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ACHIEVING QOS REQUIREMENTS USING EVOLUTIONARY COMPUTATION SCHEDULING SCHEMES IN 802.16 NETWORKS

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ABSTRACT

The exponential growth observed in the arena of wireless access technologies predominantly in the IEEE 802.16 networks put forth's a large overhead in the uplink scheduling schemes particularly when rendering real time services. This paper introduces an evolutionary computation based uplink scheduling scheme (ESS) with Quality of Service (QoS) gurantee. A service threshold time is introduced in the ESS scheme to meet the QoS requirements and it determines the adaptive weights assigned to the service. The base station based on the weights ascertains the modulation scheme required to evade QoS violation and constructs the scheduling set. In addition of the adaptive weights the channel interference parameters is also considered to construct the scheduling set. The scheduling set is optimized to achieve the desired QoS parameters utilizing evolutionary computation techniques. The performance of ESS scheduling scheme is evaluated and the results obtained not only prove higher slot success rates, higher system throughput but also prove its QoS provisioning competence and its efficiency over an existing scheduling scheme.

Keywords: *MIMO, OFDMA, IEEE 802.16, Evolutionary Computing, Quality of Service (*$\boldsymbol{QoS}$*), Uplink (*$\boldsymbol{\mathcal{UL}}$*), Uplink Scheduling, Adaptive weights, Service Threshold Time, Optimization*

1. INTRODUCTION

The user needs to attain advanced services like multimedia streaming; voice over internet protocol (VoIP), high speed internet, video conferencing services and many more services on mobile environments have fueled the rapid growth of IEEE 802.16e networks [1]. The mobile WIMAX was established as an International Mobile Telecommunication advanced technology by the International Telecommunication Union. A recent survey conducted showed the number of wimax users to grow up to 133 million by this yearend [2]. The major concern is in the provisioning QoS for such diverse services.

In the IEEE 802.16 standards the base station ($\mathcal{BS}$) receives bandwidth allocation requests from the subscriber stations ($\mathcal{SS}$)through the uplink ($\mathcal{UL}$). The onus is on the $\mathcal{BS}$ to allocate the service traffic of the $\mathcal{UL}$ $\mathcal{SS}$'s to the $\mathcal{UL}$ sub frame. The IEEE 802.16 [3] standards provide support for four types of services are supported. Each of the services offered in the 802.16 have varied QoS requirements which have to be accounted for to provide QoS gurantee. These services or $\mathcal{UL}$ scheduling classes support both nonreal time and real time traffic considered. The **Unsolicited Grant Service**(UGS) has the greatest priority of service and it provides support for constant baud rate (CBR) real time traffic patterns like VoIP .For UGS services a constant amount of resources in each frame is allocated and there exist no need for bandwidth request. The Real Time Polling Service ($rtPS$) in 802.16 is designed for variable baud rate (VBR) traffic patterns like video streaming. The $rtPS$ traffic is considered to be delay sensitive traffic hence it can be stated that the delay requirement is an important QoS parameter for consideration in the $rtPS$ traffic. The resources allocated for such traffic change dynamically based on the packet delay time of the$\mathcal{SS}$. Also the packet drop rate should be within the within the requirement of the$\mathcal{SS}$.As the name suggests in $rtPS$ a poolling mechanism can be used to request for additional bandwidth provided the delay requirement of the $\mathcal{SS}$ is achieved. In IEEE 802.16 the **Non-Real-**

Time Polling Service ($nrtPS$) is provided to maintain the delay tolerant traffic support. This kind of traffic requires minimum transmission rates requested by the$\mathcal{SS}$. FTP and HTTP traffic could be considered as examples of $nrtPS$ traffic and a polling service could be utilized in scheduling such traffic based on the buffer criteria. The lowest priority is provided to the Best Effort (BE) kind of services. These traffic kinds are scheduled only after theUGS, $rtPS$ and the $nrtPS$ are serviced and post that if some resources remain. E-Mail services could be considered as an example of BE traffic.

