WEDF – Distance Aware Scheduler for Real-Time Applications in Wimax

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ABSTRACT: *Scheduling is an important factor for the performance of Wimax system, especially for real-time applications. Earliest Deadline First (EDF) is a delay-optimal scheduling discipline commonly used in real-time applications in wired and wireless networks. Traditional schedulers like EDF do not take the packet destination distance into account. In this paper, we present a scheme that differentiates real-time packets according to their destination distance and assigns them to the dedicated queues which are long distance, middle distance and short distance queues. To the best of our knowledge none of the existing schedulers take destination into account. The proposed scheduler called Weighted Earliest Deadline First (WEDF) gives more precedence to long distance packets than short distance packets. The preliminary simulation results are promising.*

Keywords: Wimax, EDF, WEDF, Distance-aware scheduler, IP2Geo

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1. Introduction

IEEE Standard 802.16 (called Wimax) WirelessMAN is a broadband wireless technology that provides high rate wireless connections with high bandwidth [1]. Wimax is designed as an alternative wired broadband network for cable modem, fiber optic, and xDSL (digital subscriber line) lines. Wimax is a last mile technology that has a target range up to 50 km and transmission rate between 30 Mbps with non-line of sight (NLOS) and 100 – 1000 Mbps with line of sight (LOS). Wimax promises high-bandwidth, low-deployment cost and high-speed deployments.

Wimax technology supports two modes: Point-to-Multipoint (PMP) mode and Multipoint-to-Multipoint (Mesh) mode. In PMP mode, a base station coordinates and distributes traffic to subscribers. Existence of a base station provides a centralized solution and also decreases complexity of MAC protocols. However in mesh mode, there is no a centralized coordination, subscriber stations can communicate directly with each other.

The IEEE 802.16 standard Wimax specifies MAC services, however the scheduling mechanism, call admission control (CAC), traffic policing and traffic shaping are not defined in the standard and these mechanisms are independent to vendors for implementing their needs. Since these undefined components directly affect the performance of the Wimax system, many researchers from both industrial and academic areas focus on these components especially on schedulers. At the beginning, the legacy schedulers such as Deficit Round Robin (DRR) [12], Weighted Round Robin (WRR) [11], Earliest Deadline First (EDF) [13], Weighted Fair Queuing (WFQ) [22] and Worst-Case Fair Weighted Fair Queuing (WF2Q) [23] are applied to Wimax which are proposed previously for different demands in literature. Then, some schedulers are proposed especially for Wimax, e.g., Temporary Removal Scheduler (TRS) [5] and Frame Registry Tree Scheduler (FRTS) [6].

Then, hybrid and opportunistic schedulers are developed for Wimax. Hybrid schedulers combine the existing legacy schedulers for different scheduling services in order to satisfy scheduling services for QoS demands. Vinay et al. [7] propose the EDF+WFQ hybrid scheduler scheme for satisfying scheduling services. It uses EDF for handling rtPS traffics and WFQ for nrtPS and BE traffics. Also, Wongthavarawat and Ganz [8] propose the EDF+WFQ+FIFO hybrid scheme, EDF for rtPS, WFQ for nrtPS and FIFO for BE service class. In addition, some opportunistic (cross-layer) schedulers are proposed in literature [9, 10], to adapt medium, maximize throughput of the system and provide proportionally fairness among service classes.

However, none of these schedulers scheme considers the destination of real time packets. For example, EDF scheduler does not consider packets' destination address, therefore far destination packets and close destination packets share same destiny in the scheduler if their arrival times and maximum latency parameters are the same. In this paper, we propose a distance-aware scheduler called Weighted Earliest Deadline First (WEDF) for Wimax networks that perform scheduling based on the estimate end-to-end delay of packet. The proposed scheme differentiates long distance and short distance real time packets in order to decrease end-to-end delay of all packets. IP protocol helps us to understand the destination distance of packets because IP addresses are hierarchical. The packets are separated according to their destination address, and long distance packets are given more precedence than short distance packets.

