International Journal of Engineering & Technology, 7 (2.7) (2018) 69-76

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

Suboptimal resource allocation scheme for scalable video multicast in integrated mobile WiMAX/WLANs network

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Abstract

The goal of Resource Allocation Scheme (RAS) is to accomplish maximum usage of resources, assures Quality of Service (QoS), exploit throughput and diminish power consumption with viable algorithm complexity and scalability of system. RA algorithm for dynamic RAS in downlink Mobile WiMAX is to maximize the minimum rate of user while satisfying power constraint. This study emphasizes on scalable video transmission in Downlink Mobile WiMax BS with 5 WLAN's each comprised of 10 users with different QoS requirements. Convex optimization techniques in scheduling algorithms marginally improve the performance measure as compared to traditional iterative non-linear methods. This study proposes Active-Set optimization technique for power allocation (PA) amongst sub-carrier per Subscriber Station (SS) and Greedy Weighted Algorithm (GWA) for sub-carrier allocation. Finally simulation results show that the proposed GWA and Active-Set optimization technique can effectively achieve maximum network throughput and number of satisfied users.

Keywords: *Active-Set optimization, Greedy Weighted Algorithm, Mobile WiMAX, multicast, resource allocation, scalable video coding (SVC).*

1. Introduction

WiMAX can provide data rates of 75Mbps, 350Mbps for single and multiple channels respectively [6] [7].
Bandwidth Allocation Algorithm have been designed for efficient utilization of scares radio resources [1], [2], [3], [10], [14] in order to meet the large scale wireless network by sharing radio resources among multiple users. The load of resource obligation is placed on the base station to achieve effective spectrum utilization [1].
Orthogonal Frequency Division Multiple Access (OFDMA) has potential to reduce transmit power and flexible multiple access technique that can accommodate many users with QoS requirements with variation in data rates [1], [11], [12], [13].
Subcarriers and PA to subscriber in mobile WiMAX system has been area of active research [26], [27]. WiMAX network was proposed to meet the demands of both WiMAX service providers and subscribers [3], [9], [15], [24] in downlink resource management frame of multi-user. RAS is crucial in handling heterogeneous traffic load in a WiMAX network [8], [26], [27]. Despite of standard physical layer specification for IEEE 802.16e air interface remains open issue. Hence this open issue motivated us to design and propose novel downlink resource management framework for integrated mobile WiMAX and WLAN for efficient allocation of two key resources

i) Determination of aggregated downlink data rate if each subscribers within WLAN with optimized radio power and
ii) Accessing bandwidth assigned on different subscribers local network application.

Researchers have presented numerous RAS proposed in [10], [12], [13], [15], [16], [17], [19], [20], [24], [26] for data unicast in IEEE 802.16e networks. These algorithms allocate resource with different performance objective like low complexity [15], [17], [26] through put maximization [15], [26], [27] and number of satisfied users [27].
This study makes thorough investigation by designing a novel subcarrier allocation algorithm to provide a solution for subcarrier allocation and PA problem of data like video multicast in integrated IEEE 802.16/WLAN network. The proposed algorithm targets to maximize channel capacity, maximize data rate for each subscriber, maximize network through put, and maximize number of satisfied users under the constraint of bandwidth. Maximization problems of network performance are Non deterministic Polynomial (NP) hard [16], [17], [19], [27]. The projected algorithms decipher NP hard problems using Active Set algorithm which is convex to find sub- optimal solutions in polynomial time. In proposed algorithm an Active Set method. This approach reduces the computational complexity as it is achieved using approaches used in [15], [16], [17], [20], [28], [29], [30], [31].
This paper proposed following main contributions:

1. Propose GWA for sub-carrier allocation amongst various Subscriber Stations (SS).
2. Propose Active-Set optimization for RAS to maximize data rate of individual subscriber and at the end network throughput for PHY layer specifically.
3. Integrate proposed algorithm for WiMAX/WLAN network as system model.

4. Simulate proposed network with proposed algorithms for maximizing Network Throughput and Number of Satisfied users.

The remainder of this paper is organized as follows: Section 2 assesses related work on RAS in mobile WiMAX. Section 3 provides details of proposed network model and notations used in Objective function formulation. Section 4 describes proposed GWA scheme for sub-carrier allocation. Section V provides in detail analytical model of proposed Active-Set optimization for basic OFDMA system model used in [15], [16], [17], [18], [19], [20], [26] and apply to proposed; integrated WiMAX/ WLAN network described in Section 3. Section 4 shows simulated results for channel capacity, satisfied number of users and throughput of the network. Finally in section 7 we put our concluding remarks on proposed algorithms.

