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Enhanced Call Admission Control based on History in BWA Networks

Dr. A. Christy Jeba Malar[1] and Dr. M. Deva Priya[2]
[1] Assoc. Professor, Sri Krishna College of Technology/IT Department, Coimbatore, Tamil Nadu, India
Email: a.christyjebamalar@skct.edu.in
[2] Assoc. Professor, Sri Eshwar College of Engineering/CSE Department, Coimbatore, Tamil Nadu, India
Email: devapriya.m@sece.ac.in

Abstract: WiMAX is a wireless technology that supports many blooming applications. To efficiently assign resources to traffic flows, bandwidth allocation and Connection Admission Control (CAC) modules are included in MAC layer and Burst Allocation (BA) module is added to PHY layer. It is essential to lessen delay and effectively schedule requests for BA. In this paper, CAC-based on History (CACH) and scheduler based on Delay Tolerance (SDT) for BA are proposed for WiMAX networks. CACH accepts/ rejects connections based on values in Contention Window (CW) in former Time Frame (TF). SDT and a Bucket-based BA (BBA) assign resources to flows with least amount of DT. Performance is analyzed based on throughput, Packet Loss Ratio (PLR) and delay.

Index Terms: WiMAX, Contention Window, Contention Delay, Delay Tolerance, Traffic Priority, Connection Admission Control, Burst Allocation

I. Introduction

Worldwide Interoperability for Microwave Access (WiMAX) facilitates ubiquitous distribution of wireless broadband service for fixed or mobile users [1, 2]. The forum supports IEEE 802.16 standards for offering Broadband Wireless Access (BWA). IEEE 802.16 standard offers Line of Sight (LoS) communication at 10 - 66 GHz frequency bands [3]. IEEE 802.16a supports non-LoS (NLoS) mode in the frequency range 2 - 11 GHz [4].

WiMAX grants resources in 2 ways. Bandwidth may be allocated using one of the modes namely: Grant Per Connection (GPC) and GP Subscriber Station (GPSS) [5, 6].

- **GPSS:** BS assigns a share of resources to a Mobile Station (MS) with several connections. The MS is responsible for assigning resources to distinct connections, satisfying QoS demands as well as priority agreements. The scheduler takes control of order in which services are offered to connections. It is suitable for real-time applications which are delay-sensitive.
- **GPC:** In this mode, BS individually offers bandwidth to every connection. It is appropriate for a MS involving reduced amount of connections. Requests are piggybacked to data which is forwarded and is appropriate for Point-to-Multipoint (PMP) as well as mesh modes. Extra bandwidth is consumed to deal with Radio Link Control (RLC) demands of MS.

GPSS is better in contrast to GPC mode [7].

In this paper, CAC-based on History (CACH) and Scheduler based on Delay Tolerance (SDT) and Bucket-based Burst Allocator (BBA) are proposed. The CACH module focuses on call acceptance or rejection based on Contention Delay (CD). SDT takes DT of traffic into consideration and BBA assigns resources by prioritizing flows with minimum DT. They are closely coupled and are inseparable. Burst profiles are negotiated with BS.

II. Related Work

In this section, works related to CAC and BA in WiMAX networks are detailed.

Mamman et al (2017) [8] have propounded Adaptive CAC along with bandwidth reservation for downlink LTE networks. It focuses on offering efficient use of resources to evade starvation of BE traffic. The proposed mechanism includes dynamic threshold that regulates network resources under dense traffic. Reservation as well as degradation method to accept users with restricted amount of bandwidth is also achieved. It uses Call Blocking Probability (CBP) as well as Call Dropping Probability (CDP) with dynamic threshold for regulating network status. Finally, it uses analytical model using Markov chain for measuring performance of propounded mechanism. The scheme admits calls effectively and guarantees QoS to all kinds of traffic.

