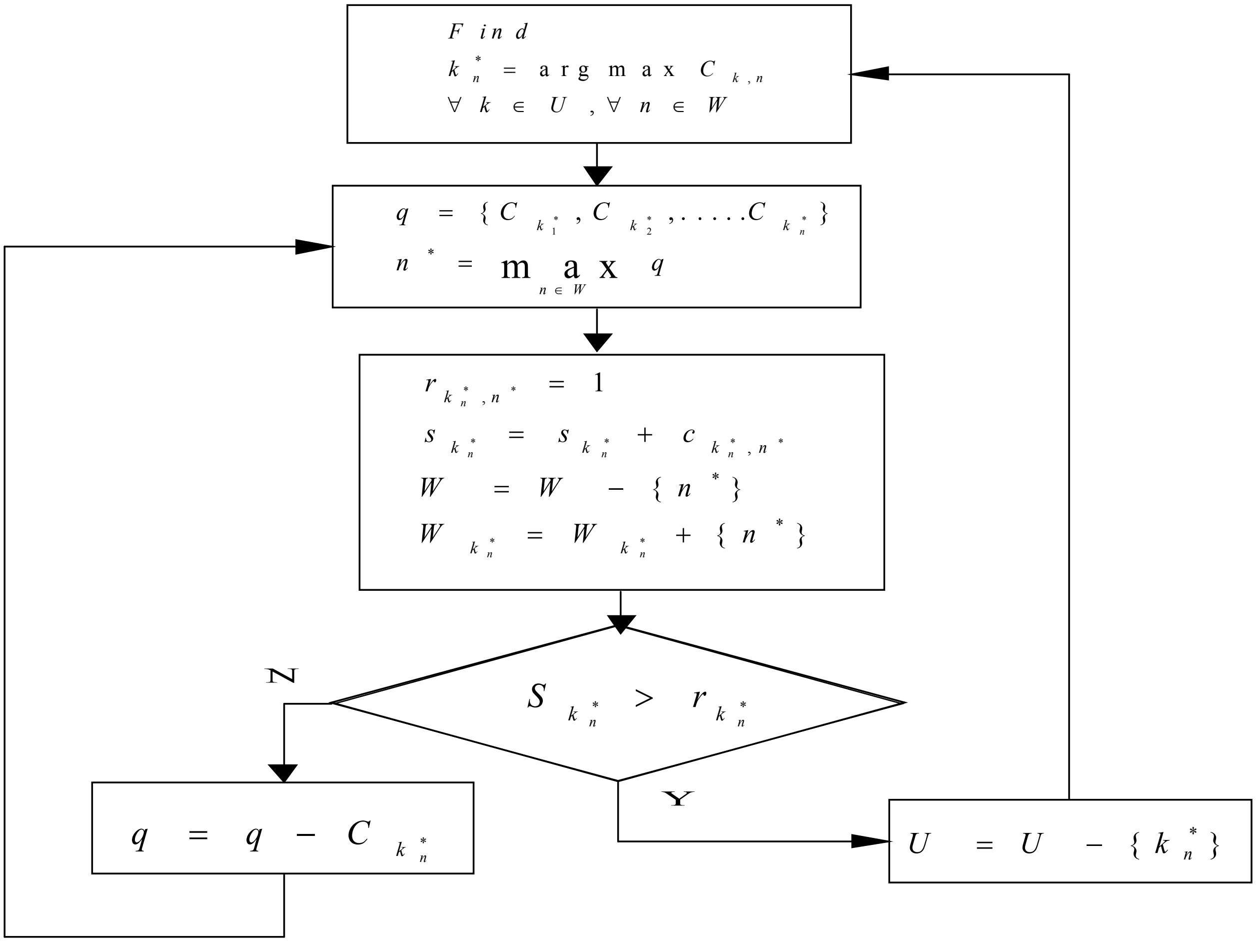

Figure 3 RA algorithm through best user and best sub-carrier step

$W = \{1,2,\ldots n,\ldots, N\}$
$U = \{1,2,\ldots k,\ldots, K\}$
$While$
$W \neq \phi \ \& \ U \neq \phi$