2. Related work

RAS formulated in such a way that to minimize transmission power with constraint on user data rate [15], [18], [19] or vice versa. Rate Adaptive Algorithm proposed in [15], [16], [17], [22], [26] are applicable only to general data traffic and basic downlink point to multiple point (pmp) OFDMA based system in WIMAX system. Simple RAS for ARIMA model is proposed in [29] for mobile video to represent MPEG4 video formats with five mobile stations only. Similarly ARIMA model is used for designing RAS for high definition HD videos [34]. Opportunistic layered multicasting scheduling and RAS using SVC technology is proposed in [30], [33]. To improve received video quality two level SCM scheme is introduced [31] which consequences in high computational complexity. Utility function is used to allocate resources amongst subscribers with SVC [32]. The convex optimization techniques to achieve low complexity by maintaining good through put of the network used in RA. The notion following the proposed scheme for scalable video coding for integrated WiMAX/WLAN network is different from those in related work.

3. Resource Allocation Scheme (RAS)

Proposed network model with specifications of WiMAX and WLAN described in this section, notations used in analytical model and then proposes an optimize RAS in the considered network.

3.1 Network Model and Notation

Fig.1. shows system model where one WiMAX Base Station provides Service to five WLAN. It is assumed that each WLAN comprised of 10 users with different QoS requirement. Also Each WLAN is situated at various distances from main WiMAX Base Station i.e. *d1>d2 & d4>d3&d5*. With respect to distance and QoS requirement WiMAX Base Station (BS) allot different number of sub-channels to those WLAN also PA is also done by Base Station.

It is assumed that WLAN network 1 is situated at longer distance i.e. in between 800m-1.6km, WLAN Network 2 and 4 are situated in between 400m to 800m and WLAN Network 3 and 5 are situated below 400m distance. Hence after sensing their distance and QoS requirement WiMAX Base Station decides to allot highest QoS Resources for WLAN Network 2 and 4 with 64QAM , for WLAN 1 and 3 Base Station provides burst profile with 16 QAM and for WLAN Network 1 Base Station uses Burst Profile with QPSK. Video data stream is transmitted by modulation schemes with more reliability when channel quality is not good. Proposed network consist of one Base Station, *K* Subscriber Stations (SS). SS associate with BS through access point of WLAN.

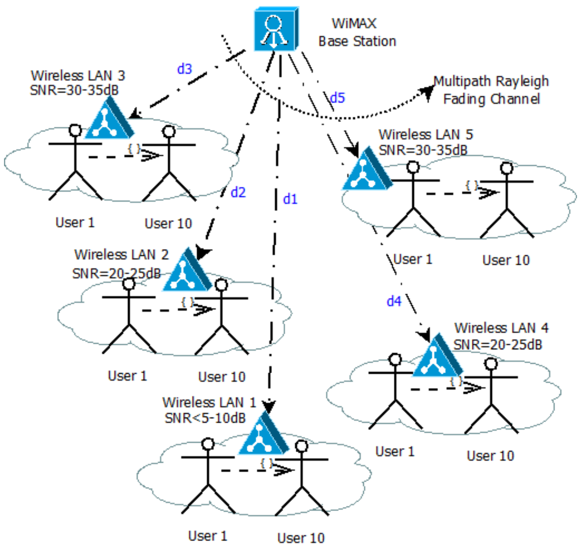


Fig.1. The proposed network model

BS consist of 1024 point IFFT, total bandwidth B=10MHz, total transmission power P=1W. $P_{k,n}$ power assigned to particular SS on subcarrier. For each SS (i.e. $1\leq k\leq K$) number of subcarriers should be $1\leq n\leq N$. Total data rate for SS denoted by R_k. Diverse data rates generated through SVC / H.264 which allows a video stream to be divided into one base layer and multiple enhancement layers. A Subscriber Station can select a level of quality video [44] depending on its device quality. In case if SS demands a video under quality level 1 then BS should guarantee a 176kbps data rate to that SS. Table I and Table II lists video workload parameters and OFDMA parameters for mobile WiMAX and WLAN considered for proposed network model.

Table 1: Video Workload Parameters [43]

Applications	Format	Data rate	Notes
Mobile phone video	H.264 ASP	176 kbps	176 x 144, 20 frames per second
Smartphone video	H.264 ASP	324 kbps	320 x 240, 24 frames per second
IPTV video	G,264 Baseline	850 kbps	480 x 480, 30 frames per second
Sample video trace	MPEG 2	350 kbps	Average Packet Size= 984 Bytes

Table 2: OFDMA Parameters for mobile WiMAX and WLAN [1], [2], [43]

Mobile WiMAX	
System Bandwidth (MHz)	10
Sampling factor	28/25
Sampling frequency (F_s, MHz)	11.2
Sample time ($1/F_s$, nsec)	89
FFT size (N_{FFT})	1,024
Subcarrier spacing (Δf, kHz)	10.93
Useful symbol time ($Tb = \frac{1}{\Delta f}$) μs	91.4
Guard Time ($T_g = \frac{T_b}{8}, \mu s$)	102.8
WLAN	
System Bandwidth (MHz)	10
FFT size (N_{FFT})	1,024
Modulation scheme	QPSK, 16QAM, 64 QAM