Rest of the papers is organized as follows. Section 2 presents benefits of Wimax and functionality of Wimax components. Section 3 describes the Wimax Schedulers. Section 4 draw proposed algorithm and simulation. Section 5 concludes the paper and summarizes the results.

2. Wimax Services and Schedulers

Wimax has a polling-based MAC architecture whose performance is more deterministic than the contention-based MAC used in 802.11 (WiFi). When it is compared to the other wireless access technologies, it has many features that provide many advantages. First, Wimax supports multiple QoS classes that need different services, for example real-time application data (voice and video data) and best effort data (FTP, Web). Second, in order to adapt to the channel condition, Wimax supports adaptive modulation and coding techniques. For example, according to the distance from BS and channel condition, best modulation and coding scheme is selected by BS. Third, Wimax supports multiple physical layers such as WirelessMAN-SC (Single Carrier), Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Access (OFDMA). Each of them has different characteristics and it is used for different purposes and demands [3, 4].

Also Wimax supports Time Division Duplex (TDD) and Frequency Division Duplex (FDD) duplexing techniques. FDD requires two distinct channels, one for transmitting and the other for receiving frame. TDD requires only one channel that receives and transmits frame at different time slots. Last but not least, security mechanism is handled more sophistically in Wimax when it is compared with other wireless technologies like WiFi. Wimax MAC has a Security Subleyer that is responsible for encryption and authentication.

IEEE 802.16-2004 standard defines four QoS classes [3] and ertPS scheduling service is added in IEEE 802.16-2005 [4]. Scheduling services and characterization of them are listed as follows:

- Unsolicited Grant Service (UGS): UGS is designed for transporting a real-time application with fixed-size (constant data rate (CBR)) packets at periodic intervals such as, E1/T1 and Voice over IP (VoIP) without silence suppression. Subscriber Stations (SSs) do not need to send bandwidth request for each frame, because Base Station (BS) reserves fixed-size packet grants for each frame at periodic intervals at the UGS flow.
- Extended Real-Time Pooling Service (ertPS): ertPS is designed for transporting the real-time traffic with variable data rate (VBR) such as VoIP with silence suppression. It combines efficiency of UGS and rtPS scheduling mechanisms and it can also deliver variable packet sizes like rtPS and use periodic grants like UGS.
- Real-Time Pooling Service (rtPS): This scheduling service is designed for the real-time VBR traffic, such as streaming MPEG video or VoIP with silence suppression. BS provides periodically unicast (uplink) requests opportunities and SS responds desired bandwidth for transmission.
- Non-Real-Time Pooling Service (nrtPS): It is designed for non-real-time traffic that requires variable packet size grants on a regular basis. Applications that are using this scheduling service are delay tolerant, for example File Transfer Protocol (FTP) is an example of this class. BS regularly provides unicast poll for SS request, but requests are provided with longer intervals.
- Best Effort (BE): This service is designed for applications that do not require QoS such as HTTP, Telnet.

Wimax defines service flow concepts which are unidirectional flow associated with QoS parameters. These parameters are associated with scheduling services:

- Maximum latency (ML)
- Maximum jitter (MJ)
- Maximum sustained traffic rate (MSR)
- Minimum reserved traffic rate (MRR)
- Traffic priority (TP)

Each connection is associated with one of the scheduling service and each scheduling service is associated with specified QoS parameter sets shown in Table 1.

Scheduling service	**Mandatory QoS parameters**
UGS	M_L, M_J ,MSR
ertPS	M_L,MRR,MSR
rtPS	M_L,MRR,MSR
nrtPS	MRR,MSR,TP
BE	MSR,TP

Table 1. QoS parameters of scheduling services

Even though the packet scheduling algorithm is not defined in the IEEE 802.16 standard, several legacy, opportunistic (cross-layer) and hybrid schedulers are proposed in the literature. These proposed scheduler algorithms can be classified according to several factors. For example, a scheduler can be Work-Conserving or Non-Work-Conserving, flow-based or class-based. Also fairness, computational complexity and scalability are important issues in performance of scheduler algorithms. In the following, we briefly describe the legacy scheduler schemes for classifying schedulers.

