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Design and Evaluation of Scheduling Architecture for IEEE 802.16 in Mobile Ad-Hoc Network

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ABSTRACT

A worldwide demand for high speed broadband wireless systems across commercial and residential regions is emerging rapidly due to the increasing reliance on web for information, business, entertainment and new upcoming high bandwidth intensive or real-time applications. The IEEE 802.16 standard which has emerged as Broadband Wireless Access (BWA) solution is promising to meet all such requirements and becoming the most popular way for wireless communication. The IEEE 802.16 advantages includes variable and high data rate, last mile wireless access, point to multipoint communication, large frequency range and QoS for various types of applications. We propose Weighted Fair Queue (WFQ) based MAC scheduling architecture for IEEE 802.16 in both uplink and downlink direction. Our scheduling architecture accommodates parameters like traffic priority, minimum reserved bandwidth and queue information for various applications. Comparing with the traditional fixed bandwidth allocation schemes, the proposed architecture incorporates the traffic scheduling mechanism based on weights of flows and provides more fairness to the system

Keywords: *Broadband Wireless Access, IEEE 802.16, AD-HOC, MAC*

INTRODUCTION

deployment, high speed data rate, large spanning area, and large frequency spectrum. The IEEE 802.16 standard provides Quality of service to all different kinds of application including real time traffic in the form of flow type associa with each application. The IEEE 802.16 MAC layer is divided in three parts–Privacy Sublayer (lower), MAC Common Part Sublayer (middle) and Convergence Sublayer (upper). The core MAC layer is Common Part Sublayer (CPS). The MAC CPS is designed to support PMP and mesh network architecture. The IEEE 802.16 MAC is connection oriented. Upon entering the network, each SS creates one or more connections over which their data packets are transmitted to and from the BS. Each packet has to be associated with a connection at MAC level. This provides a way for bandwidth request, association of QoS and other traffic parameters and data transfer related actions. Each connection has a unique 16-bit connection identifier (CID) in downlink as well as in uplink direction. The MAC PDU is data unit used to transfer data between MAC layers of BS and SS.

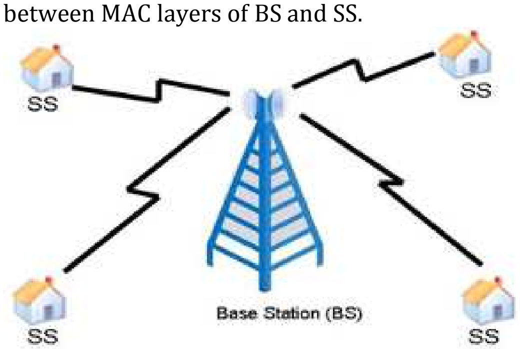

Fig1.1 IEEE 802.16 Architecture

Comparison of Our work with Previous Work

In this section, we will compare our work with available literature for IEEE 802.16. We have given the brief description of literature in previous section. Now we will compare our work in Table 1.1 to make a clear distinction of our work with others.

Study	Uplink	Downlink	Simulation	Analytical model
Our architecture	WFQ	WFQ	NS-2	–
Parekh	min-max fairness	WFQ	QualNet	–
Chu	WRR	–	–	–
Hawa	WFQ+FIFO	–	–	–
Chen	DFPQ+EDF+WFQ+RR	–	Yes	–
Oh	–	–	OPNET	Yes
Moraes	Priority Scheduling	–	–	Yes
Lee	–	–	Yes	Yes
Ganz	SP+EDF+WFQ	–	Yes	–

Table 2.1: Comparison of our architecture with prior work

OUR SCHEDULING ARCHITECTURE

Design Goals:

We have designed our scheduling algorithm with the following goals:

- We want to provide delay bound scheduling for real-time traffic (UGS and rtPS flows) and maximum throughput for data traffic (nrtPS and BE flows).
- We believe that the scheduling algorithm should provide best QoS for all types of applications. This means the number and types of flow matters to us rather than number of SSs. So we have designed our scheduling algorithm for the GPC grant mode and not for the GPSS grant mode.

Proposed Architecture:

The IEEE 802.16 standard divides the uplink sub-frame into three periods namely ranging period, bandwidth contention period and data uplink period. We call this the Band Width Contention (BWC) mode. We also consider a case where we completely remove the bandwidth

Contention period in our architecture and call this the No Band Width Contention (NBWC) mode. In NBWC mode, the uplink sub-frame is divided between two parts only–ranging period and data uplink period. Consequently the total number of data uplink slots is more in NBWC mode.

