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An embedded fuzzy expert system for adaptive WFQ scheduling of IEEE 802.16 networks

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ABSTRACT

WiMAX is a futuristic technology which provides simultaneous support for web, video, and voice applications. WiMAX networks are best suitable to real time traffic however the quantity of non real time and best effort traffic cannot be neglected. Distribution of resources in such heterogeneous applications is therefore a challenging task. There are many schedulers available for WiMAX but adaptive and adequate schedulers are still in growing stage of development. This paper introduces a novel method using which a system is developed based on concepts of fuzzy logic to schedule traffic in WiMAX networks. The proposed fuzzy expert system simplifies fair allocation of resources to real as well as non real time traffic. The implementation is based on changing the weights of the queues serving real and non- real time traffic adaptively. New weights will be calculated for each bandwidth request made to base station and these weights will in turn decide amount of bandwidth allocated to different traffic classes. The weights are calculated based on three parameters that are amount of real time and non real time traffic in queues, change in throughput requirement for non real time flows and latency requirement of real time input data. Results obtained by virtue of simulations justify the significance of the proposed method.

1. Introduction

The growth of multimedia devices and advances in communication technology has led to a flood of heterogeneous information on internet. Handling such a large, assorted and rich media applications requires constantly more powerful networks. WiMAX technology is seen as answer to this problem because of its ability to satisfy diverse QoS requirements. WiMAX is a broadband wireless access network for metropolitan areas, also commercially known as WiMAX (IEEE, 2005; IEEE, 2010). It has been quite successful over the years of its inception to meet anticipated growth of real time applications. Researchers believe that future of telecommunications belong to a technology like WiMAX which has support for handling varied applications simultaneously. The process of resource allocation in such systems plays very critical role in it. Designing schedulers for such systems that support applications like file transfer, web surfing, voice, video over the web is one of the hardest tasks as there is always a shortage of resources to satisfy varying application requirements. Need of an efficient scheduler becomes more significant considering fact that number of users using WiMAX standard have increased from 6.8 million in 2010 to 33.4 million in 2014 (stastista.com-2014). Number of user applications has exploded and telecommunication industry is very quickly shifting towards technology like WiMAX because of its tremendous qos support for these applications. WiMAX has an added advantage that it could run over their already deployed infrastructure. Teleoc have started viewing WiMAX as technology that could bail them out of already prevailing financial crisis. Industry can be benefitted by improved performance of scheduler as more number of user applications may be admitted and supported per cell. End users will also be benefitted with improved quality and low costs.

QoS support in WiMAX is provided by five different traffic classes namely UGS [Unsolicitated grant service], rtPS [real time polling service], nrtPS [non real time polling service], BE [best effort] and ertPS [extended real time polling service] for providing support to different applications having diverse requirements. The current IEEE 802.16 standard does not specify any scheduler for WiMAX network and vendors are free to innovate and research with algorithms of their choice in this field (IEEE 2005). The standard only associates priorities for these service classes. The incoming traffic is classified into one of these categories by traffic classifier in WiMAX and schedulers serve these classes according to algorithm implemented. The algorithm shall make sure that

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delay and throughput requirement for both real and non real time applications are met. The bandwidth allocation algorithm shall strive to provide more user satisfaction simultaneously optimizing system performance and resources.

Scheduling in WiMAX is possible in both uplink i.e. from Subscriber station (SS) to Base station (BS) and downlink from BS to SS. In the downlink, all decisions related to the distribution of bandwidth to various SSs are made by BS on per connection identifier (CID) basis depending upon QoS requirements and does not require involvement of the SS. Once dedicated resources are allocated, BS indicates to SS about this using DL-MAP messages and further distribution of resources among various flows lies with SS only. In the uplink, WiMAX uses grant-request protocol in which SS requests resources by either using a stand-alone bandwidth-request MAC PDU or piggybacking bandwidth requests on a generic MAC PDU. Bandwidth requests in the UL can be incremental or aggregate requests and uses *Type* field in the bandwidth-request header to indicate it. SS estimates the amount of bandwidth it requires and sends request to BS for allocation, BS responds to the request by allocating required bandwidth to SS. Scheduling decision in uplink are difficult to make as BS may have only limited or outdated information about current state of each uplink connection because of delay and likely collisions on the network. There is always a time gap between resource request and allocation during which queues at SS can grow unpredictably because of real time applications. The low priority non-real time traffic classes may be malnourished by traffic from high priority real time classes. Scheduler needs to have a mechanism to strike a balance among competing needs of these traffic classes. This decision shall be based on instantaneous information about state of traffic present at various SS associated with BS.