3.2 Objective function formulation

Shanon-Hartley theorem used to estimate the bandwidth requirement [14] per SS. This theorem states that channel capacity $C \leq 2B\log 2(Ḍ)$ bits per sec, B represents bandwidth in Hertz and $Ḍ$ represents number of discrete signal elements for modulation scheme. $Ḍ$ is 4 for QPSK, 16 for 16QAM and 64 for 64 QAM. For proposed network it is assumed that $Ḍ$ is 64 for WLAN3 and WLAN5, 16 for WLAN2 and WLAN4 and 4 for WLAN1. If SS under WLAN3 links to the BS with maximum data rate (D_R) requirement of 850kbps, the minimum bandwidth consumption for serving that subscriber would be 850kbps/log2(64) (i.e. from BS to access point of WLAN3) + 850kbps/log2(64) (i.e. from access point of WLAN4 to SS)≈284kbps.The purpose of RA is devised as shown in (1) [15],[16],[17],[20],[25],[26],[27],[35],[36],[37] where $C_{k,n}$ is sub-carrier allocation indicator, $P_{k,n}$ is PA indicator and $H_{k,n}$ is effective sub-channel signal to noise ratio (SNR), ω is weight of the user for estimation of priority.

$$\max_{c_{k,n}, p_{k,n}} \frac{B}{N}\sum_{k=1}^{K}\sum_{n=1}^{N} C_{k,n}\log_2(1+P_{k,n}H_{k,n}) \tag{1}$$

$$C1: C_{k,n} \in \{0,1\} \forall\, k,n$$
$$C2: p_{k,n\geq 0}\ \forall\, k,n$$

Subject to:

$$C3: \sum_{k=1}^{K} C_{k,n} = 1\ \forall n$$
$$C4: \sum_{k=1}^{K}\sum_{n=1}^{N} C_{k,n}p_{k,n\leq P}$$
$$C5: R_i : R_j = \omega_i : \omega_j\ \forall i,j \in \{1,2,3,\dots K\}, i \neq j$$

Note that (1) is a Non Deterministic Polynomial (NP)-hard combinational optimization problem with non-linear constraints.

4. Proposed Sub-Carrier Allocation Scheme

GWA developed to find optimum solution of NP-hard problems that determines set of Subscriber stations with priority. While assuming limited bandwidth we attempts to maximize network throughput. GWA maximizes channel capacity and finally network throughput using weighted values ω_k estimated as ratio of expected data rate for SS to minimum bandwidth consumption. To elaborate basic idea of this algorithm consider five users scenario each SS within WLAN. Assume SS1 belongs to WLAN1; SS2 belongs to WLAN2 likewise SS5 belongs to WLAN5. We assume that WLAN situated at less distance from BS has good channel quality. Estimation of ω_k shown as in Table III for scenario described. SS 3 and 6 belong to WLAN 3, D_R for SS3 is 850kbps and for SS6 it is 176kbps. Priority of SS 3 is 1 and SS 6 is 5, BS allots 284 KHz of the BW to SS 3. After serving SS 3 BS schedule to serve (SS 5, SS 2 and SS 4) of WLAN 5, WLAN 2 and WLAN 4. When BS starts to serve WLAN 3's SS i.e. SS 6 whose data rate requirement is only 176 kbps means 117 kHz.

Table 3: Estimation of Weight (ωk)

SS→WLAN	D_R (kbps)	Modulation Scheme at WiMAX/WLAN	Minimum BW Consumption (Bmin)KHz	ω→S_{pri}
1→1	176	QPSK / 64QAM	176/2+176/6=117	1.5→6
2→2	350	16QAM/64QAM	350/4+350/6=146	2.39→3
3→3	850	64QAM/64QAM	850/6+850/6=284	2.99→1
4→4	350	16QAM/64QAM	350/4+350/6=146	2.39→4
5→5	850	64QAM/64QAM	850/6+850/6=284	2.99→2
6→3	176	64QAM/QPSK	176/6+176/2=117	1.5→5

Previously assigned BW is 284 kHz and now its 117 kHz hence (284-117 = 167 kHz) bandwidth gets utilized for WLAN 3 which can be used to serve other SS for same WLAN. If 167 kHz is insufficient to satisfy an SS in a greedy stage then algorithm simply skip that SS and proceed to serve next SS. Detail algorithm explained as follows.

Algorithm_1. The proposed GWA for sub-carrier allotment.

