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Full Length Research Paper

Dynamic resource allocation in mobile WiMAX using particle swarm optimization techniques

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Allocating radio resources dynamically in wireless network is highly complex and non-linear. It becomes even more complex when the wireless network is designed for heterogeneous traffics with different quality of service (QoS) requirement like WiMAX network. In this paper, we proposed a low complex algorithm for subcarrier allocation in multiuser OFDM of WiMAX system. The proposed algorithm uses particle swarm optimization (PSO) technique to search subcarrier with high channel gain and allocate it to users. The proposed method has a complexity of $M\log_2 N$ for M users and N number of subcarriers using big O O(.) notation. The proposed algorithm has been compared with previous works, and it has been shown that this algorithm has an average of 22.5% less central processing unit (CPU) time usage for allocating resources.

Key words: Subcarrier allocation, complexity, CPU usage optimization, particle swarm optimization.

INTRODUCTION

WiMAX is one of the recent broadband wireless communication technologies, which supports five different scheduling services. It has a large coverage area per base station which can be up to 30 miles in radius (WiMAX F 2008, and IEEE802.16 Standard 2005). To increase the coverage and throughput, relay stations were introduced by IEEE. This eventually increases the chance of more traffic to compete for the limited bandwidth. To handle these increasing traffics, WiMAX supports adaptive modulation and coding, such that the distance between the subscriber station (SS) and the base station (BS) determines the type of modulation to be used (WiMAX F 2008, and IEEE802.16 Standard 2005).

The IEEE802.16 standard 2005 defines five scheduling classes, but it does not provide any information about the standard algorithms that should be used to provide QoS to the service flows (SFs). CAC plays an important role especially when combined with scheduling service, since they are meant to manage and guarantee the QoS requirements as shown by Shu'aibu et al. (2010). A single CACs algorithm cannot guarantee the QoS without the support of scheduling algorithm and vice versa. Although these algorithms can be designed separately, each has to be efficient in managing the network resources. The CAC handles the performance of the link bandwidth while the scheduling handles other QoS parameters like delay, jitter, latency and slot allocation.

To allocate subcarriers which form the slots is highly complex in WiMAX. WiMAX uses orthogonal frequency division multiple access (OFDMA) which is a multiuser OFDM that divides the entire transmission bandwidth into a number of orthogonal subchannels. As such, different users can transmit data within one OFDM duration (WiMAX F 2008, Han and Ray, 2008). This utilizes the advantage of multiuser diversity, since each user sees the channel differently. It was shown by Shen et al. (2003), Han and Ray (2008) that, allocating subcarriers with high channel gain to a user improved the user data rate. A lot of methods have been presented in literature on how to allocate resources which are generally classified as either dynamic resource allocation (DA and KO, 2009; Wong et al., 1999, 2004; Rhee and Cioffi, 2000) or fixed resource allocation (Lawrey, 1999). In dynamic resource allocation, the

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allocation of the resources is dynamically changed as the channels change. In fixed resource allocation, the resources are allocated to users when admitted throughout the call duration.

It does not utilize multiuser diversity mostly used in time division multiple access (TDMA) system. In dynamic resource allocation, there are two optimization techniques that exist in literature, one minimizes the total transmit power subject to users data rate and the other maximizes the user data rate with constraint to total transmit power. Shen et al. (2003) and Wong et al. (1999), allocated subcarriers to minimize the total transmit power with constraint on users' data rate, which is called margin adaptive. While for Wong (2004), Rhee and Cioffi (2000), each user data rate is maximized with constraint to total transmits power, which is called rate adaptive.