Al-Maitah et al (2018) [9] have proposed Dynamic Weighted Round Robin-CAC (DWRR-CAC) mechanism that focuses on reducing blocking rates of connections. But it wastes resources owing to fixed reservation as well as employed degradation schemes. The proposed algorithm deals with resource wastage by including pre-check, adaptive degradation and weight computation scheme. It accepts connections depending on Maximum Sustained Traffic Rate (MSTR) in case resources are under-utilized. It admits queued connections based on WRR weight. When resources are not adequate to accept new connections, it uses a pre-check scheme to find whether non-UGS connections which degrade offer necessary bandwidth for admitting connections. It admits connections depending on WRR weight. The proposed scheme offers improved call blocking rate and mean throughput.

Gupta et al (2020) [10] have proposed Fuzzy Game based Channel Allocation (FGCA), a hybrid multi-channel assignment formulated using Game Theory (GT) scheme. Fuzzy-based systems may be used for eliminating approaches that are unrealistic. The proposed optimization mechanism focuses on channel allocation using Fuzzy GT (FGT). FGCA diminishes channel interference and improves complete performance of WiMAX system based on factors

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like channel acquisition delay, utilization and mean throughput.

Ababneh (2021) [11] have proposed Joint Routing and Rate Assignment Protocol (JRRA) for offering better utilization as well as throughput. The proposed routing scheme involving fully distributed ST is bandwidth-aware. The protocol offers maximum remaining capacity routes and guarantees improved data rates thus offering better throughput, capacity as well as fairness. The problem is expressed as Mixed Integer Linear Program (MILP) which improves system efficacy by offering improved QoS. It allocates resources to nodes fairly based on needs as well as priorities.

Taranum (2022) [12] focuses on mobility in an environment with multiple cells where an MS moves from a Base Station (BS) to another based on signal quality. The main aim is to sustain connectivity in heterogeneous network for which thresholds based on Receiver Signal Strength (RSS) are determined. Performance is analyzed in terms of throughput determined using RSS for diverse data rates, mean jitter and delay.

Bandwidth allocation in WiMAX networks dismisses association amid self-centered Service Providers (SPs). Maher et al (2022) [13] have offered Semi-Dynamic Bandwidth Allocation (S-DBA) scheme which determines interest points during the process of integration. In auction-based scheme, optical line terminal implements auction allocate most eminent bidders depending on available bandwidth. The proposed approach uses Stackelberg and coalition game based on throughput as well as delay. Auction on bandwidth need not be repeated in successive short duration, particularly user demands do not vary rapidly.

It is not essential to link a user to a neighboring Relay Station (RS). Banna (2022) [14] has considered standards to improve network efficiency in terms of throughput, network delay and interference while assigning link between MS and RS. The algorithm forms a tree which directs communication amid MS and BS through RS in a multi-hop network. An algorithm that focuses on balancing load amid RSs is proposed along with directing radiations of MSs based on path of minimum interference. The proposed scheme offers improved throughput and reduced delay.

Zou et al (2023) [15] have dealt with optimization of resource organization for supporting adapted service slicing and placing functions produced by varied devices into existing resources. The combinatorial optimization problem is handled by designing Particle Swarm Optimization (PSO)-based scheduling approach based on improved inertia weight, particle disparity as well as non-linear learning factor, thus balancing local as well as global solutions and increasing speed of convergence to global near-ideal solutions. It includes Random Walk (RW)-based model developed with adjustable step size, non-linear learning factor and inertia weight for improving particle survivability, variability and adaptation. The proposed scheme involves better convergence speed as well as efficient use of resources in contrast to variations of PSO.

III. Call Admission Control (CAC)

Decision to make call admissions depending on traffic descriptor specifies traffic features and QoS demands. CAC module focuses on rejecting calls when incoming as well as outgoing traffic exceeds pre-specified thresholds. It offers assured signal quality, Call Dropping Probability (P_D), prioritization to various categories of traffic, maximum revenue, fair resource sharing, rate of transmission as well as packet-based QoS.

