PERFORMANCE IMPROVEMENT USING FUZZY BASED DYNAMIC BUFFER SCHEME FOR EFFICIENT RRM IN WIMAX 16M NETWORKS

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Abstract

The IEEE 802.16m standard for Advanced mobile broadband wireless access provides a seamless application connectivity to other mobile and IP networks like UMTS, LTE and WLAN. In order to meet the ubiquitous service delivery for users, Wimax 16m supports integration of these diverse networks which are having great difference in terms of data transmission rate, Coverage, cost and supporting of service types. Here, buffer allocation is the major problem to be handled for offering Quality of Service (QoS). The lack of buffers increases the packet loss and queuing delay. In order to overcome these issues, in this paper we propose a fuzzy based dynamic buffer scheme to improve RRM in WiMAX 16m network. The base station (BS) estimates the parameters such as number of user requests, flow rate, queue length and received signal strength for each user and updates them periodically. When a request arrives at BS, buffer allocation factor is estimated by applying fuzzy logic over these parameters. Then the flow request with high buffer allocation factor is admitted first and rest of the flow requests waits in a queue. Upon new request arrival, if its buffer allocation factor is low, the request is rejected. Otherwise, the pending request packet in the queue is emptied on analyzing their channel condition and buffer is allocated for new request. By simulation results, we show that the proposed technique FBDBM achieves better utilization when compared with MWRR scheme, while increasing the traffic flows.

Index Terms – Wimax 16m, buffer management, fuzzy, BAF, channel condition, bandwidth utilization

1. Introduction

The IEEE 802.16 standard [1] is a promising standard for next-generation broadband wireless access networks. It provides last mile solution and supports high-speed data-rate transmissions, extensive-area coverage, and high-speed mobility for users with multimedia applications. The IEEE 802.16e amendment [2] enhances IEEE 802.16 with mobility support for users moving at vehicular speeds. Wimax 16m play an important role in shaping 4G mobile networks by supporting IMT-A requirement by updating its IEEE 802.16 standards to meet the requirements of next generation mobile networks targeted by the cellular layer of IMT-Advanced.

The key features of Wimax 16m network systems include (1) increased spectral efficiency and bandwidth (2)improved cell edge (3)performance and mobility support (4) reduced Control and User plane latency (5) reduced handover interruption time (6)Coexistence of multi-technologies like Bluetooth, Wi-Fi and WiMAX and (7) Inter Radio Access technology handovers(3GPP).

The IEEE 802.16e is based on Orthogonal frequency division multiple access (OFDMA), described as a key technology for Wimax physical layers [1,3,6,12], is used to adjust channel bandwidth and to allocate subscriber station (SS) subcarriers according to channel state. OFDMA also allows multiple SSs to use various subcarriers to simultaneously transmit OFDM symbols, so called SOFDMA (Scalable-OFDMA). In a base station (BS), all OFDMA subcarriers are divided into groups (known as subchannels) that are allocated to different SSs with matching bandwidth and quality of service (QoS) requirements [14]. Adaptive modulation, fast channel feedback and link adaptation, coding, and asynchronous hybrid-automatic repeat request (H-ARQ) in DL and UL are used in the mobile W MAX air interface to enhance its coverage and capacity.

SOFDMA (Scalable-OFDMA) has several advantages to be considered for the Wimax networks, such as flexibility of allocating subcarriers to users; high spectral efficiency, low receiver complexity, and simple implementation by fast Fourier transform (FFT) and inverse FFT are also considered. In addition, adaptive modulation and coding (AMC) technology allows SOFDMA PHY to facilitate data transmission in a high mobility environment, and makes wireless resources fully utilized. This AMC technology uses the CQI (Channel Quality Information) channel to determine the appropriate Modulation and coding scheme. The channel quality is determined by the instantaneous received Signal-to-Noise Ratio (SNR). To determine the mode of transmission (i.e., modulation level and coding rate), an estimated value of SNR at the receiver is used. To avoid possible transmission error, no packet is transmitted when the SNR is less than the predefined threshold Value [9,15,19].

