A NEURAL BASED PROPOSAL FOR SCHEDULING OF IEEE 802.16 NETWORKS

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Abstract:

The goal of this paper is to survey the core issues in the design of schedulers for IEEE 802.16 networks and study the various techniques available in literature. Neural Networks have been utilized by researchers over the years to solve a large set of optimization problems in the field of active queue management techniques and network communication. This paper proposes a back propagation neural based approach for scheduling of IEEE 802.16 networks. The proposed technique is novel and has sound theoretical and practical base available in other fields of communication.

Keywords: IEEE 802.16; Soft Computing; QoS; AQM.

I. INTRODUCTION

Wireless and mobile communications have changed the communication systems over the past decades. IEEE 802.16 also known as WiMAX (Worldwide Interoperability for Microwave access Networks) has been designed to provide wireless and wired broadband access with QoS guarantees in Metropolitan area networks [1]. This next-generation wireless technology is specially designed to enable high-speed, mobile Internet access to the wide array of devices. It delivers low-cost, open networks as well as solution for the efficient transmission with QoS (Quality of Service) support at the Media Access Control (MAC) layer for guaranteeing multimedia transmissions. WiMAX forum is the organization in charge for its creation, monitoring and deployment and involve most of major stakeholders in ICT industry [2]. WiMAX will scale dynamically with worldwide interoperability, whilst adapting to demands and changes in the industry. It also gives network operators the economy of scale and flexibility enabling them to address each market differently and efficiently. With these capabilities WiMAX provides a new option for the initiatives to solve connectivity problems facing rural remote areas of the world [3].

IEEE standard	**802.11 b**	**802.11 g**	**802.11 a**	**802.16**	**802.16 a**	**802.16 e**	**802.20**
Date ratified	1999/9	2003/6	1999/9	2001/12	2003/1	2005/6	2006
Access Type	LAN			MAN			WAN
Mobility support	Portable			Fixed	Portable	Pedestrian speed (<150kmph)	Vehicular speed (<250 kph)
Channel conditions	NLOS			LOS	NLOS	NLOS	NLOS
Max cell range	100m	50m	50m	2-5 km	7-10 km(max 50km)	2-5 km	20 km
Spectrum	License Exempt	License Exempt	License Exempt	License and License exempt			Licensed
Frequency Band	2.4 GHz	2.4 GHz	5 GHz	10-66 GHz	2-11 GHz	2-6 GHz	<3.5 GHz
Max Data rate	11 Mbps	54 Mbps	54 Mbps	32-134 Mbps in 28 MHz	Upto 75 Mbps in 20 MHz	Upto 15 Mbps in 5 MHz	> 4 Mbps
Channel Bandwidth	20 MHz			20,25,28 MHz	1.25-20 MHz	1.25-20 MHz	1.25 -40MHz
Spectrum Efficiency (bps/Hz)	0.55	2.7	2.7	4.8	3.75	~3	>1
Modulation	QPSK	BPSK, QPSK, 16-,16- QAM	BPSK, QPSK, 16-,16- QAM	QPSK, 16QAM and 64QAM	OFDM 256 carriers plus QPSK 16 QAM, 64QAM and OFDMA 2048 carrier		OFDMA
QoS	802.11e(not ratified) will introduce QoS functionality			Yes			Yes
Mesh	Vendor Proprietary			No	Yes	Yes	No
Access Protocol	CSMA/CA			Request Grant	Request Grant	Request Grant	Request Grant

Table I: Properties and Evolution of WiMAX and comparison with IEEE 802.11 and 802.20

In comparison to WiFi, which in most cases is limited to a few hundred feet range WiMAX can provide BWA for several tens of miles. A comparison of WiMAX with its counterpart wi-fi and IEEE 802.20 which is another upcoming standard for WAN networks is presented in Table I.

Once a SS enters a network, it has to go through registration, and authentication with the BS. A unidirectional link is established between MAC layers of BS and SS [1]. Connections between BS and SS are referenced by 16-bit connection identifiers (CID) and may require continuously granted bandwidth or bandwidth on demand. There are two types of connections: **Data and Management.**

Management connections can be either basic (urgent), primary(less urgent) or secondary and are used to transfer management messages such as RNG-REQ/REP-RSP/RST etc. These three connections reflect the three different QOS requirements used by different management levels. Basic connection is used to transfer short, time-critical MAC and radio link control (RLC) messages while Primary management connection is used to transfer longer, more delay-tolerant messages, such as those used for authentication and connection setup.[7] The secondary management connection transfers standards-based management messages such as Dynamic Host Configuration Protocol (DHCP), Trivial File Transfer Protocol (TFTP), and Simple Network Management Protocol (SNMP).A management CID is bi-directional ie same CID can be used for both uplink and downlink transmission. Every BS-SS pair will require at least a basic and primary management connection identifier to communicate. **Data connections** are also known as service flows and are identified by a 32-bit number called SFID or service flow ID and is assigned whenever a data service/connection is created and it lasts for the entire life of service. Each service flow could be in any one of the three types (or modes): Provisioned, admitted or active. According to the standard, the type of service flow is determined by the availability of corresponding QoSParamSet. Both SS and BS can set the type of a service flow through DSA or DSC three-way handshaking procedure.