BS defines contention period during which MS forwards bandwidth requests. When more than one MS contends for medium and sends requests simultaneously, collision occurs. Contention Window (CW) includes slots for packets which wait for getting into medium. It holds packets until the medium is free. The amount of contention slots represents chances given to MS for sending requests. The MS waits for pre-set amount of slots for receiving Uplink (UL) maps and gets to back-off process. Contentions are resolved depending on Truncated Binary Exponential Backoff (TBEB). CD refers to interval amid packet arrival time at Head of Queue (HoQ) and time at which it is sent on PHYsical medium. It depends on contention features of channel existing between adjoining nodes.

CACH considers former CW (CW_{PRE}) values, determines present values and accepts MSs with improved (CW_{CUR}) values.

IV. CAC Based on History (CACH)

A call is accepted only when it does not lead to deterioration of QoS of calls prevailing in network. Once bandwidth is assigned to every flow, scheduled calls in every flow are admitted based on the fact that accepting it does not lead to increased CD. CAC depends on available bandwidth. Checking availability of remaining bandwidth is not adequate for accepting calls. Channel should be verified for collision as CD increases when medium is fully occupied.

CACH framework admits requests for establishing connection from every service flow, verifies CW and decides whether to accept or reject calls. CACH accepts calls based on demand of resources, traffic behavior, availability, network conditions as well as CD.

CACH Policy

CW comprises of values of CD. Requests from MSs involving less CD are included in the medium. Requests from MSs with '$CD < CD_{TH}$' are only accepted. CD differs based on kinds of request made by MS. Time for servicing a request differs based on flow type. Figure 1 shows complete flow of CACH module.

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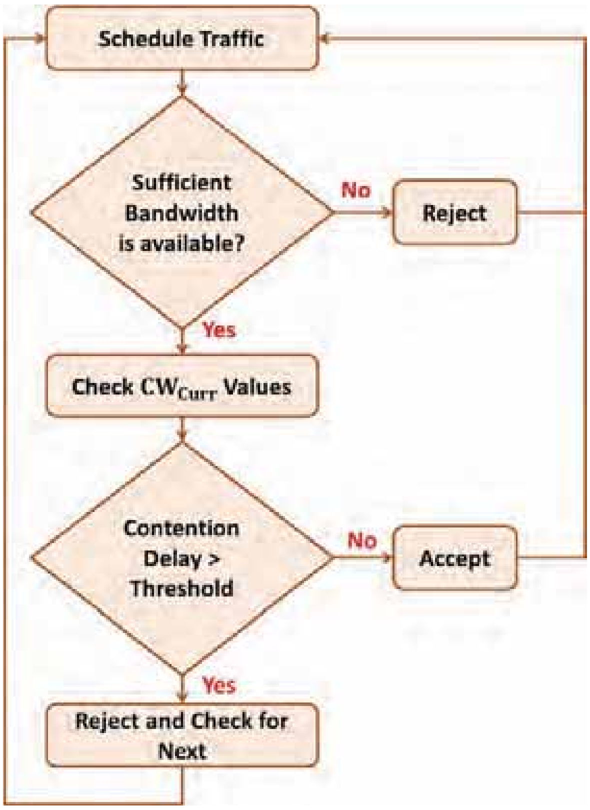

Figure 1. CACH Policy

MAC agent copies Variance of CD (CD_{VAR}) from fragment to packets. During fragmentation, the MAC agent selects contention sample from last fragment and copies from packet. Deviation of ‘CD’ can be found at a MS. Timestamp is involved in process of fragmentation to maintain ‘CD’ of fragment in contemporary MS. ‘CD_{VAR}’ is stored in fragment and ‘n^{th}’ or ‘n^{th}_{CURR}’ MS copies mean value into ‘ACK’ from segment. As value of ‘CD_{Var}’ increases, the probability of contention also increases. ‘CD’ increases with MAC contention and Retransmission Time Out (RTO) is triggered with packet losses.