The scheduling algorithms working on the $\mathcal{BS}$ are critical to provide for QoS guarantee. The IEEE 802.16 specifications provided has no mention of the scheduling algorithms to be adopted at the$\mathcal{BS}$. The IEEE 802.16 network providers decide on the scheduling algorithm to be adopted based on the network traffic observed. Researchers have proposed varied algorithms to resolve the bandwidth request strategies using fair scheduling [4][5][6] , round robin scheduling [7][8], round robin with channel dependence scheme[11], min max fair scheduling strategy [9], multi rate power controlled collision free scheduling scheme [10],collision free scheduling scheme [12], distributed fair scheduling scheme [13] , energy efficient scheduling scheme [14]. These scheduling schemes cannot be adopted in IEEE 802.16 networks owing to the specific technology specifications. Researchers have also proposed varied $\mathcal{UL}$ scheduling algorithms to provide QoSguarantee. A scheduling scheme utilizing automatic repeat request and adaptive modulation scheduling [15] exhibits effective resource utilization and meets the minimum throughput requirements for QoS but this scheme is only applied to $nrtPS$ service types. The Largest Weighted Delay First [16] and the modified Largest Weighted Delay First [17] scheduling schemes assigned weights for scheduling. The ESS proposed in this paper uses a similar adaptive weighing concept. The delay of the head of line packets is also used to provide for QoS but only for BE kind of traffic [18]. The ESS also considers the head of line packets to provide QoS guarantee for all kind of services. The dynamic classified buffer control for QoS-Aware Packet Scheduling in IEEE 802.16/wimax networks [19] algorithm is used for comparison with the ESS scheduling scheme. A detailed summary of the scheduling algorithms for IEEE 802.16 networks is presented in [20].

Optimization of the scheduling algorithms in IEEE 802.16 networks is a very critical issue to overcome the back off optimization, polling mechanisms, overhead optimizations drawbacks that exist in the existing scheduling schemes [20]. To optimize the $\mathcal{UL}$ scheduling, ESS adopts evolutionary computation. Evolutionary Computing is an evolutionary computing algorithm and it has been used by researchers to optimize varied kinds of problems defined through objective functions. The optimization efficiency of evolutionary computation over the other evolutionary algorithms has been clearly understood from [21][22] hence it is adopted in the ESS scheme proposed in this paper.

The remaining manuscript is organized as follows. In the second section the system architecture and the modeling adopted in the IEEE 802.16 system is discussed. In the next section this paper introduces the service threshold time , the adaptive weighing scheme , the modulation schemes , the scheduling set and its optimization using evolutionary computation. The penultimate section of the manuscript describes the performance evaluation of the ESS scheme and it also discusses the comparison with the existing scheduling scheme [19]. The conclusion and future work is discussed in the final section of this paper.

2. IEEE 802.16 MIMO SYSTEM ARCHITECTURE AND MODELLING FOR QoS PROVISIONING

The ESS based system model discussed in this paper is considers a MIMO IEEE 802.16 system architecture. In such architectures the Base Station ($\mathcal{BS}$) reins the communication channels via the $\mathcal{V}$ number of antennas towards the $\mathcal{U}$number of users also known as subscriber stations ($\mathcal{SS}$)Let's consider the number of subchannels to be represented as $\mathcal{C}$ and there exist a number of subcarriers per sub channel. As per the specifications set for 802.16 the orthogonal frequency division multiple access($OFDMA$) frame constitutes of two sub frames namely Uplink Frame ($\mathcal{UL}$) and a Downlink Frame ($\mathcal{DL}$). The time duration of these sub frames is assigned by the $\mathcal{BS}$ and transmitted using the Uplink Map ($\mathcal{ULMAP}$) and the Downlink Map ($\mathcal{DLMAP}$) frames to each of the $\mathcal{U}$ number of $\mathcal{SS}$ considered in the system. The $\mathcal{ULMAP}$ compromises of $\mathcal{S}$ symbols per assigned slot composed of one OFDMA symbol and one sub channel.

The QoS offered by the system incorporating the proposed scheduling algorithmESS can be enhanced by limiting or achieving the desired bit error rates in noisy channels used in the transmission of IEEE 802.16 mobile networks. It is possible to achieve lower bit error rates at the $\mathcal{U}$ number of $\mathcal{SS}$ in the system model if the transmission power available with each of the $u \in \mathcal{U}$ number of $\mathcal{SS}$ could be obtained. The power available on the channel of operation is critical to handle channel noise and interference. Higher the transmission power higher is the throughput observed.

