Fuzzy based buffer management in wireless multimedia networks

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Abstract

This paper presents 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. In this scheme, 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. Whenever a burst of data arrives and the buffers are insufficient, the scheme computes a dropping factor that uses three fuzzy parameters, namely, application priority, queue length and packet size. A buffer manager placed at the base station performs the buffer allocation as well as packet dropping. The scheme has been extensively simulated to test the performance in terms of buffer utilization, handoff/new calls acceptance and dropping probability. The results show that fuzzy based buffer allocation and packet dropping scheme performs better than conventional scheme that employs static buffer allocation and random early detection dropping strategy.

Key words: Buffer allocation; Multimedia; Fuzzy logic; Packet drop

1 Introduction

In recent years, network users are demanding mobile devices with varied services that include multimedia capabilities. Thus there is a huge market potential for wireless and mobile communication systems that employmultimedia services. Multimedia services demand real time delivery and have stringent requirements with respect to bandwidth, buffers and delays. Providing multimedia services to mobile users on unreliable and bandlimited wireless links is a tough task as compared to wired connections. Some of the important issues that arise in wireless multimedia networks are resource allocation, power management (devices have limited energy), routing, mobility management, and media synchronization.

Resource allocation is an important issue that has to be tackled to provide Quality of Service (QoS) to mobile applications. Some of the important resources are bandwidth, buffers, radio channels and computing power. In our recent work, we have addressed bandwidth allocation using fuzzy logic that borrows bandwidth from the applications that are already running in a cell for the new/handoff calls based on the fuzzy parameters such as application priority, age of the connection and bandwidth allocated during the connection time [12]. This paper deals with buffer management that performs buffer allocation and packet dropping and works in tandem with bandwidth allocation.

In certain cases, whenever bandwidth is insufficient, buffers are required to avoid packet losses. Buffers should be sufficiently more to ensure good link utilization and small to minimize queuing delays. Optimal buffers are chosen based on tradeoff of link utilization and delays. With these optimum buffers there is a demand to employ efficient and adaptable buffer allocation schemes that improve link utilization as well as keep delays as minimum as possible.

Due to finite buffers, buffer congestion may occur due to unpredictable excessive traffic that leads to dropping of packets randomly irrespective of application importance (real time or non real time). Hence there is a need for employing flexible and adaptable scheme for packet dropping, which may not deteriorate QoS of a real time application in wireless multimedia networks. Generally, dropping schemes drop the packet either randomly from the queue or at the head of queue or at the tail of queue based on queue length and priority.

Uncertainties in queue length, handoff and new call arrivals, flow rate of an application due to variable bit rate traffic and variable packet size have motivated us to use fuzzy controller for buffer allocation and packet dropping.

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Fuzzy system's characteristics are based on the concept of fuzzy partitioning of the information. The decision-making ability of the fuzzy model depends on the existence of rule base and fuzzy reasoning mechanism. The fuzzy logic solutions are better for uncertain inputs, which minimizes the random outputs. Fuzzy systems provide soft buffer allocation and packet dropping, which minimizes the burst errors in resource allocation and also provide better QoS for wireless multimedia network applications.

We have developed a fuzzy based buffer management scheme in which buffers are allocated to requesting application by using buffer allocation factor and packets are dropped for an application by using a dropping factor. A buffer allocation factor is computed adaptively based on three fuzzy parameters, priority, rate of flow and packet size. Based on allocation factor, buffers are allocated to an application. When a burst of data arrives and buffers are insufficient, the scheme computes a packet dropping factor by using three fuzzy parameters, namely, application priority, queue length and packet size. A buffer manager placed at the base station performs the buffer allocation as well as packet dropping. Our contribution in this work are as follows.

- Fuzzy parameters such as priority, packet size, rate of flow and queue length are considered for joint operation of buffer allocation and packet dropping.

- A buffer manager is developed which can do both buffer allocation and packet dropping.

- Handoff applications are given higher priority.

- Rate of flow and packet size are considered since they provide the required buffers, and

- The queue length gives the measure for buffer availability, hence dropping decisions can be based on it.

The remainder of the paper is organized as follows. In section 2, related works are reviewed. In section 3, proposed fuzzy based buffer management scheme is presented. Sections 4 and 5 discuss the simulation model and results. Finally, concluding remarks are given in section 6.

2   Related Works

Some of the works on buffer management are briefly explained in this section. Sang-Ho [27] proposes a dynamic buffer allocation scheme that allocates buffers of the minimum size in a partially loaded state, as well as in the fully loaded state. Lingxuan and Ansari [15] showed that adaptive filter based dynamic buffer allocation method provides better QoS. Hong-Soon and Je-Chan [11] present a dynamic buffer allocation scheme for non real time traffic in ATM switches that accommodate various service classes using a common buffer. A technique to reduce the waiting time portion of query processing through flexible buffer allocation is presented by Sangdon and Sukho [28].

An evaluation of a novel active queue management scheme tailored to specific characteristics of 3G links is carried out byMats and Reiner [19]. Various buffer management aspects in packet switching are presented by Pustisek and Kos [21]. Mahnoosh and Victor [18] propose a novel Head of Line Priority Cell Discard (HoL-PCD) buffer management mechanism at the earth terminal buffers of broadband satellite networks that preserves QoS for complaint traffic and improves the overall delay performance of the network. A new queue management algorithm in order to utilize high data rate efficiently in current wireless LAN is given by Yongho and Jaewoo [36]. An active queue management to limit the transmission queue length and hence queuing delay, thus eliminating expiration packet drops is discussed by Lian and Victor [5]. A random early expiration detection based buffer management algorithm for real time traffic over wireless networks is given by Yuan and Lemin [37].

Floyd and Jacobson [24] say that at any given time, RED (Random Early Detection) drops the packets of all flows with the same probability depending on queue length. RED is unfair to the flows which are low speed or have short packet length. Fuzzy based fair dropping algorithm is given by Yuan and Lemin [39] considering queue length and sharing index. Sharing index is calculated by using average queue length and present queue length in the buffer. Chonggang and Kazem [2] design an adaptive fuzzy based control algorithm, which computes the packet dropping probability according to preconfigured fuzzy logic using only queue length as input variable. Only queue length is not sufficient to describe dropping probability. Multi-rate is considered, i.e., packets with highest transmission time will be dropped with high priority so as to make efficient radio resource usage.

Subsaree and Ravichandran [30] propose a fuzzy rule base for packet discarding considering differentiated services. Rapport and Kolavennu [33] ensures guarantee of QoS requirement for handoffs by using conventional techniques that perform reservation of a fixed number of guard channels and provide a queue for handoffs. Janaki [13] performs resource allocation for non real time traffic in wireless sensor network using fuzzy logic. Dong and

Makrakis [8] replace average queue length by the product of delay and retransmission times of RTS (request to send) that is used as congestion indicator to calculate dropping probability. A RED like algorithm is proposed by Lian and Victor [16] which calculates dropping probability by using delay bounds. Yuan and Lemin [38] emphasize the influence of retransmissions for packet dropping but does not consider the channel condition variations.

