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Development Of An Improved Scheduling Scheme For Multicast Traffic Delivery Over Wimax Networks

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Abstract
The challenge in optimal resource allocation to mobile Worldwide Interoperability for Microwave Access (WiMAX) subscribers has not been fully overcome by researchers. This research aimed at developing an optimal scheduling algorithm for WiMAX resource allocation based on an improved Particle Swarm Optimization (PSO) technique. In this work, an improved PSO based technique for allocating subcarriers and Orthogonal Frequency Division Multiplexing (OFDM) symbols to mobile WiMAX subscribers is proposed using sub-group formation. The entire WiMAX network environment is sub-divided into 7 layers, and seven distinct modulation and coding schemes are proposed to be used in transmitting packets to the subscribers located within the respective layers. An enhanced model for throughput maximization and channel data rate has been developed by implementing an improved PSO based WiMAX resource allocating algorithm. A maximum throughput/aggregate data rate of 1398Mbps was achieved, which represents 88.88% of the maximum achievable aggregate data rate of the system.

Keywords: IEEE 802.16, WiMAX, Multicast, Scheduling, Channel Data Rate, Quality-of-Service

Introduction

Rising need for high speed multimedia services like Internet Protocol Television (IPTV) and mobile television has led to the introduction of broadband wireless access. One of such broadband wireless access is the Worldwide Interoperability for Microwave Access (WiMAX). It is also known as IEEE 802.16. The standard enables high-speed access to data, video and voice services [4]. It also serves as an another possibility to cabled access networks, such as fiber optics, coaxial systems using cable modems and digital subscriber lines (DSLS) [1]. WiMAX theoretically provides data rate of 4-10Mbps to 16km at 70Mbps [7]. WiMAX requires dynamic and diverse quality of service (QoS) guarantee such as optimal system throughput, maximum latency guarantees and minimal delay jitter. Some of the QoS that need to be defined for the purpose of this research work are:

i. Throughput is the measure of numbers of packets sent successfully in a network and it is measured in terms of packets per second [6].
ii. Channel Data Rate accounts for the total amount of user data transmitted by the base station over the air interface [3].

WiMAX is heterogeneous with unsystematic mix of real and non-real time traffic. The IEEE 802.16 standard provides two schemes for allotting the wireless medium [12]: (i) Point-to-Multipoint (PMP) (ii) Mesh (Optional)

Point-to-Multipoint (PMP) mode:
Nodes are arranged in a cellular structure in such a way that the Base Station is the single resource controller for bi-direction communication with a set of Subscriber Stations within the same antenna sector in a broadcast mode [12].

Mesh mode:
Nodes are arranged systematically in Ad-hoc manner and scheduling is distributed among the Subscriber Stations without transmission from the Base Station [12]. The uplink from Subscriber Station to Base Station and downlink from Base Station to Subscriber Station data transmissions in the IEEE 802.16 standard are Frame-based. The resource distribution in mobile WiMAX is in unit of slots. Each slot consists of one sub-channel allocated for the duration of some number of orthogonal frequency division multiplexing (OFDM) symbols [11]. The number of subcarriers in the sub-channel and the number of OFDM symbols in the slot depend upon the link direction, uplink (UL) or downlink (DL) and the sub-channelization mode. For example, in the partially used sub-channelization (PUSC) mode, one slot consists of one subchannel over two OFDM symbol periods for downlink and one subchannel over three OFDM symbol periods for uplink [5]. WiMAX networks operate in two Duplexing modes [7]. Which are? Time Division Duplexing (TDD) mode and Frequency Division Duplexing (FDD) mode
In FDD, the uplink and downlink sub-frames are transmitted simultaneously on different frequency bands [2]. In TDD, the uplink and downlink sub-frames are transmitted on the same carrier frequency bands at the same time [5].. The developed

