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ORIGINAL ARTICLE

Optimal Resource Scheduling Algorithm for OFDMA-based Multicast Traffic Delivery over WIMAX Networks using Particle Swarm Optimization

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ABSTRACT–Researchers are yet to entirely mapped out the difficulty in allocating optimal resources to mobile Worldwide Interoperability for Microwave Access (WiMAX) subscribers. This research presents an optimal scheduling algorithm for WiMAX resource allocation based on an Particle Swarm Optimization (PSO). In this work, sub-group creation is used to offer a PSO-based technique for allocating subcarriers and Orthogonal Frequency Division Multiplexing (OFDM) symbols to mobile WiMAX customers. The WiMAX network environment is organized into seven layers, with seven different modulation and coding algorithms proposed for sending packets to subscribers within each layer. By adopting an improved PSO-based WiMAX resource allocation method, an enhanced model for throughput maximization and channel data rate was implemented. The Aggregate Data Rate (ADR) and Channel Data Rate (CDR) for each scenario were obtained by simulating several scenarios of WiMAX multicast service to mobile users. Based on the performance evaluation of the enhanced algorithm for ADR and CDR, the results for the various layers and uniform distribution of users over the full layers were 350Mbps, 525Mbps, 700Mbps, 1050Mbps, 1050Mbps, 1400Mbps, 1575Mbps, and 1398Mbps. 6.98Mbps, 10.48Mbps, 13.97Mbps, 20.95Mbps, 20.95Mbps, 27.94Mbps, 31.5Mbps, and 28Mbps were also achieved for CDR. The significance of optimal resource allocation is to achieved a maximum ADR and CDR. The results showed a fair distribution of resources within the coverage area of the network .

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INTRODUCTION

Broadband wireless access has been introduced in response to the growing demand for high-speed multimedia services such as Internet Protocol Television (IPTV) and mobile television [1]-[2]. Worldwide Interoperability for Microwave Access (WiMAX) is one such broadband wireless access communication that uses several modes of transmisssion [3]. WiMax is an end-to-end network protocol with excellent performance, increased data rate, high fair quality of service (QoS), and highly secure data transfer with less packet latency are some of its characteristics [3], [4]. The WiMAX network is heterogeneous, with an ad-hoc mix of real-time and non-real-time traffic. The IEEE 802.16 standard specifies two wireless medium allocation schemes (i) Point-to-Multipoint (PMP) and (ii) Mesh (Optional) to enable effective data delivery [5]. In point-to-multipoint mode, the Base Station is a single resource controller for bi-directional communication with a collection of Subscriber Stations inside the same antenna sector in a broadcast mode since the nodes are placed in a cellular structure [5] while in the mesh mode there is no transmission from the Base Station, nodes are grouped systematically in an ad-hoc manner, and scheduling is divided among Subscriber Stations. Frame-based data transmissions are used in the IEEE 802.16 standard for the uplink from Subscriber Station to Base Station and the downlink from Base Station to Subscriber Station [3]. In mobile WiMAX, resource distribution is done in slots. Each slot has one sub-channel assigned to it for the duration of a certain number of orthogonal frequency division multiplexing (OFDM) symbols [6]. The link direction, uplink (UL) or downlink (DL), and the sub-channelization mode determine the number of subcarriers in the subchannel and the number of OFDM symbols in the slot [7]. In the partially used sub-channelization (PUSC) mode, for example, one slot comprises of one subchannel for downlink over two OFDM symbol periods and one subchannel for uplink over three OFDM symbol periods [8]. WiMAX networks operate in two Duplexing modes [9] Which are; Time Division Duplexing (TDD) mode and Frequency Division Duplexing (FDD) mode; In FDD, the uplink and downlink subframes are transmitted on distinct frequency bands at the same time [9]. TDD transmits both uplink and downlink sub-frames at the same time on the same carrier frequency ranges [10]. Both FDD and TDD designs can benefit from the developed technique. TDD architecture is used to keep the conversation on track. The algorithm supports a variety of network configurations, including mesh and point-to-multipoint networks; however, we are only interested in the point-to-multipoint network configuration. Broadband Wireless Access networks have been quickly changing in recent years to meet increasing user scalability and Quality of Service requirements (QoS). The main features of Mobile WiMAX are higher data rate, Mobility, Scalability, Quality of Service such as optimal system throughput. [11]. Mobile WiMAX has five types of scheduling classes to support QoS for different types of traffic which are : UGS

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(unsolicited grant scheme), rtPS (real-time polling service), nrtPS (non-real-time polling service), BE (best effort), and ERTPS (extended real-time polling service) (ertPS) [12]. The most important characteristics of these five scheduling service classes are outlined in [13]. 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 (IEEE 802.16e standard [13]. Specific QoS that need to be defined for this paper is: (i). Throughput i.e the number of packets that are successfully sent through a network, and it is measured in packets per second, (ii). Channel Data Rate refers to the total amount of user data sent over the air interface by the base station [3], [14]. The remainder of this paper is structured as follows: in section II we presented some review of related work; motivation of the research is presented in section III while in section IV we presented the implementation of the system model environment. The results and discussion is presented in section V and finally, section VI concluded the paper.