The system considers a quadratic amplitude modulation (QAM) technique for all the channels. The QAM technique adopted in the system model provides support for Quadrature Phase Shift Keying ($QPSK$), 16 QAM and 64 QAM for $\mathcal{UL}$ and $\mathcal{L}$.

Let's consider a subscriber station $u \in \mathcal{U}$ on a sub channel $c \in \mathcal{C}$ and the channel gain is represented as $g_{u,c}$. Additive white Gaussian noise model is applied to all the transmissions in the system model. The additive white Gaussian noise is considered to have a mean equivalent to≈ 0 and the variance is represented as n^2. The received signal to interference plus noise ratio $\gamma_{u,c}^{s}$is defined as

$$\gamma_{u,c}^{s} = \left(e_{u,c}^{s} |\ g_{u,c}\ |^2\right) \Big/ \left(\left(\sum_{u' \neq u} e_{u',c}^{s} |\ g_{u',c}\ |^2\right) + \ n^2\right)$$

where u represents a$\mathcal{SS}$ and $u \in \mathcal{U}$, c is the sub channel, $s \in S$ is the symbol and γ represents the allocated power. Also $u \geq 1$ and $u' \in \mathcal{U}$.$e_{u,c}^{s}$ represents the power allocated of the $u^{th}\mathcal{SS}$ of each sub carrier on the c sub channel of the symbol s.

The bit error rate $\mathcal{E}rr$ observed of the Q −QAM signal received is defined as

$$\mathcal{E}rr \ \leq 0.2\, e^{-1.5\ \times(\gamma/(Q-1))}$$

where $\mathcal{E}rr_{u}^{min}$is the targeted bit error rate of the $u^{th}\mathcal{SS}$.

To achieve the required least bit error rate $\mathcal{E}rr^{min}$the power allocated to each subcarrier on sub channel c at the s^{th} symbol of the $\mathcal{SS}\ u$ is defined as

$$e_{u,c}^{s} = \left(-(Q-1)\ln(5 \times \mathcal{E}rr_{u}^{min})\, n^2\right) \big/ \left(1.5 \times \ |\ g_{u,c}\ |^2\right)$$

The power of the $u^{th}\mathcal{SS}$in the c^{th}sub channel is defined as

$$et_{u,c}^{s} = \ q\,.\,e_{u,c}^{s}$$

3. EVOLUTIONARY COMPUTATION BASED SCHEDULING STRATEGY - *ESS*

A scheduling strategy(ESS) is designed for the $\mathcal{BS}$ utilizing an evolutionary computing algorithm. The scheduling algorithm is designed for QoS guarantee and organized resource allocation to $\mathcal{SS}$ in IEEE 802.16 systems. In the ESS the scheduling is achieved based on the weights assigned to the varied traffic services supported in the IEEE 802.16 system. To assign the weights the ESS introduces a predefined service lifetime threshold. The service lifetime threshold could be defined as the quantum of time required to process the remaining available frames for the head of line ($\mathcal{H}_{\mathcal{L}}$) packet of the considered service traffic. The ESS adjusts the weights dynamically based on the service threshold time. If the time taken process the service is greater that the predefined threshold the $\mathcal{H}_{\mathcal{L}}$packet is dropped. It can be stated that if the service lifetime threshold of a service is less the weights assigned would be greater to incorporate provisioning ofQoS guarantee. As per the standards of IEEE 802.16 the service class set $\mathcal{SC}$ can be defined as

$$\mathcal{SC} = \{UGS, rtPS, nrtPS, BE\}$$

The $\mathcal{BS}$ selects the$\mathcal{SS}$ with the highest weights for service. Let the service threshold time of a service $sc \in \mathcal{SC}$ requested by the $u^{th}\mathcal{SS}$ be represented as$\mathcal{ST}_{u,sc}$. If the service class sc is of type the UGS service threshold time is primarily set to the packet objective delay established by $u^{th}\mathcal{SS}$ and is represented as $\Delta\mathcal{T}_{u,UGS}^{Obj}$ in other words

$$\mathcal{ST}_{u,UGS} = \ \Delta\mathcal{T}_{u,UGS}^{Obj}$$

where the objective delay time $\Delta\mathcal{T}_{u,UGS}^{Obj}$ is decremented per unit time frame by frame.