1 Input : *{do,d1,……d5};*
{ ω1: ω2:--- ωk };
{WLAN1,WLAN2,…WLAN5}; WLAN index
{DR0,DR1,……DRk}; Expected data rate for every SS.
weight of SS calculated as $\omega_k = \frac{ExpectedDataRate\ (R_k)\ bySS}{MinimumBandwidthConsumption(Bmin)}$
2 Descending Sort of SSs using ω_k.
$N_1{:}N_2{:}\text{-----}{:}N_K=\omega_1{:}\ \omega_2{:}\text{---}\ \omega_k$
3 $N_k=[\omega_k N DR_k]$;Required number of Subcarrier for k^{th} user.
4 $N_{\text{var}} = N - \sum_{k=1}^{K} N_k$; Where N_{var} is not allocated sub-carriers. In second step N_k^{th} subcarriers for k^{th} user and N_{var} subcarriers allotted.
5 $C_{k,n}=0, \forall\ k \in \{1,\dots,K\}$, $n \in \{1,\dots,N\}$; Initialization
6 $R_k=0, \forall\ k \in \{1,\dots,K\}$
7 $P=P_{tot}/N^2$.
8 $(N_{set})=\{1,2,\dots,N\}$; Set of number of sub-carriers
9 ***for*** *k=1 to K*
10 Sorting of $H_{k,n}$ done in ascending order
11 $n=\arg\max_{n \in N_{var1}} |H_{k,n}|$; choose sub-carrier index where $H_{k,n}$ is maximum
12 $C_{k,n}=1$; Indication that sub-carrier allotted
13 $N_k=N_k-1$, $N_{set}=N_{set}/\{n\}$;*decrement 1 sub-carrier from un allotted subcarriers variable*
14 $R_k = R_k + \frac{B}{N}\log_2(1+P_{k,n}H_{k,n})$; Estimate data rate for specific SS applying QPSK,16QAM or 64QAM w.r.t. value of N_k.
15 ***end for***
16 ***for*** $\|N_{set}\| > N_{var}$
17 $K_{set}=\{1,2,\dots K\}$;
$k=\arg\min_{k \in Kset} (R_k/\omega_K)$; Estimate minimum k using ratio of data rate and weight
18 $n=\arg\max_{n \in Nset} (|H_{k,n}|)$; Estimate maximum *n* using Maximum value of $H_{k,n}$
19 ***end for***
20 **if** $N_k > 0$;if un allotted sub-carriers remaining then allot them amongst SS
21 $C_{k,n}=1$
22 $N_k=N_k-1$, $N_{set}=N_{set}/\{n\}$
23 $R_k = R_k + \frac{B}{N}\log_2(1+P_k H_{k,n})$
24 **else**
$K_{set}=K_{set}/\{k\}$; otherwise prepare group of sub-carriers act as a sub channel for each SS
25 $K_{set}=\{1,2,\dots K\}$
26 ***end if***
27 ***for*** *n=1 to* N_{var} ; allot remaining sub-carriers in this loop and again update K_{set}.
28 $k=\arg\max_{k \in Kset} |H_{k,n}|$
29 $C_{k,n}=1$
30 $R_k = R_k + \frac{B}{N}\log_2(1+P_{k,n}H_{k,n})$
31 $K_{set}=K_{set}/\{k\}$
32 ***end for***
33 SS_{count}=Active *SS* within each WLAN
34 $BW_{remaing}$ *= BW allotted – BW consumed by served SS.*
35 *BW efficiency=BW remaining/BW allotted*
36 Scan SS within every WLAN to allot BW remaining found in 34

The time complexity of sorting (in line 2) weights of subscriber stations in GWA is *O (N logN)*. The intricacy of sorting (in line 10) $H_{k,n}$ is *O (N logN)* and to rotate "*for loop*" until *Nset>Nvar* is *O(N)*. Thus, the total complexity is *O(N+N logN +N logN)=O(N+2N logN)=O(N logN)*. GWA maintains the low intricacy of sub-carrier allocation compared to algorithms proposed in [15], [16], [17], [18], [19], [20], [26], [35], [36] and effective in worst case.

5. Proposed Power Allocation Scheme using Active Set Optimization

Many Nonlinear equations like (1) can be reduced to linear equations by assuring that quantities of interest vary to only a small extent from some "background" state. Effective sub-channel SNR can be defined as follows.

$$H_{k,n} \triangleq \frac{h_{k,n}}{T} = \frac{g_{k,n}/\sigma^2}{-\frac{\ln(5BER)}{1.6}} \quad (2)$$

Step 1: Objective function defined by (1) is function of sub-carrier allocation indicator ($C_{k,n}$) and power allocation indicator ($P_{k,n}$) represented as $f(C_{k,n}P_{k,n})$. As we already proposed algorithm for sub-carrier allocation in 3.3.1 section in this section we only emphasis on PA using ACTIVE-SET optimization technique [42]; our objective function can be written as. Gi $(P_{k,n)}$, subjected to constraints as a) $P_{k,n} \geq 0 \quad \forall_{k,n}$ and b)$\sum_{k=1}^{k} \ \sum_{n=1}^{N}$,$C_{k,n}P_{k,n} \leq P_{total}$ which are two inequality constraint hence *i=1, 2*. Objective function in (1) can take the general for with Lagrange multiplier [38],[39],[40],[41] (λ_i) as follows.