algorithm can be used for both FDD and TDD architectures. However, to keep the discussion straight, TDD architecture is use. The algorithm allows several configurations such as mesh and point to multipoint network configurations, our focus is only on the point to multipoint network configuration. In recent years, Broadband Wireless Access networks have been rapidly evolving to satisfy increasing user scalability and Quality of Service (QoS). The salient features of Mobile WiMAX are [9]: The higher data rate, Mobility, Scalability, Quality of Service such as optimal system throughput. In order to support QoS for various types of traffic, mobile WiMAX offers five types of scheduling classes as follows [13]: Unsolicited grant scheme (UGS), Real-time polling service (rtPS), Nonreal-time service (nrtPS),Best effort (BE) and Extended real-time service (ertPS).
The pertinent characteristic of these five scheduling service classes are presented in [10]. Examples of this service application. In addition to the scheduling services, mandatory QoS parameters have been designed in the standard. The scheduling services and supported QoS parameters are shown in [8], [10].

Related Work

The authors in [3] developed a subgroup-based resource management scheme, whereby they cluster SSs with similar channel quality in the same multicast subgroup of a WiMAX cell, Different cost functions for subgroup formation to trade off fairness and throughput requirement were used to improve the system performance. The work did not give any technique for reducing the computational cost of the subgroup creation. In paper [5] the Authors developed a novel scheduling algorithm for downlink services that totally exploit the physical layer properties of the WiMAX network, which maximize the throughput of the network at the same time, guaranteed improved QoS of various services by the network. The performance of the algorithm was improved further by employing fuzzy logic design. However, they did not evaluate the performance of the algorithm on non-real time traffic scenarios. In view of this, there is also a need to develop an improve scheduling algorithm using Particle Swarm Optimization technique in order to maximize the throughput of the network and channel data rate at the same time guaranteeing other QoS of services in mobile WiMAX networks.

Development of a WiMAX Network Environment

In the proposed model, the network environment is modeled as a circular area covered by 7 concentric layers. These layers depict a set of modulation and coding schemes (MCS). The 7 MCSs are briefly described as follows:

(i) **Layer 1 (QPSK 1/2):** In this layer users receive signal through quadrature phase shift keying modulation. In this kind of modulation, each OFDM symbol has 2 bits. This layer has a coding rate of 0.5.
(ii) **Layer 2 (QPSK 3/4):** In this layer, each OFDM symbol has the same number of bits as that of layer 1 but the layer has a coding rate of 0.75.
(iii) **Layer 3 (16-QAM 1/2):** The quadrature amplitude modulation scheme is employed in this layer. In this layer each OFDM symbol has 4bits and is coded at a rate of 0.5.
(iv) **Layer 4 (16-QAM 3/4):** This layer has the same MCS as layer 3 but has a coding rate of 0.75.
(v) **Layer 5 (64-QAM 1/2):** This layer has the same MCS as that of layer 4 but has 6 bits per modulation symbol and a coding rate of 0.5
(vi) **Layer 6 (64-QAM 2/3):** This layer differs from layer 5 in that it has a coding rate of 0.67 instead of 0.5.
(vii) **Layer 7 (64-QAM 3/4):** In this layer, a coding rate of 0.75 is used instead of 0.5 as in layer 5

In the proposed WiMAX network environment model, a modulation and coding scheme is presented using the abbreviation on MCS_k where k represents the index of the layer of reference. Table 1 shows the burst profile for the various modulations and coding scheme.

TABLE 1: WiMAX Burst Profile for WirelessMAN-OFDMA PHY Layer (Channel Bandwidth 10MHz) [2]

Layer	Modulation Type	Coding Rate	SNR [dB]	SRx [dBm]
1	QPSK	1/2	5	-89.2
2		3/4	8	-86.79
3	16-QAM	1/2	10.5	-83.79
4		3/4	14	-80.29
5	64-QAM	1/2	16	-78.29
6		2/3	18	-76.29
7		3/4	20	-74.29

In Table 1, each of the modulation schemes has a specified signal-to-noise ratio (SNR) and a corresponding receiver input sensitivity. These two parameters were used to dynamically select the desired MCS for each of the layers with respect to the WiMAX Base Station. The values of S_{RX} (dBm) in Table 1 are obtained using equation (1):

$$S_{RX} = -114 + SNR_{RX} - 10\log d_k + 10\log\left[\frac{F_s N_{used}}{N_{FFT}}\right] + \text{ImpLoss} + NF \qquad (1)$$