2.1 Legacy Schedulers

FIFO: First In, First Out, also known as First Come First Served (FCFS), is a well known basic scheduling mechanism. There is no QoS support in FIFO. When network congestion increases, mean delay of queue increases and every flow is affected in the same way (increased delay, loss, and jitter).

WRR: WRR is originally designed for ATM networks which in all the packets have the same size [11]. For each flow, a weight is assigned and this weight determines the service time of flow. If larger weight is assigned to a flow, smaller delay is achieved for this flow. WRR is an unfair scheduler when the packets sizes have variable lengths.

DRR: Due to the unfairness problem of WRR scheduler in variable packet size, DRR scheduler is proposed [12]. A deficit counter is defined for every queue and DRR scheduler serves to every nonempty queue whose packet size is lower than deficit counter. Then deficit counter is decremented by the size of packet being served. Also if a packet size is greater than quantum, it is not served and deficit counter value is incremented as the quantum size.

WFQ: Fair Queuing (FQ) is based on queuing theoric approaches and it is proposed by John Nagle [14] in 1987. For each flow, a dedicated queue is reserved and packets classified by the system are assigned to this specific queue. Since each host has its own dedicated queue, all ill-behaved host-flows punish themselves, not other flows. FQ does not give more precedence to real time traffic than non-real-time traffic. WFQ allows different sessions to have different service shares. In WFQ, higher weights are assigned to real time applications, so there is smaller bounded delay in real time applications.

EDF: Earliest Deadline First algorithm is originally proposed for real time applications [13], and then it is applied in wired and wireless environments. Each incoming packet is stamped a deadline (which is addition of arrival time plus latency) and the packets are sorted according to the determined deadline with increasing order. Then the scheduler serves these packets with earliest deadline first, and if packet deadline is missed it is discarded by the scheduler.

There exist improved versions of the described legacy schedulers. For example, WF2Q and Self-Clocked Fair Queuing (SCFQ) are based on WFQ discipline. Opportunistic DRR is the enhanced version of DRR. In the literature, usage of schedulers and their performance evaluation are studied in [15, 19, 20, and 21]. Cicconetti [21] et al. use DRR as a downlink scheduler and WRR for uplink scheduler. Evaluation of performance is done, and higher priority of SS is used higher quantum value in DRR, weight of WRR assigned according to the SS priority. Sayenko [20] et al. prefer using the RR based scheduler (DRR and WRR) to using EDF and FQ because there is a big complexity gab between them. Ali [15] et al. worked on performance evaluation of the uplink algorithms in Wimax, and they demonstrated that there is no single scheduler algorithm that provides good performance with all the QoS requirements in Wimax. For example, if the main objective is providing low-delay and packet loss, EDF is a suitable scheduler, but if objective is providing high bandwidth and fairness WFQ is suitable. Chakchai [19] et al. presents an extensive survey and the classification of existing schedulers is done. And also they provide the key issues and design factors of schedulers. Since objective of this study is improving real-time applications' performance with reducing end-to-end delay, EDF scheduler algorithm is suitable, but it should be improved by considering the destination distance of packets.

3. Proposed Algorithm

Wimax defines UGS, ertPS, rtPS services for real-time application such as VoIP, Video on Demand (VoD) and Multimedia streaming. EDF scheduler is more suitable for real-time applications. In EDF packets are sorted according to their deadline and then they are served/transmitted on the basis of smallest deadline first. Also, EDF is a delay optimal scheduler [15] in deterministic environment and its scheduling policy is associated with schedulable region. And also it provides low delay and packet loss in Wimax networks [15].

Calculation of deadline is critical issue and it determined as follows:

$$\text{Deadline} = \text{Arrival Time} + \text{Latency} \tag{1}$$

Packet deadline is equal to arrival time of the packet plus maximum latency parameter of connection which initially SS send it to the BS during signaling session.

