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REVIEW ARTICLE

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Survey on MAC Scheduling Algorithms for WiMax(IEEE 802.16) Networks

Ashlin Sherry
School of Computer Science and Engineering
VIT University, Vellore
Vellore, India

Dr. Manikandan K
School of Computer Science and Engineering
VIT University, Vellore
Vellore, India

Karthik Sistla
School of Computer Science and Engineering
VIT University, Vellore
Vellore, India

Sathwasta Golla
School of Computer Science and Engineering
VIT University, Vellore
Vellore, India

Abstract: WiMax (World Wide Interoperability for Microwave Access), is an emerging wireless technology that is anticipated to replace the traditional wired broadband. Being one of the most promising technologies which supports applications like VoIP (Voice over Internet Protocol), online gaming, and the likes, it is necessary to provide best QoS (Quality of Service) for the users, and for that, an effective traffic scheduling is necessary. Today wireless networks play a critical role in connecting people to the Internet, and it is important for the network to provide proper packet flows. Algorithms for wired networks cannot directly used for wireless networks as wireless channels experience errors like burst channel and location dependent error, unlike wired networks. The objective of this paper is to discuss the various uplink and downlink MAC (Media Access Control) scheduling algorithms for a WiMax system and compare their performance with respect to each other. Classification and characteristics of different algorithms based on their fundamental working principle are considered and summarized.

Keywords: Wireless Networks**,** WiMax, Scheduling Algorithms, Quality of Service, Uplink and Downlink MAC scheduling

I. INTRODUCTION

The cost involved in establishing wireless networks is very high. Wireless networks are quite common in cities, but are yet to reach out to the rural areas. Nowadays the expansion of wireless networks into villages and other rural parts has seen a massive growth. The importance of internet and related services which aids in the ease of communication is slowly being realized in all the areas. Therefore technology and communication has been an integral part of our lives. Each technology plays a vital role in contributing solutions

Each technology has an exclusive description in contributing solutions to the opposing inflict onto wireless technologies (high variability link and fading effects). Out of all the existing technologies, WiMax (World Wide Interoperability for Microwave Access) IEEE 802.16 standard is the most capable and fastest growing technology. One of the standout feature of this technology is that it integrates its large range of frequency, last mile wireless access along with better support of Quality of Service (QoS) [1] for discrete form of applications. It also has the Metropolitan area (i.e. Wireless Metropolitan Area Networks (Wireless MAN/ WMAN) appeal, with high speed data rates and it covers an incredibly large area expanding up to several kilometers. One of the most important aspects of WiMax is to combine stations.[10]

The two stations namely base and subscriber stations (BS AND SS) are combined by WiMax. The WiMax BS can provide a broadband wireless connection up to a very large range say 50-60kms for established stations and for mobile stations, the range is from 5 to 15kms which is comparatively shorter. The data rate of the base station can go up to a maximum of 70 mbps which is pretty good. The performance levels are also very good when compared to the 802.11a which has a maximum data rate of around 54Mbps and has a range of several hundred meters. Also the EDGE network has a data rate of 384kbps and covers a range of a few kilometers. EDGE stands for Augmented Data Rates for Global Evolution (EDGE). While the EDGE network has a data rate of 384kbps, the rate of CDMA 2000 is around 2 Mbps and has a range which covers up to a few kilometers.

The research is mainly centered with WiMax as the primary and elemental platform. There are different modes of transmission. For the WiMax architecture there are three modes of transmission namely Point to Point known as (P2P), Point to Multipoint which is known as (PMP) and the final one is the Mesh architecture. The algorithms discussed in this paper in the forthcoming sections are applicable to all the three modes of architecture. Two layers of the Open System Interconnection (OSI) model are the layers through which the WiMax architecture is expressed namely the Physical and MAC Layers (Media Access Control). The WiMax architecture is expressed by two main layers of the OSI (Open System Interconnection) model which are the Physical (PHY) and the MAC layer. The WiMax PHY layers represent air interfaces like Wireless MAN, Single-Carrier (Wireless MAN-SC) PHY or multiple-carrier PHY layer. The WiMax multiple-carrier physical layers air interface are characterized as Orthogonal Frequency Division Multiplexing (OFDM) for stationery SSs and the Orthogonal Frequency Division Multiple Access (OFDMA) are used for both stationery and non-stationery SSs. These two PHY layers air interfaces use the Time Division Multiple Access (TDMA) technique as an allotting mechanism between multiple SSs. The multiple-carrier PHY spectrum works in the 2-11 GHz (Gigahertz) range for the established and portable stations [2]. The WiMax MAC layer is constructed and achieved with some leading features to provide adaptability, encrypted, error correction, link adaptation, security, resilience, power control, Automatic Retransmission Request and QoS for Uplink and Downlink traffic. The three layers namely Convergence Sub Layer known as (CS), Common Part Sub Layer known as (CPS) and the security sub layer are encompassed by the MAC layer [3].