$$\nabla f(P_{k,n}*) + \sum_{i=1}^{2} \lambda_i \nabla G_i(P_{k,n}) = 0 \quad (3)$$

Step 2: Expanding (3) and taking Lagrangian for formulation of Qudrature Programming (QP).

$$\nabla f(P_{k,n}*) + \lambda_1 \nabla G_1(P_{k,n}*) + \lambda_2 \nabla G_2(P_{k,n}*) = 0 \quad (4)$$

Taking Lagrangian multipliers as λ_1 and λ_2 to estimate total power assigned for user P_k.

$$L(P_{k,n,}\lambda) = f(P_{k,n}) + \lambda_1 G_1(P_{k,n}*) + \lambda_2 G_2(p_{k,n}*) \quad (5)$$

Objective function in (1) converting into (5) as follows:

$$L(P_{k,n,}\lambda) = \sum_{k=1}^{k}\sum_{n=1}^{N} \frac{B}{N}.\log_2(1 + P_{k,n}.H_{k,n}) + \lambda_1[P_{k,n}] + \lambda_2[P_{k,n} - P_{total}] - \frac{\lambda_1}{\lambda_k}\sum_{n\in\Omega_k}\frac{B}{N}.\log_2(1 + P_{k,n}H_{k,n}) \quad (6)$$

Set of subcarriers for user *K* denoted by Ω_k those mutually restricted. Taking derivative of (6) w.r.t. $P_{k,n}$.

$$\frac{\eth L}{\eth P_{k,n}} = \frac{B}{N}\frac{H_{k,n}}{1 + P_{k,n}H_{k,n}} + \lambda_1 + \lambda_2 - \frac{\gamma_i}{\gamma_j}\frac{B}{N}\frac{H_{k,n}}{1 + P_{k,n}H_{k,n}} = 0 \quad (7)$$

$$\frac{B}{N}\frac{H_{k,n}}{1 + p_{k,n}H_{k,n}} + \lambda_1 + \lambda_2 = \frac{B}{N}\frac{\gamma_i}{\gamma_j}.\frac{H_{k,n}}{1 + P_{k,n}H_{k,n}} \quad (8)$$

Step 3: We approximate $f(P_{k,n}*)$ to only $\sum_{k=1}^{K} \ \sum_{n=1} \log_2(1 + P_{k,n}H_{k,n})$, now onwards in the analytical analysis it is been treated as "*q*", where "*q*" reflects behavior of $f(P_{k,n}*)$ in a neighborhood of $N_{ab} = \frac{N}{B}$ around $P_{k,n}$. This is trust region sub-problem$\frac{\max}{S}\{q(s), S \in N_{ab}\}$. Current solution is updated to be $P_{k,n} + S$ if $f(P_{k,n} + S) > f(P_{k,n})$.

Step 4: for K = 1 toK

for n = 1 toN

$$H_c = H_{prev} + \frac{q_{prev}q_{prev}^{T}}{q_{prev.}S_{prev}} - \frac{H_{prev.}S_{prev}S_{prev}H_{prev}}{S_{prev.}H_{prev}S_{prev}} \quad (9)$$

end for

"H_c and H_{prev}" are current and previous values of Hessian Matrix, which gets estimated;in every iteration whichare using positive definite quasi-Newton approximation as in (10).

Where$S_{prev} = P_{k,ncurrent} - P_{k,nprev}$.

$$q_{prev} = (\nabla f_{(k,n)current} + \lambda_{1.}\nabla G_1(P_{k,n})_{current}) - (\nabla fP_{Ck,n})_{prev} + \lambda_1\nabla G_1(P_{k,n})_{prev} + \lambda_2\nabla G_2(P_{k,n})_{prev} \quad (10)$$

Step 5: Quadratic programming sub-problem formed as follow:

$$max\frac{1}{2}.d^TH_cd + \nabla f(P_{ck,n)})^Td + \nabla G1(P_{ck,n)})^T.d + G_1(P_{ck,n)}) + \nabla G_2(P_{k,n})^T.d + G_2(P_{ck,n)}) \leq P_{total} \quad (11)$$

Solution to above equation form the new iterate $(P_{k,n})_{current} = (P_{ck,n})_{prev} + \propto.d$, where step length α estimated as $\alpha = \frac{P_{total}}{N*K}$ and search direction '*d*' calculated at every iteration to maximize objective function in (1).