Where:
SNR_{RX} is the receiver Signal-to-Noise Ratio
F_S is the sampling frequency [MHz] calculated as
F_S =Floor (n・BW/8000)・8000, where n is a sampling factor
BW is the nominal channel bandwidth.
N_{FFT} is the number of point of FFT or total number of subcarriers;
d_k is the maximum allowable data rate per channel data rate

$$d_k = \frac{b_{m\_k} c_{r_{m\_k}}}{T_s}$$

N_{used} is the number of used subcarriers
ImpLoss is the implementation Loss
NF is the receiver noise figure referenced to the antenna port.
When the receiver sensitivity for a given profile is higher than the received signal level and target Bit Error Rate (BER), a more robust transport mode is chosen, if available. A channel

can be used for transmission as long as there is a burst profile which is able to cope with its present status.

WiMAX Subscriber Substations (SSs)

In the proposed model, the WiMAX network users are referred to as Subscribers and their location is referred to as Station. The characteristic of the proposed model is such that the Substations are mobile. Therefore, it is possible for the network configuration to change after each frame interval. This property makes the network dynamic and aids in maximizing the aggregate data rate of the system (system throughput). Since a circular cell is considered, users can be defined based on two parameters, namely:

(i) Radius (R)
(ii) Direction (θ)

The following command can be used to generate users randomly within the WiMAX network coverage area.

```
SS_distance = radius * rand (1,no_SS)
SS_direction = 2 * pi * rand (1,no_SS)
```

Therefore, the possibility of any user within the network environment can be completely defined using the cartecian coordinate system $[x_i, y_i]$, where x_i is the x- coordinate of the ith user and y_i is the y-coordinate of the ith user. The following can be used to define the positions of the entire users in a given WiMAX network environment.

$$X = 2\pi R[rand(1,N)].\times[\cos(rand(1,N))] \quad (2)$$

$$Y = 2\pi R[rand(1,N)].\times[\sin(rand(1,N))] \quad (3)$$

Where:
X is the x – coordinate matrix of the set of N users.
Y is the y – coordinate matrix of the set of N users
R is the range/radius of WiMAX coverage
.x signifies element wise multiplication of matrixes
Rand (1, N) is a Matlab command that generates a row of N numbers ranging between 1 and 0 (forming a one by N matrix)

User Distribution Parameters

In the proposed model, the users can be restricted from occupying various portions of the coverage area, that is, a user can be bound within a set of layer. In order to define this boundaries a set of user distribution parameters are used. These parameters are α and β. Thus equations (2) and (3) are modified to yield:

$$X = 2\pi R\left(\left(\frac{7-\alpha}{7(\beta+1)}\right)[rand(1,N)] + \frac{\beta}{\beta+1}\right).X[\cos(rand(1,N))] \quad (4)$$

$$Y = 2\pi R\left(\left(\frac{7-\alpha}{7(\beta+1)}\right)[rand(1,N)] + \frac{\beta}{\beta+1}\right).X[\sin(rand(1,N))] \quad (5)$$

It could be observed that, equations (4) and (5) will eventually become equations (2) and (3) respectively if α = β = 0. This criterion is referred to as uniform distribution of users. In general, if α equals to zero the higher the value of β the farther the users from the Base Station, While if β is equal to zero, the higher the value of α more the range of communication. In the proposed model, α and β are designed to vary from 0 to 6.

PSO Base Objective Function

In the proposed research work, PSO is proposed to solve a maximization problem. Therefore, the minimization problem in PSO has to be converted into maximization as shown:

$$\max[F_{obj}] = \min_k\left[1/F_{obj}\right] \quad (6)$$

where:
k is the population of particle
F_{obj} is the throughput of the system
$\max[F_{obj}]$ is the maximum throughput
If $\max[F_{obj}]$ is replaced by MT equation (6) can easily be rewritten as:

$$MT = \min_k\left[1/F_{obj}\right] \quad (7)$$

where:
F_{obj} is the objective function and is defined as the aggregate data rate of the entire WiMAX network.
In order to develop an objective function for throughput maximization, there is need to consider some of the PSO model parameters. These parameters include:

(i) Population size of the particles, (popsize)/number of individuals
(ii) Number of parameters in each population/individual.