Table 1 : System parameters in Wimax OFDMA environment

MCS Level	Modulation with Coding Rates	Maximum Data rate (Mbps)	No. of sub-channels	Minimum SNR Requirement (db)
1	BPSK (1/2)	0.5	14	6.4
2	QPSK (1/2)	0.75	11	9.4
3	QPSK (3/4)	6.77	2	11.2
4	16QAM (1/2)	9.02	1	16.4
5	16QAM (3/4)	13.54	1	18.2
6	64QAM (2/3)	18.05	1	22.7
7	64QAM (3/4)	20.30	1	24.4
8	64QAM (5/6)	22.56	1	27.2

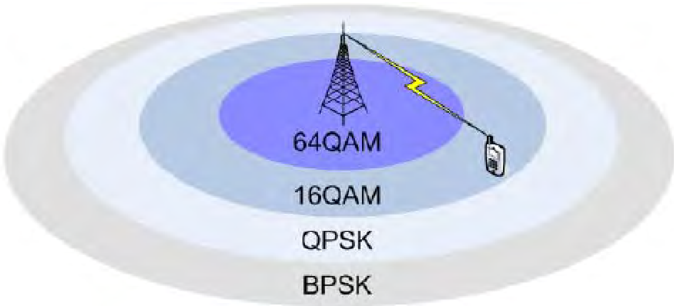


Fig 1. Adaptive modulation and coding.

Compared with IEEE 802.16e, the changes are made here are to reduce overhead, improve flexibility and facilitate channel estimation. In 802.16e systems, MIMO has mainly been addressed from the single-user perspective, and subcarriers are allocated to a given base station - mobile station pair. However, when many antennas are available at the base station, they can be used to transmit to more than one users simultaneously in each subcarrier. Use of beamforming and other Multi-user (MU-MIMO) techniques, such as Dirty Paper Coding [14], can increase the capacity of the system and/or improve reliability. Hence, algorithms are needed that allocate subcarriers and users and calculate the transmit vectors depending on the Quality of Service (QoS) requirements of each session. Design of such algorithms requires method for giving the feedback of channel information to the base station. The performance of Wimax systems can be enhanced further by performing the allocation of frequency and spatial resources at the inter-cell rather than the intra-cell level. This way, adaptive and flexible frequency reuse can be implemented and the available spectrum can be redistributed depending on the requirements and the locations of the users. Using cooperation among neighboring cells, interference avoidance techniques can also be employed, especially for users near the cell boundaries. Finally, the reliability of transmission can be improved by devising and incorporating HARQ designs.

1.1 Buffer Management

The method by which the buffer space is distributed among the various output queues can be described using buffer management. The factors to be considered while designing a buffer management algorithm are as follows

- Packet loss ratio: It is defined as the ratio of number of packets dropped to the total number of packets received
- Hardware complexity: The total hardware required to implement a buffer management algorithm. [9]

Buffer management is a fundamental technology which controls the assignment of buffer resources among different traffic classes and aggregation of the same according to certain policies. An efficient buffer management policy is required to decide at each step which of the messages is to be dropped when buffer is full and which of the messages are to be transmitted when bandwidth is limited irrespective of the routing algorithms used. [10]

The functions that are to be supported by the buffer management scheme are as follows.

- Regulating insensitive flows and fairness
- Low delay and low delay-jitter values
- Smooth sending rates for each flow
- Avoiding overflow and underflow by controlling the queue size.

1.1.1 Necessity of Buffer Management

- Traditionally, the Buffer management is utilized mainly to regulate the traffic fluctuations. [11]
- When a node receives more data to forward, the excess data has to be buffered. When the limited buffer space is full, the congestion occurs, and consequently the received data has to be dropped. [12]
- The main causes for packet loss in networks are buffer overflows due to congestion. In cases where the underlying traffic has inter-packet dependencies, indiscriminately dropping packets upon overflow may result in very poor performance. [13]
- The performance is high under infinite buffer and infinite bandwidth assumption, however, in real situations, the performance is worse when the buffer and bandwidth are limited due to the congestion control problem. [10]
- In order to overcome the above issues, an efficient buffer management scheme is required.

In paper [4], they did not consider mobility set into consideration. Also there is no approach specified for situation that involves the SSs to enter and leave the network on regular basis. The resource allocation technique described in paper [14] cannot be directly applied in the context of wireless networks due to unique characteristics of the shared wireless channel. The active queue management proposed in [15] does not give solutions to packet drops. Moreover, as per the literature survey, there are only less works related to buffer management in WiMAX. Hence in this paper, we propose a fuzzy based dynamic buffer scheme to improve RRM in WiMAX 16m networks.

2. Related Work

Wail Mardini et al [4] have proposed a modified weighted round robin (MWRR) scheduling algorithm for WiMAX. Their algorithm prevents the issues caused by weighted round robin algorithm WRR that causes unnecessary delay for lower class of services. Their algorithm minimizes the average delay and enhances the average throughput particularly for lower classes by increasing the size of service round in WRR. Their algorithm did not consider the mobility scenario.

J. D. Mallapur et al [16] proposes a fuzzy based buffer management scheme that performs buffer allocation and packet dropping for wireless multimedia networks in the context of future generation cellular networks. Buffers are allocated to requesting application by using buffer allocation factor and packets are dropped for an application by using dropping factor. A buffer allocation factor for requesting application is computed adaptively based on three fuzzy parameters of an application, namely, priority, rate of flow and packet size.