These optimization problems are highly nonlinear in nature and very complex to solve. A number of attempts were made in order to reduce the complexity for *M* users and *N* subcarriers. Shen et al. (2003), presented sorted list approach for subcarrier allocation and root finding for power allocation which has a complexity of $O(MNlog_2N)$ for subcarrier allocation and $O(N+nM)$ for power allocation using *Big-O, O*(.) *notation* given by Raphael and Smith (2003). In order to reduce the complexity in power allocation, water filling algorithm was used by Wong et al. (2004), also by DA and KO (2009) which reduced complexity to $O(M+N)$. The complexity of subcarrier allocation presented in Shen et al. (2003), Wong et al. (2004) and DA and KO (2009) works, was further reduced to $O(MN)$ by Brah et al. (2009) using Langrage dual decomposition.

In this paper, we present a reduced complexity of subcarrier allocation to $O(Mlog_2N)$ using particle swarm optimization where we maintained the same power allocation as using water filling as presented in DA and KO (2009) paper.

SYSTEM MODEL

We considered *m* users communicating with base station using *N* subcarriers. Each user *m*, feedbacks the channel condition to the allocation block, in which subcarriers, bits and power are assigned to each user as shown in Figure 1. We modeled each channel with six independent Rayleigh multipath fading, each with amplitude *A* and initial phase shift of *C.* The normalized amplitude of each channel is given by $\frac{A(i)}{\sqrt{\sum_{i=1}^{6}\left(A(i)\right)^2}}$, each channel has initial phase shift of $2\pi C(i) / \max(C(i))$ where *A* and *C* are normally distributed with mean zero and standard deviation of one.

The input angle is $2\pi n / N$ where *n* is integer ranging from 0 to *N-1* (*N* is the number of subcarriers). Each multipath has a relative energy with one sided exponential profile given by *E,* with *τ* used as the delay spread $E(i) = e^{\frac{\tau(i)}{t_o}}$ where t_o is the sampling interval. The maximum Doppler shift allowed is f_{max}, and each channel has *I* and *Q* which is modeled as in Equation (1) and (2) as follows,

$$I_{N,i} = E(i) * \frac{A(i)}{\sqrt{\sum_{i=1}^{6}\left(A(i)\right)^2}} \cos(2\pi f_{max} t \cos(\frac{2\pi n}{N} + \frac{2\pi C(i)}{\max(C(i))})) \quad (1)$$

$$Q_{N,i} = E(i) * \frac{A(i)}{\sqrt{\sum_{i=1}^{6}\left(A(i)\right)^2}} \sin(2\pi f_{max} t \cos(\frac{2\pi n}{N} + \frac{2\pi C(i)}{\max(C(i))})) \quad (2)$$

The channel gain (φ) of each user *m* on every subcarrier *n* undergoing multipath (i), is a function of *I* and *Q* from the two equations above. All users experience independent fading, the channel gain of each user m $(1 \le m \le M)$ on subcarrier n $(1 \le n \le N)$ is given by $\varphi_{m,n}$ with AWGN (Chung and Goldsmith, 2001). The channel to noise ratio of user *m* on subcarrier *n* is thus given by $H_{m,n} = \frac{\varphi_{m,n}^2}{\alpha^2}$ where α is the AWGN given by $\alpha^2 = \frac{N_0 B}{N}$, N_o is the noise power spectral density and *B* is the bandwidth. The received signal to noise ratio (*SNR*) at the receiver is given by $\beta_{m,n} = p_{m,n} H_{m,n}$, where $p_{m,n}$ is the power of subcarrier *n* on user *m*. It was given by Chung and Goldsmith (2001) that the bit error rate of a square QAM with grey bit mapping is a function of the received signal to noise ratio and the number of bits on each subcarrier for each user $b_{m,n}$. The bit error rate (*BER*) is thus approximated within 1*dB* for $b_{m,n} \ge 4$ and $BER \le 10^{-3}$ as given in Equation (3),

$$BER(\beta_{m,n}) \approx 0.2 \exp\left[\frac{-1.6\beta_{m,n}}{2^{b_{m,n}} - 1}\right] \quad (3)$$