Therefore, a generation of particles has P particles each with np parameters such that it can be represented by a matrix with p rows and np columns. In the proposed model, np is chosen to be twice the number of layer in the network; that is for the 7 layers network. np = 14. The value of p is left to be defined at the beginning of the optimization process. Since matlab is proposed for simulation, the population is generated randomly using:

$$G_i = rand(p, np) \quad (8)$$

where:
G_i is the ith generation matrix and it contains only values ranging from 0 to 1.
P is the number of particles in the swarm
np is the number of parameters in each particle (*np* = 14)
The maximum value of *i* is referred to as the number of generations I_{max}

Throughput (F_{obj})

In the proposed model, all the users in the WiMAX network environment are grouped into 7, based on the number of layers. The users' matrix can be defined using equation (9)

$$u = [u_1, u_2, \ldots \ldots, u_7] \quad (9)$$

where:
u is the user matrix of size 1 by 7
u_1 to u_7 represents the number of users in layer 1 to 7 respectively.
The user matrix u is generated and the maximum bit rate of each of the layers is also evaluated and stored in a matrix u_b of size 1 by 7. Therefore, the maximum aggregate data rate of

each layer per OFDM symbol per subcarrier can be stored in a matrix of data rates shown in:

$$ADR_i = [d_{a_1}, \; d_{a_2}, \dots \dots \dots . d_{a_7}] \tag{10}$$

where:

$$d_{a_i} = u_i \times u_{b_i} \quad [i = 1, 2, \dots \dots 7] \tag{11}$$

And

$$u_b = [u_{b_1}, u_{b_2}, u_{b_3} \dots \dots \dots \dots . u_{b_7}] \tag{12}$$

The generation matrix is used in allocating subcarriers and OFDM symbols to user of each of the layers.

Let N_{sc} be the total number of subcarriers to be allocated, let N_{os} be the total number of OFDM to be allocated. In other to generate quality of service, there is need to show that at least one subcarrier and one OFDM symbol is allocated to every layer containing at least one user, to achieve this, seven OFDMs and seven subcarriers are initially shared, one for each layer. Therefore, the allocation problem becomes that of (Nsc – 7) by (– 7) subcarrier and OFDM symbol respectively. The objective function can therefore, be formulated using Nos:

$$F_{obj} = round \left[\frac{\sum_{L=1}^{7}(N_{sc} - 7) g_L \cdot d_{a_L}}{\sum_{j=1}^{7} g_i}\right] \times round \left[\frac{\sum_{L=8}^{14}(N_{os} - 7) g_L \cdot d_{a_L}}{\sum_{L=8}^{14} g_i}\right] \tag{13}$$

where:

$$G_i = [g_1, g_2, g_3, \dots \dots \dots \dots .. g_{14}] \tag{14}$$

g_1 to g_{14} are the parameters of a candidate particle in the ith generation. In general, the objective function of the ith generations F_{obj} is defined as in:

$$F_{obj} = \begin{bmatrix} F_{obj.1} \\ F_{obj.2} \\ F_{obj.3} \\ \vdots \\ F_{obj.p} \end{bmatrix} \tag{15}$$

$$F_{obj.t} = \sum_{k=1}^{7} u_{b.kt} \otimes u_{kt} \otimes L_{s.kt} \otimes L_{0.kt} \tag{16}$$

where:

F_{obj} is the objective function of the ith generation

$F_{obj.t}$ is the objective function of the tth particle in the ith generation

$u_{b.kt}$ is the maximum bit rate of the kth layer for the tth particle in the ith generation

u_{kt} is the number of users in the kth layer for the tth population in the ith generation

$L_{s.kt}$ is the number of subcarriers allocated to layer k for the tth particle in the ith generation

$L_{o.kt}$ is the number of OFDM symbols allocated to layer k for the tth particle in the ith generation

$\otimes$ represents element wise multiplication

The objective function is used to evaluate the fitness of each of the particles while performing the PSO of the WiMAX network throughput.