As all the legacy schedulers, EDF algorithm does not consider packets destination distance. Packets that are going to the long distance and short distance share the same destiny in scheduler if arrival times and maximum latency are the same. In other words, packet destination distance, or number of hops is not considered in EDF scheduler. However, there is a close relationship between delay and distance (e.g., number of hops). When destination distance increases, delay of transmitted packet also increases [26]. For instance, End-to-End delay of packet goes from USA to Canada is much smaller than packets that goes from USA to Turkey although their deadlines are the same and their end-to-end delay are quietly different. In order to give better service to real-time applications, packet destination should be considered by the scheduler, and more precedence should be given to the long distance packet than short distance packet even if deadline of the long distance packet is greater than deadline of the short distance packet. In this study we develop a technique for considering destination distance and to best of our knowledge this is first study in the literature.

We propose a scheduler scheme called Weighted Earliest Deadline First (WEDF). WEDF classifies packets based on their destination distance or end-to-end destination delay. Each class is assigned to different queue.

WEDF e.g., to the best of our knowledge this is the first such study. There are two classifications used in the proposed system. First one is the IP2Geo classification, the other one is the original classification defined in Wimax standard [3].

IP2Geo determines the packets destination distance. It is a critical issue to understand whether the packet destination is long, middle, or short distance. IP protocol helps us to understand the destination location information such as distance or number of hops. If the destination IP address is known, there are some techniques that maps IP to geographic location information which explained in Section 3.1. The original classification in Wimax supports traffic differentiation characteristic with satisfying different traffic flows in different bandwidths. But, the classification details are not defined; i.e., real-time and non-real-time applications working on the upper layer should be mapped to one of the scheduling services such as UGS, ertPS, nrtPS, rtPS and BE. Port numbers of source and destination, IP type of Service (TOS) field, source and destination IP address are important classification factors in the literature and Wimax standard. The IP2Geo classification can be integrated into the original classification in Wimax without negative effects of the original Wimax classification.

3.1 IP2Geo

GeoTrack, GeoPing and GeoCluster [17] are well-known IP2Geo techniques that are used to determine the geographic location of IP address of host. Some of these techniques are enhanced in [18].

GeoTrack tries to find the host location from the DNS names because routers are usually assigned meaningful geographical names. It is not mandatory to assign geographically meaningful names to routers, but usually city, state and country names or airport codes which are unique are assigned to them. This makes easy to determining locations of router.

GeoTrack is used traceroute reports and the location of the destination host is the last recognizable host in the path. Traceroot is an application which uses ICMP protocol to send probe packets to the networks. At the end, it returns paths between host and destination hosts. For each path, number of hops, names of router, and three round trip time (RTT) values are returned. GeoTrack uses Traceroot dataset, and for these reasons it is a passive technique because it is not needed to send probe packets to networks. However, if a dataset does not exist, Traceroot program must be executed and this technique makes the network measurements active.

GeoPing [17] is the second technique in IP2Geo and it uses the relation between network delay and geographic distance. This technique assumes that there is correlation between delay and distance between two hosts. It calculates the delay to destination host from multiple known locations (probe machines), and at the end of the measurements, destination host estimation is done. This technique needs several geographically known probe machines, for this reason it is expensive for us to use it in our study, and also it is an active network measurement.

GeoCluster [17] is the third technique which is different from GeoTrack and GeoPing because it does not need any active network measurements. Instead, it infers the routing information from BGP table and small subset of known IP-Location information. Allocation of address and routing in the internet is hierarchical and GeoCluster identifies the topological cluster.

In addition to these techniques, there are some studies that try to infer the IP-Location information. Freedman et al. [18] worked on GeoTrack based techniques by using traceroute data to study the geographic properties of IP prefixes. In addition to these studies, Whois-based approach is used in the literature [18].