RELATED WORK

The authors in [14] developed a subgroup-based resource management scheme in which they cluster SSs with similar channel quality in the same multicast subgroup of a WiMAX cell. To improve system performance, different cost functions for subgroup formation were used to trade-off fairness and throughput requirements. There was no technique for decreasing the computational cost of subgroup generation in this study. [15] created a novel scheduling algorithm for downlink services that fully exploit the physical layer properties of the WiMAX network, while also maximizing the network's throughput and ensuring improved QoS of various network services. The algorithm's performance was further enhanced by the use of fuzzy logic architecture. Though, they fail to test the algorithm's performance in non-real-time traffic circumstances. [15] devised a proportional bandwidth giving technique based on proportional byte-based that stored individual bandwidth requests in byte format, which was the original value derived from the bandwidth request message. The second mechanism, which was used before any bandwidth allocation calculations was the proportional physical slot, which provided greater average throughput and jitter than the conventional bandwidth granting mechanism approach. However, as the number of subcarriers to be shared and the user distribution factor increased, their planned mechanism became inefficient. In the work of [1], they developed a novel scheduling algorithm for downlink services that completely utilities the physical layer properties of the WiMAX network, which optimally allocates the network resources from the Base Station to all the Subscribers irrespective of the Subscriber locations within the network range. This was achieved by modeling the network environment as a circular area covered by 7 concentric layers. The performance of the algorithm was evaluated by optimally distributing the resources and maximizing the network throughput (Aggregate Data Rate) using Particle Swarm Optimization (PSO) algorithm. However, the performance of the algorithm was not evaluated on the maximization of Channel Date rate while guaranteeing other QoS. [16] described packet scheduling problem as an application for reinforcement learning. It was shown how the reinforcement learning approach can be used to develop scheduling policies that meet the quality of service needs of numerous traffic classes in a range of scenarios. The proposed method was created to be able to accommodate integrated traffic in networks while using efficient scheduling schemes. In [17], they proposed a three-tier architecture comprising vehicular cloud, roadside cloudlet, and centralized cloud. The optimization process was carried out using the Hybrid Adaptive Particle Swarm Optimization (HAPSO) algorithm, which is a combination of Genetic Algorithm and Adaptive Particle Swarm Optimization. The developed optimized resource allocation and scheduling algorithm were employed to efficiently serve a large number of task requests incoming from one road user while sustaining enhanced Quality of Service. The task requests were optimally mapped to cloud resources amongst the three cloud layers. Although, the work is exposed to security and privacy bridge amongst the three-tier architecture. More so, in the work of [18], they proposed a three-step method to maximize the total throughput of a Non-orthogonal Multiple Access (NOMA). The three sequential steps were deployed as follows: The first step matches users to channels using a heuristic matching algorithm, while the second step utilizes a Particle swarm Optimization algorithm to allocate power to an individual channel. Lastly, power was allocated to individual channels to further distribute to multiplexed users based on their respective channel gain. However, the work could not mitigate the interference amongst different wireless communication technologies considered. Simulation tests were conducted to assess the performance of the suggested scheduling method without explicitly documenting the performance metrics of the proposed algorithm. In light of this, an improved scheduling algorithm based on the Particle Swarm Optimization technique is required to maximize network throughput and channel data rate while also ensuring another QoS of services in mobile WiMAX networks is presented in this paper.

MOTIVATION

The key challenges in optimal resource distribution to users of mobile WiMAX that belong to the same multicast group that is spread over different positions are throughput disparity (fluctuations) and channel degradation. because they experience different fading and path losses in time-varying wireless channels. This presents a problem to providing satisfactory multicast service to all subscribers within the network area [1]. To improve the system throughput, there is a need to partition the multicast group into smaller sub-groups to allow multiuser diversity to be exploited more efficiently, to maximize the system throughput and channel data rate. In this paper, a PSO algorithm for multicasting wireless traffic over a mobile WiMAX network based on sub-groups formation technique is proposed to improve the system throughput and channel data rate while guaranteeing the QoS for each of the users in the network.

METHODOLOGY

The proposed model depicts the network environment as a circular area with seven concentric layers. These layers show a variety of coding and modulation systems (MCS). The following are brief descriptions of the seven MCSs:

i. Layer 1 (QPSK 1/2): Users receive signals via quadrature phase-shift keying modulation in this layer. Each OFDM symbol has two bits in this type of modulation. The coding rate of this layer is 0.5.
ii. Layer 2 (QPSK 3/4): Each OFDM symbol in this layer has the same number of bits as layer 1, but the layer's coding rate is 0.75.
iii. Layer 3 (16-QAM 1/2): This layer uses the quadrature amplitude modulation technique. Each OFDM symbol in this layer has 4 bits and is coded at a rate of 0.5.
iv. 16-QAM 3/4 (Layer 4): The MCS of this layer is the same as layer 3, but the coding rate is 0.75.
v. (64-QAM 1/2) Layer 5: This layer has the same MCS as layer 4, but with a coding rate of 0.5 and 6 bits per modulation symbol
vi. (64-QAM 2/3) Layer 6: The coding rate of this layer is 0.67 instead of 0.5, which distinguishes it from layer 5.
vii. (64-QAM 3/4) Layer 7: Instead of 0.5, as in layer 5, a coding rate of 0.75 is employed in this layer.

A modulation and coding scheme is described in the proposed WiMAX network environment model using the abbreviation MCS_k, where k indicates the index of the layer of reference. The burst profile for various modulations and coding schemes is shown in Table 1.

Table 1. WiMAX Burst Profile for WirelessMAN-OFDMA PHY Layer (Channel Bandwidth 10MHz) [3]

Layer (k)	Modulation Type	Coding Rate ($Cr_{m.k}$)	SNR [dB]	S_{RX} [dBm]
1	QPSK	1/2.	5	-89.2
2	QPSK	3/4.	8	-86.29
3	16-QAM	1/2.	10.5	-83.79
4	16-QAM	3/4.	14	-80.29
5	64-QAM	1/2.	16	-78.29
6	64-QAM	2/3.	18	-76.29
7	64-QAM	3/4.	20	-74.29

The WiMAX environment is depicted in Figure 1 as a 7-layer design. A coverage area of 1257km^2 was adopted based on the COST-231 Hata model [18] which specifies a coverage radius of 20km.