The IEEE 802.16 supports five Qualities of Services (QoS) [4], namely, Unsolicited Grant Services (UGS): designed to support constant bit-rate services like voice applications. Real-Time Polling Services (rtPS): for real-time services that generate variable size data packets on a periodic basis, but is sensitive to delay, such as an MPEG (Moving Picture Experts Group) video. Extended Real-Time Polling Services (ertPS) are employed in order to support real-time applications with variable data-rates that require guaranteed data with delay. Examples are VoIP. Non-Real-Time Polling Services (nrtPS): to support non-real-time delay tolerant services that require variable size data grant burst on a regular basis, ex: Best Effort (BE): to support data streams that do not require any assurance in QoS such as HTTP (Hyper Text Transfer Protocol). [9]

II. ARCHITECTURE

The Wi-Max Network Working group has created and developed a new network model. This network model acts as the architectural framework for Wi-Max. It also offers a lot of flexibility between the Wi-Max equipment and Wi-Max operators' thereby ensuring interoperability amongst them.

The network model developed by the Wi-Max Networking group is loosely built upon an Internet Protocol Service Model. The architecture of the Internet Protocol based Wi-Max is as follows. There are three essential parts of this network.

The first are the Mobile Stations. These mobile stations make the network accessible to the end user. The second is the Access Service network or (ASN) which consists of a number of base stations. This main function of the base station is to provide the air interface to the mobile station amongst many other functions. The ASN also has many ASN gateways that form the radio access network. The third and the final network is the connectivity service network (CSN) which as the name suggests gives IP (Internet Protocol) connectivity. The network reference model specifies a number of objects and also defines the interfaces between those objects. The network reference model developed by the Wi-Max Forum defines a number of functional entities and interfaces between those entities.

- **Base station (BS) –** As discussed above the base station offers air interface to the mobile station. This is only one function of the base station. The base station also performs a lot of additional tasks like managing sessions, radio resources, multi cast groups and keys etc.
- **Access service network gateway (ASN-GW) –** The ASN gateway serves as the traffic aggregation point within the Access Service Network. Like base stations it also does radio resource management, Quality of Service policy enforcement etc. Other functions include intra ASN location management, taking subscriber profile information and caching them etc.
- **Connectivity service network (CSN) –** As the name suggest CSN is responsible for offering internet access and connectivity. Not only internet access, it also offers connections to various public and corporate networks. The CSN is owned and maintained by the service provider. It also includes authentication mechanisms in order to authenticate devices and the users of these devices. Like ASN and BS it also offers QoS.

III. LITERATURE REVIEW

In [5], the authors have shown a scheduling architecture with GPSS (General Purpose Simulation System) grant mode and min-max fair allocation for uplink scheduling and Weighted Fair Queue for downlink scheduling. Weights are used for UGS, rtPS, nrtPS, and BE flows. The weights chosen are constant. In the SS uplink scheduler of the architecture, the SS sends bandwidth request packets to BS in unicast uplink slots. In the simulation analysis, the authors focused more on the number of SS rather than the number of flows.

In [6] the authors propose QoS enhancement of IEEE 802.16 standard based on cross layer optimizations. The optimizations include traffic classifications, packet mapping strategies for different services. The authors also design some admission control mechanism at the BS. A hierarchical scheduling algorithm is used at BS. Six queues are defined according to their direction, namely uplink and downlink, and service classes like rtPS, nrtPS, and BE. Fixed bandwidth is allocated to UGS flows. Deficit Fair Priority Queue is used as first layer scheduling algorithm. With respect to scheduling algorithms for different flows, Early Deadline First used rtPS, WFQ for nrtPS and Round Robin for BE flows. This study is more towards QoS cross layer optimization rather than QoS scheduling algorithm for the IEEE 802.16 architecture.