Shiann andMeng [29] employed fuzzy rules to bandwidth allocation taking into consideration two fuzzy parameters such as real time application blocking probability and channel free portion. The output parameters used are switching factor and borrowing factor. The borrowing factor decides the bandwidth allocation. Giuseppe and Vincenzo [9] present a fuzzy buffer management scheme that utilizes the unused buffer for low priority traffic to maximize the throughput. Kazemian and Li [10] present a traffic-shaping buffer whose role is to prevent excessive back-to-back cells being generated during the peak transmissions of MPEG video sources using fuzzy controller. A fuzzy buffer controller is developed by Constance [6] to minimize cell loss in ATM switches, which sequences the cells in buffers based upon the corresponding priority class, end-to-end delay parameter and congestion status.

Oscar and Fransico [2O] present a evolutionary adaptive defuzzification method and their common general expression, interpretation, and accuracy. Layes and Soumya [17] explores the use of fuzzy logic for threshold buffer management in wireless ad hoc networks. The fuzzy logic is applied due to dynamic nature of buffer occupancy, congestion at a node and uncertainty of information due to network mobility. Wanqing and Weijia [35] propose an adaptive playback buffer (APB) based on the probing scheme, by which instantaneous network situations are collected, and then the delay margin and the delay jitter margin are employed to calculate the step length which is used to adjust the playback buffer in each time.

Choggang and Bo [3] propose a rate based algorithm for active queue management works in two modes: queue-independent and queue-dependent. In the queue-independent mode, it only relies on the aggregate traffic input rate to regulate the input rate to the expected value. In the queue-dependent mode, it also uses the instantaneous queue length to further adjust the packet drop probability and to regulate the queue length to the expected value. A fuzzy logic based congestion estimation with proposed QoS architecture having QoS management and control module is shown by Saad and Munir [26]. Razavi and Fleury [22] present a fuzzy logic control of ARQ (Automatic Repeat Request) based on send buffer fullness and the head-of-line packet's deadline that reduces the impact of delay causing retransmissions.

Gazi and Ghassemlooy [1] suggest that buffer space occupied by an output port decays as the queue size of the port increases and/or empty buffer space decreases, because of the threshold-based dynamic buffer management policy. Thomas and Martin [32] present an analytical model for RED performance and describes the impact of RED on the loss and delay suffered by bursty and less bursty traffic. Victor andMarty [34] investigates internet congestion control in general and RED in particular by considering traffic problems. Dhiman and Georgios [7] present different buffer sizes which can utilize high speed TCP better, the study is made for drop tail and RED active queue management. Yuan and Lemin [37] compare the performance of tail drop and three different flavors of the RED (Random Early Detection) queue management mechanism: RED with a standard parameter setting, RED with an optimized parameter setting based on TCP flows and gentle RED.

Jeong and Dong [14] propose a dynamic buffer management scheme that can be applied to TCP flow and data flow for transfer of real-time applications to provide routers with a minimum QoS, resulting less delay, reduced delay-jitter, more fairness, and smooth sending rates, TCP-Friendly rate control. A buffer management scheme for differentiated services is given by Roman and Burkhard [23], which uses the feedback parameter such as bandwidth and delay from the scheduler. Anand and Chockalingam [25] present an admission control scheme for voice and data traffic applying SIR (Signal to Interference Ratio) and showed an improvement in capacity for voice transmission.

L. A. Zadeh [40] has summarized fuzzy logic as progression from bivalent logic to fuzzy logic is a significant positive step in the evolution of science. In large measure, the real-world is a fuzzy world, fuzzy logic is likely to grow in visibility, importance and acceptance. L. A. Zadeh [41] has represented general theory of uncertainty as a significant change in both perspective and direction when dealing with uncertainty and information.

3 Proposed Work

In this section, we present a fuzzy based buffer management scheme that performs buffer allocation and packet dropping in wireless multimedia networks. The scheme considers joint problem of buffer allocation and packet dropping dynamically and continuously, which has not been addressed in the recent surveyed works. The scheme operates at the base station of a cell. The scheme considers partitioned buffers. Partitions used are normal (normally 90% of maximum buffers) and critical buffers (normally 10% of maximum buffers). The components of the scheme are shown in figure 1 which comprises of a knowledge base, buffer manager, and fuzzy based buffer allocator and
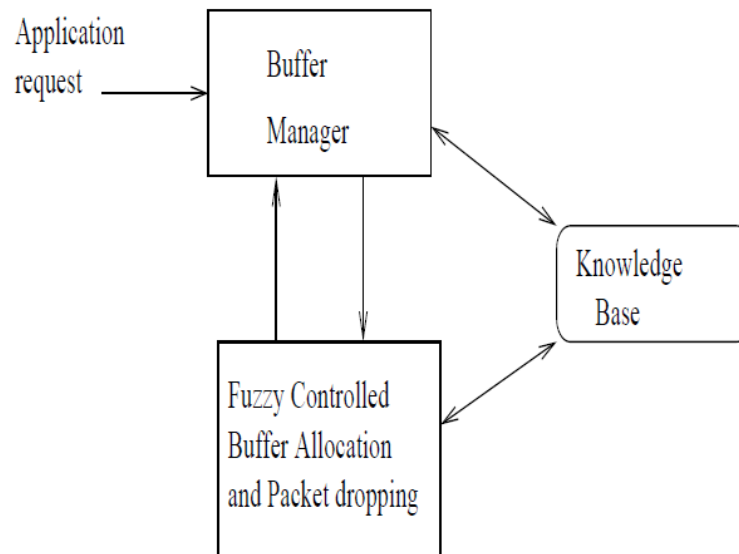
Figure 1: Fuzzy based buffer management scheme

packet dropper. The components are explained below.

- *Knowledge base*: the knowledge base can be split into two parts: base station status information and application details (see figure 2). Base station details at different time instants are stored are as follows: maximum buffers available, maximum available bandwidth, bandwidth under use, buffer under use, number of applications accessing base station, queue length and application connection identifications (ID) with a pointer to application details. Application details stored are as follows: application ID, priority, packet size, flow rate, maximum and minimum buffers required, and buffers allocated. The buffer manager utilizes this knowledge base to perform buffer allocation and packet dropping. The data in knowledge base is updated periodically depending upon the running applications' parameters, which will be used for computing buffer and bandwidth utility at the base station.