Throughput Maximization Algorithm

In the proposed research, the conventional Particle Swarm algorithm (PSO) is modified to suit application in WiMAX network for throughput maximization. This algorithm comprises the step by step approach required to maximize throughput/aggregate data rate and channel data rate in WiMAX networks while considering resource allocation. The following steps of instructions are executed logically in order to effectively maximize the network utilization. However, the proposed model considers the allocation of the network resource based on the channel quality. The sequence of instructions is as follows:

i. Initialize
ii. Enter the parameters of both WiMAX network and particles
iii. Determine the maximum number of frame to be transmitted
iv. If the number of transmitted frame is less than the maximum number of frame then perform (v)
v. Generate a population of particles and their velocity and update frame
vi. Apply modification to the parameters of each particle to suit throughput maximization and channel data rate
vii. Evaluate the fitness of each of the particle
viii. Determine the best particle and assign it to be the global best
ix. Increment generation
x. Determine weighting factor
xi. Update the velocity of particle based on weighting factor
xii. Update the particles using the updated velocity
xiii. Eliminate parameters that are outside the boundaries of the swarm
xiv. Evaluate fitness of the new population
xv. Determine the best particle in the current generation
xvi. If the best is less than global
xvii. Then make global best equal to best
xviii. Output the maximum throughput for the stimulation period.

Simulation and Results

Simulation Setup

The performance of the proposed scheduling algorithm in maximizing throughput/aggregate data rate of WiMAX network, a scenario of 50 users uniformly distributed and when they were restricted within each of the layers over a coverage area of 400km^2 was evaluated by simulation. Details of the simulation parameters are shown in Table 2:

TABLE 2: Simulation Parameters

Parameter	Value
Channel bandwidth	10MHz
Frequency band	3.5MHz
DL/UL ratio	35/12
Population size	500
Maximum number of generation	10

Cognitive parameter	1
Constriction factor	1
Number of used subcarriers	720
Number of OFDM symbols	35
Radius of coverage	20km
Number of subscriber stations	50
Number of bits per modulation symbol for the 7 layers	See Table 1
Sampling factor (n)	28/25
Cyclix prefix ratio (G)	1/8
Number of frames	500
Duplexing Mode	TDD

The simulated WiMAX network environment is such that layer 7 is the closest to the Base Station while layer 6 to 1 follows respectively. Fig 1 illustrates the simulated WiMAX environment based on 7 layer architecture. A coverage area of 400km^2 was chosen.

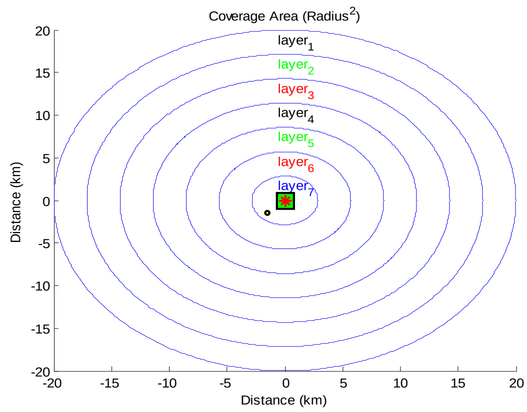

Fig.1. The Proposed WiMAX Layered Architecture

Figs 2(a) to 2(d) are the plots of 50 users/MSs in the proposed WiMAX environment for different values of α and β, when the users were uniformly distributed and restricted to layer 7,5 and 3 respectively.