The service threshold time for $sc \ = rtPS$ for the $u^{th}\mathcal{SS}$ whose packet objective delay represented $\Delta\mathcal{T}_{rtPS}^{Obj}$as can be defined as

$$\mathcal{ST}_{u,rtPS} = \ \Delta\mathcal{T}_{rtPS}^{Obj} - \ \mathcal{ST}'_{u,rtPS}$$

where $\mathcal{ST}'_{u,rtPS}$represents the number of frames received of the $rtPS$ packet of the$\mathcal{SS}$at the considered time.

For the $nrtPS$ traffic for a $u^{th}\mathcal{SS}$ where the minimum transmission rate required to service such traffic is $R_{u,min}^{Req}$ the service threshold time $\mathcal{ST}_{u,nrtPS}$ could be obtained from $R_{u,min}^{Req}$. To obtain $\mathcal{ST}_{u,nrtPS}$we shall represent the number of bits remaining to serve the $\mathcal{H}_{\mathcal{L}}$of the considered traffic as $\mathcal{H}_{\mathcal{L}_{u,sc}}$ and $sc \in \ \mathcal{SC}$. Considering $T_{u,nrtPS}$is the number of bits already transmitted for the

$nrtPS$ packet and $\tau_{u,nrtPS}$number of active frames, the service provided by the $\mathcal{BS}$ should fulfill the minimum rate requirement set by the $u^{th}\mathcal{SS}$. In order to achieve the desired rate of transmission the number of frames that could transmit the $\mathcal{H}_{\mathcal{L}}$ packet is defined as

$$\Delta\mathcal{T}_{nrtPS}^{Obj} = [(T_{u,nrtPS} + \mathcal{H}_{\mathcal{L}_{u,sc}})/R_{u,min}^{Req}] - \tau_{u,nrtPS}$$

The service threshold time for $nrtPS$ traffic is defined as

$$\mathcal{ST}_{u,nrtPS} = \Delta\mathcal{T}_{nrtPS}^{Obj} - \mathcal{ST}'_{u,nrtPS}$$

For traffic services of type BE QoS is not of prime importance. To provide better QoS to even BE services the ESS considers a minimum transmission rate to be assigned to such services. Hence the service threshold time could be defined as

$$\mathcal{ST}_{u,BE} = \Delta\mathcal{T}_{BE}^{Obj} - \mathcal{ST}'_{u,BE}$$

where $\Delta\mathcal{T}_{u,BE}^{Obj}$is defined as

$$\Delta\mathcal{T}_{BE}^{Obj} = [(T_{u,BE} + \mathcal{H}_{\mathcal{L}_{u,sc}})/R_{u,min}^{Req}] - \tau_{u,BE}$$

The ESS scheduling scheme allocates the bandwidth based on the weights assigned dynamically. The weights assigned to the services are based on the service threshold time assigned to the services and the packet objective delay established by the $\mathcal{SS}$ being serviced. In the ESS scheduler the weights are adaptive in nature. The adaptive weight denoted as $\Delta\mathcal{W}_{ad}$ can be defined as

$$\Delta\mathcal{W}_{ad} = \mathcal{ST}_{u,sc}/\Delta\mathcal{T}_{u,sc}^{Obj}$$

Normalizing the above equation such that the weights attain values between 0 and 1

$$\Delta\mathcal{W}_{ad} = (af/ad)\left(\mathcal{ST}_{u,sc}/\Delta\mathcal{T}_{u,sc}^{Obj}\right)$$

where ad represents the required adaption degree and af represents the adaption factor such that $0 < af \leq ad$

In the ESS proposed in this paper we consider the ad is assumed to be four i.e. $ad = 4$. Hence af could take the values $\{1, 2, 3, 4\}$

The bandwidth to be allocated to the $u^{th}\mathcal{SS}$ for a service sc depends on the number of bits to be transmitted hencein the proposed ESS scheduling scheme it is critical to identify the quantum of bits for a service $sc \in \mathcal{SC}$ for the $u^{th}\mathcal{SS}$ and is defined as