Step 6: For simplicity we write (11) as follows

$$||S||for\nabla G_i(P_{ck,n)})^T.dG_i(P_{ck,n)}) \quad (12)$$

We can write $||S|| \leq \delta_k$ or P_{total}astrustregionradius.

This sub-problem may be infeasible because there may be no intersecting points between the trust-region constraints. $||S||\leq\delta_k$ or $||S||\leq P_{total}$ and the hyper-plane as follows:

$$G_i(P_{ck,n)}) + \nabla G_i(P_{ck,n)})^T.S = 0 \quad (13)$$

They can intersect if the trust-region radius δc decreased. *S* can be written as (14).

$$S_k = S_k^n + Z_kS_k^{-t} \quad (14)$$

Where Z_ka matrix is whose columns form an orthonormal basis for the null space of $\nabla G_i(P_{k,n})^T$. Now our aim is to find following parameters. Here *n*is allotted subcarriers to user *k*.

S_k^n : orthonormalcomponent$S_k^n = S_{kprev}^n + \mu d_i$ and

S_k^{-t} : tangentialcomponent. Need of estimating $\mathbf{S_k^n}$and$\mathbf{S_k^{-t}}$is to follow constraint C5 of objective function in (1).

Algorithm for estimating: a) $\mathbf{S_k^n}$

fori = 1, 2, … n

$S_n^k = S_i^n + \mu d_i$ (15)

Compute μ such that $||S_i^n + \mu.d_i|| = \delta_k$

set$\rho_0 = -\nabla G_iG_i(P_{k,n})$

$d_0 = \rho_0$

Update residual

$$\rho_{i+1} = \rho_i - \nabla G_i(P_{k,n})\nabla G_i(P_{k,n})^Td_i$$

Estimating new value for direction parameter

$$d_{i+1} = \rho_{i+1} + \frac{\rho_{i+1}^T\rho_{i+1}}{\rho_i^T\rho_i}d_i$$

end

Algorithm for estimating: b) S_k^{-t}

1 for $i = 1,2,\ldots n$

2 $$S_{i+1}^{-t} = S_i^{-t} + \frac{\rho_i^T \rho_i}{d_i^T Z_k^T H_{next} Z_k d_i} \quad (16)$$

3 Update Residual

$$\rho_{i+1} = \rho_i - \frac{\rho_i^T \rho_i}{d_i^T Z_k^T H_{next} Z_k d_i} Z_k^T H_{next} Z_k d_i$$

4 Estimating new direction

$$d_{i+1} = \rho_{i+1} + \frac{\rho_{i+1}^T \rho_{i+1}}{\rho_i^T \rho_i}$$

5 end

Optimize solution for (13) can be written with the estimated values of S_n^k and S_k^{-t} in (15) and (16).

$$\nabla G_i\,(P_{k,n})^T \left[\mu\left(\rho_i + \frac{\rho_{i+1}^T \rho_i}{\rho_i^T \rho_i}\right) + \frac{\rho_i^T \rho_i}{d_i^T Z_k^T H_c Z_k d_i}\right] + G_i(P_{k,n}) = 0 \quad (17)$$

Solving (17) optimal solution obtained in terms of μ and ρ as follows.

$$P_{k,n} = (1+\mu)\rho_n \quad (18)$$

Analytical experiment is carried using four subscriber stations, it is assumed that all four subscribers situated at same distance hence distance *d0=d1=d2=d3* and weights are also same $\omega_0 = \omega_1 = \omega_2 = \omega_3$. For simplicity in calculation we have considered only 8 total sub-carrirers. Hence 2 subcarriers allotted to each user. We applied both Linear [15], [16], [17], [18], [19], [20] and Active-set algorithm.

Table 4: Distribution of Power and achieved Data Rates

SA Matrix ($C_{k,n}$)	SS1	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*1*
	SS2	*0*	*1*	*1*	*0*	*0*	*0*	*0*	*0*
	SS3	*0*	*0*	*0*	*0*	*0*	*1*	*1*	*0*
	SS4	*0*	*0*	*0*	*1*	*1*	*0*	*0*	*0*
Effective Subchannel SNR $H_{k,n}$ Matrix	SS1	*189*	*265*	*0*	*0*	*0*	*46*	*0*	*87*
	SS2	*0*	*0*	*301*	*363*	*288*	*0*	*230*	*0*

Power Allocation by							
Linear Algorithm [15],[16],[17],[18],[19],[20]				**Active-Set**			
SS1’	SS2’	SS3’	SS4’	SS1’	SS2’	SS3’	SS4’
0.356	*0.382*	*0.1903*	*0.071*	*0.25*	*0.25*	*0.25*	*0.25*

Capacity Achieved in bits/sec/Hz by			
Linear Algorithm [15],[16],[17],[18],[19],[20]		**Active-Set**	
SS1 & 2	SS & 4	SS1 & 2	SS3 & 4
4.2463	*3.3577*	*4.4274*	*3.839*

It is found that channel capacity achieved using Active-Set optimization is more as compared to Linear Approach. The time complexity of step no. 4 in Active-Set Optimization is *O(N)*. The complexity in calculating S_n^k (in step no. 6) is *O(N)* and to calculate S_k^{-t} is O(N). Thus, the total complexity is O(N+N+N)=O(3N)=O(N). Note that Active-Set optimization algorithm maintains the low complexity of power-carrier allocation algorithms proposed in [15], [16], [17], [18], [19], [20], [26], [35], [36] while further providing a performance bound.