Let ‘n_{Max}’ represent maximum quantity of MSs and ‘n_{Curr}’ represents quantity of MSs presently serviced by BS. There are chances for ‘n_{Curr}’ to be more than ‘n_{Max}’. This happens when MSs enter range of BS and maximum quantity of MSs is surpassed. When number of users increase, network will not be capable of including MSs. This increases quantity of requests competing for medium, thus raising the value of ‘CD’.

‘VCD’ is computed from past values.

$$E_{Curr} = \frac{(n_{Curr}-1).E_{Prev} + CD_{Curr}}{n_{Curr}} \quad (1)$$

if $n_{Curr} < n_{Max}$

$$VCD_{Curr} = \frac{(n_{Curr}-1)(V_{Prev} + E^2_{Prev}) + CD^2_{Curr}}{n_{Curr}} - E^2_{Curr} \quad (2)$$

$$E_{Curr} = E_{Prev} + \frac{CD_{Curr} - CD_{Prev}}{n_{Max}} \quad (3)$$

if $n_{Curr} \geq n_{Max}$,

$$VCD_{Curr} = \frac{n_{Max}\,(V_{Prev} + E^2_{Prev}) + CD^2_{Curr} - CD^2_{Old}}{n_{Max}} - E^2_{Curr} \quad (4)$$

‘CD_{Th}’ is initialized. Based on former values, when threshold of ‘CD_{Var}’ (CD^{Th}_{Var}) is exceeded, $CD_{Var} > CD^{Th}_{Var}$, then request from incoming MS will not be accepted as contention degree is high. Every MS updates ‘CD_{Var}’ for present transmission before comparing with ‘CD_{Th}’.

V. SDT For Burst Allocation

DT of ‘k^{th}’ packet of priority class ‘j’ represents the time consumed by a packet to get into UL channel.

$$DT^j_k = W^j_k + \sigma^j_k + P^j_k + F_L \quad (5)$$

Where,

W^j_k - Waiting time of packet

σ^j_k - Time taken for transmitting ‘k^{th}’ packet of class ‘j’

F_L - Mean latency

P^j_k - Propagation delay

Scheduling is performed depending on priority of incoming traffic. With each type of traffic, a combination of factors is included depending on which MSs are sorted. SDT schedules MS depending on following factors.

- Current Rate of Transmission (TR^i_{CUR})
- Allowable Data Rate (ADR_i)
- Quantity of Pending Data (PD_i)
- Serviced Data (SD_i)
- DT (DT_i)

Permitted delay for every flow is taken into consideration for scheduling requests. UGS as well as rtPS flows do not tolerate delays, whereas nrtPS as well as BE flows can withstand delays. Although UGS and rtPS flows are serviced first, DT is a significant factor that must be taken into account. If UGS flows are serviced before rtPS, then rtPS flows will suffer delay. In case there is no pending UGS traffic, rtPS flow is serviced.

‘TR^i_{Curr}’ is forwarded to scheduler and BA. The scheduler has details of updated ‘PD_i’ lined up in every flow. ‘ADR_i’ is dynamically fed to scheduler. The quantity of Data Serviced (SD_i) is considered by the scheduler to find Factor representing Contentment ($Ḉ_i$) for delay-independent traffic. Resources are assigned based on Assignments (AS) given by scheduler.