The data rate $b_{m,n}$ can be derived from equation (3) as,

$$b_{m,n} = \log_2(1 + \frac{\beta_{m,n}}{\gamma}) \quad (4)$$

where $\gamma = -\frac{\ln(5 * BER)}{1.6}$ and $\beta_{m,n} = p_{m,n} * H_{m,n}$

Our target is to maximize each user data rate. The

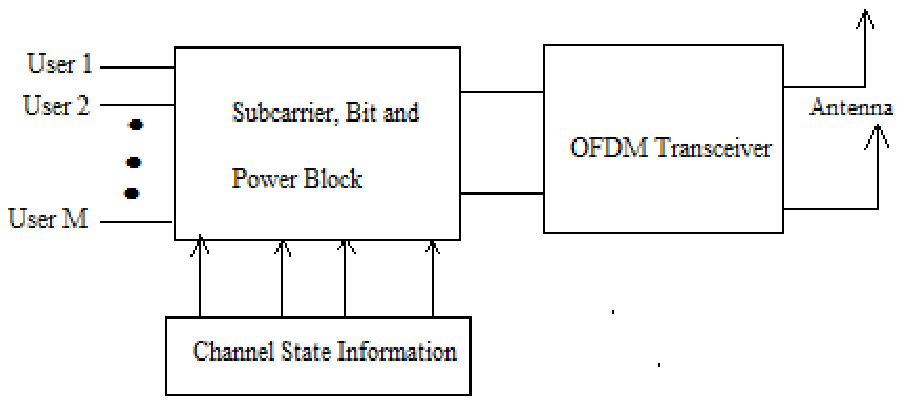

Figure 1. OFDM transmitter.

objective is formulated as follows,

$$\max \frac{B}{N} \sum_{m=1}^{M} \sum_{n=1}^{N} d_{m,n} \log_2\left(1+\frac{p_{m,n}H_{m,n}}{\gamma}\right) \qquad (5)$$

Where $d_{m,n}$ is binary function, 1 when subcarrier *n* is allocated to *m* and zero otherwise. The constraint associated with objective in Equation (5) is formulated as follows;

$$d_{m,n} \in (0,1) \forall m,n \qquad (6)$$

$$\sum_{m=1}^{M} d_{m,n} = 1 \forall N \qquad (7)$$

$$p_{m,n} \geq 0 \forall m,n \qquad (8)$$

$$\sum_{m=1}^{M} \sum_{n=1}^{N} d_{m,n} p_{m,n} \leq p_0 \qquad (9)$$

p_0 is the total power transmitted by the base station. Constraint in Equation (6) indicates that each subcarrier is allocated once, while constraint (7) indicates that each subcarrier is allocated to one user. Constraint (8) shows that each subcarrier is allocated a power and (9) indicates total power across all users over all subcarriers should be less or equal to the total transmit power. The
total data rate of user m is thus given by,

$$R_m = \frac{B}{N} \sum_{n \in j} b_{m,n} \qquad (10)$$

where *j* is the set of subcarriers assigned to user *m*.

PROPOSED PARTICLE SWARM OPTIMIZATION TECHNIQUES

Particle swarm optimization is a bio-inspired optimization technique, where particles are randomly deployed in search space with *n*-dimensions. The literature of PSO is covered by Kennedy and Eberhart (1995) and selecting best PSO parameters in engineering application was given by Robinson and Rahmat-Samii (2004), the particle move with velocity is given by;

$$\begin{aligned} v_n &= w * v_n + c_1 * rand() * (P_{best} - x_n)... \\ &+ c_2 * rand() * (G_{best} - x_n) \end{aligned} \qquad (11)$$

