CHAPTER 5

CROSS LAYER SCHEDULING ALGORITHM WITH WRR

5.1 INTRODUCTION

Multimedia applications are gaining much attention with the advent of new broadband technologies has been emphasized by Scalabrino et al (2006). In recent years users are changing their preferences from net surfing and email to multimedia services such as VoIP, video conferencing, video streaming, etc. To address the individual user needs for important set of multimedia applications, service providers are looking for broadband wireless networks. The IEEE 802.16 standard (IEEE 802.16 Working Group) has been designed as an access network to fulfill the users’ needs of multimedia applications. WiMAX provides a cost effective infrastructure to service providers, and promises QoS to the end users without increasing the complexity in the core network, as well as on the user side. WiMAX is easy to deploy and integrate with the existing IP core network, which acts as a backbone infrastructure. The IP core offers the support of advanced technologies and protocols to WiMAX, that fulfills the required QoS and security features Khaled Shuaib (2009).

Recently the VoIP over WiMAX has been emerging as an infrastructure to provide broadband wireless voice service with a cost efficient, reliable, and guaranteed QoS. Implementation of the VoIP over the WiMAX network faces major challenges, as compared to the wired DSL
network. Therefore, the VoIP over WiMAX raises several deployment issues concerning the network architecture, system design, network capacity, configurations, and QoS provisioning. The purpose of this study is to evaluate the performance of VoIP CODECS over the WiMAX network, using the cross layer scheduling algorithm, and examine the capability of a WiMAX network to deliver sufficient QoS to voice and data applications, under different numbers of subscriber stations.

The proposed algorithm includes creating the WiMAX network, deploying the required applications like streaming video, and VoIP telephony, the configuration of QoS parameters within the WiMAX core network as well as in the WiMAX access network, and QoS configurations within the WiMAX core network for voice applications. Simulations are performed using the NS-2 simulator for different CODECS under different packetization times, buffer sizes and with different subscriber station loads.

In the simulation analysis, a cross layer WiMAX module has been developed, based on the NS-2. The performance of the modified cross layer algorithm is evaluated using the NS-2. The NS-2 is a widely used tool for the simulation of packet switched networks. The layer parameters, the cross layer designs and their interactive relationships in the cross layer infrastructure, are defined in NS-2. The signaling approach is used to pass the information among the layers. The information is piggybacked at the end of internal packets, and propagated through packet headers and original payloads.

5.2 THE WRR ALGORITHM

Al-Howaide et al (2011) stated that in the WRR algorithm, the packets are categorized into different service classes and then assigned to a
queue that can be assigned different percentages of BW, and served based on the RR order, as shown in Figure 5.1. This algorithm addresses the problem of starvation by guaranteeing that all service classes have the ability to access at least some configured BW.
decreases and this reflects the reduction in the number of packets received after the onset of congestion in queues. This reduction is the result of a request for throughput reduction at sources. The great number of nodes which represent the network congestion affects the behavior of jitter in rtPS, BE flows, and then a steady state for the UGS flow. This could be explained by the added delay in the queues caused by congestion. The performance, in terms of the average throughput of rtPS, and BE flows is decreased, due to the growth of the number of nodes, but the average throughput of UGS flows remains constant.

5.3 CROSS LAYER ALGORITHM

For each service class, there is one buffer maintained with length ‘bufferLength’. The packets received from the SS in the uplink sub frame are stored in each buffer along with its serial number, service class ID, SNR, packet size and timestamp.

During the downlink interval the scheduler scans the buffers and the packets are slotted on to the downlink sub frame. The overview of the algorithm is given below.