- *Buffer manager*: it receives application's connection request either from handoff/new calls with required specifications (buffers required, flow rate, priority and packet size). Handoff calls are given higher priority than new calls. Packet is either allocated buffers by using buffer allocation factor or dropped by using dropping factor. The allocation and dropping factors are computed by using a fuzzy controller. Allocation is done in normal buffers whereas critical buffers are used to store the application packets that have dropping factor above certain threshold.

- *Fuzzy based buffer allocation and packet dropping*: this component calculates the allocation factor by using three fuzzy parameters of an application such as priority, packet size and flow rate. The computed allocation factor is informed to buffer manager for further allocation decision. Whenever allocation is not possible by buffer manager, fuzzy based packet dropping is done by computing dropping factor based on three fuzzy parameters such as priority, packet size and present queue length. The dropping factor is informed to buffer manager for further dropping decision.

3.1 Fuzzy controller for buffer allocation and packet dropping

A fuzzy controller based buffer allocation factor and packet dropping factor computation is shown in figure 3. There are three steps involved in the controller such as fuzzification, inference with rule base and defuzzification. In the fuzzification step, crisp inputs are converted into linguistic values (such as low, high or medium), each of which is represented by a fuzzy set. Each fuzzy set is associated with a membership function used to characterize how certain the crisp input belongs to the set. For a given crisp input, the membership function returns a real number in the range [0,1]. The closer the membership value is to 1, the more certain the input belongs to the set. A single crisp value can take more than one linguistic value if the membership values overlap.

Base station status information

Time instant	Max buffer in packets	Max bandwidth	Buffer under use	Bandwidth under use	Queue length	Connection id	Appln count	Application details
t1	1000	5Mbps	550	15Mbps	150	20	50	●
tn−1	1000	5Mbps	800	10Mbps	200	100	150	●

Application details

Appln id	Priority	Packet size	Flow Rate	Buffer Required max	min	Buff Allocated
10	0	100	32Kbps	500	450	1Mbps
30	1	150	16Kbps	700	550	1.25Kbps

Figure 2: Knowledge Base
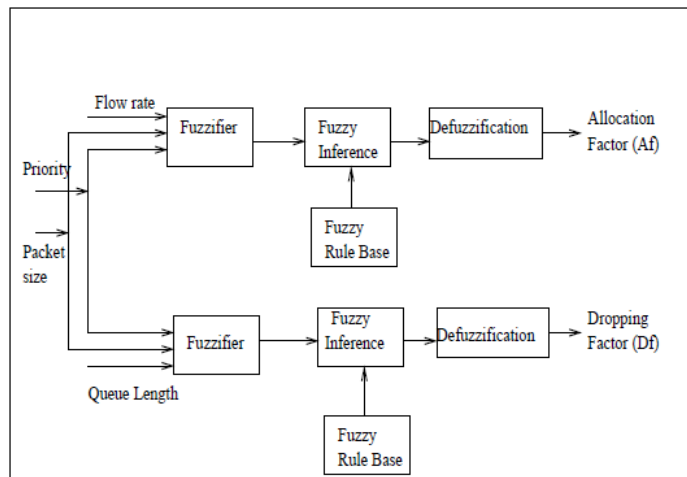
Figure 3: Fuzzy controller for buffer allocation and packet dropping

In the inference step, a set of rules called rule-base, which emulates the decision-making process of a human expert is applied to the linguistic values of the inputs to infer the output fuzzy sets which represents the actual control signal for the buffer allocation and packet dropping. The output fuzzy sets are defuzzified to generate the crisp values of allocation factor and dropping factor using centroid defuzzification method. We refer the reader to [31] for more complete background information on the fuzzy control. The proposed scheme considers flow rate, priority and packet size as fuzzy parameters for buffer allocation, whereas priority, packet size and queue length are used as fuzzy parameters for packet dropping. The computation of allocation factor and dropping factor are explained as follows.

3.2   Fuzzy based buffer allocation factor computation

Fuzzy based buffer allocation factor considers three input parameters for fuzzification: priority of an application (P), packet size of an application (PS) and the rate of flow of an application (R). The output parameter is the buffer allocation factor for an application that is computed based on input parameters and inference engine.
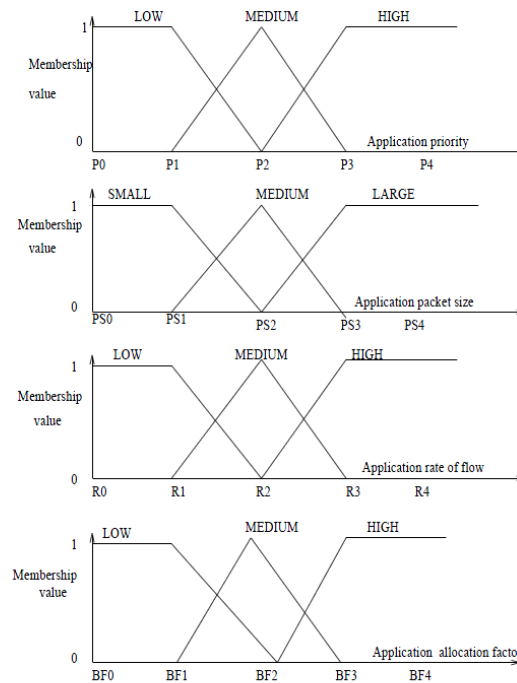
Figure 4: Membership function for input and output fuzzy parameters for buffer allocation

3.2.1   Fuzzification

Membership functions G(P), G(PS), G(R) and G(AF) for each of the considered fuzzy parameters priority, packet size, rate of flow, and allocation factor, respectively, are depicted in figure 4 along with the linguistic values. Each of the fuzzy parameter is represented by triangular membership function [42], since it represents minimum and maximum boundary conditions. The triangular membership become convenient, when the fuzzy parameters are more than one or two. It also helps in reducing the complexity of the computation. The membership to each of fuzzy variables is assigned using intuition method.

- *Priority (P)*. Priority is used to describe type of an application (handoff/new call). Priority is assigned with the linguistic values associated with certain membership; low (P0 to P2), medium (P1 to P3) and high (P2 to P4).

- *Packet size (PS)*. There are different packet sizes used by each application. This demands varied buffer allocations in the buffer for each application. The range of variations in the packet sizes are represented with three linguistic values associated with certain membership; small (PS0 to PS2), medium (PS1 to PS3) and large (PS2 to PS4). Packet size is initially negotiated during call request, later it changes with time due to type of data and application coding.

- *Rate of flow (R)*. Each application has different flow rate based on the requirements. The range of variations in the rate of flow is represented by linguistic values associated with certain membership; low (R0 to R2), medium (R1 to R3) and high (R2 to R4). This parameter is initially based on the requirements of a flow, later it changes with time.

- *Allocation factor (AF)*. Output of three input linguistic value is allocation factor. The allocation factor is represented by linguistic values associated with certain membership;low (AF0 to AF2), medium (AF1 to AF3) and high (AF2 to AF4).