6. Simulation results for proposed algorithms in 4 and 5

The multipath channel used is same as we used in our previous paper [35] with total power to be *1W* with available total BW of *10MHz* operates on 1024 subcarriers. Subscribers increased from 2 with increment of 2 up to Maximum range of 50 Subscribers.

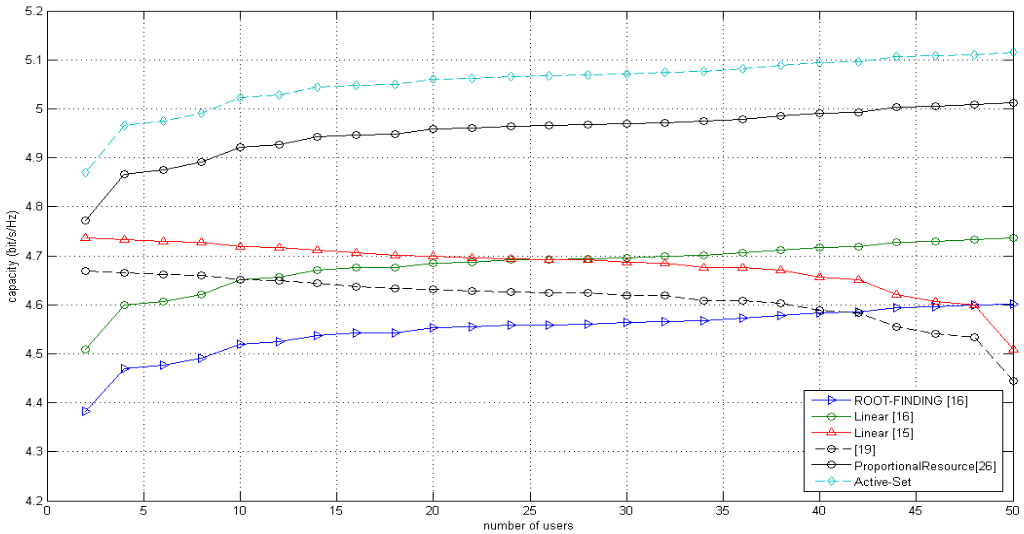


Fig.2: Total capacity versus number of users in a downlink Mobile WiMAX with N=1024 sub-carriers.

Fig.2. shows the comparison of the total capacities between the proposed method Active-Set optimization and algorithms proposed in [15],[16],[19],[26]. Capacity is maximum for WiMAX system using Active Set Algorithm due to increase in WLAN users because of Multi user Diversity gain. Proposed optimization scheme sounds more attractive for heavy traffic loads like video signal transmission. Table V shows estimated values of number of slots and number of OFDM symbols for various applications using modulation schemes QPSK-1/8, 16QAM-¾ and 64QAM-5/6. If video file has size of 'S_z' bits and N_{sub} number of allotted subcarriers then we can estimate desired number of OFDM Symbols as follows.

$$[S_z] = \left[\left(\frac{N_{sub}}{2}\right) - 1\right] * 2 * (Number\ of\ OFDM\ Symbols) \qquad (18)$$

Downlink byte 'DB' per slot calculated using bits per symbol 'bs' as per modulation scheme selected , CR coding rate and Ss symbols per slot and *Dsub=48* as data subcarriers.

$$D_B = b_s C_R S_s \frac{1}{8bits} D_{sub} \qquad (19)$$

For 176kbps data rate BS should send 22,528Bytes per second. While considering 5ms of frame only 112.64Bytes transmitted. If QPSK-1/8 scheme is selected then DB can be estimated using (19) as DB=2*(1/8)*1*(1/8)*48=1.5Bytes.