It updates its position in the search space as in (12)

$$x_n = x_n + \Delta t V_n \qquad (12)$$

We considered 2-dimensional space x, y correspond to *I, Q* of the channel gain. The search space is from -2 to 2 in both dimensions. The fitness function is thus given by; $f = f(I,Q)$ and $d_{m,n}$ this forms the un-assigned channel gain of a subcarrier. This is stored in form of matrix with dimensions $M \times N$. The subcarrier gain represents the solution space given by $\varphi_{m,n} = [\varphi_{m,1}, \varphi_{m,2}, \varphi_{m,3}.......]$ the fitness function of m-user $f_m(n)$ is the nth subcarrier gain obtained from gain profile as $f_m(n) = \varphi_{m,n} d_{m,n}$. The system is optimized when the PSO converged or the number of iterations reached its maximum defined value, in case of non-convergence condition due to many solutions. P_{best} is the local channel gain found by any particle while G_{best} is the global channel gain found by all the particles, which has not been assigned to any user. The general PSO algorithm is as follows;-

Initialize the particles across the search space
for each user, calculate the no. of subcarriers required
Loop while not optimized or less than no. of iteration

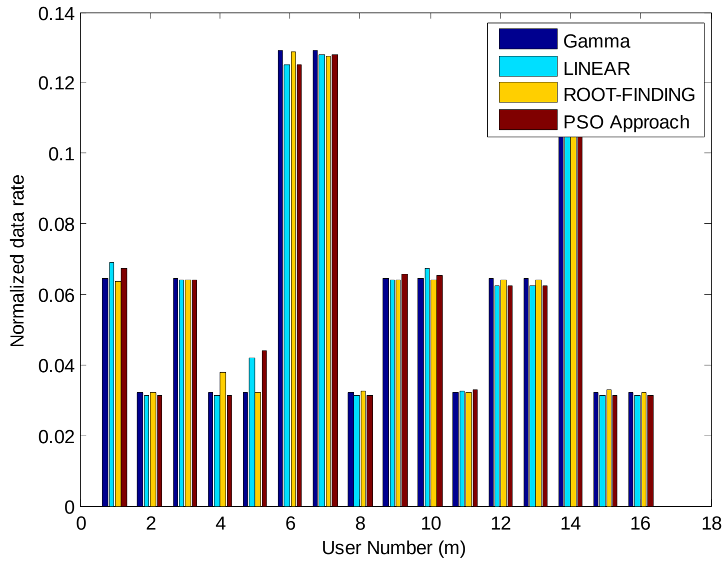

Figure 2. Normalized data rate of users.

for each particle in the search space
if (local gain > global gain)
Replace the global gain with local gain
Calculate the local gain
Calculate new position and velocity
Move to the new position
end if
end loop
return the global channel gain.
end for

SIMULATION RESULTS

The simulation parameters set up are as follows; maximum delay spread across the multipath of 5 µs and 30 Hz Doppler shift is used. The total power was set to 1W, a total of 64 subcarriers were used. The channel information was sampled every 0.5 ms to update the channel condition. For the PSO settings, 30 particles are used, with W=1, C_1 and C_2 are set to 2.0. We used gamma function to set the target data rate for each user. The approach Shen et al. (2003) used is called root-finding; while that of Wong et al. (2004) is linear method and the proposed method presented in this paper is called PSO approach. Figure 2 shows the normalized data rate for 16-users and how the 3-approaches adhere or deviate from the target rate.

The proposed approach adhered to the target data rate with maximum deviation in user 5. The algorithms take two users at a time. Linear method has less complexity than root-finding method; we compared the performance of linear approach with the proposed.

Figure 3 shows the spectrum efficiency of the three approaches, it can be seen that the deviation among the 3-approaches is less than 6%. Figure 4 shows the CPU time usage of the 3-approaches and we can see that, the time required to allocate resources for user index 2, 6, 8, 10, 12, 14 and 16 is 40, 70, 20, 10, 30, 5 and 5% less in PSO approach compared to linear method. This gives overall average of 22.5% reduction in CPU time usage for 16 users when PSO is used. Figure 5 shows a situation of non-convergence for user index 10 and 14 which required a little more time to allocate resource using PSO than linear. The complexity of the proposed approach is $Mlog_2N$ *using Big-O* O(.) *notation* (Raphael and Smith, 2003), because PSO uses unsorted list, every potential particle can be a solution, no sorting of subcarriers is required, while the approach presented by Wong et al. (2004), DA and KO (2009), used sorted list with complexity of $MNlog_2N$, each subcarrier N, is sorted N times to all users M.