The fuzzy buffer allocation scheme forms a fuzzy set of dimension G(P)*G(PS)*G(R). The values assigned to fuzzy variables depend on the network administrator, i.e., he/she can assign the different values at different instants of time subjected to network conditions.

Priority	Rate of flow	Packet size	Allocation factor
HG	HG	LR	HG
HG	HG	ME	HG
HG	HG	S	HG
HG	ME	LR	ME
HG	ME	ME	ME
HG	ME	S	ME
HG	LO	LR	ME
HG	LO	ME	ME
HG	LO	S	ME
ME	HG	LR	ME
ME	HG	ME	ME
ME	HG	S	ME
ME	ME	LR	ME
ME	ME	ME	ME
ME	ME	S	ME
ME	LO	LR	LO
ME	LO	ME	LO
ME	LO	S	LO
LO	HG	LR	ME
LO	HG	ME	ME
LO	HG	S	ME
LO	ME	LR	LO
LO	ME	ME	LO
LO	ME	S	LO
LO	LO	LR	LO
LO	LO	ME	LO
LO	LO	S	LO

HG−High ME−Medium LO−lowLR−Large S−Small

Figure 5: Fuzzy rule base table for buffer allocation

3.2.2 Inference and defuzzification

Since there are three input linguistic values P_k, PS_k and R_k, thus the total number of rules will be 27. The fuzzy rule base with 27 rules is shown in figure 5. The fuzzy rules are normally chosen based on the experimental data and the traces. We have chosen the fuzzy rules based on the intuition and the network simulation runs in various environments.

If the condition is true, we call the rule as being active. Each rule i is written as follows. For example, Rule i: IF P_k is *low* and R_k is *low* and PS_k is *small*, THEN $AF_K = low$.

AF_K linguistic values are decided based on membership functions G(P), G(R), and G(PS). To decide an appropriate output membership function, the strength of each rule must be considered. For this reason, the output membership function is a complicated function and center of area method [31] is used for defuzzification. This method finds the center point of the fuzzy output membership function, which is used for allocating buffer for requesting application. As a result, the application QoS is maintained.

To illustrate defuzzification, let us consider an application with high priority, large packet size and high flow rate. Assume that all the values are normalized between 1 to 10 and priority = 8, packet size = 9 and rate of flow = 9. The membership values for each parameter is shown in figure 6. By using center of gravity method, defuzzified value for allocation factor can be computed.

Defuzzified output Z_* is calculated by using equation 1.

$$\frac{\int_{x1}^{x2} \mu(z) * z dz + \int_{x2}^{x3} \mu(z) * z dz + \int_{x3}^{x4} \mu(z) * z dz}{\int_{x1}^{x2} \mu(z) dz + \int_{x2}^{x3} \mu(z) dz + \int_{x3}^{x4} \mu(z) dz} \tag{1}$$
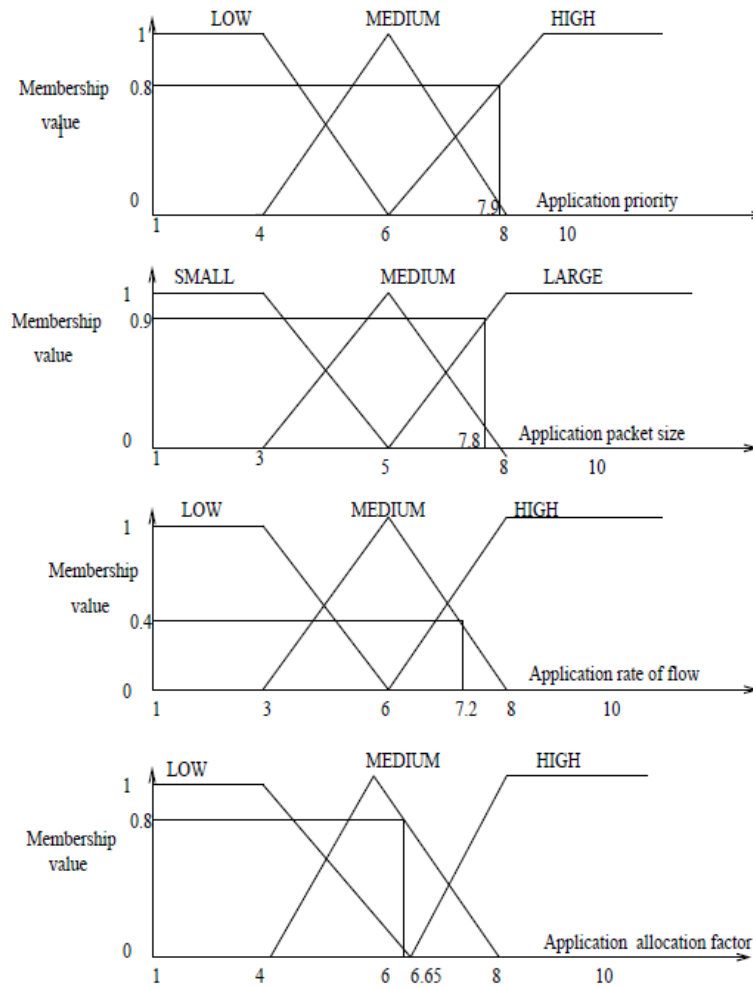
Figure 6: Defuzzified example for buffer allocation

Where $\mu(z)$ with boundary conditions x1 and x2, $\mu(z)$ with boundary conditions x2 and x3, $\mu(z)$ with boundary conditions x3 and x4, represent membership values for priority, packet size and rate of flow, respectively. Substituting the values by using figure 6, we obtain as follows.

$$\frac{\int_0^7 0.4zdz + \int_7^8 0.8zdz + \int_8^9 0.9zdz}{\int_0^7 0.4dz + \int_7^8 0.8dz + \int_8^9 0.9dz} \qquad (2)$$

By solving equation 2, we obtain Z_* equal to 6.65, which is the defuzzified output representing allocation factor. This value will be later denormalized. The fuzzy based allocation gives flexibility to the network administrator to perform soft buffer allocation.

3.3   Fuzzy based dropping factor computation

3.3.1   Fuzzification

Fuzzy based packet dropping scheme considers three parameters for fuzzification: priority of an application (P), packet size of each an application (PS) and the queue length (Q). The output of linguistic parameter is the packet dropping factor of an application. The membership to each of fuzzy variables is assigned by using intuition method. For each of the considered fuzzy parameter, their range of linguistic values are depicted in figure 7.

- *Priority*. This parameter is similar to the one discussed earlier in section 3.2.1.