IV. SCHEDULING ALGORITHMS

A. Uplink Scheduling Algorithms

1. Weighted Round Robin (WRR): Weighted Round Robin is a work-conserving algorithm which will continue allotting bandwidth to the SSs as long as they have waiting packets. Each SS is assigned a weight by the WRR algorithm, and the bandwidth is allocated according to the weights. As the bandwidth allocated to each SS is based on

the assigned weights only, the algorithm provides sub-optimal performance when there are variable size packets.
The WRR scheduling algorithm is used to evaluate the IEEE 802.16 MAC layer on how effectively it supports QoS demands of the multi-class traffic. The crucial portion of the WRR scheme is assignments of weights to the SS. The weights are assigned to indicate the relative priority and QoS requirements of the SSs.

2. Earliest deadline first (EDF): EDF is a work conserving algorithm proposed for real-time applications in wide area networks. The algorithm assigns a deadline to each packet and allots a bandwidth to the SS that has the packet with the earliest deadline. Deadlines are assigned to packets of a SS based on the SS's maximum delay. The EDF algorithm is appropriate for SS under the UGS and rtPS scheduling services, as SSs in this class have rigid delay requirements. Since the SS belonging to the nrtPS service does not have a delay requirement, the EDF algorithm will schedule packets from the SS only if there are no packets from the SS of UGS or rtPS class.

EDF is one the most widely used scheduling algorithms for real-time applications as it chooses SSs based on the delay requirement. The algorithm assigns a deadline to the arriving packets of a SS. Since each SS specifies a value for max latency parameter, the arrival time of the packet is added to the latency to form its tag. The maximum latency for SSs of the nrtPS and BE classes is set to infinity.
3. Weighted Fair Queuing (WFQ): Weighted Fair Queuing is just like the Generalized Processor Sharing (GPS) Algorithm but it is not exactly like the GPS, more of an approximation [7]. GPS is an algorithm that supposes that a packet can be divided into smaller bits, and then each bit can be scheduled separately. The WFQ algorithm gives superior performance compared to the WRR for variable size packets. The WFQ algorithm doesn't take into consideration the start time of a packet. The disadvantage that occurs due to this is that WFQ will begin to service the packets even when the packets have not yet started getting serviced under the GPS algorithm. Both WFQ and WRR scheduling algorithms award weights to SSs. Unlike the WRR algorithm, WFQ algorithm also takes into account the channel capacity and packet size when allotting bandwidth to the SSs. An arriving packet is tagged with completion time that is calculated based on the weight assigned to the SS, the packet size and the capacity of uplink channel. In WFQ, weight of SS is calculated in the same way as it is in WRR. Once the weight is set, arriving packets of the SS are labeled with virtual finish time.[8]
4. Latest Time Limit First with Reserved Bandwidth (LTL-RB): The algorithm is based on the idea of reserving a minimum of the bandwidth for each class of service during each frame-time, and then allocating the reserved bandwidth for every class of service among the related connections of that class. The remaining bandwidth is shared among all the connections according to their instant bandwidth requirements. The excess bandwidth is shared according to the priority from highest priority to lowest priority. The method is basically made up of the following two phases: Reserved bandwidth of each priority class is shared among the admitted connections of that class, according to the scheduling policy. The surplus bandwidth would be allotted to those connections that have not been granted in part or in total of their requested bandwidth.