$$\mathcal{B}_{u,sc} = \begin{Bmatrix} \left(\mathcal{H}_{\mathcal{L}_{u,sc}}/\mathcal{ST}_{u,sc}\right) \forall\ 0.75 \leq \Delta\mathcal{W}_{ad} \leq 1 \\ f_{min}\left(\left(2 \times \mathcal{H}_{\mathcal{L}_{u,sc}}/\mathcal{ST}_{u,sc}\right), \mathcal{H}_{\mathcal{L}}\right) \forall\ 0.5 \leq \Delta\mathcal{W}_{ad} \leq 0.75 \\ f_{min}\left(\left(4 \times \mathcal{H}_{\mathcal{L}_{u,sc}}/\mathcal{ST}_{u,sc}\right), \mathcal{H}_{\mathcal{L}}\right) \forall\ 0.25 \leq \Delta\mathcal{W}_{ad} \leq 0.5 \\ \mathcal{H}_{\mathcal{L}_{u,sc}} \forall\ 0 \leq \Delta\mathcal{W}_{ad} \leq 0.25 \end{Bmatrix}$$

where $f_{min}(m,n)$ represents the function which returns the minim value amongst the variablesm,n.

From the above definition it is clear that the ESS provides additional bandwidth to a service $sc \in \mathcal{SC}$ if the adaptive weight is higher providing for better QoS . Also the ESS scheme limits the transmission overheads by cumulatively transmitting the service bits of varied services for the $u^{th}\mathcal{SS}$. The ESS scheduling introduced is designed to maximize the throughput of the system under consideration and also to achieve the QoS for all the $\mathcal{SS}$. The ESS also considers the system constraints that exist like the buffer capacity constraints, the ranking constraints and the power constraints. The use of evolutionary computing algorithms is considered in the ESS to determine the bandwidth modulation type and to determine the pair of sub channels for the users. The number of bits carried by the modulated transmitted wave from the$\mathcal{BS}$ to the u $\mathcal{SS}$ per sub carrier in the sub channel c when there exist b number of symbols is represented as$b_{u,c}^{x}$. The number of bits assigned is based on the modulation scheme. If the modulation scheme is 64_QAM then $b_{u,c}^{x} = 6$ and if it is 16_QAM the number of bits carried is 4. $b_{u,c}^{x} = 2$, if the modulation scheme is $QPSK$ and $b_{u,c}^{x} = 0$ if no modulation scheme is assigned. The $b_{u,c}^{x}$is based on the assigned modulation type. The assignment scheme of the b number of symbols $b^{x}$is defined as

$$b^{x} \equiv [\, b_{1,1}^{x}, b_{1,2}^{x}, \dots \dots, b_{1,C}^{x}, \dots \dots, b_{u,1}^{x}, \dots \dots, b_{u,2}^{x}{}^{T}, \dots \dots, b_{u,C}^{x}, b_{U,1}^{x}, b_{U,2}^{x} \dots \dots \dots, b_{U,C}^{x}]$$

The assignment matrix for the $\mathcal{UL}$ frame is defined as

$$b = [b^{1}, b^{x}, \dots \dots, b^{X}]$$

Also each sub channel $c \in \mathcal{C}$ is said to constitute of a sub carriers. Based on the assignment matrix b the total bits allocated to the $u^{th}\mathcal{SS}$ is defined as

$$R_{u}(b) = \sum_{x=1}^{X} \sum_{c=1}^{C} a \times b_{u,c}^{x}$$

The power or energy assigned $e_{u,c}^{x}$to the $u^{th}\mathcal{SS}$ follows the following equation

$$\sum_{c=1}^{C} e_{u,c}^{x} \le e_{u,max}$$

where $e_{u,max}$denotes the maximum energy of the $u^{th}\mathcal{SS}$

The buffer $Buffer_u$ used to store the total bits allocated to the $u^{th}\mathcal{SS}$ is governed by the following definition

$$R_u \le Buffer_u$$

The use of evolutionary computation algorithm in the ESS is to construct the bandwidth assignment matrix assuring QoS parameters are satisfied and is defined as

$$QoSb^{mat} = (max\ b)\left(\sum_{u=1}^{U} R_u\right)$$

Multiple users $u \in \mathcal{U}$ are assigned bandwidth on the same sub channel c hence it is very complex to accurately determine the transmission energy to be set. Channel correlation [26] can be utilized to solve the above hindrance as it is said to be independent of the sub channel c on which 2 users $u_p \in \mathcal{U}\ and\ u_q\ \in \mathcal{U}$ are operating and is defined as