In our study, GeoCluster or GeoTrack technique can be used to infer IP location. Since GeoCluster does not need active measurements and GeoTrack is based on Traceroot data and one of them can be easily integrated into the developed Wimax system. The classification details are not defined in standard in Wimax and we assume that classification of real-time packets to long, middle and short distance is done by GeoCluster. In this way, we do not need to change original Wimax architecture and it is preserved the original Wimax standard.

3.2 WEDF algorithm

EDF algorithm is a class-based algorithm that every packet in a class is put in the same queue. A queue is a sorted list where the packets are sorted according to their deadline. In our WEDF algorithm, we assume that the real-time packets are classified according to their destination (short, middle and long distance) by using GeoCluster technique and they are assigned to the dedicated queues. There are several dedicated queues where short, middle, and long distance packets are assigned (Figure - 1). We do not restrict the number of queues; there can be several queues each represent a specific distance.

Each queue is working on EDF manner which packets are sorted according to their deadlines, but weights of queues are not the same.

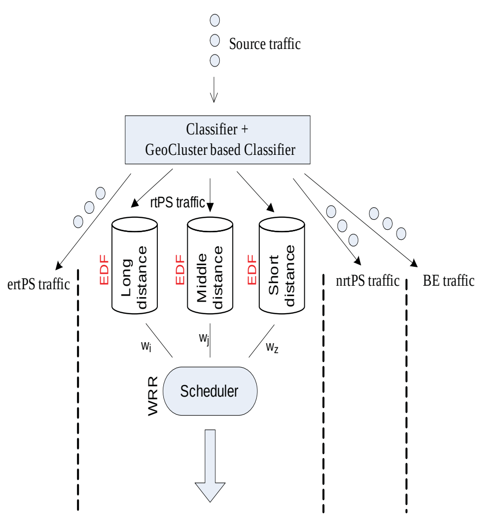

Figure 1. WEDF Scheduler

At this point we assume that higher distance value is the higher end-to-end delays. The weight of the long distance (W_L) queue is greater than the weight of the middle distance (W_M) queue, and also the weight of the middle distance queue is greater than the short distance (W_S) queue. Weights of queues can be calculated dynamically according to their queue size. In this way, our WEDF algorithm better adapts to the dynamic load changes in the queues.

Complexity of EDF algorithm is O(N) [15], where N is the number of SSs, and in WEDF algorithm there are M different queues. The complexity of WEDF algorithm is O(M*N). Since M << N, WEDF algorithm's complexity is asymptotically O(N).

4. Simulation Environment and Results

Simulation environment is developed in Java and it is an event-driven simulator. Different types of multimedia applications under the rtPS scheduling service are evaluated. High quality movie traces encoded with MPEG4, H.263 and H.261 video traces [24, 25] are used in the simulation and these movie traces produce VBR packet size with 16, 64 and 256 Kbps. Several SSs generate long, middle and short distance real-time packets and send them to the BS in Wimax. BS differentiates incoming packets to dedicated queues according to their destinations and it serves weighted round robin manner where WL > WM > WS and packets are sent to their destinations.

In order to evaluate the performance of WEDF scheduler, EDF scheduler is implemented and performance evaluations of both schedulers are done. Results show that WEDF algorithm balances delay between long distance packets and short distance packets. The traditional EDF scheduler does not consider end-to-end delay of real-time application, but WEDF with GeoCluster based classification improves end-to-end delay of application in order to meet delay requirement of the application.

Figure-2 and Figure-3 shows that developed WEDF scheduler provides smaller delay than EDF scheduler in the long and middle distances. In the simulation, delay is time elapsed between packet creation and arrival to the destination.

In the communication network, packets are encountered across the network with transmission, propagation and queuing delays. Additionally queuing delay is random and this causes a variance in delay which is known as a jitter. Also, jitter is an important QoS factor in real-time applications, because large jitter values affect the performance of real time applications and it is unfavorable.

In WEDF scheduler, packets belonging to same flow go to same queues. For this reason, we expect jitter value is not increased dramatically. It should be favorable region for a real time application. Figure- 4 and Figure-5 show that WEDF scheduler provides nearly same jitter with EDF scheduler in the long and middle distance. There are no dramatically changes in jitter, and this makes WEDF scheduler better than EDF.