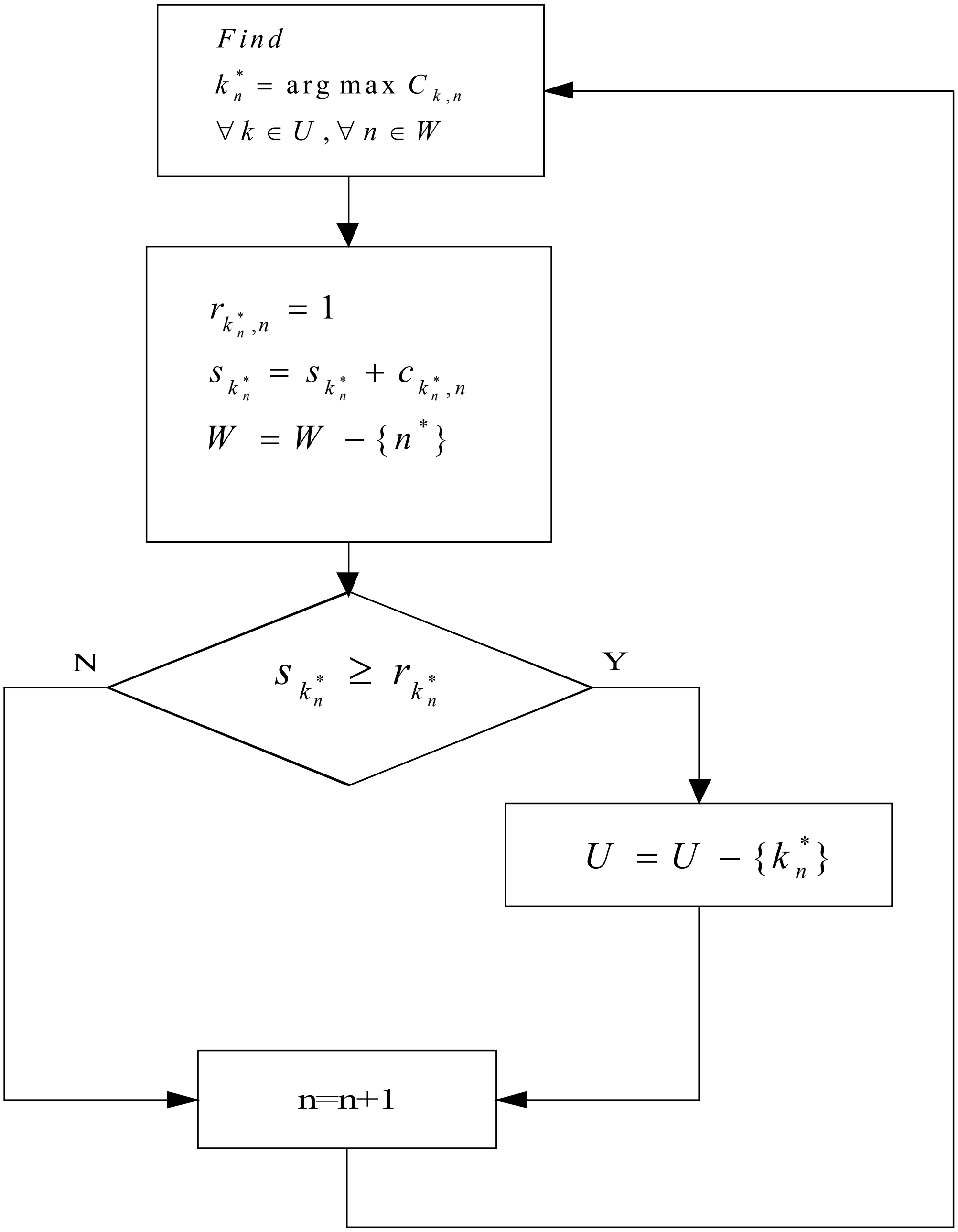

Figure 4 RA Algorithm further simplified, one by one allocation mode

The performance of the proposed RA algorithm in regard to the received power level at the boundary of a cell (Worst SNR) and the spectrum efficiency of our algorithm in comparison with others is as per the figure 3.