Mapping of SFID to CID: Number of SFID (2^32) is very large as compared to number of CID (2^16) because SFID is assigned to every service flow where as CID is only assigned to a service whenever it is active ie only those SFID are mapped to CID who are in active mode. Eg if a BS-SS want to transmit data, at least 4CIDs are required: one each for basic and primary management connection and one each for downlink and uplink data transmission.

II. LITERATURE SURVEY

WiMAX operates in two modes: Compulsory point to multi point mode (PMP), which comprises of a base station (BS) and a number of subscriber stations (SS), and optional Mesh mode in which each SS have the ability to communicate among themselves ie every SS/node may be treated as BS. A central node connected to outside world may be considered as mesh BS. Problem of scheduling is different in both the modes. In mesh mode scheduling is either central in which the mesh BS schedules all SSs or distributed where each station in two hop neighbourhood must have their transmissions coordinated to avoid collisions. PMP mode is the focus of discussion in this study. WiMAX supports five scheduling services unsolicited grant services (UGS), real-time polling service (rtPS), non-real-time polling service (nrtPS), best-effort (BE) service, and the extended real-time polling service (ertPS). Every scheduling service has different QoS requirements and these requirements can change dynamically. Therefore QoS delivery depends upon the performance of the service scheme employed by the uplink scheduler. But the standard does not specify any scheme/algorithm and vendors are free to implement their own algorithms therefore a number of techniques are present in literature. The majority of these studies are based on application of queuing theory principles to different service flows. These have been categorized into 5 different categories namely (i) **Traditional Schedulers** implementing traditional algorithms namely Round Robin, Weighted Round Robin(WRR), Deficit Round robin(DRR), opportunistic-DDD, PF etc . (ii) **Hierarchal Schedulers** which combine several scheduling techniques in order to meet the particular needs of different traffic classes. Resources are distributed as first level of hierarchy and employs different types of techniques to schedule different types of service flows. Usually traditional approaches are combined with a certain level of admission control to avoid starvation (iii) **Cross Layer** scheduling techniques whose objective is to optimize communication among different layers of network and utilize information available at different layers to make the scheduling process effective (iv) **Dynamic schedulers** in which the process of bandwidth allocation and scheduling is treated as a dynamic problem and scheduling is performed as per the changing parameters of network environment (v) **Soft Computing** based scheduling techniques where scheduling problem is studied as an optimization problem whose aim is to optimize the allocation of resources to different SS/service flows and simultaneously providing desired levels of QoS while keeping network performance high. Soft computing techniques like dynamic programming [4], Genetic Algorithm [5] [6], game theory [7] [8] and Neural Networks [9-12] had been implemented to solve such problems. This present study draws inspiration from such techniques and an approach based on theory of artificial neural networks is proposed.

Artificial Neural Networks had been proposed as a model for solving a wide variety of problems in diverse fields as combinatorial optimization computing, vision, pattern recognition, queuing theory etc because of their ability to solve problems with large input space and adapting themselves to the problem environment. The solution to the problem of scheduling in computer networks using neural networks is not new as neural networks have been proposed and implemented to solve such problem for WiMAX, ATM and other wireless/wired networks. [9-14].

Marchese, M [9] *et al.* have proposed a function for the allocation of bandwidth to specific class on the basis of neural networks that employs priority. Raliean *et al*. [10] had used the theory of neural networks to predict the traffic characteristics in WiMAX. They had proposed an approach for predicting traffic time series based on the association of the Stationary Wavelet Transform (SWT) with Artificial Neural Networks (ANN). They had focused on comparing the quality of forecasting obtained using different configurations of the ANN and tested different configurations using real traffic data recorded at each base station that belongs to a WiMAX Network developed by Alcatel. This is the rarest of the work in which data taken is the real world data. The authors of [11] Kumar *et al.* have used the neuro-fuzzy based methods to provide QoS and solve scheduling problem for WiMAX. They divided the scheduling problem in two stages. In stage I fuzzy logic has been used to provide priorities to different services based on queue size and at stage two a multi layer neural network has been used for scheduling. The input to the first layer of neural network is the output of fuzzy network while layer two and three have been implemented as Kohenen and Grossberg layers respectively. The results demonstrate that the proposed method is capable of providing the desired QoS hoever system is not tested under peak load conditions.