5.3.1 Cross Layer Scheduling Algorithm

for each Frame < totalFrames;
while time <= uplink Interval
Subscriber Station >> packets (SNR)
Assign Running Serial No, service class ID & timestamp for each Packet
Queue the packets in appropriate buffers
End
while time <= downlink Interval
Dequeue the packets from UGS buffer based on earliest timestamp
Since UGS packets = fixed Size && different SNR values
If frame = Un Allocated (No Packet inside Frame)
Allocate slot for current packet & mark slot as Allocated
Process Next Packet;
Else If frame = Allocated (Some Packets inside Frame)
Scan for UnAllocated slots
If (Empty Slots)
If(packet latency == valid)
Allocate slot for current packet & mark slot
Else
Drop Packet
Process Next Packet;
Else
Wait & Scan for UnAllocated Frame
End If
End If
End Dequeue
Dequeue the packets from rtPS buffer based on earliest timestamp
Sort the packets based on latency delay && SNR
If frame = UnAllocated (No Packet inside Frame)
Allocate slot for current packet & mark slot as Allocated
Process Next Packet;
Else If frame = Allocated (Some Packets inside Frame)
Scan for UnAllocated slots
If (Empty Slots)
If(packet latency == valid)
Allocate slot for current packet & mark slot
Else
Drop Packet
Process Next Packet;
Else
Wait & Scan for UnAllocated Frame
End If
End If
End Dequeue
Scan the BE buffer size for maximum queue length & then Dequeue all packets
If frame = UnAllocated (No Packet inside Frame)
Allocate slot for current packet & mark slot as Allocated
Process Next Packet;
Else If frame = Allocated (Some Packets inside Frame)
Scan for UnAllocated slots
If (Empty Slots)
If(packet latency == valid)
Allocate slot for current packet & mark slot
Else
Drop Packet
Process Next Packet;
Else
Wait & Scan for UnAllocated Frame
End If
End If
End Dequeue
End Downlink While.
5.3.2 Cross Layer Scheduling

The scheduling consists of two parts: the first part defines the sources or the SSs and the second part defines the BS.

The scheduling algorithms show significant results when they are studied under different mix of traffic. Thus, we have created three sources each one emitting a specific type of traffic. The type of traffic based on UDP protocol uses the CBR applications which are assigned to the UGS class. The second source is the rtPS class that uses the VBR applications based on the UDP protocol. Finally the fourth source uses the FTP applications based on TCP protocol which is assigned to the BE class. The simulation time is fixed to 100 seconds to analyze and evaluate each algorithm to guarantee the QoS for all types of applications. During the simulation we increase the number of sources (nodes) to evaluate the behavior of each algorithm also when the network is congested.

5.4 EXPERIMENTAL SETUP

5.4.1 Simulation Parameters

The cross layer scheduling algorithm has been evaluated through a series of experiments and different kinds of multimedia applications. First, the VoIP CODEC G.711 has been chosen for evaluation of the cross layer scheduling algorithm, with three different QoS service flows of IEEE 802.16 standard.

For the CODEC scheme G.711, the number of subscriber nodes with the VoIP traffic is varied as 1, 3, 5, 7, 9, and 11. The experiment is repeated only for the following service flows defined by the IEEE 802.16 standards BE, rtPS and UGS. In the following sections, the results of the
G.711 CODEC are presented. For each service flow, the cross layer scheduling algorithm and WRR have been compared.

The uplink duration is 4.5ms and the downlink duration is 5.3ms. Each buffer can store 250 packets at a time. The simulation parameters are shown in Table 5.1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical layer</td>
<td>Wireless MAN-OFDM,TDD</td>
</tr>
<tr>
<td>No of OFDM symbols and sub channels</td>
<td>19,32</td>
</tr>
<tr>
<td>Bandwidth and frame duration</td>
<td>10 MHz and 5 ms</td>
</tr>
<tr>
<td>Minimum resource allocation unit(slot)</td>
<td>2 OFDM symbols in time, 1 subchannel in frequency</td>
</tr>
<tr>
<td>Max PDU size</td>
<td>2048 byte</td>
</tr>
<tr>
<td>Traffic</td>
<td>Voice G.711 CODEC</td>
</tr>
</tbody>
</table>

The instantaneous throughput variation over simulation time has been measured. The proposed approach outperforms the traditional scheme, since the average system throughput has been enhanced almost all through the simulation.