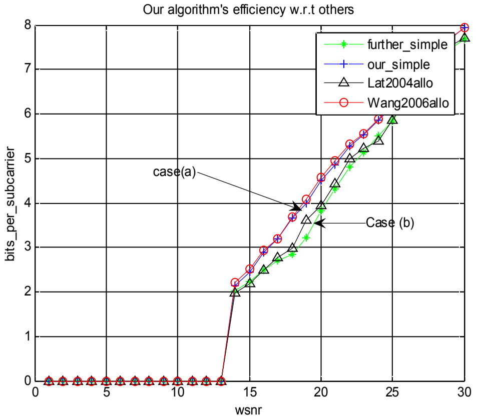

Figure 5 Results corresponding to Fig 2

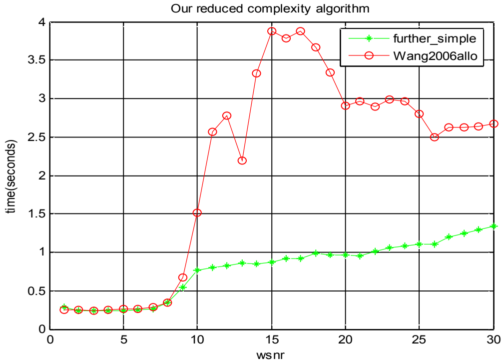

Figure 5 Relative convergence of our algorithm

Though the proposed low-complexity algorithm doesn't claim to yield the exact optimum solution, numerical results show that it can achieve a very satisfying solution particularly when with case (a).

With outage probability defined as the probability of having a condition in which a user is completely deprived of service by the system, it is proportional to the amount of resources required by user as well as the amount of resources that have been occupied by other users in the same cell, inversely proportional to the available resources. The Fig.5 shows the relative performance of our subcarrier-and-bit allocation algorithm in outage probability vs. wsnr situation.

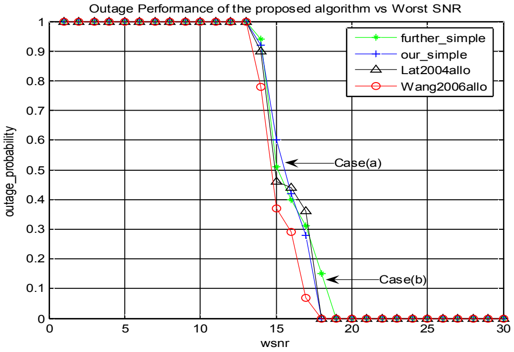

Fig 6 Outage performance

4. Conclusion

The traditional resources that have been used to add capacity to wireless systems are radio bandwidth and transmitter power where these two resources are among the most severely limited in the deployment of modern wireless networks; radio bandwidth, because of the very tight situation with regard to useful radio spectrum, and transmitter power because mobile and other portable services require the use of battery power, which is limited. With Hostile wireless channels, proved to be the bottleneck for high speed wireless systems and likely to cause ISI, the multi-carrier transmission and particularly OFDM has surfaced recently to be used for the on-development and future generations of wireless systems to combat most of the odds of wireless channels with low cost and less complexity. Channel-aware adaptive resource allocation has been shown to achieve higher system performance than static resource allocation, and the latter is becoming more critical in current and future wireless communication systems as the user data rate requirements increase. In this paper the core section of Radio Resource Allocation strategy was described,

→ Two Reduced complexity resource allocation (RA) algorithms are proposed.
→ Attributes of the proposed algorithms are
❖ Reduced Complexity
❖ Performance improvement (Outage probability and Spectrum efficiency).

Both attributes are demonstrated by graphs obtained through system simulation using Matlab. The current work contribution consists in complexity reduction shown through its convergence speed in comparison with other proposed Resource Allocation (RA) algorithms. The second contribution is the performance improvement by spectrum efficiency metric.

Some of the Used Abbreviations

1G	1^{st} Generation
AMC	Adaptive Modulation and Coding
AMR	Adaptive Multi-Rate
BS	Base Station
BSC	Base station controller
BTS	Base transceiver station
CCI	co-channel interference
CDMA	Code Division Multiple Access
CSI	
EDGE	Enhanced Data Rates for GSM Evolution
EVRC	Enhanced Variable Rate Coding
FA	Foreign agent
FDMA	Frequency Division Multiple Access
HA	Home agent
HLR	Home location register
IEEE	Institute of Electrical and Electronics
IMS	IP multimedia subsystem
ISI	Inter-symbol-interference
ISM	Industrial, Scientific and Medical
ISP	Internet service provider
LA	Location Area
LDAP	Lightweight directory access protocol
LMDS	Local Multipoint Distribution Service
LTE	Long term evolution
MAC	Medium access control
MAP	Mobile application part
MIP	Mobile IP
MMDS	Multichannel multipoint distribution service
MN	Mobile node
MT	Mobile Station
NM	Network Manager
OAM	Operations, administration and maintenance
OFDMA	Orthogonal Frequency Division Multiple Access
QoS	Quality of service
RAN	Radio access network
RF	Radio Frequency
RRA	Radio Resource Allocation
RRM	Radio Resource Management
TDMA	Time Division Multiplexing Access
UMB	Ultrawide Mobile Broadband
WCDMA	Wideband Code division multiple access
WLAN	Wireless local area network

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