Yuan Xue et al [14] investigates the problem of TCP performance anomaly issue over multi-rate wireless networks. It presents an optimization-based framework for flow control in multi-rate wireless networks. This framework provides analytical insight to the performance anomaly problem of TCP and establishes a theoretical foundation for a joint flow control and active queue management scheme that solves this problem. The presented active queue management scheme operates based on channel conditions as well as queue lengths.

Jani Lakkakorpi et al [15] have studied the end-to-end performance of different applications in WiMAX network with and without active queue management (AQM). Their AQM technique helps in minimizing the queuing delay caused by base station downlink (BSDL) buffering. As their technique offers adequate buffer space, the TCP goodput can be maximized. However, their approach could be applied to Best effort and non real time polling service connections only.

Muhammad Rizwan et al [3] have proposed a quality of service architecture for base station. Their approach makes use of the available bandwidth that is left unused or wasted that further leads to efficient use of WiMAX resources. They proposed a combined approach of queue management and bandwidth allocation algorithm for difference services. They did not take the connection blocking and dropping states into consideration for reducing the connection requests.

As per the literature survey[4,5,13,16,18], there are only less works related to dynamic buffer management in WiMAX for radio resource management during handoff. Hence in this paper, we propose a adaptive dynamic buffer scheme to improve Radio Resource Management (RRM) in Wimax 16m networks.

3. Fuzzy Based Dynamic Buffer Management

3.1 Overview

In this proposal, we proposed a fuzzy based dynamic buffer management in WiMAX 16m network which performs buffer allocation and packet dropping. This technique operates in the base station (BS). As per application requirements, BS estimates the parameters such as number of user requests, flow rate, queue length and received signal strength and updates periodically. When a buffer request packet arrives, buffer allocation factor (BAF) is estimated using the fuzzy logic applied over the parameters estimated in the BS. The user requests are sorted in the descending order of BAF. This reveals that the flow request with more BAF is admitted and rest of the flow requests await in queue. When a new request arrives, its BAF is tested. If the value is low, the request packet is dropped. Otherwise, the pending request packet in the queue is emptied on analyzing their channel condition and buffer is allocated for new request.

3.2 Estimation of Metrics

3.2.1 Estimation of Queue Length and Flow Rate

Let $Q_{ij}(t)$ be the queue length of aggregated traffic flow of service type j, ($j \in [1, 2]$ for direct and relay cooperation transmission modes respectively) at base station i ($i \in \{1, 2,\ldots, M\}$) at time t.

The vector of the queue status of all base stations is given as

$$Q = \{Q_{11}(t), Q_{12}(t) \ldots, Q_{M2}(t)\}]^T$$

By considering the liquid fluid model, the queue length is evaluated as follows.

$$Q_{ij}(t) = N_{ij}(t)\, IR(t) - (1 - R_{ij}) BW_{ij}(t)\, \eta_{ij} \quad (1)$$

$\forall\, i \in \{1,2,\ldots M\}, j \in \{1, 2\}$

where

$N_{ij}(t)$ = Number of base stations

$IR(t)$ = input traffic flow to the subscribed base station.

$N_{ij}(t)\, IR(t)$ = aggregate downlink flow rate at base station i

R_{ij} = average packet error rate (PER) for abstracting the channel quality.

η_{ij} = average spectral efficiency (in bits/s/Hz)

$BW_{ij}(t)$ = bandwidth assigned for draining the queue

$BW_{ij}(t)\, \eta_{ij}$ = queue depletion rate

The initial state of the queue $Q_{ij}(0)$ represents the initial size of the backlogged data of the queue. There is a possibility that IR(t) may get fluctuated over time depending on the source behavior and can be viewed as the disturbance to the system. In general it is denoted as

$$IR(t) = IR_n + \omega(t) \quad (2)$$

where IR_n is a normal value of the input rate and

$\omega(t)$ is a disturbance which can be either stochastic (e.g. white noise Gaussian process) or deterministic (e.g. impulse traffic load). This disturbance can occur due to the randomness of the packet arrival from the applications. [19]