- *Packet size*. This parameter is similar to the one discussed earlier in section 3.2.1.
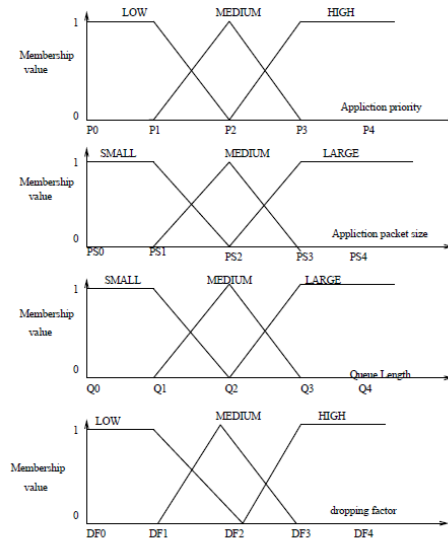
Figure 7: Membership function for input and output fuzzy parameters for packet dropping

- *Queue length (Q).* This is also an important parameter to be considered for packet dropping. As queue length increases, the dropping increases in critical conditions. Hence dropping factor is directly proportional to queue length. It is represented with triangular membership function with minimum and maximum boundary functions. The queue length is represented by linguistic values associated with certain membership; low (Q0 to Q2), medium (Q1 to Q3) and high (Q2 to Q4).

- *Dropping Factor (DF).* Output of the three input linguistic values is dropping factor. The dropping factor is also represented by triangular membership function. The dropping factor is represented by linguistic values associated with certain membership; low (DF0 to DF2), medium (DF1 to DF3) and high (DF2 to DF4).

3.3.2   Inference and defuzzification

Since there are three linguistic values P, PS and Q, the total number of rules is 27. DF linguistic value is decided based on membership functions of input fuzzy parameters. To decide an appropriate output crisp value for DF, we consider the center of gravity method [31]. The fuzzy rule base is given in figure 8.

To illustrate the defuzzification let us consider application with high priority, large packet size and high queue length. All the values are normalized between 1 to 10 and priority = 6, packet size = 6 and queue length = 7. All these are having membership values as shown in the figure 9. Using center of gravity method, defuzzified value for dropping factor is found out similar to allocation factor as discussed in earlier section.

Defuzzified output Z_* is calculated by using equation 3.

$$\frac{\int_{x1}^{x2} \mu(z) * zdz + \int_{x2}^{x3} \mu(z) * zdz + \int_{x3}^{x4} \mu(z) * zdz}{\int_{x1}^{x2} \mu(z)dz + \int_{x2}^{x3} \mu(z)dz + \int_{x3}^{x4} \mu(z)dz} \tag{3}$$

Where $\mu(z)$ with boundary conditions x1 and x2, $\mu(z)$ with boundary conditions x2 and x3, $\mu(z)$ with boundary conditions x3 and x4, represent membership values for priority, packet size and queue length, respectively. Substituting the values, we get the equation 4.

$$\frac{\int_0^4 0.5zdz + \int_4^6 0.9zdz + \int_6^7 0.4zdz}{\int_0^4 0.5dz + \int_4^6 0.9dz + \int_6^7 0.4dz} \tag{4}$$

The defuzzified output is around 4.8. The fuzzy based dropping provides flexibility to the network administrator to perform soft packet dropping.

Priority	Queue Length	Packet size	Dropping factor
HG	LR	LR	LO
HG	LR	ME	LO
HG	LR	S	LO
HG	ME	LR	LO
HG	ME	ME	LO
HG	ME	S	LO
HG	S	LR	LO
HG	S	ME	LO
HG	S	S	LO
ME	LR	LR	ME
ME	LR	ME	ME
ME	LR	S	ME
ME	ME	LR	ME
ME	ME	ME	ME
ME	ME	S	ME
ME	S	LR	LO
ME	S	ME	LO
ME	S	S	LO
LO	LR	LR	HG
LO	LR	ME	HG
LO	LR	S	HG
LO	ME	LR	HG
LO	ME	ME	HG
LO	ME	S	HG
LO	S	LR	ME
LO	S	ME	ME
LO	S	S	ME

HG−High ME−Medium LO−Low: LR−Large S−Small:

Figure 8: Fuzzy rule base table for packet dropping
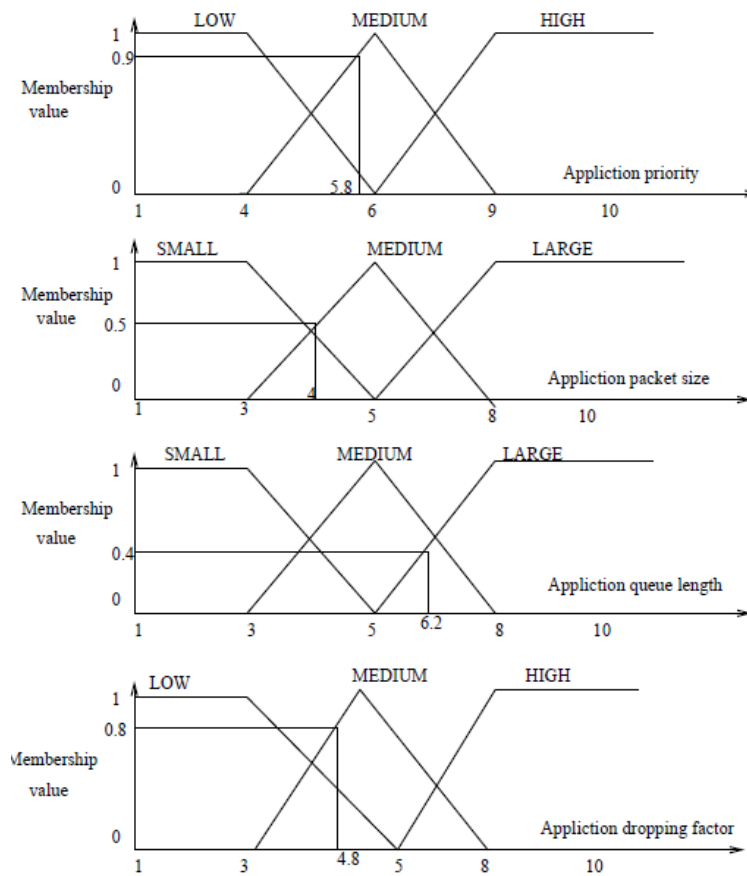
Figure 9: Defuzzified example for packet dropping

4 Algorithms

This section presents the pseudocode for functioning of the proposed scheme. Algorithm depicts the functions of a buffer manager when an application packet arrives whereas Algorithms 1a and 1b present the working of fuzzy controller that computes buffer allocation and packet dropping factors.