$$\overleftrightarrow{\mathcal{C}hnl}(u_p, u_q) = \left\{\begin{matrix} \left|\dfrac{\left(1 - e^{\left(im\times 2\pi\times(d/\lambda)\times M\left(\sin\left(\theta_{u_p}^{Rx}\right) - \sin\left(\theta_{u_q}^{Rx}\right)\right)\right)}\right)}{\left(1 - e^{\left(im\times 2\pi\times(d/\lambda)\left(\sin\left(\theta_{u_p}^{Rx}\right) - \sin\left(\theta_{u_q}^{Rx}\right)\right)\right)}\right)}\right|^{(1/M)} \\ if\ \theta_{u_p}^{Rx} \ne \theta_{u_q}^{Rx} \\ 1\ if\ \theta_{u_p}^{Rx} = \theta_{u_q}^{Rx} \end{matrix}\right\}$$

where im is the imaginary part, λ is the wavelength, θ is the angel and the distance between the antennas of u_p, u_q is d.

Based on the above equation it is evident that if $\overleftrightarrow{\mathcal{C}hnl}(u_p, u_q)$is low then the $\mathcal{SS}\ u_p\ and\ u_q$ could be serviced on the same sub channel as the interference amongst them would nearly be cancelled. Based on the $\overleftrightarrow{\mathcal{C}hnl}$the ESS performs varied slot assignment to the $\mathcal{SS}'s$ to minimize the interference effects. To incorporate QoS provisioning the observed$\mathcal{E}rr < \mathcal{E}rr^{min}$.Let the set of $\mathcal{SS}'s$ who's $\overleftrightarrow{\mathcal{C}hnl}$amongst themselves is high be represented as $\mathcal{ss}_{g,h}^{set}$where g represents the set number and h represents the number of $\mathcal{SS}$ in the set . The scheduling set of h sets is defined as

$$\mathcal{SS}^{set} = \left\{\mathcal{ss}_{1,h1}^{set}, \mathcal{ss}_{2,h2}^{set}, \mathcal{ss}_{3,h3}^{set}, \dots\dots\dots \mathcal{ss}_{h,hh}^{set}\right\}$$

Evolutionary Strategies [23][24] are investigative procedures incorporating the natural evolution properties of species in the usual environments and is represented as $\mathbb{ES}_i$ where i represents the number of individuals. The evolutionary strategies is composed of individuals and the i^{th} is defined as

$$\mathbb{es}_i = (QoSb^{mat}, \mathcal{SS}^{set})$$

A population of h number of Evolutionary Strategies individuals ($\mathbb{es}_h$) is randomly constructed and can be represented as

$$\mathbb{ES}_h = \{\mathbb{es}_1, \mathbb{es}_2, \mathbb{es}_3, \mathbb{es}_4, \dots\dots\dots\dots\dots \mathbb{es}_h\}$$

A set of$i$ indivudals$\mathbb{es}$ amongst the population is $\mathbb{ES}_h$selected based on the fitness ($\mathbb{F}$) of each individual and is represented as$\mathbb{ES}_i^{Best}$ where $0 < i < h$. The fitness $\mathbb{F}$ is defined as

$$\mathbb{F}\left(\sum_{u} R_u(b), \Delta\mathcal{W}_{ad}\right) = \left(\left(\sum_{u} R_u(b)\right) \Big/ (\mathrm{a}.\,\mathcal{U}_{\mathcal{s}\ell t})\right).\, e^{-\sigma\Delta\mathcal{W}_{ad}}$$

where σ represents the exponential decay constant and $\mathcal{U}_{\mathcal{s}\ell t}$is the used slots of the current frame.

Using $\mathbb{ES}^{Best}$the next population consisting of parents and off springs is generated using the recombination and mutation operation [25]. During the mutation operation generally it is observed finer changes occur frequently when compared to larger changes a random variable$\mathbb{R}$, generated based on the normal distributions are added i.e.

$$\mathbb{es}_i = \mathbb{es}_i + \mathbb{R}$$

where $\mathbb{R} \sim N(0, \mathcal{ss}_{h,hh}^{set})$

Prior to changing the $QoSb^{mat}$ the standard derivations are mutated using

$${\mathcal{ss}_{h,hh}^{set}}^{t} = {\mathcal{ss}_{h,hh}^{set}}^{t-1} e^{\left(\alpha' N(0,1) + \alpha N_{hh}(0,1)\right)}$$

where $e^{\left(\alpha' N(0,1)\right)}$induces a global change and $e^{\left(\alpha N_{hh}(0,1)\right)}$induces a mean change in the off spring generation.