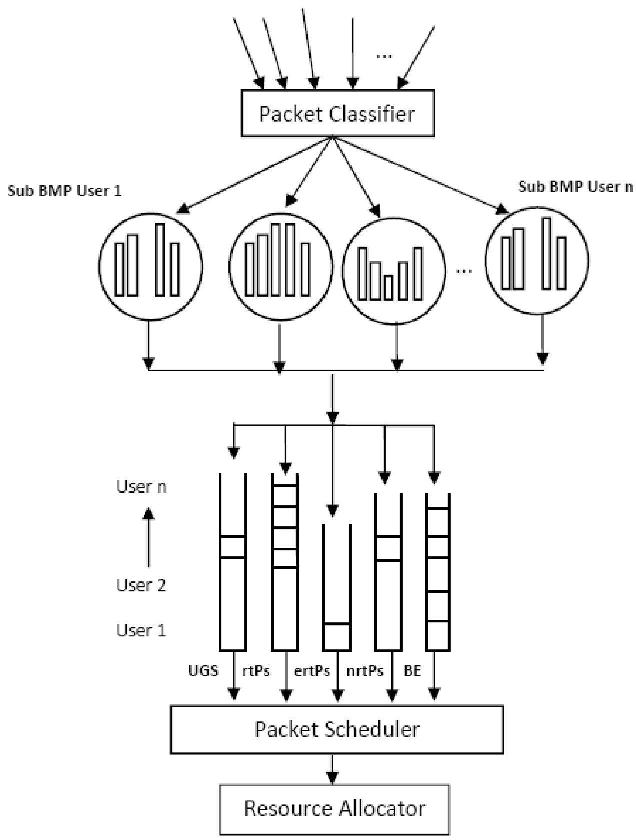


Fig. 2. Framework for QoS Specific Dynamic buffer management in Wimax 16m BS.

3.2.2 Estimation of Channel Condition

The physical layer constraints such as channel fading, multi-path propagation, reflection, scattering and other climatic effects on the channel reveals the channel condition. This channel condition can be estimated based on the received signal strength (RSS) and signal to noise ratio (SNR) at the receiver.

The received signal strength (RSS) is estimated using Friis equation which is shown in Eq: (3)

$$RSS = \frac{P_{tx} * \alpha * \beta * H_{tx} * H_{rx} * \gamma^2}{(4 * \gamma * d)^2 * \delta} \quad (3)$$

Where

P_{tx} = transmission power

α = transmitter gain

β =receiver gain

H_{tx} =height of the transmitter

H_{rx} =height of the receiver

γ =wavelength

d=distance between the transmitter and receiver

δ =system loss

From the above computed RSS, the signal to noise ratio (SNR) is computed using Eq: (4)

$$SNR = \log_{10}(P_{tx}) - \log_{10}(P_{rx}) \text{ dB} \quad (4)$$ [18]

3.3 Proposed Work

Our proposed scheme operates in the base station (BS). BS stores the following parameters at different time intervals.

- Maximum available buffer (B_{av})

- Total Buffer under execution process (B_e)
- Number of applications accessing base station(NA)
- Queue length (Q)
- Flow rate(R)
- Receive Signal Strength (RSS)

BS updates the above parameters periodically as per the application requirements. When a buffer request packet (BRP) arrives from a specific application, the request packet is either allocated with available buffer or dropped. This is demonstrated in following section.

3.3.1 Fuzzy based buffer allocation

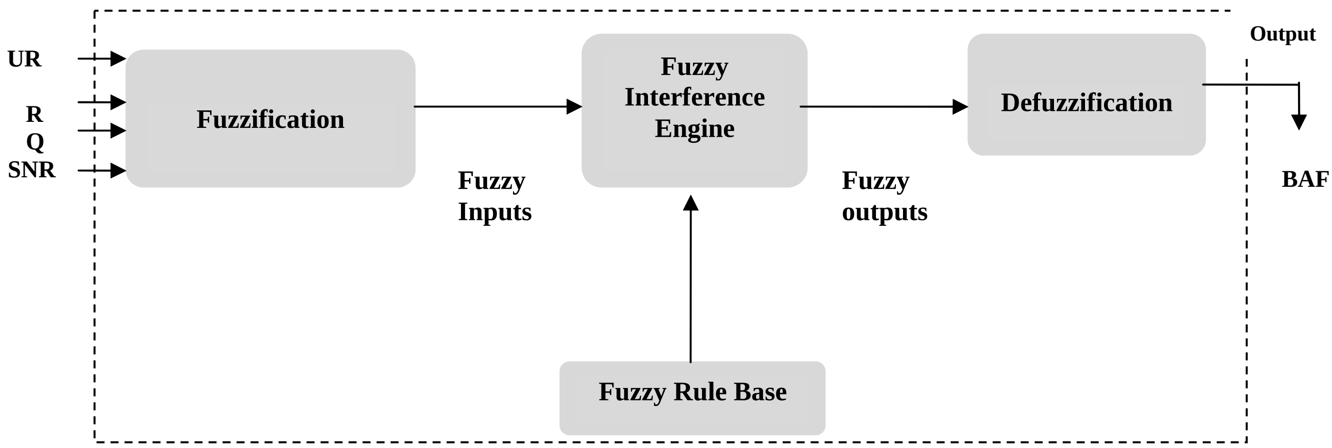
Upon receiving BRP, the buffers are allocated using buffer allocation factor (BAF). It is estimated with the help of fuzzy controller. The steps involved in the fuzzy logic technique are detailed below.