The use of PSO has reduced the complexity of arranging the subcarriers n times in descending order of the channel gain. Each PSO particle is a potential solution, because it can get the subcarrier with highest channel the first time it moves into the solution space.

Conclusion

In this paper we have presented subcarrier allocation for *m* users in WiMAX using PSO, in which the conventional approach of sorting subcarriers to all users in descending order of the channel gain is eliminated, hence, the

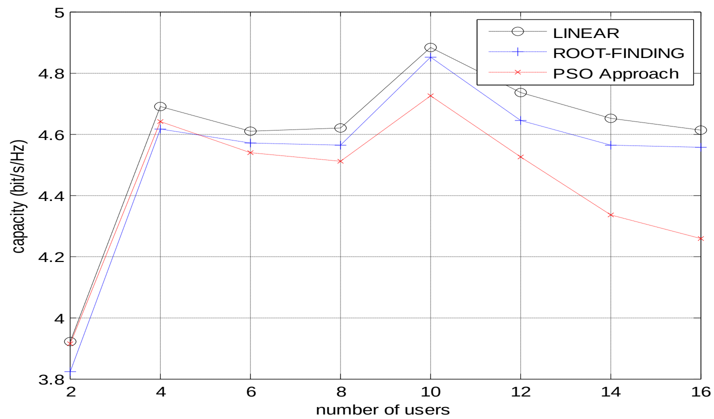

Figure 3. Spectrum efficiency.

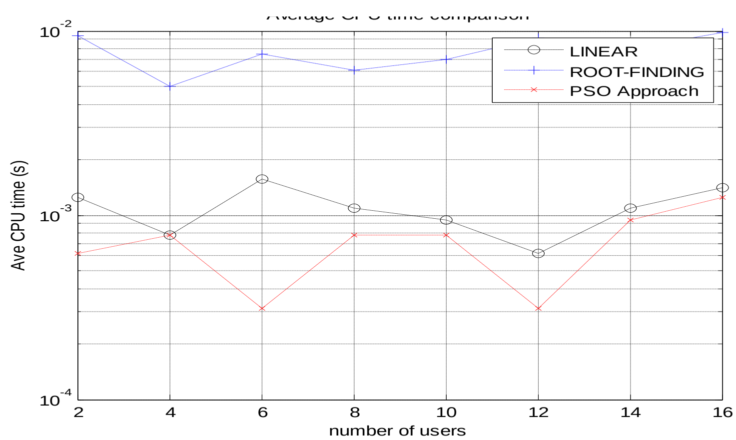

Figure 4. CPU time usage.(Average CPU time comparison).

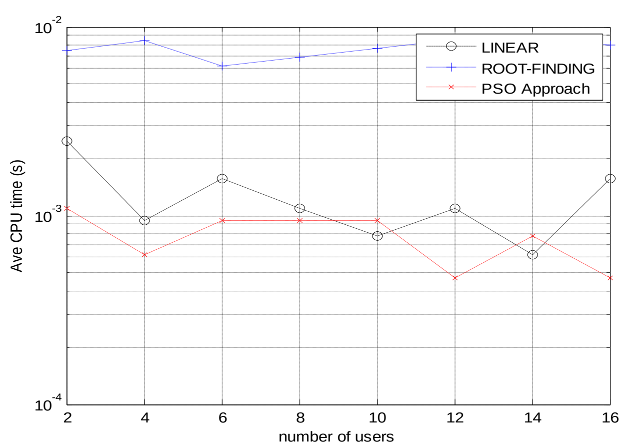

Figure 5. Time for non-convegence problem.(Average CPU time comparison.).

complexity of the resource allocation techniques in form of CPU time usage is reduced by an average of 22.5% of the time required in linear method.

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