Algorithm 1 : Buffer manager

{Nomenclature: bw req = bandwidth required (rate of flow), P = priority of an application (based on handoff and new applications), PS = packet size, buf req = buffers requested by user, buf alloc = buffers allocated, DF tshld = dropping threshold, AF = allocation factor, DF = dropping factor, qlen = queue length.}

begin

1. Receive an application packet request for transmission with specifications: bw req, P, PS, and buf req;

2. If normal buffers are available then compute the allocation factor (AF) for application with required specifications using Algorithm 1a; allocate the buffers, buf alloc = buf req*AF;

3. If normal buffers are not available and critical buffers available, then compute the dropping factor (DF) using Algorithm 1b; drop the packet if DF is greater than DF tshld otherwise allocate in critical buffers, where buf alloc = buf req; goto step 5;

4. If normal and critical buffers are not available then drop the packet;

5. Stop.

end

Algorithm 1a : Computation of allocation factor

{Nomenclature: Similar to Algorithm 1}.

begin

1. Receive request from buffer manager with application packet specifications;

2. Initialize fuzzy controller with fuzzy values P, bw req, and PS;

3. Find the membership value of P, bw req, and PS;

4. Compute AF by using inference, rule base and defuzzification;

5. Return AF;

end.

Algorithm 1b : Computation of dropping factor

{Nomenclature: Similar to Algorithm 1}.

begin

1. Receive request from buffer manager with application packet specifications;

2. Initialize fuzzy controller with fuzzy values P, Q, and PS;

3. Find the membership value of P, Q and PS;

4. Compute DF by using inference, rule base and defuzzification;

5. Return DF;

end.

4.1 Benefits of the scheme

By adopting fuzzy controller in wireless multimedia network, there are many benefiting issues such as.

1. Efficient buffer utilization and low packet dropping.

2. Prioritize scaling for handoff calls than the new calls.

3. Smooth control of buffer utilization and handoff calls acceptance.

4. More than one parameter can be involved controlling buffer utilization, acceptance and dropping of the calls.

5 Simulation

The simulation of proposed work is carried out by using C programming language in different network scenarios on a pentium IV machine. In this section, we describe the network model, fuzzy model, traffic model and channel model.

Network model

A cell covers an area of $X * Y$ sq. kms. Base station is located at some median point of the area. The given area is divided into several grids of area $W * Z$ sq. ms. Some fraction f of the grids in the area are considered to be blocking areas (connection cannot be established in such areas), and f is randomly distributed between $f1$ and $f2$. n mobile nodes are randomly placed in the cell and classified as nodes within the cell or coming from the adjacent cells. Mobile nodes are randomly placed in grids within the cell with probability nin and adjacent cells with probability $1 - nin$. Maximum bandwidth of a cell is assumed to be bw_m. Maximum buffer size at the base station of the cell is assumed to be bu_m Gbytes. Maximum buffer size is divided into two regions: normal region of size bu_n Gbytes and critical region of size bu_c Gbytes.

Channel model

Channel is divided into fixed lengths and each length consist of C time slots. Each time slot can be used by either new calls, handoff calls and existing calls. Errors in the channel are modeled by using probability, i.e., probability of receiving correctly is given as $psend$ and probability of receiving error data is denoted as $1 - psend$.

Traffic model

num applications may be generated by the mobile nodes that arrive at a given instant of time. Buffer request by each application is bu_{req}.

Fuzzy model

The fuzzy parameters for allocation factor and dropping factor are given as below. Application request with different priorities are: P0 to P2 as low, P1 to P3 as medium and P2 to P4 as high. Rate of flow of data is randomly distributed between R0 to R2 as low, R1 to R3 as medium and R2 to R4 as high. Packet size of each application is randomly distributed between PS0 to PS2 as small, PS1 to PS3 as medium and PS2 to PS4 as large. Buffer queue length ranges from Q0 to Q2 as small, Q1 to Q3 as medium and Q2 to Q4 as large. The allocation factor is given by AF0 to AF2 as low, AF1 to AF3 as medium and AF2 to AF4 as high. The dropping factor is given by DF0 to DF2 as low, DF1 to DF3 as medium and DF2 to DF4 as high.

Simulation procedure
Simulation procedure is as follows.
Begin
1. Generate a wireless network of mobile nodes within the cell and outside the boundary of the cell.
2. Generate the traffic.
3. Apply the proposed scheme.
4. Compute the performance parameters of the system.
End.
Performance parameters
The performance parameters measured are as follows:

- Buffer utilization: It is defined as the ratio of buffers utilized to the maximum size of buffers available at base station.

- Handoff calls accepted: It is defined as the ratio of handoff calls accepted to the total handoff calls arrived at the base station.

- New calls accepted: It is defined as the ratio of new calls accepted to the total new calls arrived at the base station.

- Dropping probability: It is defined as the ratio of packets dropped to the total number of packets arrived at the base station.

Simulation inputs
We consider the following inputs for simulation to present the results. X = 5 kms., Y = 10 kms., $W = 10$ mts., $Z = 10$ mts., $f1 = 10\%$, $f2 = 20\%$ n = 500, nin = 0.75, num = 500, $bw_m = 20$ Mbps, bw_req = 5 to 30 Mbps, bu_m = 20 to 40 Gbytes, bu_n = 80% of bu_m, bu_h = 20% of bu_m, bu_{req} = 2 to 5 Mbytes.

Fuzzy inputs: P0 = 1, P1 = 4, P2 = 5, P3 = 8, P4 = 10, R0 = 1 Mbps, R1 = 1.5 Mbps, R2 = 2 Mbps, R3 = 2.5 Mbps, R4 = 3 Mbps, PS0 = 1 Kbyte, PS1 = 1.1 kbyte, PS2 = 1.2 kbyte, PS3 = 1.3 kbyte, PS4 = 1.4 kbyte, AF0= 0, AF1 = 0.2, AF2 = 0.4, AF3 = 0.6, AF4 = 0.8, DF0 =0.0, DF1 = 0.3, DF2 = 0.5, DF3= 0.7, DF4 = 1.0.

6   Results

This section presents the performance of fuzzy based buffer management scheme by comparing with static buffer allocation (abbreviated as Nonfuzzy in figures 10 to 15) scheme. Also, packet dropping results of the proposed scheme are compared with RED scheme. The performance evaluation is carried out for two cases of buffer capacities (20 and 40 Gbytes).

The buffer utilization for different call arrivals is shown in figure 10. The fuzzy scheme results are better than the nonfuzzy scheme as the call arrivals increase. This is because, fuzzy based allocation factor makes better buffer utilization due to soft allocation nature.

The buffer utilization as function of time is shown in the figure 11. This performance study shows that variation in the buffer utilization is smooth in the case of fuzzy scheme rather than nonfuzzy scheme, which helps in soft controlling of the system.

The acceptance of handoff calls is high in case of fuzzy scheme than the nonfuzzy scheme as observed in figure 12 since handoff calls are given higher priority and critical buffers may be utilized to save the packets.