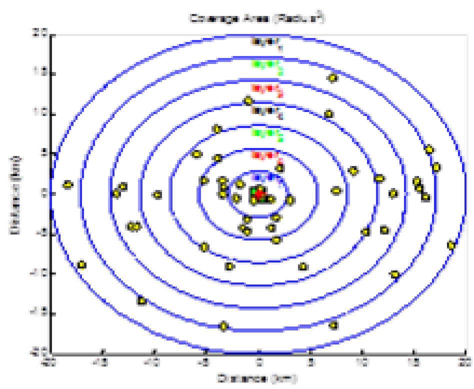

Fig.2(a). Uniform distribution

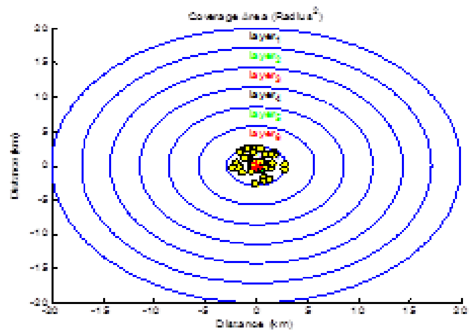

Fig.2(b). Users at layer 7

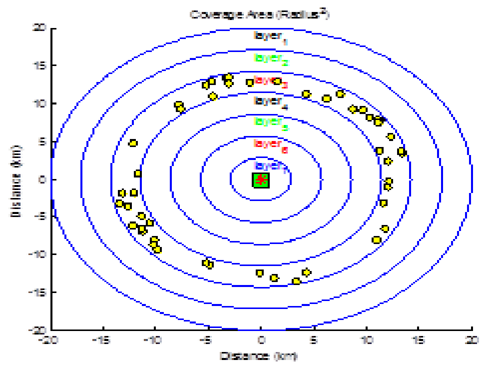

Fig.2(c).Users at layer 3

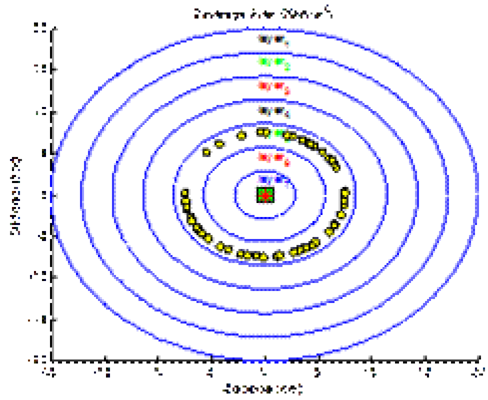

Fig.2(d).Users at layer 5

Results and Discussions

In the proposed model of WiMAX network environment, the radius of coverage of the WiMAX network was chosen to range from 20/7 km to 20km, which forms a maximum coverage area of 400km^2 and gives rise to a 7 layered architecture. The seven layers are arranged in a concentric manner and in descending order of layer index (7, 6, 5…1) as shown in Figure 1. A modulation and coding scheme (MCS) is assigned to each of the layers as shown in Table 2. Fifty subscriber substations (50) where considered for each of the scenarios.

Fig 3 is bar chart showing the throughput obtained in various scenarios of the distribution of subscriber substations over the WiMAX coverage area. The first bar (0) represents the maximum throughput obtained when the users are randomly distributed over the entire WiMAX coverage. The plots generated by the developed PSO algorithm for this case (bar

0) are also shown in Figs 4, and 5. The rest of the bar (1, 2, 3...7) represent the throughput/aggregate data rates obtained by restricting the users to exist only within a single layer respectively. It could be observed that the highest achievable aggregate data rate corresponds to that obtained when all the users are within layer seven. This is so because layer 7 uses a MCS that offers the highest bit rate per subcarrier per OFDM symbol (64-QAM-3/4). It could also be observed that the height of the bar gradually decreases as the layer index decreases (from layer 7 to 1) which correspond to the aggregate data rate obtained as the distance from the WiMAX base station increases. Layers 4 and 5 were found to have the same aggregate data rate which corresponds to bar 4 and 5 respectively. This is so because they have equal data rate per subcarrier per OFDM symbol due to their respective MCS (16-QAM-3/4 and 64-QAM-1/2).