1) Fuzzification
2) Inference with rule base
3) Defuzzification

Fuzzification:

In this step, the crisp inputs are changed into linguistic values. Each of these values is represented using a fuzzy set. Each fuzzy set is related to a membership function which is utilized to describe the way by which the crisp input belongs to the set.

Our technique considers four input parameters for Fuzzification such as number of user requests (UR), flow rate (R), queue length (Q) and received signal strength (RSS). Based on the input parameters and inference engine, the output obtained is the buffer allocation factor (BAF). Each of the fuzzy parameters is represented using triangular membership function as it represents minimum and maximum and maximum boundary conditions.



UR - Number of User Requests
R - Flow Rate
Q - Queue Length
SNR - Signal to Noise Ratio
BAF- Buffer Allocation Factor

Fig 3: Fuzzy Controller for Buffer Allocation

The membership to each of fuzzy variables is assigned using intuition method. This technique minimizes the computation complexity.

The membership function for these input parameters and output is represented as f (UR), f(R), f (Q), f (RSS) and f (BAF).

- **Number of user requests:** Based on the count of user request, linguistic values associated with the membership function f (UR) are low, and high. The low UR is preferred for buffer allocation.
- **Flow rate:** The flow rate varies based on the user requirements as per the applications. They considered since they provide the required buffers. The variation level in the rate of flow is represented by using linguistic values related to the membership function f(R) such as low and high. The high R is preferred for buffer allocation

- **Queue length:** The queue length is measured based on the number of tasks in each queue i.e. it gives the measure for buffer availability. The linguistic values associated with the membership function f (Q) are low and high. The higher Q is preferred for buffer allocation
- **Received Signal Strength:** The received signal strength describes the communication quality among the two nodes. The linguistic values associated with the membership function f (RSS) are low and high. The higher RSS is preferred for buffer allocation

Buffer Allocation Factor: Output of four input linguistic value is Buffer Allocation Factor. The allocation factor is represented by linguistic values associated with membership values such as low, medium and high.

The fuzzy buffer allocation scheme forms a fuzzy set of dimension f (UR)* f(R)*f (Q)* f (RSS).