Figure 13 shows acceptance probability of handoff calls as function of time. There is less space for controlling of acceptance at every time instant in case of fuzzy scheme compared to nonfuzzy scheme, hence reducing the overheads of controller.

We observe from figures 14 and 15 that acceptance of new calls in fuzzy scheme is more compared to nonfuzzy scheme. It is also seen that the variation in acceptance of new call with respect to time is less, hence fuzzy scheme is more stable.

Figures 16 and 17 depicts percentage of dropping probability with respect to call arrivals and time. We observe that packet dropping is less compared to random early detection scheme. The variations in percentage of dropping probability with respect to time are less in the fuzzy scheme.
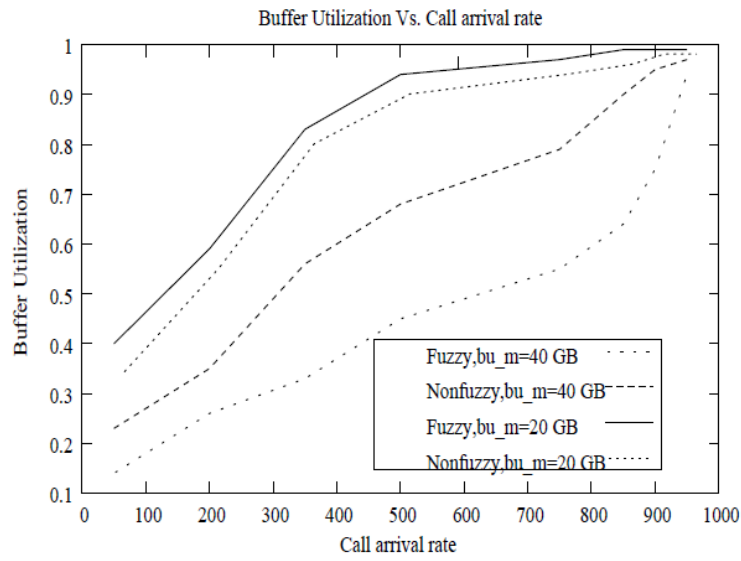
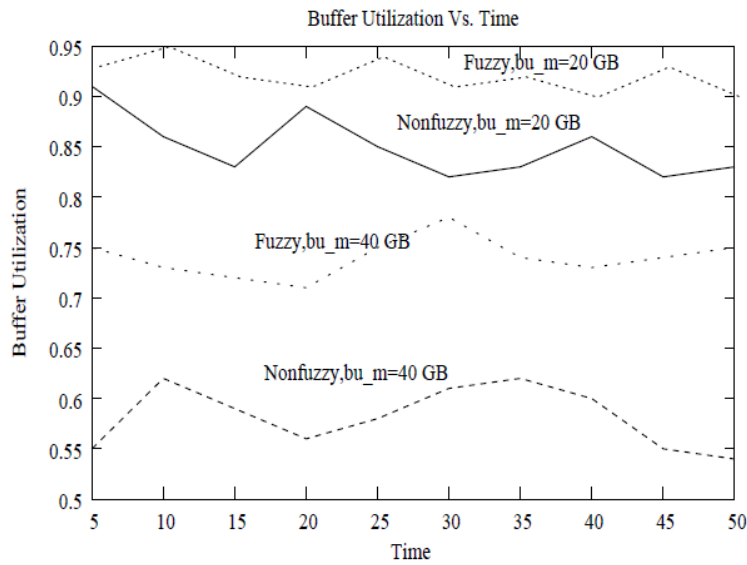Figure 10: Buffer utilization .Vs. Call arrival rate

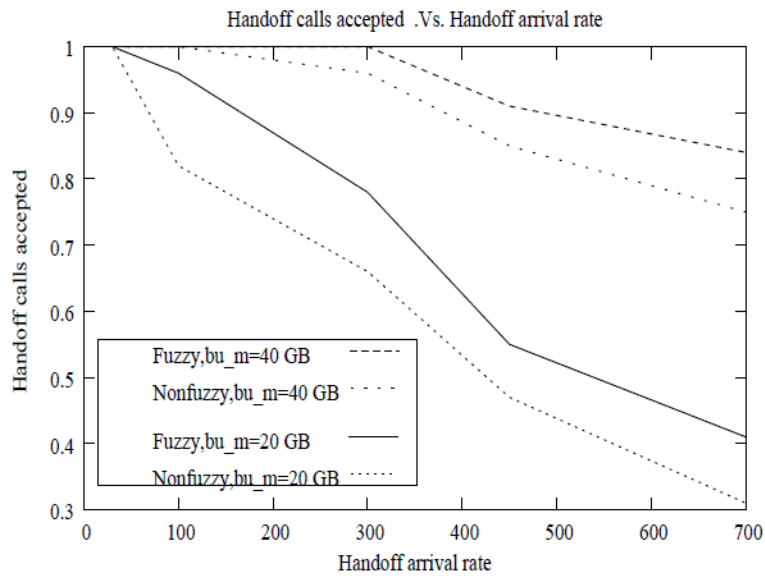Figure 11: Buffer utilization .Vs. time

Handoff calls accepted .Vs. Handoff arrival rate

Figure 12: Handoff calls accepted .Vs. Handoff calls arrival rate.

7   Conclusions

The fuzziness in the QoS parameters of the wireless multimedia network are identified and used in buffer alloca-
tion and packet dropping strategies. This reduces problems such as unnecessary packet dropping, inefficient buffer
utilization, inefficient bandwidth utilization, etc. In this paper, we have proposed a scheme for buffer management
that does buffer allocation and packet dropping for multimedia applications by using fuzzy logic. The main objec-
tive of the proposed work is to use the base station buffers efficiently and decrease the packet dropping especially
for handoff calls. One important characteristic of our fuzzy based buffer allocation and packet dropping scheme
is that allocation and dropping is done by buffer manager looking at fuzzy parameters priority, packet size, rate
of flow and queue length. Extensive simulation results reveal that proposed scheme features low call dropping
probability, good buffer utilization and better handoff and new calls acceptance. Scheme shows that utilization,
acceptance and dropping do not vary much with time using fuzzy logic. The scheme can be extended to perform
buffer allocation and packet dropping by considering the importance of an application such as defense calls, VIP
calls, etc., apart from the real-time and non real-time characteristics of an application.
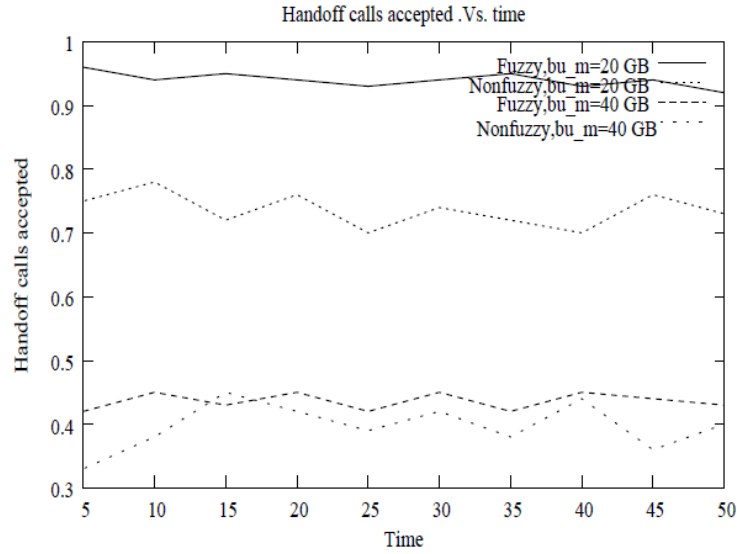
Handoff calls accepted .Vs. time