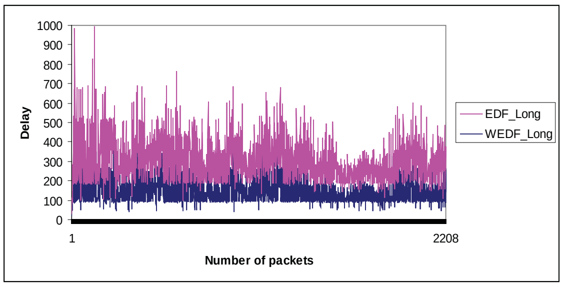

Figure 2. Delay performances of WEDF and EDF schedulers in the long distance destination

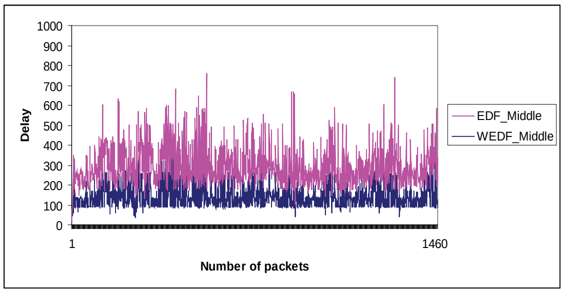

Figure 3. Delay performances of WEDF and EDF schedulers in the middle distance destination

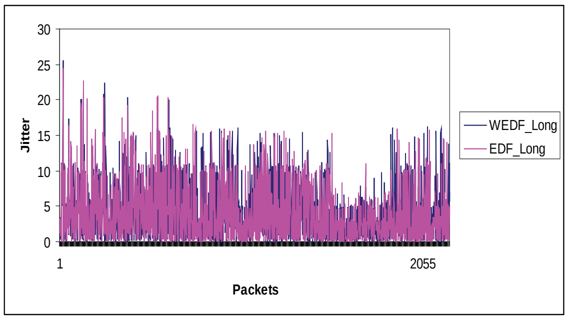

Figure 4. Jitter of WEDF and EDF schedulers in long distance destination

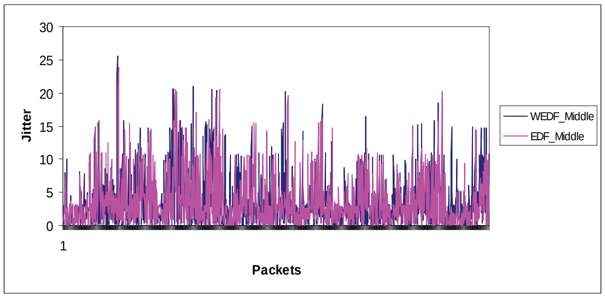

Figure 5. Jitter of WEDF and EDF schedulers in middle distance destination

5. Conclusion

Scheduling is a critical component in Wimax, and it is significantly affects the performance of the system. And there is no single scheduler algorithm that provides good performance for all the QoS requirements in Wimax. EDF scheduler is suitable for real-time application that provides low-delay and packet loss, but it should be improved for considering destination distance.

In this paper, we developed WEDF algorithm for Wimax that consider packets' destination address into account. In order to differentiate packets according to their destination GeoCluster, which is IP2Geo technique, is used. To the best of our knowledge none of the existing schedulers taking destination into account, and this is the first study.

There is a relationship between delay and distance (e.g., number of hops), and in order to satisfy maximum tolerated delay of application, destination of real-time packets should be considered by the scheduler, and sometimes far distance packets can be given more precedence than short distance packets.

In this study WEDF scheduler algorithm is created, and our idea is supported by simulation that is written in Java. Simulation results show that WEDF give better performance than legacy EDF with low-delay value. In addition to low-delay, jitter value is not increased dramatically; it is approximately same like EDF.

In this study we use GeoCluster, which is IP2Geo technique, passive measurement. Next study we consider to use active measurement delays for adapting better random queuing delay.

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