Neural networks for TCP, ATM and other networks have been implemented in [12] [13] [14] to act as a queue controller in Active Queue management in which queues consist of variety of traffic and each queue acts as buffer for one kind of traffic. A recurrent neural network with Multi-layer Perceptron-Infinite Impulse Response (MLP-IIR) structure is used to train three different neural AQMs to be used under different network scenarios with low, high and intermediate traffic levels. One of these neural is selected based on probability theory of incoming traffic. Authors of [13] have proposed a new energy function based on Hopfield networks for ATM switches as a solution to multiple input queue problems. Neural networks have also been proposed to solve bandwidth allocation and dynamic load balancing problem by Wang Y.T *el al*[14]. The automatic learning of the back-propagation network (BPN) model is applied with five inputs: CPU, memory, I/O, network and run-queue length and the output designates a system into three tags: under loaded, moderately loaded and over-loaded based upon which load is transferred from one mobile agent to another.

III. THE APPROACH

In a PMP based network all communication between different SS is managed at BS where network traffic from different SS is classified into various queues by the classifier provided by IEEE 802.16 standard. The role of the classifier is to add the incoming packet to the correct queue based upon its characteristics. The number of queues for a particular kind of traffic is dependent on the network design and applications running. As the communication goes on, en-queuing and de-queuing of these queues goes on continuously and values of various parameters like queue length (occupancy), average inter packet arrival time, average time in the system ie time from message entry to exit (delay) for rtPs, ertPS, nrtPS and BE traffic classes keeps on changing. Weighted fair queuing can be thought of as an alternative to handle different priority of traffic by assigning higher weight to high priority traffic but the problem is that the weights always remain static. The static weights can be serious bottleneck in situations where the pattern of traffic is diverse and demands real time adaptability. The ideal scenario will be the changing of the weights as per the changes in the traffic characteristics. This change in scheduling strategy can be incorporated by the use of neural network based approach (described next) over a weighted queuing approach. Initial weights of the queues can be assigned by WFQ or any other algorithm. The weights may be assigned according to the priority of various traffic classes defined by standard as UGS>ertPS > rtPS>nrtPS>BE. A neural network trained with suitable training data can then be employed to make decision regarding the change in scheduling policy as per the information of the traffic flow (Fig 1). The change will be managed by changing weights of different traffic queues as the value of weight will be increased or decreased according to traffic characteristics.

*A***:** *Neural Architecture*

A multi layer neuron with input, hidden and output layer will be employed. The values of parameters like queue length(queue occupancy), average inter packet arrival time, time in the system(delay) etc for nrtPS, rtPS, ertPS and BE traffic classes will be extracted from various queues/flows and will act as input to input layer neurons. Each neuron can receive either a vector of these values or individual value for single neuron.