In this paper, a dynamic expert system employing concepts of fuzzy logic has been implemented to solve scheduling problem in WiMAX networks. The developed system will work as component of base station and will cater to the changing requirements of applications being handled by it. The system aims to allocate resources to queues of both real and non real service classes effectively and fairly there by trying to optimize overall performance of the network. The system handles latency sensitive real time applications quite well and simultaneously takes care of the fact that queues for non real traffic do not grow infinitely. This is being implemented be designing a system operating on fuzzy logic fundamentals. Fuzzy system accepts three input parameters:- share of real time and non real time traffic data, throughput change for non-real time traffic and latency requirement for real time traffic. Fuzzy system works as fully automatic approach absorbing changes in traffic densities by updating weights of queues serving these traffic classes. The overall performance of the network will increase and starvation of non real time classes will be avoided. Results of the study are quite promising. This paper is organized as follows. Related work on schedulers in WiMAX is introduced in Section 2. Section 3 covers details of the developed fuzzy based system and its reasoning model. Simulation model and results are provided in Sections 4 and 5 followed by conclusion and future work in next section.

2. Related work

Allocation of resources in packet switching network like WiMAX is very hot research area and records of numerous theories are available in literature. There have been studies that summarize the implementation of number of schedulers for WiMAX. Some of the noticeable work has been done by Msadaa, Câmara, and Filali (2010) and Akashdeep, Kahlon, and Kumar (2014) which provides a comprehensive coverage of various scheduling mechanism in PMP mode. Queuing theory models have also provided solid foundation to offer solutions to scheduling problem in WiMAX as varying qualities of traffic can be characterised into different queues and these queues may be served by single or multiple processors using number of algorithms. The most common among these include FIFO, LIFO, Processor Sharing, Priority, Shortest Job first, class based queuing etc. These algorithms have also been implemented for scheduling resources in WiMAX.

Shreedhar and Varghese (1996)proposed Deficit Round Robin (DRR) which is variant of RR and WRR schedulers and can achieve complexity of order O(1) if specific allocation constraints are met. DRR provides fair queuing but it requires that each packet flow shall be reserved a minimum bandwidth which means even BE class shall be provided with a minimum rate. It provides fairness for variable length packets but the major problem in DRR for WiMAX is calculating the size of head of queue packet which was not possible for uplink traffic in WiMAX as this information lies with different SS infact the BS is only able to estimate the overall amount of backlog of each connection, but not the size of each backlogged packet.

Round Robin distributes equal channel resources to all the SSs without assigning any priority to any specific flow. This is the simplest of all the schedulers with minimal complexity and was implemented so that decision time required to be taken to schedule every packet can be nullified. It was proposed and implemented by Ball, Humburg, Ivanov, and Treml (2006); they argued that schedulers like fair queue were not desired as they may lead to waste of bandwidth. However, this technique is not suitable for systems with different levels of priority and systems with varying sizes and types of traffic. Weighted Round Robin (WRR) scheduler is another variant of RR scheduling in which weights are assigned to every flow/queue. These weights are static and once assigned are never changed. The weights determine the number of packets that will be scheduled for that flow. More weight is assigned to flows with more priority but Sayenko, Alanen, Karhula, and Hämäläinen (2006) insisted that WRR because of its work conservative behaviour is not fit for IEEE 802.16 networks which has a fixed size frame and secondly weights are floating numbers while slots allotted are integers. Moreover WRR may not perform well for WiMAX which has inherent support for multiple applications and require a constant monitoring of weights.

Cicconetti, Lenzini, Mingozzi, and Erta (2006) and Cicconetti, Lenzini, Mingozzi, and Erta (2007) surmise that minimum reserved traffic rate is a basic QoS parameter required by a flow therefore class of latency-rate (LR) scheduling algorithms may not be suited for implementing schedulers in 802.16 MAC and divided traffic into two categories; first having QoS requirement and second without any QoS requirements. The authors demonstrated that the performance of 802.16 systems, in terms of throughput and delay, depends on several metrics such as frame duration, the mechanisms used to request UL bandwidth, the offered load partitioning—how traffic is distributed among SSs, the connections within each SS, and the traffic sources within each connection. However the performance of classes with latency requirements is degrading as scheduling decisions are made on basis of throughput requirements.

Nuaymi and Belghith (2008) proposed a new maximum signal-to-interference ratio (mSIR) scheduler which was based on the allocation of radio resources to subscriber stations having highest signal-to-interference ratio (SIR) but it may lead to starvation of the flows having lower SIR as no mechanism had been proposed to deal with such situations. A new variant of DRR scheduler that handles latency critical applications has been proposed by Rath, Bhorkar, and Sharma (2006) namely Opportunistic Deficit Round Robin (O-DRR) scheduler in which BS polls subscribers periodically however manipulation of quantum size and deficit count for every