B. Downlink Scheduling Algorithms

1. Round Robin (RR): One of the simplest scheduling algorithms that is designed especially for a time sharing system, where a scheduler assigns time slots to each queue in equal proportions without priority. Once a queue is served, it is not visited again until all the other MS's (Mobile Stations) in the system have been served. RR offers same visit time-slot to all queues irrespective of their channel conditions, resulting in fairness and low channel capacity. Another disadvantage of RR algorithm is that there is no multi-user diversity gain. Also, it cannot guarantee different QoS requirements for each queue.
2. Proportional Fairness (PF): The goal of this packet scheduling scheme is to enhance the system throughput as well as provide fairness among the queues. Although PF is easy and at the same time, effective, it cannot assure any QoS requirement such as delay and delay jitter due to its design for saturated queues with non-real-time data service.
3. Adaptive Proportional Fairness (APF) scheme, is introduced, which aims at extending the PF scheduling to the real time service and provides the various QoS requirements. The scheduling system is based on the Grant per Type-of-Service principle, which aims at discerning the delay performance of each queue. An innovative priority function is used for all the QoS guarantee queues, including UGS, rtPS, nrtPS and ertPS, for assigning time slots on the queues with the highest priority value.
4. Integrated Cross-layer Scheduling: Since it is difficult for RR and PF to manage a tedious task like resource allocation they grant an apt QoS per connection. This scheduler works according to the priority, there is a function for priority for each queue. The priority is determined based on its service status in the physical layer along with its channel condition. Thus, the scheduler can provide the prescribed QoS guarantee. This scheduler is difficult to be practically deployed due to its high implementation difficulty and the delay performance of each type is not good.

V. PERFORMANCE ANALYSIS

The algorithm LTL-RB in uplink follows priority rule to meet delay and loss requirements of different classes. It also tries to maintain its fairness by reserving a minimum amount of bandwidth for each class of service, during each frame time. The size of this amount of reserved bandwidth for each class of service reacts with a degree of scheduler fairness towards that class. It can also be said that the size of the reserved bandwidth is a trade-off between providing an improved QoS support for higher priority classes and being fair to lower priority classes as compared with the other uplink algorithms discussed in this paper. Downlink algorithm together considers the effect of the current channel conditions and the transmission fulfilment of the previous time frames. Compared with RR and PF,APF outperforms in service differentiation and QoS provisioning by choosing an appropriate set of T. APF is flexible to the system size in terms of the number of accommodated MS's.

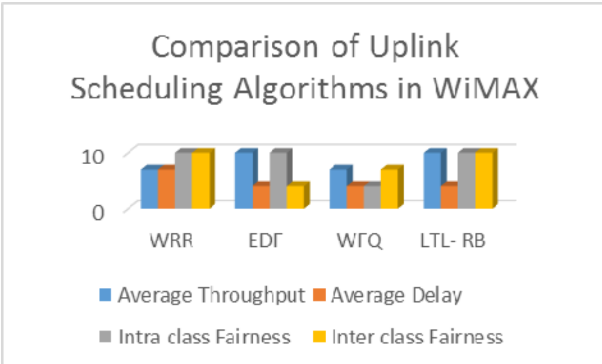

Figure1: Comparison of Uplink Scheduling Algorithms in WiMax

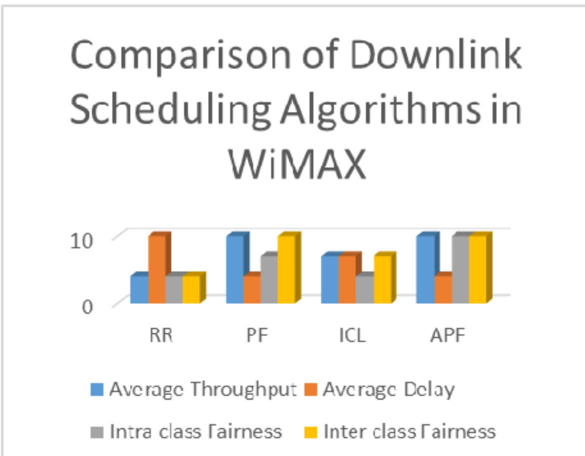

Figure 2: Comparison of Downlink Scheduling Algorithms in WiMax

VI. CONCLUSION

The MAC scheduler in WiMax technology is a central issue to design. Fulfilling design constraints like minimum throughput, guarantee of QOS are of the utmost importance. In this paper, we discussed various scheduling algorithms that serve these design constraints out of which, for Uplink, Weighted Fair Queuing Algorithm (WFQ) is found to be the best for WIMAX MAC scheduler. Although complex in design, it guarantees throughput, delay, and fairness with dynamic weight allocation to each queue of connections. Its dynamic nature makes it more appropriate than the other algorithms. For Downlink, Adaptive Proportional Fairness (APF) scheduling algorithm has better performance compared to other algorithms.

VII. ACKNOWLEDGMENT

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