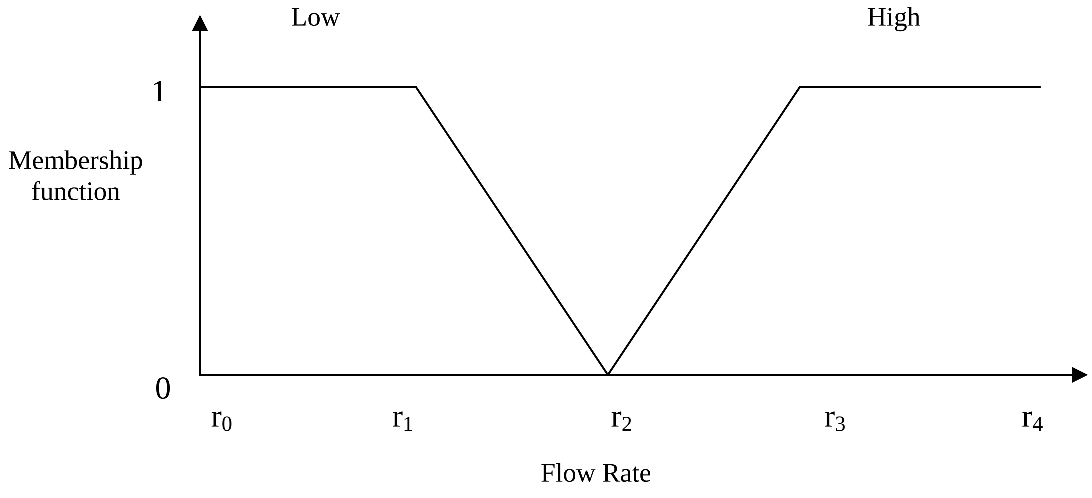


Fig 4: Membership Function for Flow Rate

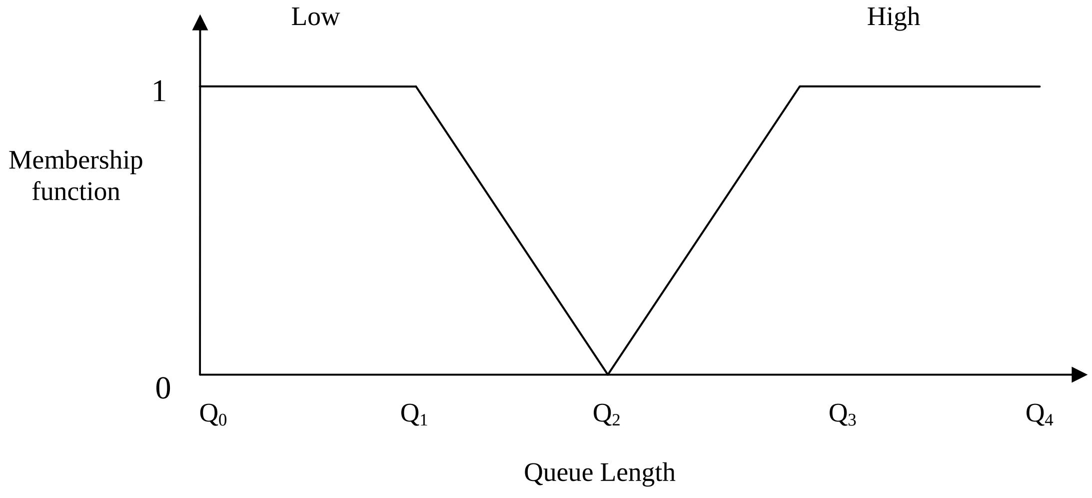


Fig 5: Membership Function for Queue Length

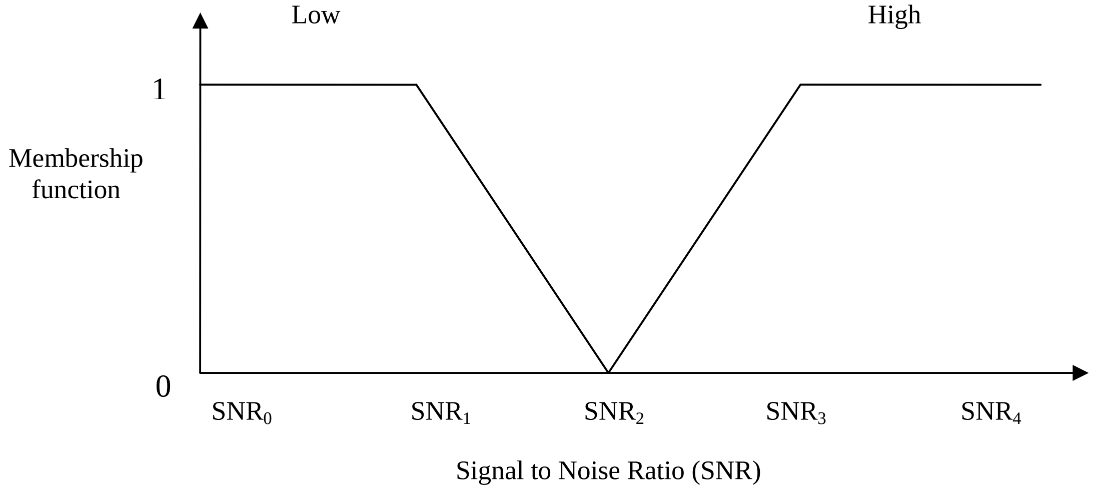


Fig 6: Membership Function for Signal to Noise Ratio

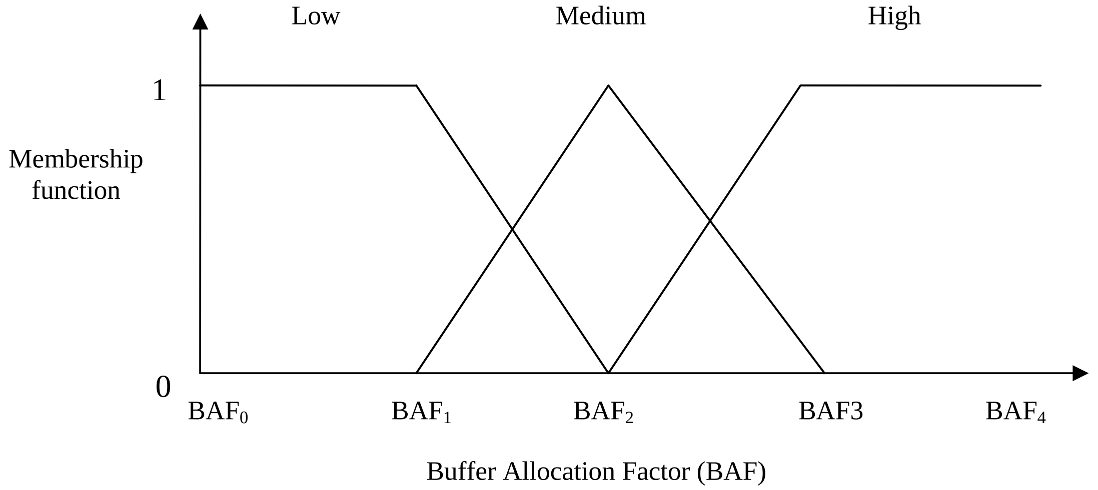


Fig 7: Membership Function for Buffer Allocation Factor

Inference Mechanism

Inference mechanism in fuzzy logic is based on fuzzy rules that connect input and output parameters (fuzzy rule base), and the membership functions for input and output parameters. To create an inference engine, first the membership functions for input and output parameters are developed; both a range of values and a degree of membership define membership functions.

The fuzzy inference system is designed based on 16 rules described in table 2. In order to demonstrate the designed fuzzy inference system, one rule is taken into account to show how the inference engine works and outputs of each rule are each rule are combined for generating fuzzy decision.

Rule

If (UR=low, R=high, Q=high and RSS=high)

Then

BAF=high

End if

Table 2: Fuzzy Rules

User Requests	Flow Rate	Queue Length	RSS	BAF
Low	Low	Low	Low	Low
Low	Low	Low	High	Medium
Low	Low	High	Low	Medium
Low	Low	High	High	High
Low	High	Low	Low	Medium
Low	High	Low	High	Medium
Low	High	High	Low	High
Low	High	High	High	High
High	Low	Low	Low	Low
High	Low	Low	High	Low
High	Low	High	Low	Low
High	Low	High	High	Medium
High	High	Low	Low	Low
High	High	Low	High	Medium
High	High	High	Low	Medium
High	High	High	High	High

Defuzzification

It is the method by which a crisp value is extracted from a fuzzy set as illustration value. During fuzzy decision making, the centroid of area technique is taken into account for defuzzification. The Defuzzifier is based on Equation (1).

$$F\_priority = [\sum_{All\_rules} z_i * \eta(z_i)] / [\sum_{all\_rules} \eta(z_i)] \quad (1)$$

Where F_priority = Degree of decision making,

z_i = fuzzy variable

$\eta(z_i)$ = membership function.

The output of the fuzzy priority function is altered to the crisp value based on the above defuzzification method.

3.3.2 Algorithm for Buffer Allocation

Step 1 : BS estimates the parameters such as flow rate, queue length, number of user requests and received signal strength and updates the values periodically