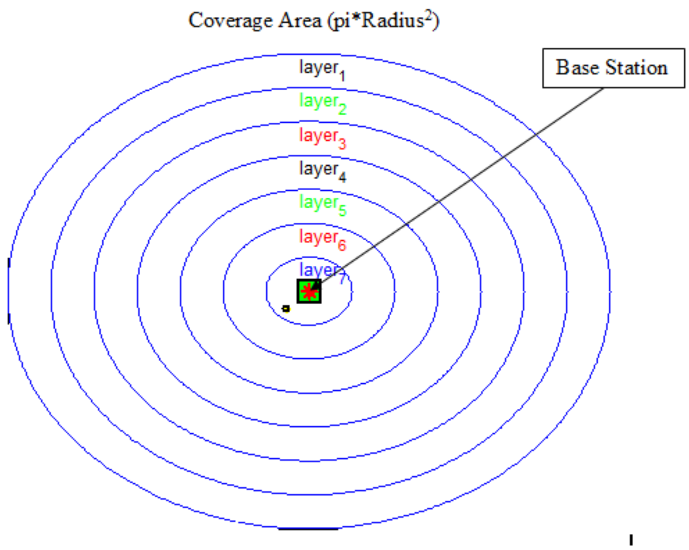


Figure 1: Proposed WiMAX Layered Architecture

Each modulation technique has a predetermined signal-to-noise ratio (SNR) and associated receiver input sensitivity, as shown in Table 1. With relation to the WiMAX Base Station, these two parameters were used to dynamically choose the desired MCS for each of the layers. Equation (1) was used to calculate the SRX (dBm) values in Table 1:

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

where:
SNR_{RX} is the receiver Signal-to-Noise Ratio
F_S is the sampling frequency [MHz]
N_{used} is the number of used subcarriers
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
ImpLoss is the implementation Loss
NF is the receiver noise figure referenced to the antenna port.

$$d_k = \frac{b_{m.k} \cdot cr_{m.k}}{T_s} \tag{2}$$

$$F_S = \text{Floor}\,(n \cdot BW/8000) \cdot 8000 \tag{3}$$

where:
n is a sampling factor
BW is the nominal channel bandwidth

If a more robust transport mode is available, it is used when the receiver sensitivity for a given profile is higher than the received signal level and target Bit Error Rate (BER). A channel can be used for transmission as long as it has a burst profile that can handle its current condition.

WiMAX Subscriber Substations (SSs)

Users of the WiMAX network are referred to as Subscribers in the proposed model, and their location is referred to as Station. The proposed model has the feature that the Substations can be moved around. As a result, the network configuration is subject to change at each frame interval. This attribute makes the network dynamic and helps to maximize the system's aggregate data rate (system throughput). Because it is a circular cell, users can be defined using two parameters:

(i) Radius (R)
(ii) Direction (θ)

To generate users at random inside the WiMAX network coverage area, the following command are used.
SS_distance = radius * rand (1,no_SS)
SS_direction = 2 * pi * rand (1,no_SS)

As a result, any user capability within the network environment may be completely specified using the cartecian coordinate system $[x_i, y_i]$, where x_i is the ith user x-coordinate and y_i is the ith user y-coordinate. In a WiMAX network context, the following can be used to specify the positions of all users.

$$X = 2\pi R[rand(1,N)].\times\ [\cos(rand(1,N))] \tag{4}$$

$$Y = 2\pi R\ [rand(1,N)]\ .\times\ [\sin(rand(1,N))] \tag{5}$$

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

Users can be confined from occupying various areas of the coverage area in the proposed model, that is, a user can be contained inside a set of layers. A collection of user distribution settings is utilized to define these boundaries. These parameters are α and β. As a result, equations (4) and (5) are adjusted to produce:

$$X = 2\pi R\left(\left(\frac{7-\alpha}{7(\beta+1)}\right)[rand(1,N)] + \frac{\beta}{\beta+1}\right) .X\ [\cos(rand(1,N))] \tag{6}$$

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

If α = β = 0. It can be seen that equations (6) and (7) will eventually become equations (4) and (5), respectively. The uniform distribution of users criteria is used to describe this criterion. In general, if α is zero then β determines the position of the users from the base station, While if β is zero, then α determines the position of the user from the base station. In the developed algorithm, α and β are designed to vary from 0 to 6. α is a user distribution parameter that is used in shifting the user towards the base station while β is used in shifting the user away from the base station.

Proposed Objective Function based on PSO

PSO is presented to handle a maximization problem in the proposed research work. As a result, the PSO minimization problem must be transformed to maximization as follows:

$$\max[F_{obj}] = \underset{k}{min}\left[{}^{1}/_{F_{obj}}\right] \tag{8}$$

where:
k is the particle population
F_{obj} is the throughput of the system(includes channel data rate)
$\max[F_{obj}]$ is the maximum throughput
If $\max[F_{obj}]$ is replaced by MT, Then, equation (8) can easily be rewritten as:

$$\text{MT} = \underset{k}{min}\left[{}^{1}/_{F_{obj}}\right] \tag{9}$$

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. Such as:

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

As a result, a particle generation consists of p particles, each having np parameters, and represented as a matrix with p rows and np columns. In the generation approach, np is selected to be twice the number of layers in the network, that is, for a 7-layer network, np is chosen to be twice the number of layers in the network. np equals 14. The value of p was set at the start of the optimization procedure. Since simulation is proposed in Matlab, the population is produced at random using:

$$G_i = rand(p, np) \tag{10}$$

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}

Proposed Objective Function based on PSO

In the developed algorithm, all WiMAX network users are divided into seven groups based on the number of layers. The users' matrix can be defined using equation (12).

$$u = [u_1, u_2, \dots\dots. u_7] \tag{11}$$

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.