The ESS scheduling considers a global recombination strategy and could be defined as

$${\mathcal{ss}_{h,hh}^{set}}' = \sum_{l=1}^{\varsigma} \mathcal{ss}_{l,hl}^{set}$$

where ς represents the number of parents.

This process is repeated till a suitable $\mathcal{SS}^{set}$ is constructed and the $\mathcal{SS}^{set}$ satisfies the QoS parameters and all the slots are assigned.

4. PERFORMANCE EVALUATION

The This section of the paper discusses the performance evaluation of the ESS proposed in this paper. The ESS scheme is compared with the QoS aware packet scheduling scheme [19]. The IEEE 802.16 system supports traffic services namely $UGS, rtPS, nrtPS$ and BE services. The traffic of the varied services followed a geometric distribution pattern. The simulation model considers a single $\mathcal{BS}$ and the number of $\mathcal{SS}$ is varied. The data rate per $\mathcal{SS}$ was set to 320 kbps. The simulation considers ricean fading channels and the base frequency is 2.5 GHz.The fast Fourier transform size was set to 1024 bits. The ESS scheme proposed provided QoS gurantee. The QoS parameters could be analyzed based on the Slot Success ratio and the Packet Throughput of the traffic. The Slot Success Ratio and the Packet Throughput statistics have been considered to prove the efficiency in scheduling. The QoS aware packet scheduling scheme is denoted as ES.

The ESS and the ES scheduling scheme was developed and the number of $\mathcal{SS}$was set to 5. The efficiency of scheduling algorithms measured in terms of the slot success ratio against the simulation time is shown in Figure 1 given below. From the figure it could be observed that the proposed ESS scheme achieves super QoS provisioning and effectively schedules traffic of $UGS, rtPS, nrtPS$ and BE type. The ESS scheduling scheme achieves about 8.7% and 13.81% additional slot success ratio for $UGS, rtPS$ traffic type when compared to the QoS aware packet scheduling scheme and about 15% additional slot success ratio for $nrtPS$ and BE traffic.

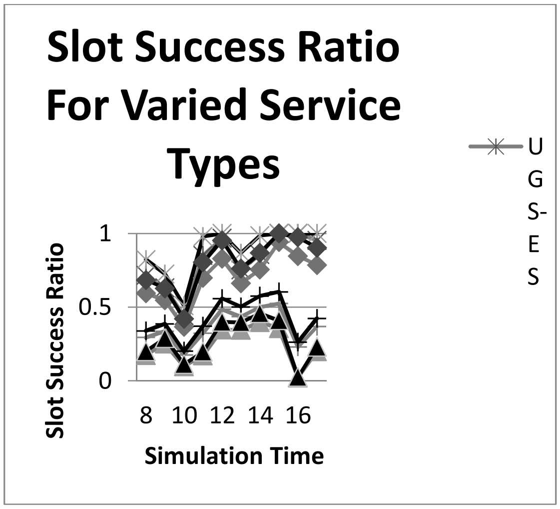

Figure 1 : Slot Success Ratio for Varied Services using ESS and ES (Number of $= \mathbf{5}$ *)*

To further investigate the QoS provisioning performance of the ESS and the ES, the number of $\mathcal{SS}$ considered in the simulation model were varied from$\mathcal{SS} = 5\ ,10\ ,15$ and 20. The average traffic scheduled was analyzed and the results obtained are shown in figure 2 given below.From Figure 2 it could be observed that both the scheduling schemes ESS and ES considered perform better when the number of $\mathcal{SS}$ increase. Also it was observed that the scheduling scheme proposed in this paper achieved a slot success rate of 13.86% higher than that of the ES hence providing for enhanced QoS input to the ANN is the value