Step 2 : When the buffer request packet arrives, BAF is estimated as per step 3.

Step 3 : BAF estimation involves fuzzy logic technique which takes the estimated parameters in step 1 as input and BAF values are obtained as output.

Step 4 : The user requests are sorted in the descending order of BAF

i.e. If BAF = high
Then
    Allocate the Buffer
    Buffer Allocated = (Buffer Requested by User*BAF)
    Remaining flow requests waits in a pending queue.

End if

3.3.3 Packet Dropping

After buffer allocation, when a new request arrives, the following steps are executed.

Step 1 (When a new request arrives, its BAF is estimated.)

If BAF=low
Then
    The request is rejected.
Else
    Goto step 2
End if

Step 2 (The flow requests (F_i) in the pending queue is verified for the channel condition.)

If RSS (F_i) = low
Then
Fi is dropped.
Buffer allocated for new request.
Else
New request waits in the queue.
End if

4. Simulation Results

4.1. Simulation Model and Parameters

Network simulator (NS2) [20] is used evaluate performance of the proposed Fuzzy Based Dynamic Buffer Management (FBDBM) scheme. The proposed scheme is implemented over IEEE 802.16 MAC protocol. In the simulation, clients (SS) and the base station (BS) are deployed in a 1000 meter x 1000 meter region for 50 seconds simulation time. All nodes have the same transmission range of 500 meters. In the simulation, variable CBR traffics are used. There are 8 downlink traffic flows from BS to SS. The simulation settings and parameters are summarized in Table 3.

Table 3: Simulation Settings

Area Size	1000 X 1000
Mac	802.16
Clients	10
Radio Range	500m
Simulation Time	50 sec
Routing Protocol	DSDV
Traffic Source	CBR
Physical Layer	OFDM
Channel Error Rate	0.01
Packet Size	1500 bytes
Frame Duration	0.005
Transmission Rate	250Kb,500Kb,750Kb, 1000Kb
No. of Flows	2,4,6,8

4.2 Performance Metrics

We compare our proposed FBDBM scheme with the MWRR (Mardini and Alfoul, 2011) scheme. We mainly evaluate the performance according to the following metrics:

Aggregated Bandwidth

We measure the received bandwidth (in Mb/s) for CBR traffic of all flows

Bandwidth Utilization

For each flow, we measure the utilization as the ratio of bandwidth received of each flow to the available channel bandwidth.