A defined Matlab function 's substation' is used to produce the user matrix u. The matlab function is also used to determine the maximum bit rate of each layer. 'ubitrates' and is kept in a 1 by 7 matrix called u_b. As a result, a matrix of data rates can be used to hold the maximum aggregate data rate of each layer per OFDM symbol per subcarrier:
rates shown in:

$$ADR_i = [d_{a_1}, d_{a_2}, \dots\dots\dots. d_{a_7}] \tag{12}$$

where:

$$d_{a_i} = u_i \times u_{b_i} \quad [i = 1, 2, \dots \dots 7] \tag{13}$$

and

$$u_b = [u_{b_1}, u_{b_2}, u_{b_3} \dots \dots \dots \dots . u_{b_7}] \tag{14}$$

The generation matrix is used to assign subcarriers and OFDM signals to each layer users.

Let Nsc represent the total number of subcarriers to be assigned, and Nos represent the total number of OFDM to be assigned. To increase service quality, it is necessary to demonstrate that each layer having at least one user has at least one subcarrier and one OFDM symbol. To accomplish this, seven OFDMs and seven subcarriers are originally shared, one for each tier. As a result, the (Nsc – 7) subcarrier and OFDM symbol allocation problem becomes (Nos – 7) subcarrier and OFDM symbol, respectively. As a result, the objective function may be written as:

$$F_{obj} = round \left[\frac{\sum_{L=1}^{7}(N_{sc}-7) g_L \cdot d_{a_L}}{\sum_{j=1}^{7} g_i}\right] \times round \left[\frac{\sum_{L=8}^{14}(N_{os}-7) g_L \cdot d_{a_L}}{\sum_{L=8}^{14} g_i}\right] \tag{15}$$

where:

$$G_i = [g_1, g_2, g_3, \dots \dots \dots \dots .. g_{14}] \tag{16}$$

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:

$$F_{obj} = \begin{bmatrix} F_{obj.1} \\ F_{obj.2} \\ F_{obj.3} \\ \vdots \\ F_{obj\ .p} \end{bmatrix} \tag{17}$$

$$F_{obj.t} = \sum_{k=1}^{7} u_{b.kt} \otimes u_{kt} \otimes L_{s.kt} \otimes L_{0.kt} \tag{18}$$

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. Figure 2 is a flow chart for evaluating the fitness of particles (Throughput) for each generation.

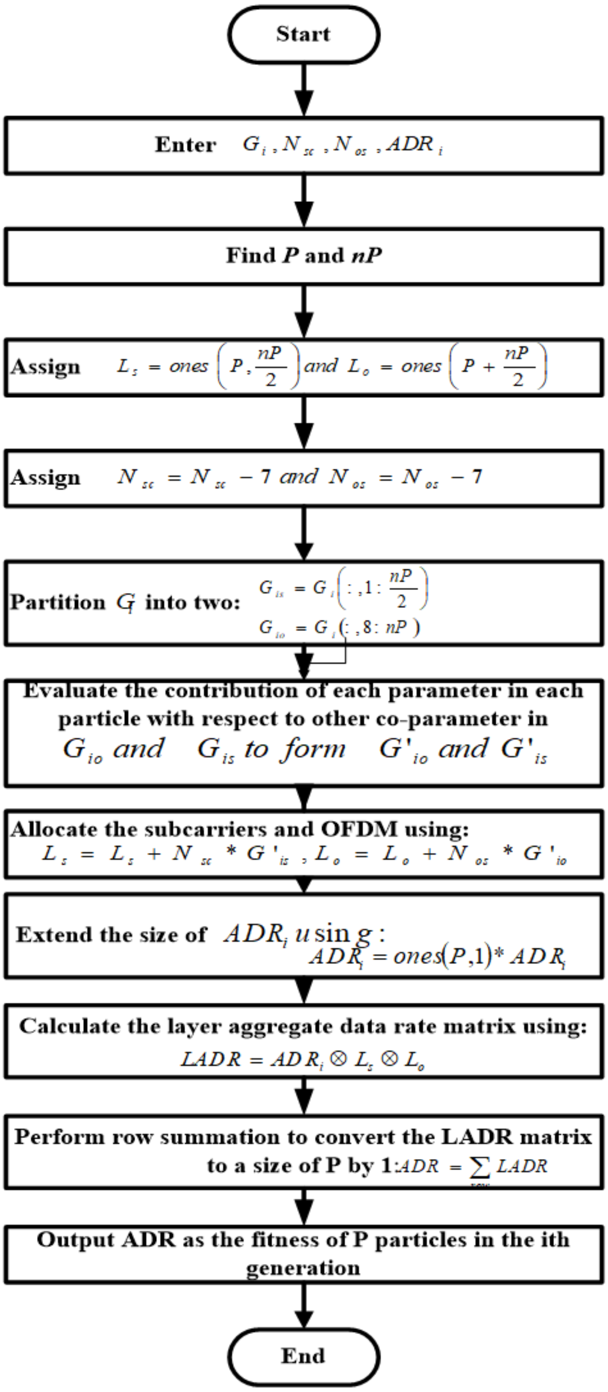


Figure 2. Flow Chart for the Objective Function

Proposed PSO Algorithm for Throughput and Channel Date Rate Maximization

In the proposed research, the conventional Particle Swarm algorithm (PSO) is modified to suit the application in WiMAX network for throughput maximization. This algorithm comprises step by step approach required to maximize throughput/aggregate data rate and channel data rate in the WiMAX networks while considering resource allocation. The following steps of instructions are executed logically 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 shown in Figure 3 as follows:

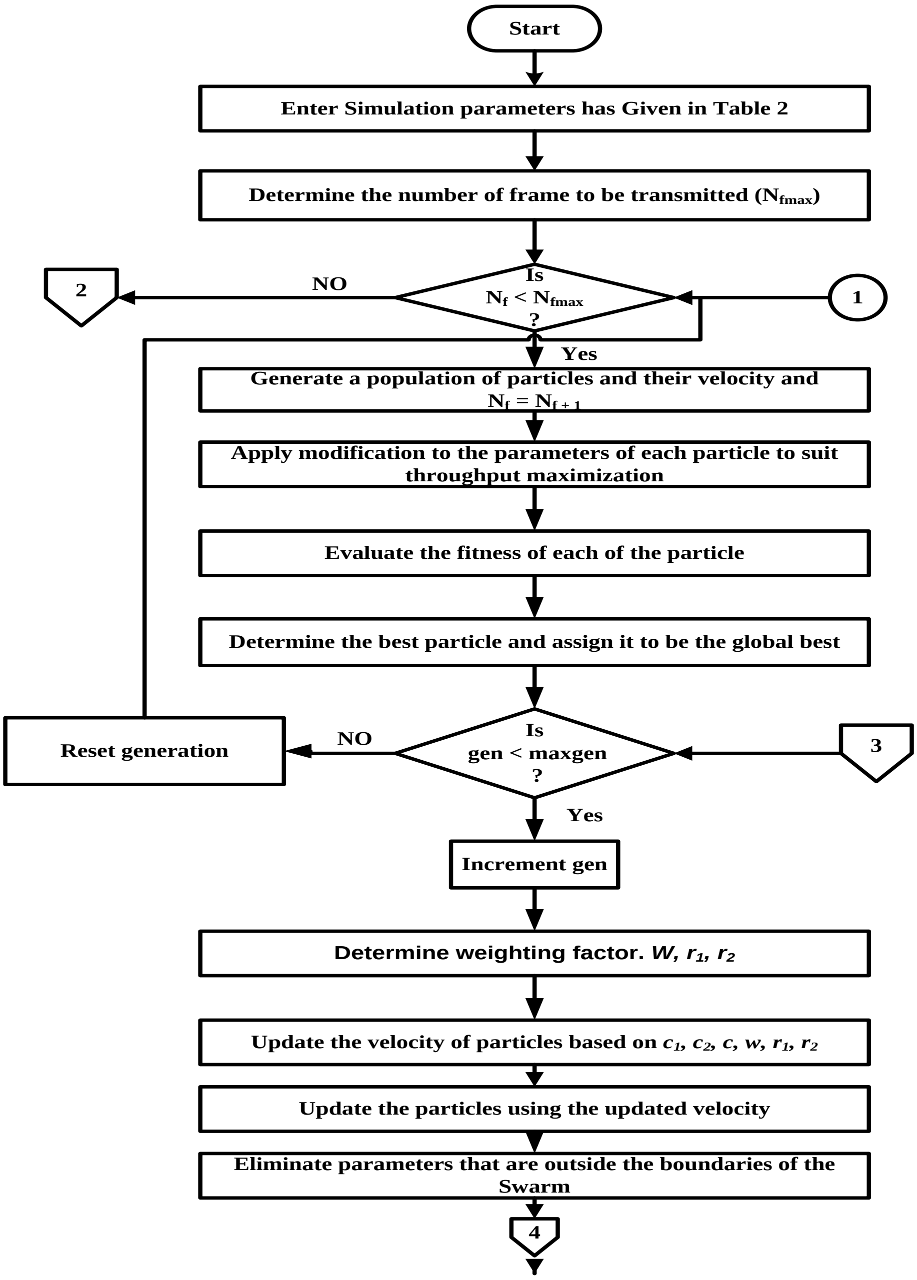


Figure 3. Flow Chart for the Improved PSO Algorithm

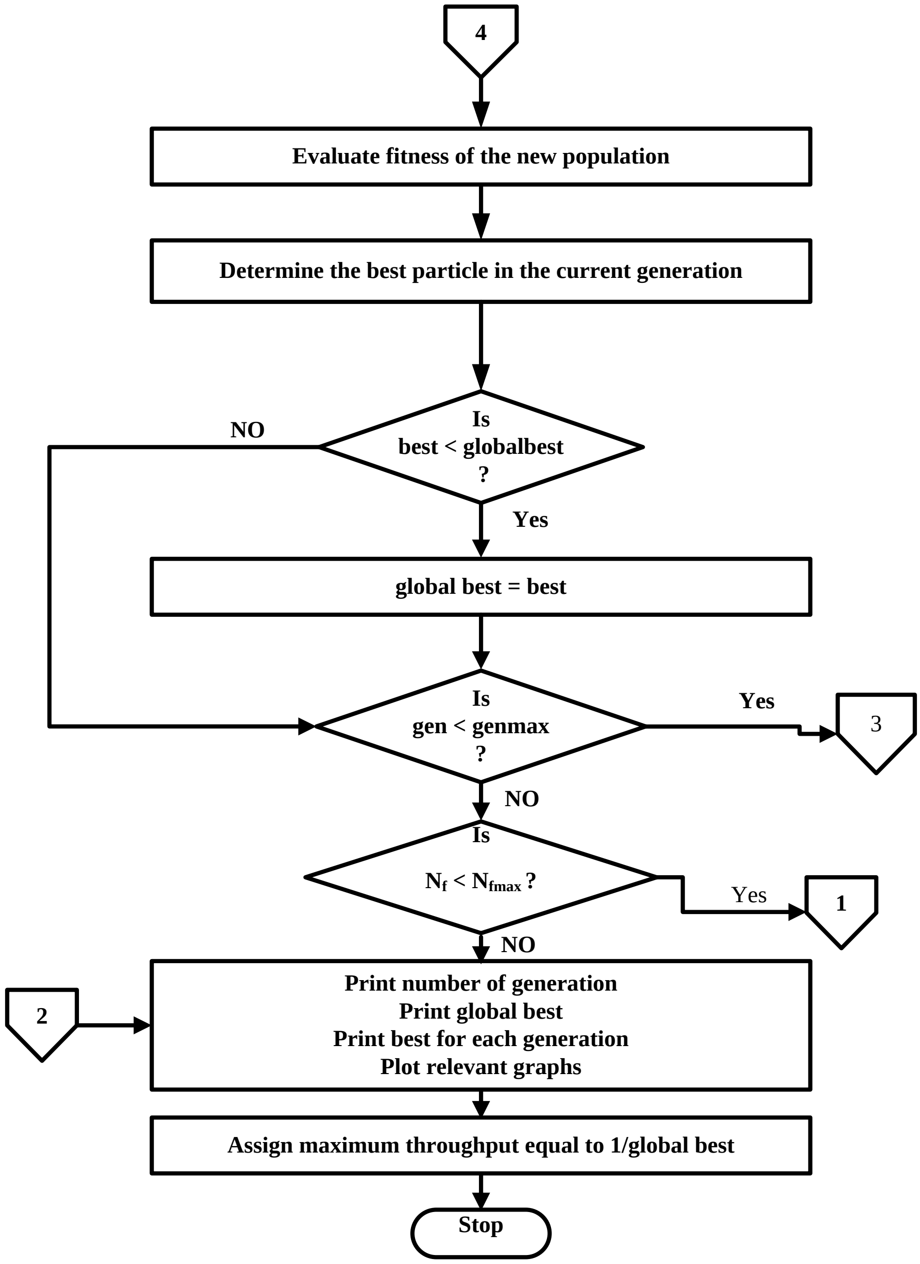


Figure 4. Flow Chart for the Improved PSO Algorithm

A simulation was used to test the performance of the proposed scheduling algorithm in maximizing WiMAX network throughput/aggregate data rate in a scenario with 50 users equally distributed and confined within each of the layers over a coverage area of 400km^2. Table 2 lists the simulation parameters in detail:

Table 2. Simulation Parameters

Parameters	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 subscriber stations	50
Number of bits per modulation symbol for 7 layers	See Table1