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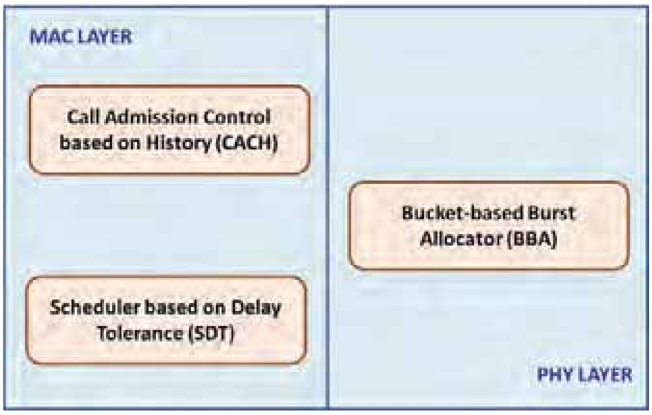

Figure 2. CACH and SDT coupled with BBA

A 2-tier framework, in which scheduler allocates priorities to MS' traffic and assigns resources to traffic depending on priority is designed. In initial tier, traffic is categorized by kind as well as priority is allotted in the following order: UGS, rtPS and nrtPS flows.

Excessive UGS traffic is circumvented in ensuing frame and nrtPS flow does not starve. In second tier, traffic of same priority in 1st tier is allocated varying priorities based on ensuing factors - present and mean transmission rates, accepted data rates as well as length of queues.

As shown in Figure 2, admitted traffic is given to SDT. SDT schedules flows depending on quantity of delay tolerated by each type of traffic. In a round, BBA finds available free space and allowable bucket size (Δbkt). SDT focuses on mapping traffic to buckets and forwarding them to BBA. BBA organizes IEs as well as bursts to every MS. Information regarding burst assigned traffic for each MS is forwarded to SDT. Both UGS as well as rtPS flows are scheduled based on DT value.

In case of UGS flows, MS with least DT and increased data rate is given priority.

$$\rho_i = \frac{1}{DT} \quad (6)$$

$$P_i^{UGS} = TR_{Curr}^{i} * \rho_i \quad (7)$$

- In case DT is less, then specific request must be serviced before the rest. So a least DT yields a larger 'ρ_i'.
- For rtPS, 'TR_{Curr}^{i}' is considered along with 'PD_i' and 'ADR_i'. Like UGS, DT determines priority of traffic.

$$P_i^{rtPS} = TR_{Curr}^{i} * \frac{PD_i}{ADR_i} * \rho_i \quad (8)$$

- For nrtPS, '$\acute{Ç}_i$' is considered. It depends on ratio of quantity of SD in former Time Frames (TFs) to mean 'TR_{Curr}^{i}'. 'T' represents current TF.

$$P_i^{nrtPS} = TR_{Curr}^{i} * \frac{1}{\beta_i} \quad (9)$$

where

$$\beta_i = \frac{\sum_{i=0}^{T-1} SD}{T * \frac{\sum_{i=1}^{N} TR_{Curr}^{i}}{n}} \quad (10)$$

Algorithm: SDT Algorithm
UGS: Sort MSs in descending order of Priority
do
  if (MS 'i' with $DT_i^{rtPS} > DT_i^{UGS}$ is present)
    Service MS that has rtPS traffic
  else
    Service MS that has UGS traffic
  end
  if (Free Space is present)
    Assign resources
  else
    Adjust resources
  end
while (MS that has UGS traffic is present)
  Service MSs in rtPS flow

rtPS: Sort MS in descending order of Priority
do
  Service MS that has UGS traffic
  if (Free Space is present)
    Assign resources
  else
    Adjust resources
  end
while (MS that has rtPS traffic is present)
  Service MSs in nrtPS flow

nrtPS: Sort MSs in descending order of Priority
do
  Service MS that has UGS traffic
  if (Free Space is present)
    Assign resources
  else
    Adjust resources
  end
while (MS that has nrtPS traffic is available)
  Adjust resources

Flows are organized based on determined priorities. As SDT of requests are taken into consideration, requests at HoQs are the ones with reduced DT. They are scheduled first, thus dropping packet losses and increasing throughput.

BA allocates bursts to traffic depending on priority defined by scheduler. BA forwards information about availability of resource along with assignment to scheduler.

