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RESEARCH ARTICLE

Dynamic Bandwidth Allocation Scheme for Efficient Handover in IEEE 802.16e Networks

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Abstract* - Mobile *Worldwide interoperability for Microwave access (WiMAX), IEEE 802.16e is a promising solution that provides ubiquitous wireless access with high data rates, high mobility and wide coverage. The main issue in mobile WiMAX networks is managing user mobility. Queues associated with the arriving packets should have enough bandwidth to meet the requirements; else the Handoff Call Dropping Probability (HCDP) will be high. The Dynamic QoS based Bandwidth Allocation Algorithm (DQBA^2) is proposed to increase the system utilization and to reduce the Dropping Probability. Traffic with high Bandwidth Allocation Factor (BAF) is given high priority. The number of users is increased by dynamically allocating bandwidth based on the Arrival Rate (λ). To improve the efficiency of the proposed scheme, a Scanning with Self-back off (SSB) scheme is included. The proposed system shows better performance in terms of Throughput, delay and packet loss.

Keywords— WiMAX; Metropolitan Area Networks; Self Scanning Backoff Scheme; Hard handover; Fast Base Station switching

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I. INTRODUCTION

IEEE 802.16, a standard for Metropolitan Area Networks (MAN) is one among the most reliable wireless access technologies for upcoming generation all-IP networks. To provide better Quality of Service (QoS) to the users, the Differentiated Services (DiffServ) QoS scheme is utilized and operator's revenue is maximized [1].

The IEEE 802.16e standard, known as mobile WiMAX enables WiMAX to support mobility. It permits a Mobile Subscriber Station (MSS) to perform handover from one Base Station (BS) to another. Handovers may be homogeneous or heterogeneous based on the technology used [2]. Incessant needs in terms of speed, data rates and QoS demand different traits of wireless networks.

IEEE 802.16e protocol specifies two different modes of operation.

1) *Point-to-Multipoint (PMP) mode:* It operates with a central BS and a sectored antenna and has the capability to handle multiple independent sectors simultaneously [3]. Within a given frequency and antenna sector, when the BS transmits, all the Subscriber Stations (SSs) receive the same transmission.

The BS owns the control of the Downlink (DL) and manages the network by coordinating the transmission of the SSs. It is not necessary to coordinate its transmission with other stations.

2) *Mesh mode:* Access points are interconnected by wireless links. In the mesh mode, bidirectional links are established between WiMAX nodes and the information is transmitted on a hop-by-hop basis. The system access follows a frame-based approach where each channel is divided into a series of time frames. The number of frames in a series is defined when the network is created. Three types of link layer handover procedures in a homogeneous environment exist in WiMAX mobility structure [4]. They are Hard Handover (HHO) which is the default handover mechanism and two soft handover mechanisms - Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS), which are optional.
3) *Hard Handover (HHO):* During hard handover, the MSS communicates with only one BS at a time. Connection with the old BS is broken before the new connection is established. Handover is executed after the signal strength from neighbor's cell exceeds the signal strength of the current cell.
4) *Macro-Diversity Handover (MDHO):* Both the MSS and the BS maintain a "Diversity Set", a list of BSs involved in the handover procedure. It is defined for each MSS in the network. MSS communicates with all the BSs in the diversity set. For DL in MDHO, two or more BSs transmit data to the MSS such that diversity combining can be performed at the MSS. For Uplink (UL) in MDHO, MSS' transmission is received by multiple BSs and selection diversity of the received information is performed.
5) *Fast Base Station Switching (FBSS):* In FBSS, similar to MDHO, the MSS and the BS diversity sets are maintained. The MSS continuously monitors the BSs in the diversity set and defines an "Anchor BS". Anchor BS is the only BS in the diversity set with which the MSS communicates for all UL and DL traffic including management messages. This is the BS where MSS is registered, synchronized, performs ranging and has a DL channel for control information. The Anchor BS can be changed from frame to frame depending on BS selection scheme.

II. SERVICE CLASSES

Ensuring Quality of Service (QoS) is vital and deals with improving the performance of IEEE 802.16 network [5]. WiMAX defines five different service classes to support its wide range of applications as endorsed by the standard.