Figure 13: Handoff calls accepted .Vs. time.
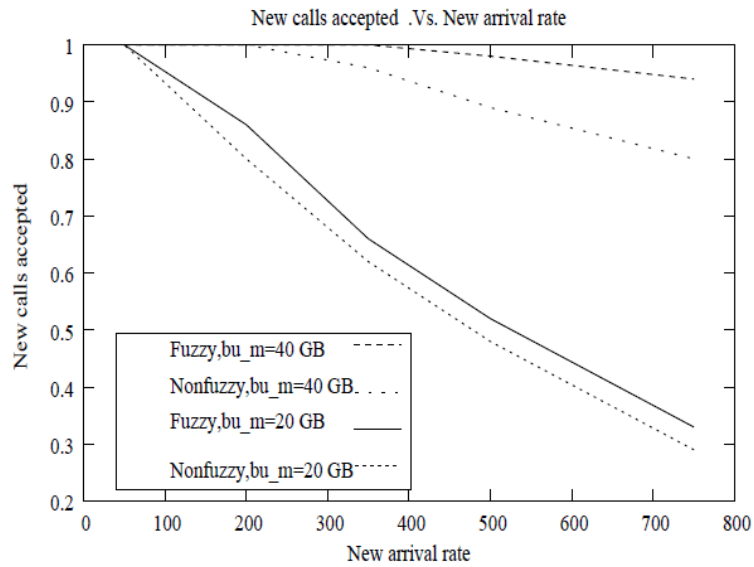
New calls accepted .Vs. New arrival rate
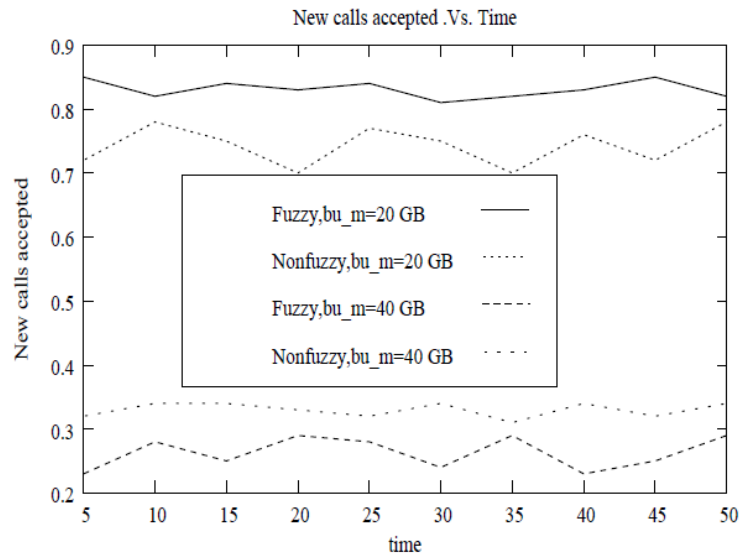

Figure 14: New calls accepted .Vs. New calls arrival rate

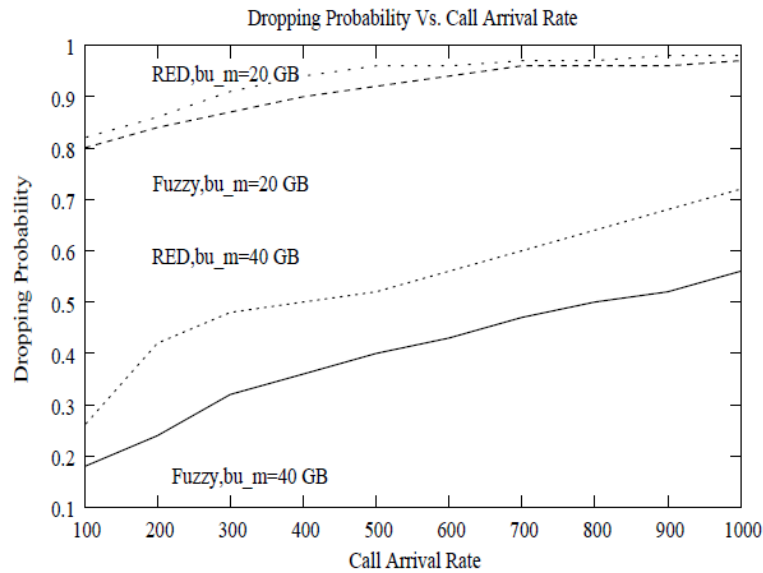Figure 15: New calls accepted .Vs. Time

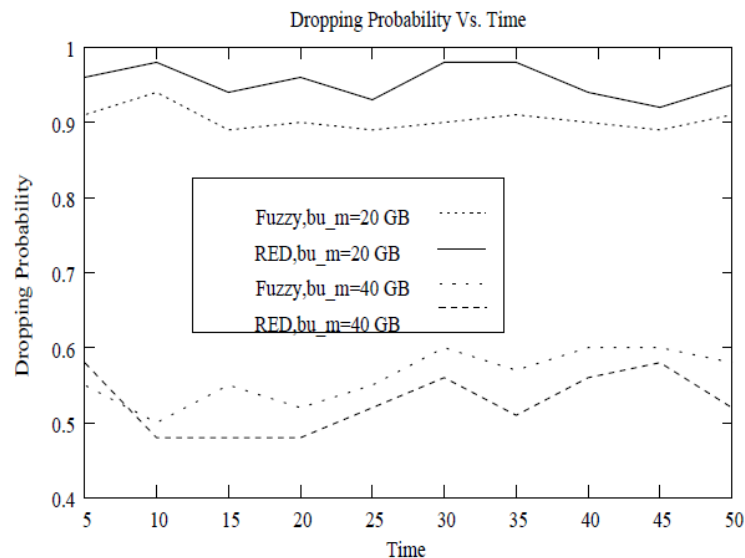Figure 16: Dropping Probability .Vs. Call arrival rate

Dropping Probability Vs. Time

Figure 17: Dropping Probability .Vs. time

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