Table 5: Estimated number of slot and OFDM symbols for various applications

			Slot calculation per 5ms of frame								
Applications	Format	Data rate	QPSK 1/8			16-QAM ¾			64-QAM 5/6		
			Slot	Subcarrier	OFDM Symbols	Slot	Subcarrier	OFDM Symbols	Slot	Subcarrier	OFDM Symbols
Mobile phone video	H.264 ASP	176 kbps	*75*	*150*	*6*	*7*	*14*	*73*	*4*	*8*	*120*
Smartphone video	H.264 ASP	324 kbps	*139*	*278*	*6*	*12*	*24*	*73*	*7*	*14*	*120*
IPTV video	G,264 Baseline	850 kbps	*363*	*726*	*6*	*31*	*62*	*73*	*19*	*38*	*120*
Sample video trace	MPEG 2	350 kbps	*150*	*300*	*6*	*13*	*26*	*73*	*8*	*16*	*120*

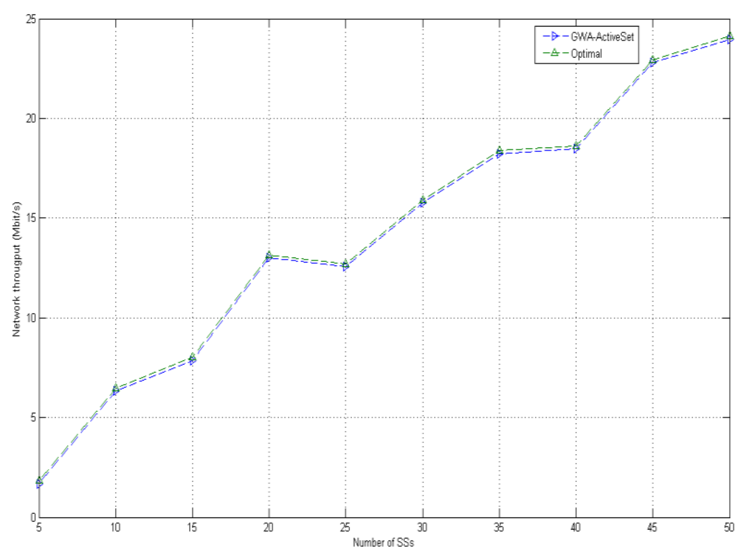
Taking ratio of bytes transmitted in 5ms frame to DB i.e. 112.64/1.5=75.09 slots means 150 subcarriers. S_z=112.64*8bits, $N_{sub}=150$ using this data we can easily estimate number of OFDM symbols=6 using (19).We further tested our proposed algorithm discussed in 3.3.1 and 3.3.2 for downlink transmission one video file of 1sec time duration with all types of video applications, applying 64-QAM 5/6 modulation scheme with same channel model used in [15], [16]. Subcarrier allocation per frame is 8 for mobile phone video, 14 for smart phone video, 38 for IPTV video and 16 for MPEG 2. We got excellent results of received Peak SNR for received video.

Table 6: Estimated number of slot and OFDM symbols for various applications

Application	PSNR (dB)	
	Linear Approach [15,16,19,16]	Active-Set Optimization
Mobile Phone	29	*34*
Smartphone	*27*	*34*
IPTV	*22*	*30*
Sample video trace	*26*	*32*

GWA and Active-Set Optimization simulated to maximize quantity of users those satisfied on specified parameters (ω_k=*SS/Minimum BW consumed* (B_{min})). To compare our results we simulate optimal algorithm with brute force method to solve the *0/1* knapsack problem. Network proposed in Fig. 1. varies number of SSs from *10 to 50* and bandwidth *1MHz*. Fig. 3 shows comparison where we can conclude that our method is close to optimal algorithm.

Fig.4. shows number of satisfied users using proposed method which found good approximation of optimal algorithm. Practically optimal solution is impossible for NP-hard complex systems.



7. Conclusion

This study first models the sub-carrier allocation problem of scalable video multicast in integrated WiMAX / Wireless LAN network. Objective of maximizing network throughput and maximizing number of satisfied users are both NP-hard. This study provides the polynomial-time suboptimal solution, GWA + Active-Set optimization, to those NP-hard problems using GWA that incorporate convex optimization technique. Computational complexity reduced using this scheme while maximizing network throughput and number of satisfied users for multicast video. Received PSNR of transmitted video using GWA+Active Set is more as compared to Linear Approach [15], [16], [17], [18], [19], [20], [26], [35], [36] for RA and power allocation in the literature.

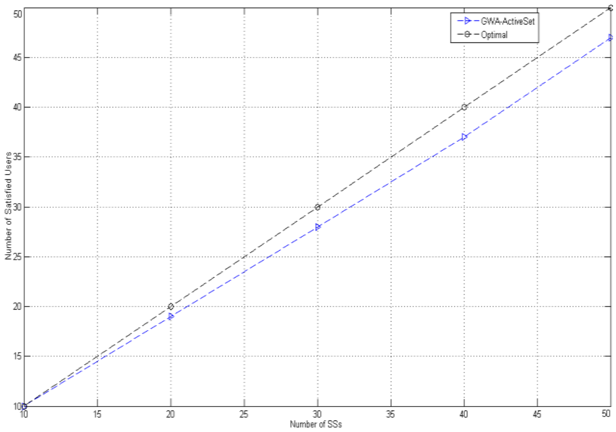


Fig.4. Number of satisfied users for different number of SSs.

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