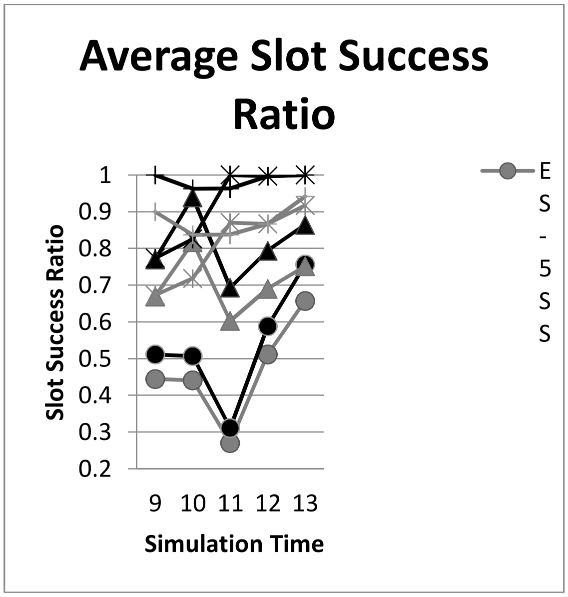

Figure 2: Average Slot Success Ratio with Varying Number of$\boldsymbol{\mathcal{SS}}$

System Throughput or Packet Throughput observed in the IEEE 802.16 networks is also considered by researchers to prove QoS provisioning efficiency.The packet throughput observed for the heterogeneous traffic considered when the number of SS is varied is as shown in Figure 3.

From Figure 3 it could be observed that the QoS aware scheduling scheme denoted as ES and the proposed scheduling ESS scheme allocate bandwidth to the high priority UGS traffic hence the system throughput achieved is100%. For traffic of $rtPS$ kind the ESS scheduling scheme achieves 100% system throughput where as the ES scheduling scheme achieves an average packet throughput of 90.05%. The average throughput observed for the $nrtPS$ and BE service kind of traffic using the ESS scheduling scheme was observed to be 75.19% and 63.76%. The QoS aware scheduling scheme (ES) achieved an average packet throughput of 65.38% and 55.44% for the servicing $nrtPS$ and BE kind of traffic.

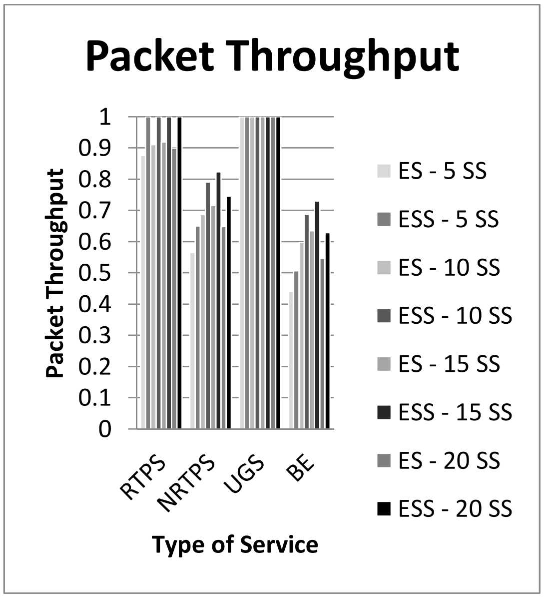

Figure 3: Packet Throughput Observed for Varying Number of SS and for Varied Service Types

From the experimental observations presented in this section of the paper it can be concluded that the ESS scheduling scheme proposed in this paper provides enhanced QoS when compared to the QoS aware packet scheduling scheme, for varied service types in the IEEE 802.16 networks. Better QoS is provided owing to the fact that the scheduling scheme proposed achieves a further efficiency of 9% in the packet throughput and 13.86% in terms of the slot success ratio.

5. CONCLUSION

This paper introduces an evolutionary computation based uplink scheduling scheme named ESS with QoS gurantee. Efficient scheduling is achieved by introducing a service threshold time. Using the service threshold time, the weight assigned to a service is attuned. The adaptive weights ascertain the bandwidth that is allocated using adaptive modulation to the SS^' s creating a scheduling set with QoS gurantee. The scheduling set created is further optimized using evolutionary computation techniques. The ESS scheme not only provides for higher slot success rates but also facilitates higher system throughput for the UGS,rtPS,nrtPS and BE services supported in IEEE 802.16 systems, which is proved in this paper through the experimental evaluation presented. Furthermore the simulation results confirm that the ESS scheduling scheme accomplishes higher slot success ratio and packet throughput by 13% and 9% than the QoS aware packet scheduling scheme for IEEE 802.16 Networks. For the future work the efficiency of the ESS scheduling scheme with higher data rates to theSS and the packet delay analysis of the scheduling scheme is considered using Rayleigh fading channels.

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