5.4.2 Simulation Configuration

The cross layer WiMAX scheduler proposed in this research work, was implemented in the IEEE 802.16 module in NS-2 MIRACLE simulator. The simulated network uses a PMP topology with a centralized BS and the SS. The distance between the SS and the BS ranges from 1600 to 1800 meters. In our simulation unicast polling is used for sending the BW request
from all SSs. Here, the Grant per Subscriber Station (GPSS) BW allocation scheme is used. In the simulation, the number of calls generated by the SSs is varied, and is randomly generated.

### 5.4.3 Scheduling Operation

The BS receives all transmitted packets from the subscriber stations; assigns packet serial number, packet service flow identification and arrival time and stores the packet in the appropriate buffer of the service flow. Each transmitted packets has its own estimated SNR value as shown in Table 5.2. The BS schedules the packets based on the cross layer scheduling algorithm during the downlink session. According to the values of the packet size and SNR value, the required numbers of slots are allotted for each of the packets.

If the required number of slots on the current frame is not enough to schedule the current packet, then the packet is lost. The buffers are used for handling the different service flows. If the buffer is full and there is a packet in the queue, the packet is considered to be lost, since there is no memory to hold it. Once the packet is scheduled, it should be removed from the buffer and then the memory is considered to be empty to store the next packet. For each of the scenarios, the simulation time is 40s. The following simulation results are obtained based on the average of 10 independent simulations presented in 95% confidence intervals. The experiment was conducted with the proposed cross layer scheduling algorithm, and compared with the WRR scheduling algorithm with VoIP CODEC scheme G.711 scheme. The QoS parameters of throughput, BW efficiency, and transmission efficiency were calculated for different kinds of traffic with varied number of SSs.
5.5 COMPARATIVE SIMULATION RESULTS

This experiment was performed with the weighted round robin algorithm and also the proposed algorithm. The proposed algorithm was more efficient in all three service flows. The use of the dead line defined in our work reduces the average delay, when several MCS used. The same did not occur in WRR scheduling algorithm. The reason for the low throughput for WRR algorithm is the increase in average delay. WRR considers only the weights of the connections and thus allows the connections to exceed their desired MRTR. This happened because WRR uses a circular list to define the transmission order without considering the dead line time of the applications.

5.5.1 VoIP Traffic over BE Service Flow

In the first case, the VoIP is setup over the BE service flow. A graph is prepared using the number of the subscriber stations and the throughput in Kbps. In Figure 5.2, the horizontal axis represents the number subscriber stations while the vertical axis shows the throughput values. From the graph, it is understood that there is a great improvement in throughput for the proposed cross layer approach.

Figure 5.2 shows the throughput for the number of subscriber nodes, which increases from 1 to 11. As we can see, the graph shows better throughput of the BE service flow for the cross layer algorithm, when compared to the conventional WRR scheduling algorithm.
Figure 5.2 Comparative throughput for the BE service flow

When the number of nodes increases, the throughput also increases. This is one of the expected periods, when the number of nodes increases with the number of packets being transmitted. Each node transmits 180 byte packets at the rate of 60 packets per second in the G.711 CODEC scheme. The packets are generated at the rate of 64 kbps. So, the throughput for 3 nodes is around 120 kbps. For 11 nodes, the value reaches around 525 kbps. This is due to the loss of packets.

5.5.2 VoIP Traffic over rtPS Service Flow

The variation of throughput has been presented in Figure 5.3, where the VoIP traffic over the rtPS service flow is carried over the G.711 CODEC scheme is used for the VoIP. Similar to the BE service flow case, the throughput increases steadily as the number of nodes increases. The throughput is 116 kbps for 2 nodes and goes up to 520 kbps for 11 nodes. As the Figure 5.3 shows, the performance of the cross layer algorithm consistently excels that of the conventional WRR scheduling algorithm.
5.5.3 VoIP Traffic over the UGS Service Flow

The variation of throughput for the VoIP traffic over the UGS service flow is shown in Figure 5.4. Again, there is a steady increase when the number of nodes increases.
The values range from 120 kbps for 3 nodes and 580 kbps for 11 nodes. From the above Figure, it is proved that the throughput of the cross layer algorithm is better than that of the WRR algorithm.