We chose WFQ as the scheduling mechanism for uplink and downlink direction because of mainly two reasons–WFQ provides bit wise bit fairness (according to the assigned weights) to all active flows, secondly WFQ also provides flow isolation. As mentioned in Miguel paper that flow isolation is also necessary at the router (BS is an router also) in the case of unresponsive flows. Our proposed scheduling architecture broadly contains five parts–WFQ module, BS allocation module, SS uplink module, BS downlink module, and Classifier module. WFQ module has been used twice in our architecture. One copy of WFQ module is inside the BS allocation module (for uplink slot allocation) and the other standalone copy is used for downlink scheduling. The Figure 1.2 shows our IEEE 802.16 scheduling architecture. We will discuss each of these modules in detail below:

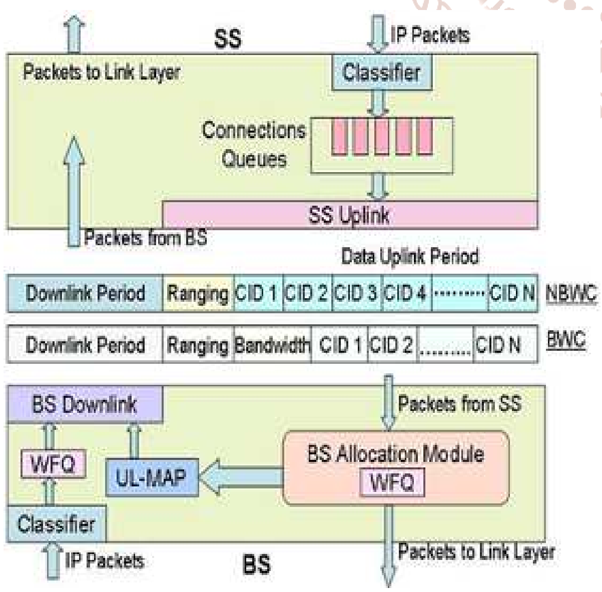

Figure1.2: Our IEEE 802.16 MAC Scheduling Architecture

NS-2 IMPLEMENTATION DETAIL

Modified NS Architecture:

Network Simulator (ns version 2.29) is a discrete event network simulator. Ns-2 is designed to simulate all type of traffic and wired and wireless support. The original ns-2 package comes with IEEE 802.11 Link Layer (LL), MAC and PHY implementation. To the best of our knowledge, our implementation is the first implementation of IEEE 802.16 on ns-2. We have implemented IEEE 802.16 on version 2.29 but we believe that that supplied patch files on [nsWL16 06] will work with other version also.

Ns-2 is an Object Oriented (OO) simulator package. The software structure is divided into two OO languages C++ and Object TCL (OTCL) to separate the control and packet level processing. C++ is used for packet level processing while OTCL is used to define simulation configuration. OTAL and C++ share the class hierarchy. The input simulation script is has to be written in OTCL with mentioned node topology, type of scheduler, starting and end time of flows, type of flows with source and destination node ids. As shown in Figure 1.3 (the old architecture) a wireless node (or mobile node) in ns-2, is a collection of address classifier, port classifier, agent, link layer, MAC layer, interface queue (IFQ) and physical channel. These classifiers distribute in incoming packets to the correct agent or outgoing link. The protocol agent represents the application layer and routing agent represent the IP layer. When packet travels from protocol agent to routing agent, the routing agents puts the next hop destination in this packet and sends this packet to Link Layer (LL). The LL determines in MAC address of destination hop using Address Resolution Protocol (ARP). LL puts this MAC address in the packet and forwards this packet to MAC layer. MAC layer determines the time needed to send this packet on wireless channel and then forward this packet to PHY layer (or network interface).

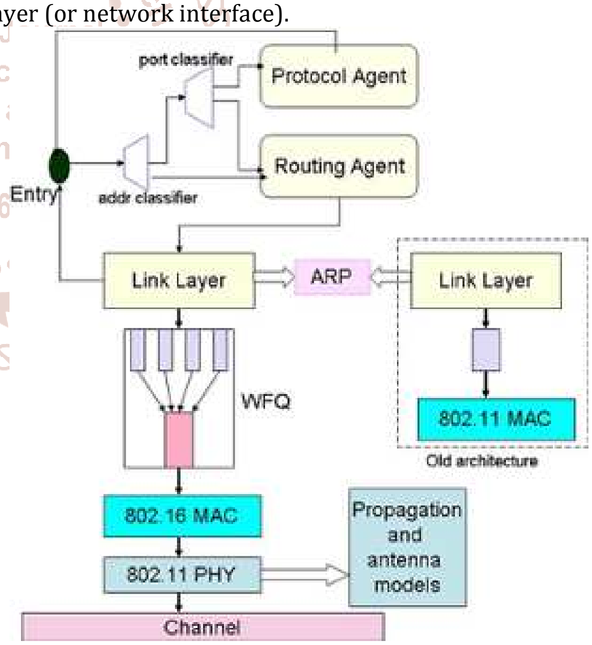

Figure1.4: Modified BS Node Architecture

SIMULATION ANALYSIS

We have used Network Simulator (ns version 2.29) as our simulation platform. We have performed extensive simulations in both uplink and downlink directions to show the effectiveness of WFQ

scheduling algorithm. More specifically we want to evaluate the following in our architecture:

- Effect of one type of flow on other type of flow. That is keeping a constant number of one type of flow, evaluate the average performance degradation (delay for UGS and rtPS flows and throughput for nrtPS and BE flows) of this type of flow with the increment in the number of other type of flow.

- Choice of appropriate bandwidth contention period in BWC mode with a constant number of flows of same flow classes.
- Performance comparison of BWC and NBWC mode with above choice as bandwidth contention duration in BWC mode.

In our simulations, we have used the following weights: The UGS and rtPS flows have 22.4 Kbps and 64.0 Kbps as average bandwidth respectively.

Flow type	Weight
UGS	22.4
rtPS	64.0
nrtPS	100.0
BE	10.0

Table 1.2: Weights for different flow type

The weights for nrtPS and BE traffic are taken in such way that, with a given number of nrtPS and BE flows, the maximum available part of whole bandwidth should not acquired by these flows only. In this manner, we are giving preference to UGS and rtPS flows with the proper choices of weights and number of flows. The length of polling time is 2 frame length (=20 msec). Running time for our all the simulations is 20 sec. For all our simulations, the calculated delay are application level (or agent level in ns2 terms) one way delay and then averaged over the number of flows.

Delay Analysis for Uplink Flows:

The default used data rate is 11Mbps. It is same as the maximum data rate in IEEE 802.11b standard. The higher data rate may affect our simulations in the context of 802.11 PHY implementation of ns-2. It might be possible BS and SS not able to communicate at higher data rate. On the other hand, we will send data packets in fewer number of slots on higher data rates. We chose 11Mbps because we are using of IEEE 802.11 PHY channel for data communication.

Parameters	Value
Data Rate	11Mbps
Basic Rate	1Mbps
Slot Time	8 micro sec
Frame Length	10 msec
Downlink Frame	2 msec
Uplink Frame	8 msec
Ranging period	100 slots (=0.8 msec)
Bandwidth Contention	100 slots (=0.8 msec)
Data Uplink Slots (BWC)	800 slots (=6.4 msec)
Data Uplink Slots (NBWC)	900 slots (=7.2 msec)

Table 1.3: Simulation parameters for uplink flow analysis

Effect of BE increment on 30 UGS flows:

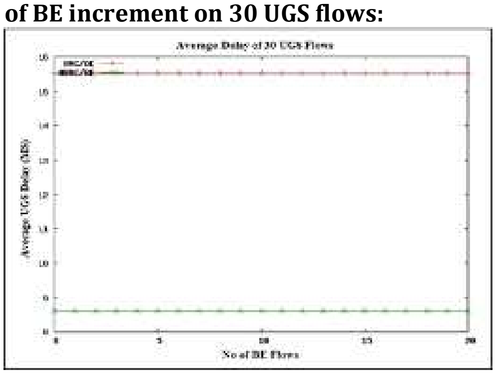

Figure 1.5: Average UGS delay with BE flows

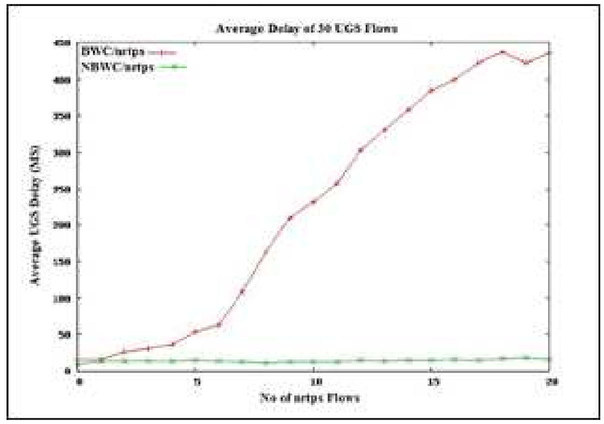

Figure 1.6: Average UGS delay with nrtPS flows

Effect of rtPS increment on 30 UGS flows:

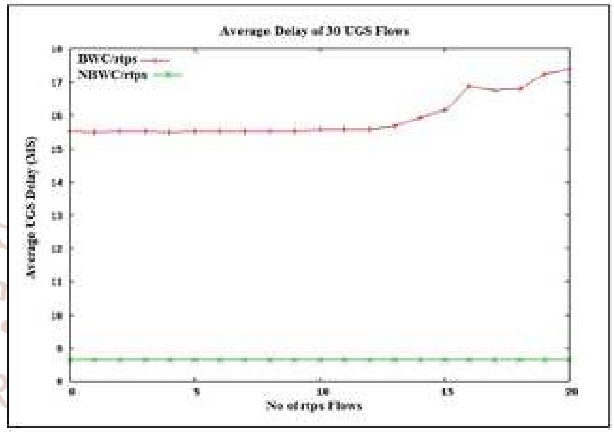

Figure 1.7: Average UGS delay with rtPS flows

Effect of BE increment on 20 rtPS flows

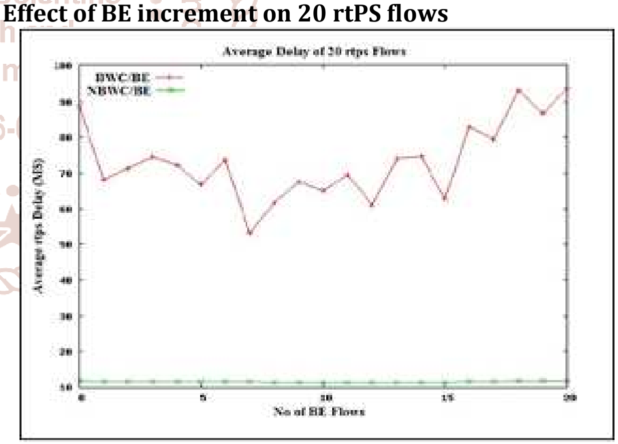

Figure 1.8: Average rtPS delay with BE flows

Effect of nrtPS increment on 20 rtPS flows:

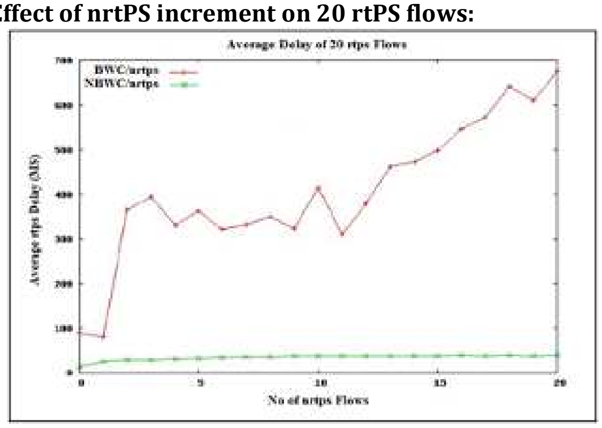

Figure 1.9: Average rtPS delay with nrtPS flows

Effect of UGS increment on 20 rtPS flows:

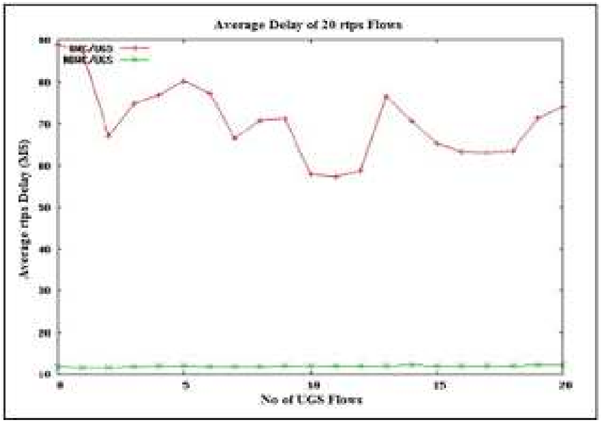

Figure 1.10: Average rtPS delay with UGS flows

Throughput Analysis for Uplink Flows:

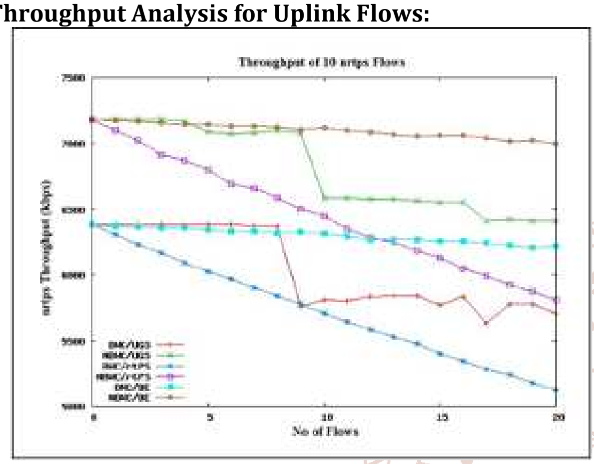

Figure 1.11: Throughput of nrtPS flows

Total Throughput in BWC and NBWC:

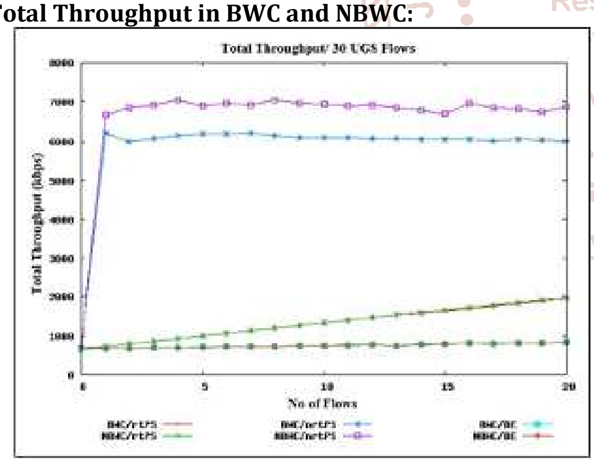

Figure 1.12: Total throughput with 30 UGS flows

Total Throughput with 20 rtPS flows:

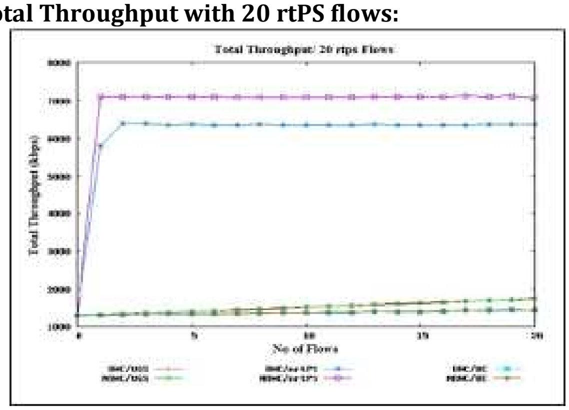

Figure 1.13: Total throughput with 20 rtPS flows

Total Throughput with 10 nrtPS flows

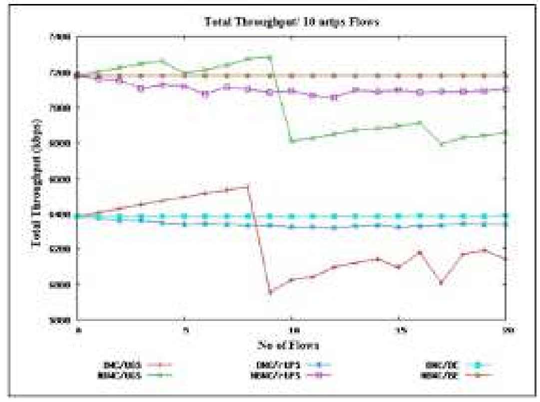

Figure 1.14: Total throughput with 20 rtPS flow

Conclusion:

In this thesis we presented a scheduling architecture for IEEE 802.16 standard. Our scheduling architecture use a WFQ as the downlink as well as the uplink scheduling algorithm. Downlink scheduling is easy because only involve entity is BS and it has all the required information for the same. For uplink scheduling, each SS has to send its queue information to BS. As defined in the standard, SSs can send their bandwidth request to BS either in bandwidth contention period or in unicast slots which is allocated to SSs in each frame or through piggyback the connections demands with data packets. In the NBWC mode of operation, we completely remove bandwidth contention period and send bandwidth request piggybacked with data packets thus we are removing any possibility of collisions at BS. We propose polling time concept to remove this drawback.

Our simulation results shows that NBWC mode performs better in terms of delay for real time traffic and in terms of through for high data rate traffic in both uplink and downlink direction. We chose a very simple approach to design our architecture and showed that this architecture indeed satisfy the QoS requirements of different application flows. The simplicity lies in our scheduling algorithm (WFQ) also which is known from last 2 decades and is able to perform satisfactory for newly designed IEEE 802.16 architecture. Besides this, the developers do not need to bother about the two different scheduling algorithm for uplink and downlink direction. In the performance analysis to NBWC mode, we have shown that it is possible to omit the bandwidth contention period from IEEE 802.16 standards.

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