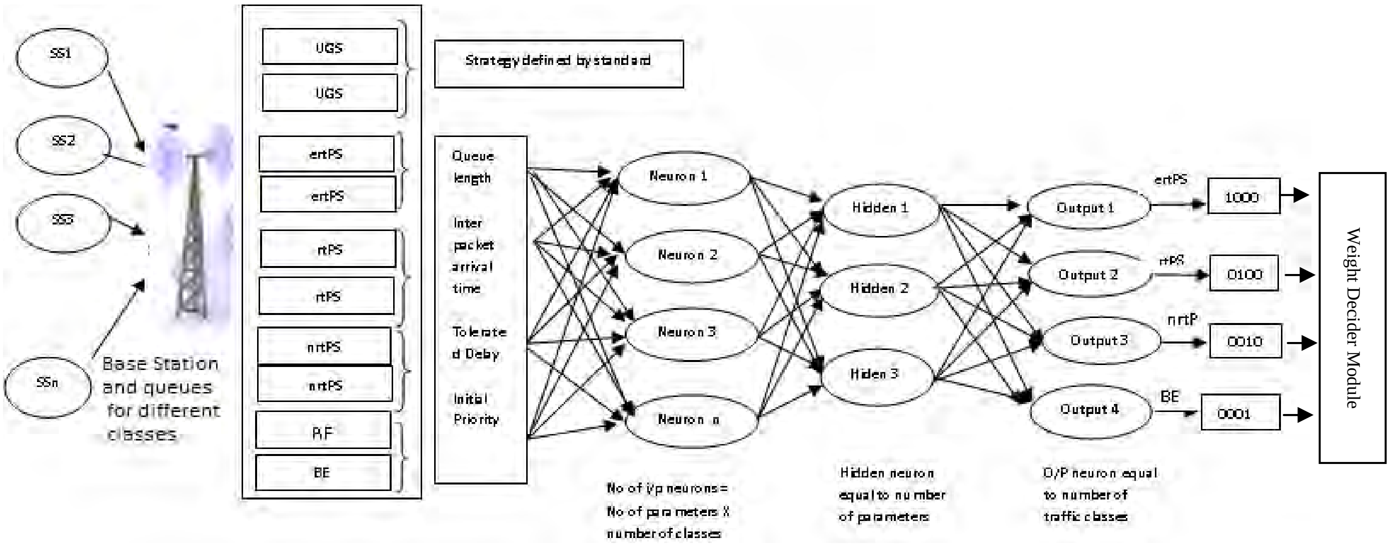

Fig 1: Neural Network approach for scheduling of IEEE 802.16

The number of neurons in the input layer will depend on the number of queues considered of each flow and number of parameters in consideration. For simplicity one queue per flow has been considered. The number of neurons at hidden layer will be equal to the number of parameters employed as same parameter but from different queues will account for one neuron in the hidden layer. The output layer will consist of 4 neurons one for each type of traffic classes. The output of neural will be fed to weight decider module. The weight decider module will be implemented as a fuzzy/rule based network that will in turn calculate the weights to be assigned to different traffic flows.

B: Algorithm

1. ***For each queue at BS:Use WFQ to initialize weights as per the priority of the standard ertPS > rtPS>nrtPS>BE.***
2. ***Extract value of parameters and store in variables q_len[4], int_pkt_ar [4], q_delay[4].***
3. ***Input the above calculated parameters to the input neurons of Back propagation based Neural Network***
4. ***Training Algorithm:***
    a. ***Initialize weights and learning rate(small random numbers)***
    b. ***For each training i/p and o/p pair***
    c. ***Repeat until weights convergence or till a required number of epochs are completed***
        i. ***Receive i/p signal as it will be extracted from various queues***
        ii. ***Propagate the error backward from output layer to hidden and input layer.***
        iii. ***Calculate new weights in accordance with Back Propagation Network learning algorithm.***
5. ***Replace old weights of the network by new Weights as taken from training algorithm***
    a. ***After every ' t' time units***
    b. ***Measure performance of the network(P)***
    c. ***Repeat until performance falls below a threshold level(∆) else Go to Step 4***
    d. ***Set activation of input unit. Inputs to input layer will be actual packets that are to be scheduled.***
    e. ***Compute output of hidden and output layer using sigmoid activation function***
    f. ***Output will be fed to weight decider module which will calculate the required change in weights of the queues.***

C: Working of the Network: - Weights of the network will be initialized randomly and network will be trained using back-propagation training algorithm for artificial neural networks. Back propagation algorithm is supervised learning algorithm invented in 1969 by Bryson and Ho. The accuracy of the neural network will depend on the amount of training and the quality of training data. The training data for such a network can be obtained from the real world usage or can be obtained manually from the traffic generated by a network simulator. Once the network had been trained it will be used to generate appropriate weights. The data that is to be scheduled will be inputted to the neural network and its output will be calculated. This output will act as input to the weight decider module. This module will be used to make adjustments to the weights of the queue for different traffic classes if needed. The performance of the network (P) will be studied regularly and network will be re-trained if the performance of the network falls below a certain threshold value (Δ). Network performance will be calculated as a function of different system parameters like packet loss, throughput, round trip time etc.

IV. CONCLUSION AND FUTURE SCOPE

This paper has tried to explore various optimization techniques available in literature for the scheduling of 802.16 networks. Although a number of solutions based on dynamic programming, genetic algorithms are available but the results are not that promising and use of neural networks is limited. A new approach for the scheduling of IEEE 802.16 based networks is proposed. The approach is based on the concepts of back propagation neural networks and active queue management techniques and has sound theoretical and practical implementations. The study is expected to provide required Quality of Service levels for diverse traffic in WiMAX however the results need to be verified by implementing it on a test-bed or by way of simulations with the help of simulator like QualNet, OpNet, ns-2/3 etc.

The study is significant as WiMAX is the future technology in a developing country like India where problem of connectivity of villages is prominent. WiMAX with its wider reach can cover number of villages with minimal investments. The application of neural networks will attract researchers from the field of AI to explore opportunities in technologies like WiMAX which are currently under development and can augment to its growth. This paper is an attempt in this direction.

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