VI. Bucket based Burst Allocator (BBA)

Burst Allocator (BA) splits free space of every DL sub-frame into 'buckets' and organizes bursts in form of buckets. For 'k' requests in a sub-frame, the burst allocation mechanism produces 'k' in addition to a constant quantity of IEs. BA organizes bursts based on priority from scheduler so that BA satisfies traffic demands.

Free space of every Downlink (DL) sub-frame is split horizontally into a number of 'buckets'. Bursts are organized as buckets of size 'Δ_{bkt}'. Assignments made by scheduler for real-time/non-real-time traffic are in multiples of 'Δbkt'. Resources involving less number of bursts and IEs are well-used. Quantity of IEs varies with amount of scheduled MSs as well as split bursts.

With 'k' requests to be filled in sub-frame, BBA produces atmost 'k' bursts with small amount of IEs. Further, BBA organizes bursts based on scheduler's suggestions. BBA involves less computation complexity and is implemented on chips involving less cost.

Based on information from scheduler, BA allocates bursts and IEs. BA is based on DT-based scheduler of MS. The scheduler connects with BA to gain knowledge about 'Δbkt' and existing Unexploited Space (US) in current DL sub-frame. This facilitates scheduler to distribute resources to different flows.

$$US = t \times c - (FCH_{Size}) - (UL\_MAP_{Size}) - (DL\_MAP\_CF_{Size}) \quad (11)$$

Where,
t - Starting time
c - Starting sub-channel
FCH - Frame Control Header

UL_MAP size is pre-determined as UL sub-frame is assigned before. The Control Fields of 'DL_MAP' (DL_MAP_CF) include portions of 'DL_MAP', excluding IEs that are found by BA.

The above-mentioned model offers ensuing advantages.

- As scheduler and BA are joined together, traffic from MSs may be prioritized leading to reduced amount of request dropping.
- Fewer amounts of IEs are used as scheduler knows about burst organization.
- As DT of traffic plays a dominant role, MS with delay-intolerant traffic obtains priority.
- Unnecessary UGS/rtPS traffic is not produced in following TF. The nrtPS traffic need not wait for a long time.

VII. Results And Discussion

The proposed system is simulated using ns2. Simulation parameters are shown in Table 1.

Table 1. Simulation Parameters of HRA

Parameter	Value
MAC	IEEE 802.16e
Routing Protocol	DSDV
Duration of Frame	0.004
VCD Threshold	0.8
Length of Queue	50
Size of Packet	1492 bytes
Number of MSs	50
Start Time	20 Sec
Stop Time	120 Sec

SDT offers 13.12% better throughput in contrast to Priority Scheduler (PS) (Figure 3). SDT offers 2.4 times lesser average delay when compared to PS (Figure 4). Similarly, SDT involves 10.16% lesser PLR in contrast to PS (Figure 5).