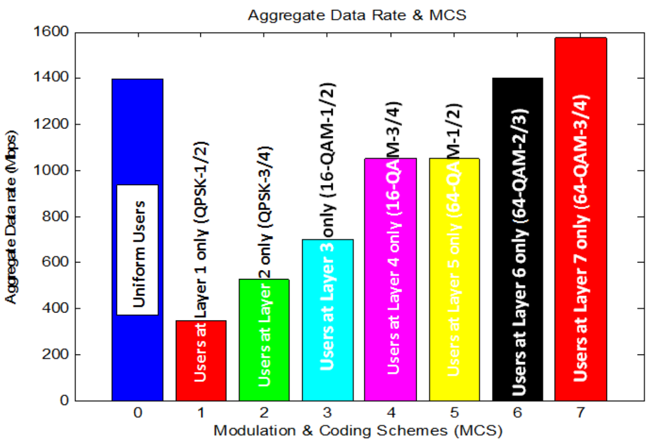

Fig.3. Maximum Throughput / Aggregate Data Rate versus User Distribution

With reference to Fig 4, the improved PSO algorithm was found to converge to the maximum throughput at the fourth generation. It could be observed that the blue and green dotted lines which correspond to the local maximum and average throughput have their peaks at the 4th and 10th generation, and falls far low at any other generation. This shows that, the entire populations of particles in the entire generations are closely alike and has very low fitness value compared to the global best particle. This is as a result of large number of particle in each swarm at each of the generations (about 750000 particles were used in this case).

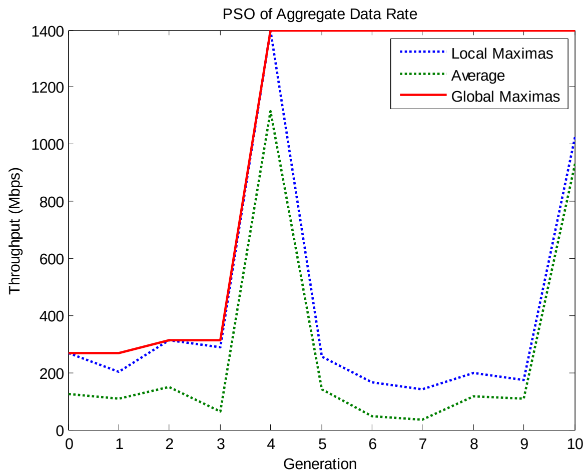

Fig.4.The Rate of Convergence of the Proposed Improve PSO algorithm (Aggregate Data Rate)

Fig 5: shows the WiMAX coverage at the end of the simulation process. It could be observed that the users are randomly distributed over the WiMAX coverage area. This users move randomly after each frame is transmitted forming a mobile WiMAX.

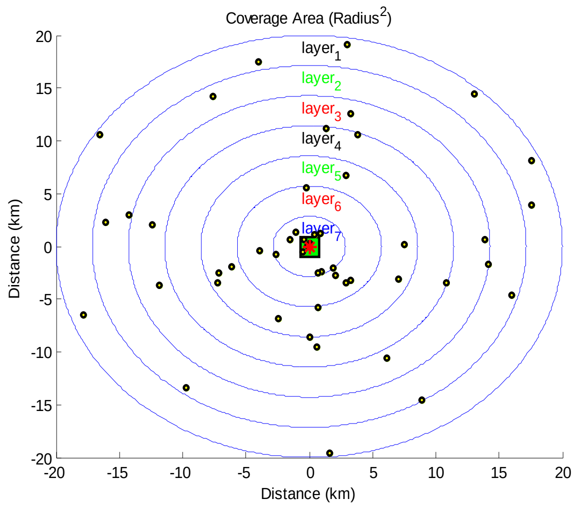

Fig.5.The WiMAX Network Topology at PSO Convergence (Uniform Users)

Summary of Results Obtained of Proposed Algorithm

Table 3 is summary of the results obtained for the various layers and the uniform distribution of users over the entire layers.

TABLE.3.Summary of Results obtained of Proposed Algorithm

Layer	ADR (Mbps)
Uniform	1398
1	350
2	525
3	700
4	1050
5	1050
6	1400
7	1575

Conclusion

WiMAX environment has been modeled on seven layers, based on modulation and coding schemes which have been proposed for packet transmission to subscriber substations within the WiMAX coverage area. An enhanced model for an improved PSO based on network throughput maximization, have been developed, to achieve an improved rate of convergence of the conventional PSO algorithm. A maximum throughput/aggregate data rate of 1398Mbps was achieved, which represents 88.88% of the maximum achievable aggregate data rate of the system throughput.

Future Recommendation

An enhanced scheduling algorithm should be developed to maximize the channel data rate of the network while guaranteeing other QoS.

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