Sampling factor (n)	28/25
Cyclic prefix (G)	1/8
Number of frames	500
FFT size	1024
Duplexing mode	TDD
Link orientation	DL
Traffic	RTPS
Sub-channelization	PUSC

The reasons for choosing the various simulation parameters of WiMAX are obtained in IEEE 802.16 standard [17]. The simulated WiMAX network environment is such that layer 7 is the closest to the Base Station while layers 6 to 1 follows respectively. Figures 5(a) to 3(h) 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 layers 7,5, and 3 respectively.

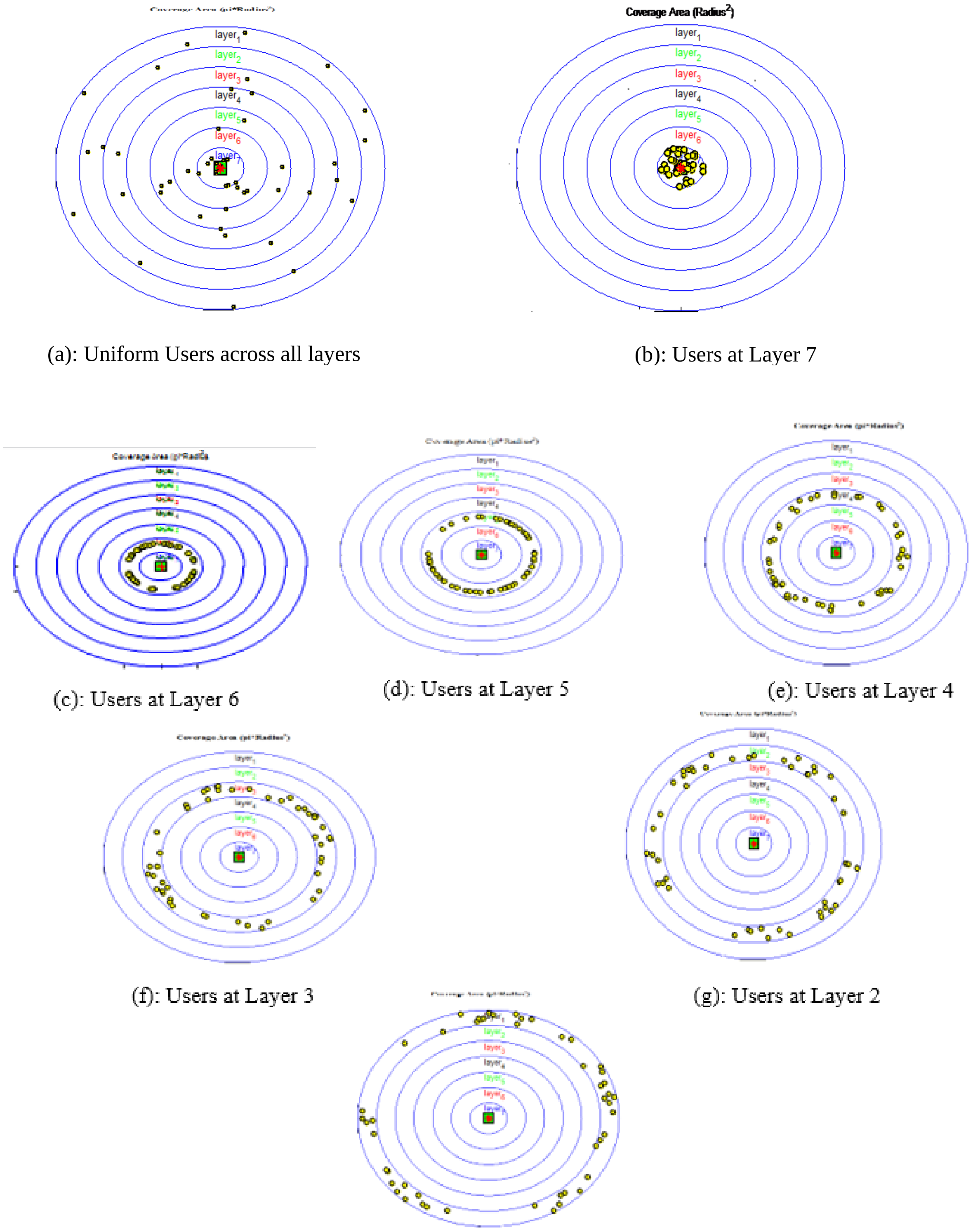
The various parameters used for the distribution of users are shown in Table 3