5.5.4 Comparative Results Analysis

In this section a channel aware cross layer scheduling algorithm has been presented with its throughput evaluation for the WiMAX QoS service classes. A cross layer scheduling algorithm, which aims at providing QoS for WiMAX improved the performance, and guaranteed throughput by 12.8 % when compared to WRR algorithm, as shown in Table 5.2. To validate the proposed algorithm, a WiMAX simulation platform NS-2 based on the NS-MIRACLE has been implemented.

<table>
<thead>
<tr>
<th>Total Throughput (kbps)</th>
<th>Algorithm</th>
<th>Service classes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>UGS</td>
</tr>
<tr>
<td>Cross-layer</td>
<td>276.6667</td>
<td>278.5</td>
</tr>
<tr>
<td>WRR</td>
<td>236.6667</td>
<td>253.1667</td>
</tr>
<tr>
<td>Improved throughput (%)</td>
<td>16.9</td>
<td>10</td>
</tr>
<tr>
<td>Average throughput(%)</td>
<td></td>
<td>12.8</td>
</tr>
</tbody>
</table>

The performance improvement of the proposed scheme is validated through numerous repetitions of experiments. The optimal outputs were illustrated through the simulation results. In this work, the static IEEE 802.16 network is considered. In future work, subscriber mobility will be considered and more CODEC schemes for VoIP will be taken for more real-time operating environment and mesh mode communication will be considered. In
addition to the basic service classes, the nrtPS, ertPS service classes will be considered for further research.

5.6 BANDWIDTH UTILIZATION AND TRANSMISSION EFFICIENCY

The BW utilization ratio and the transmission efficiency are presented in Figures 5.5, 5.6 in which the number of SS is increased from 1 to 30. Generally, the WRR achieves the scheduling fairness by allocating slots to the connections, based on the quantum size. If the SSs are larger, then more packet fragmentation will occur. This causes a low BW utilization ratio and low transmission efficiency. Since the cross layer scheduling algorithm selects only qualified rtPS connections according to predefined criteria, the ULMAP overhead and MAC overhead are smaller, which results in good BW utilization ratio and transmission efficiency.

![BW utilization ratio](image)

**Figure 5.5** BW utilization versus the number of SSs
Figure 5.6  Transmission efficiency versus the number of SSs

When the number of SS is large, there is a quick decrease in the BW utilization ratio and transmission efficiency is shown in Figure 5.6. A big SDU can be fragmented into many parts. If all the fragmented parts should reach the BS MAC layer, the SDU can be defragmented successfully and delivered to the upper layer. If it does not arrive on time, then the fragments will be dropped in the BS MAC layer. When the number of SS is large, only part of the fragments can be successfully transmitted, therefore the received payload number decreases rapidly.

BW utilization ratio: \( R/S_K \)  \hspace{1cm} (5.1)

Transmission efficiency=\( R/S_d \)  \hspace{1cm} (5.2)

\( R \) = total received SDU size (in bits) in BS MAC layer i.e the total payload size which is delivered to the upper layer.

\( S_K \) = the total PDU size sent in SS;

\( S_d \) = the slot number for sending the PDUs
5.7 SUMMARY

In this chapter, the channel aware cross layer scheduler which optimizes the physical and MAC parameters of an OFDM based PMP WiMAX network has been presented. The proposed cross layer scheduling algorithm is based on the SNR value from the physical layer and compared with conventional WRR algorithm. The cross layer algorithm was tested on the different multimedia applications with different service classes. The simulation results show that the cross layer interaction approach is able to meet the QoS requirements of service classes and improves the average throughput by 12.8%, using the minimum amount of BW.