Average End-to-End Delay

The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Results

Effect of varying the Traffic Flows

In order to measure the impact of buffer allocation on the traffic flows, we vary the CBR downlink traffic flows from 2 to 8.

When the number of traffic flows is increased, naturally the received bandwidth should also increase gradually, as we can see from the **Figure 8**. It gives the aggregated received bandwidth for various traffic flows. From the figure, it can be seen that FBDBM has received slightly more bandwidth when compared to MWRR scheme, since buffer space is allocated based on traffic rate and queue size for each SS.

Figure 9 gives the average end-to-end delay for various traffic flows. From the figure, we can see that the average end-to-end delay of the proposed FBDBM scheme is less when compared to the MWRR scheme.

Since FBDBM allocates the buffer based on the number of user requests, it has better utilization. **Figure 10** gives the bandwidth utilization for different traffic flows. From the figure, it can be seen that FBDBM achieves better utilization when compared with MWRR scheme, while increasing the traffic flows.

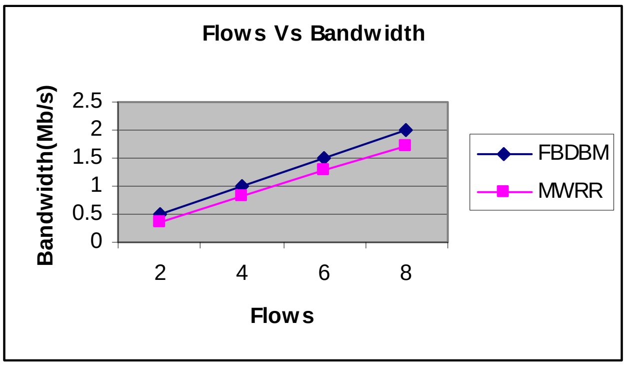


Fig 8: Flow Vs Received Bandwidth

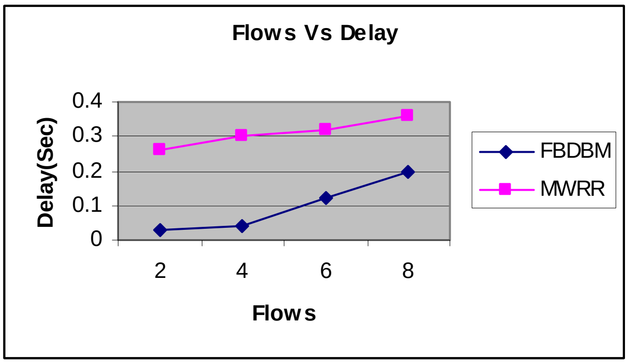


Fig 9: Flow Vs Delay

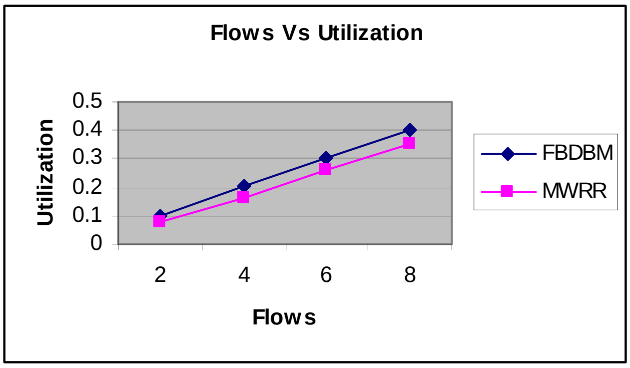


Fig 10: Flow Vs Utilization

5. Conclusion

In this paper, we have proposed a fuzzy based adaptive dynamic buffer scheme to improve Radio Resource Management (RRM) in Wimax 16m networks. The base station (BS) estimates the parameters such as number of user requests, flow rate, queue length and received signal strength and updates periodically. When a buffer request packet arrives at BS, buffer allocation factor is estimated using the fuzzy logic applied over the parameters estimated in BS. The user requests are sorted in the descending order of BAF. This reveals that the flow request with more BAF is admitted and rest of the flow requests await in queue. When a new request arrives, its BAF is tested. If the value is low, the request packet is dropped. Otherwise, the pending request packet in the queue is emptied on analyzing their channel condition and buffer is allocated for new request. By simulation results, we have shown that the proposed technique FBDBM achieves better utilization when compared with MWRR scheme, while increasing the traffic flows.

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