Table 3. User Distribution Parameters

Figure 5	**α**	**β**
a	0	0
b	0	6
c	4	3
d	6	1.5
e	6	0.9
f	6	0.5
g	6	0.2
h	6	0

RESULTS AND DISCUSSION

The radius of coverage of the WiMAX network was chosen to vary from 20/7 km to 20km in the proposed model of WiMAX network environment, resulting in a maximum coverage area of 400km^2 and a 7-layered architecture. As illustrated in Figure 1, the seven layers are organized in a concentric pattern and declining sequence of a layer index (7, 6, 5...1). Each layer is given a modulation and coding scheme (MCS), as illustrated in Table 2. For each scenario, fifty subscriber substations (50) were considered. Figure 3 is a bar chart depicting the throughput obtained in various scenarios of subscriber substation distribution within the WiMAX coverage region. When users are randomly distributed across the whole WiMAX coverage, the first bar (0) reflects the maximum throughput. Figures 4 and 5 show plots generated by the developed PSO algorithm for this scenario (bar 0). The remaining bars (1, 2, 3,...7) reflect throughput/aggregate data rates obtained by constraining users to only residing within a single layer. It can be shown that the highest possible aggregate data rate is achieved when all users are within layer seven. This is because layer 7 employs the 64-QAM-3/4 MCS, which provides the maximum bit rate per subcarrier per OFDM signal. The height of the bar likewise steadily drops as the layer index (from layer 7 to 1) lowers, which corresponds to the aggregate data rate gained as the distance from the WiMAX base station reduces. The aggregate data rate of layers 4 and 5 was found to be the same, which corresponds to bars 4 and 5 respectively. Because of their respective MCS, they have the same data rate per subcarrier per OFDM signal.



(a): Uniform Users across all layers

(b): Users at Layer 7

(c): Users at Layer 6

(d): Users at Layer 5

(e): Users at Layer 4

(f): Users at Layer 3

(g): Users at Layer 2

(h): Users at Layer 1

Figure 3. User Representation of Different Layers

The radius of coverage of the WiMAX network was chosen to vary from 20/7 km to 20km in the proposed model of WiMAX network environment, resulting in a maximum coverage area of 400km^2 and a 7-layered architecture. As illustrated in Figure 1, the seven layers are organized in a concentric pattern and in a declining sequence of a layer index (7, 6, 5...1). Each layer is given a modulation and coding scheme (MCS), as illustrated in Table 2. For each scenario, fifty subscriber substations (50) were considered. Figure 3 is a bar chart depicting the throughput obtained in various scenarios of subscriber substation distribution within the WiMAX coverage region. When users are randomly distributed across the whole WiMAX coverage, the first bar (0) reflects the maximum throughput. Figures 4 and 5 show plots generated by the developed PSO algorithm for this scenario (bar 0). The remaining bars (1, 2, 3,...7) reflect throughput/aggregate data rates obtained by constraining users to only residing within a single layer. It can be shown that the highest possible aggregate data rate is achieved when all users are within layer seven. This is because layer 7 employs the 64-QAM-3/4 MCS, which provides the maximum bit rate per subcarrier per OFDM signal. The height of the bar likewise steadily drops as the layer index (from layer 7 to 1) lowers, which corresponds to the aggregate data rate gained as the distance from the WiMAX base station reduces. The aggregate data rate of layers 4 and 5 was found to be the same, which corresponds to bars 4 and 5 respectively. Because of their respective MCS, they have the same data rate per subcarrier per OFDM signal.