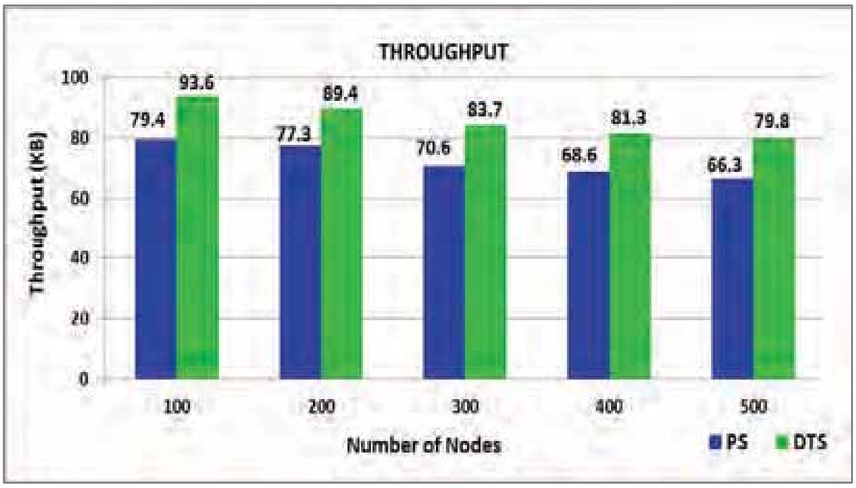

Figure 3: Throughput

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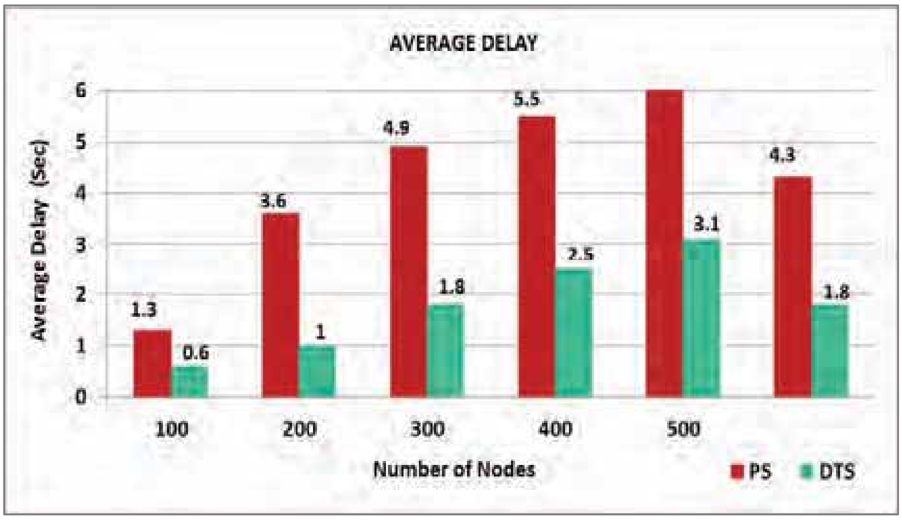

Figure 4: Average Delay

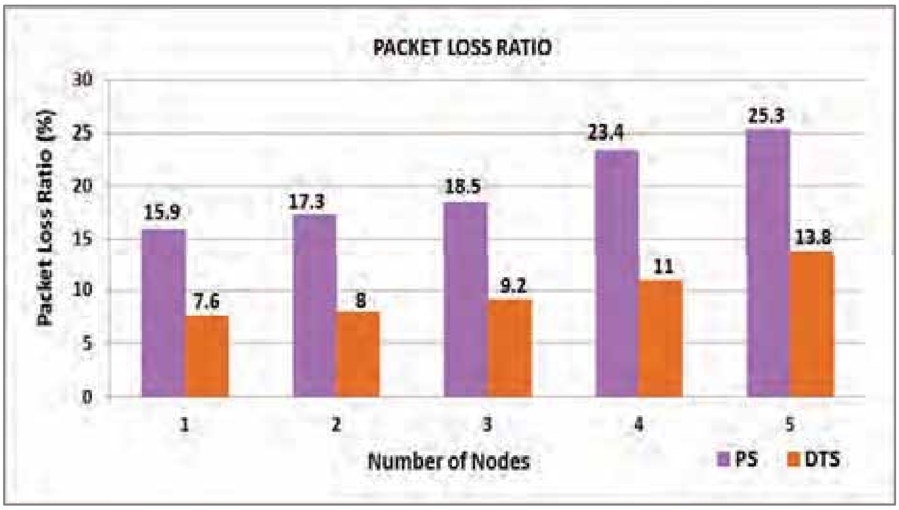

Figure 5: Packet Loss Ratio (PLR)

VIII. CONCLUSION

The CAC based on History (CACH) schemes accept calls only when an incoming call has no impact on QoS when new calls are accepted. This avoids QoS degradation to a larger extent when compared to present mechanisms. Further DT-based BA considers allowable delay of every flow and assigns bursts depending on priority and DT of every request. It is obvious that proposed cross-layer framework offers better results based on throughput, average delay and PLR.

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