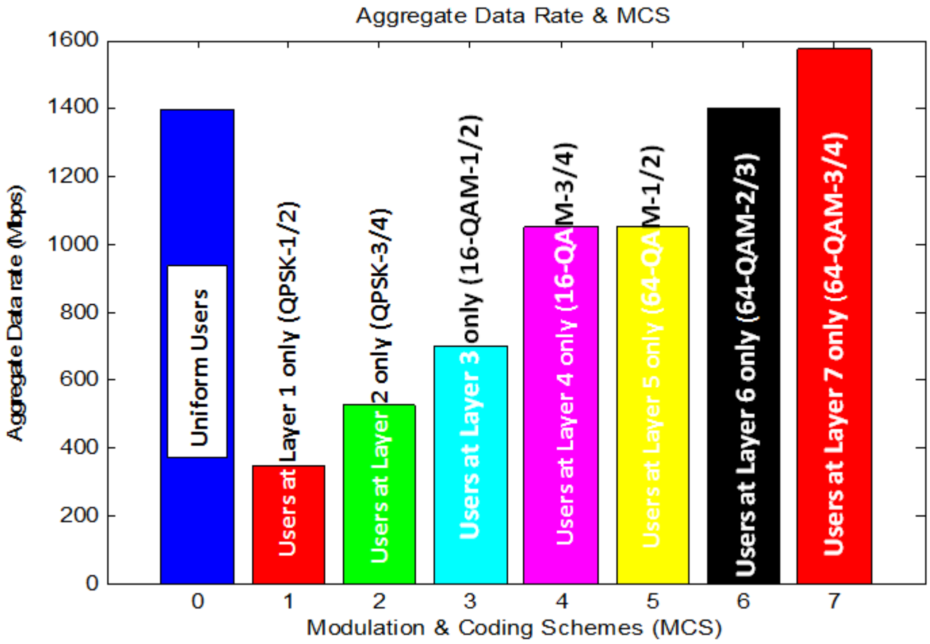


Figure 6. Maximum Throughput (Aggregate Data Rate) versus User Distribution

The enhanced PSO algorithm was shown to converge to the maximum throughput at the fourth generation, as shown in Figure 7. The blue and green dotted lines, which correspond to the local maximum and average throughput, peak at the 4th and 10th generations, respectively, and drop dramatically at any other generation. This demonstrates that all particle populations in all generations are highly similar and have a very low fitness value when compared to the global best particle. This is due to the enormous amount of particles present in each swarm during each generation (about 750000 particles were used in this case).

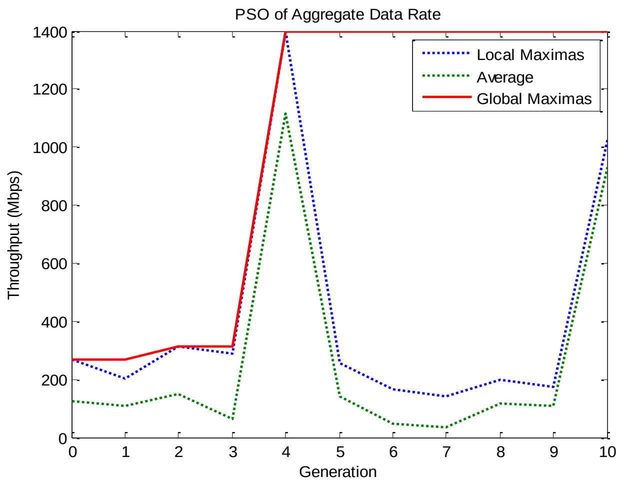


Figure 7. Rate of Convergence of the Improved Algorithm for Aggregate Data Rate

The developed improved PSO algorithm is produced in Figure 8. The CDR, as shown in Figure 8, follows the same trend as the Aggregate Data Rate (ADR). The maximum data rate (bit rate) a user can have over a WiMAX channel is known as ADR. The modified algorithm converges on the fourth generation, which corresponds to the best CDR result in scheduling processing.

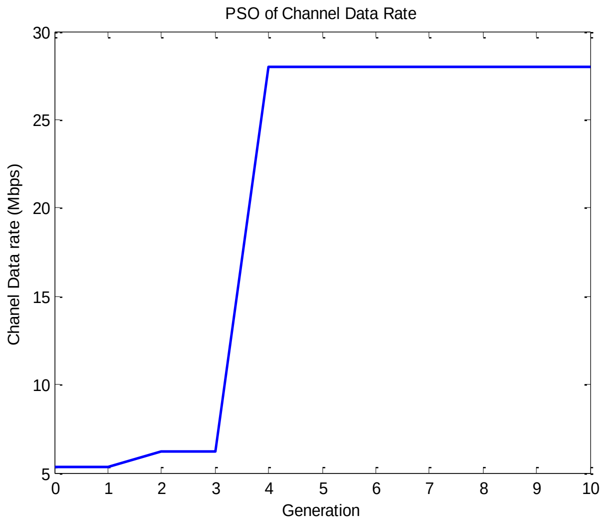


Figure 8. Rate of Convergence of Improved algorithm for Channel Data Rate

Discussions of Results

Table 4 is a summary of the results obtained for Aggregate Data Rate (ADR) and Channel Data Rate (CDR) for the various layers and the uniform distribution of users over the entire layers.

Table 4. Summary of Results Obtained of Improved PSO Algorithm

Layer (k)	**ADR (Mbps)**	**CDR (Mbps)**
Uniform distribution	1398	28
1	350	6.98
2	525	10.48
3	700	13.97
4	1050	20.95
5	1050	20.95
6	1400	27.94
7	1575	31.5

CONCLUSION

This study provided a general introduction to machine learning-based phishing attack detection. Unlike the approaches used in some of the past studies, two categories of learning classifiers were used to build phishing detection models. Specifically two single and two ensemble machine learning algorithms were used to build models for the identification of phishing-based cyber attacks. The learning algorithms chosen were trained and tested using the phishing dataset. The metrics used for the evaluation were accuracy, precision, recall and F1-score. It was observed that the two ensembles generally performed better than the two selected classifiers. The results of the experimentation showed that the ensemble techniques that were used performed better than the single classifiers in phishing url identification.

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