1) *Unsolicited Grant Services (UGS):* It is designed to support fixed-sized data packets at a Constant Bit Rate (CBR) that can tolerate real-time data stream applications. This service provides guaranteed throughput, latency and jitter at the necessary levels as Time Division Multiplexing (TDM) services. UGS is used to support CBR services such as Voice over IP (VoIP). It involves QoS parameters like Jitter Tolerance, Maximum Latency Tolerance and Maximum Sustained Rate.
2) *Extended real-time Polling Service (ertPS):* It supports real-time applications with periodic variable-sized data packets that require guaranteed data rate and delay with silence suppression. During silent periods, no traffic is sent and no bandwidth is allocated. ertPS is featured in VoIP with silence suppression. It involves QoS parameters like traffic priority, Jitter Tolerance, Maximum Latency Tolerance, Maximum Reserved Rate and Maximum Sustained Rate.
3) *Real-time Polling Services (rtPS):* It is designed to support real-time service flows that generate variable-sized data packets periodically with a guaranteed minimum rate and guaranteed delay. The mandatory service flow parameters that define this service include Minimum Reserved Traffic Rate, Maximum Sustained Traffic Rate, Maximum Latency and Request/Transmission Policy. rtPS is used extensively in MPEG video conferencing and streaming.
4) *Non-real-time Polling Service (nrtPS):* It is designed for non-real-time traffic with no delay guarantees. The delay tolerant data stream consists of variable-sized data packets. It supports applications that are time-insensitive and involve minimum amount of bandwidth and is especially suitable for critical data application such as File Transfer Protocol (FTP). It involves QoS parameters like Traffic priority, Maximum Reserved Rate and Maximum Sustained Rate.
5) *Best-Effort Services (BE):* It supports data streams with no minimum service-level guarantee. The service flow parameters that define this service include Maximum Sustained Traffic Rate, Traffic Priority and Request/Transmission Policy.

III. RELATED WORK

One of the most important issues in offering real-time communication services in a mobile environment is support for seamless handover between BSs, thus preserving communication. In Mobile WiMAX, a MSS may perform scanning and association process before handover, leading to service disruption.

In [6] bandwidth allocation is done by distributing available data slots among different users. A mathematical model is established to theoretically analyse the delay performance in a multiuser environment by considering the Automatic Repeat reQuest with Selective Acknowledgement (ARQ-SA) scheme for erroneous wireless channels.

In [7], Adaptive Modulation and Coding rate based is proposed to adjust the transmission rate adaptively in each frame time according to channel quality to obtain multi-user diversity gain.

In [8], Highest Urgency First (HUF) algorithm is proposed by considering adaptive Modulation and Coding Scheme (MCS) and the urgency of requests. Downlink (DL) and Uplink (UL) sub-frames are determined by reserving the bandwidth for the most urgent requests and then allocating the remaining bandwidth for others.

In [9], a Two-Phase Proportionating (TPP) algorithm is presented, in which the first phase dynamically determines the sub frame sizes while the second phase differentiates service classes and prevents bandwidth waste.

In the gradient-based scheduling framework in [10], the resources are allocated to maximize the projection onto the gradient of a total system utility function to model application-layer Quality of Service (QoS).

In the scheme proposed in [11], Unsolicited Grant Service (UGS) connections are given high priority and bandwidth utilization is maximized by employing bandwidth borrowing and degradation. An upper bound is set for blocking probabilities of all scheduling services using Poisson Pareto Burst Process (PPBP) model for fractal traffic and Gaussian model for aggregated traffic.

A non-cooperative two-person non-zero-sum game is formulated in [12], where the BS and a new connection are the players of this game. A queuing model is designed to analyse QoS and is used by the bandwidth allocation and admission control mechanism to ensure that the utilities for both the BS and the new connection are maximized.

A queue-aware UL Bandwidth Allocation mechanism that adaptively allocates bandwidth by polling service in the presence of higher priority UGS is proposed in [13]. The rate control mechanism dynamically limits the transmission rate for the connections under polling service.

In [14], an energy efficient small cell discovery mechanism for heterogeneous networks by means of flexible inter-frequency scanning is proposed.

In [15] paper, the MSS Movement Direction Prediction (MMDP) based handover scanning scheme is introduced, wherein the BS coverage area is divided into zones and sectors. In this scheme, only two BSs are shortlisted and become candidates, thus reducing the scanning delay and the number of exchange messages during the handover scanning.

A scanning algorithm to optimize the scanning parameters such as Scan duration, Interleaving Interval and Scan Iterations for different MSS speeds and BS densities is proposed in [16].

In [17], scan and association latency in Mobile WiMAX is investigated.

IV. QOS ADJUSTMENT ALGORITHM

The media streaming service is started by the process of sending the RSVP (Resource Reservation Protocol) request message by the MSS. After the request is received, the RSVP path which consists of the hop address of the previous router, hop count and traffic specification is sent back to the MSS by the router. Each packet is classified based on the traffic.

As soon as the MSS receives the reservation message from the router, it verifies whether bandwidth is available. If there is enough bandwidth, then the MSS triggers the Handoff procedure, or else the QoS adjustment algorithm is initiated. In this algorithm, the data rate of the MSS, bandwidth requirement of the MSS and the hop count of the MSS before and after the handover are estimated. For every traffic, the available bandwidth is obtained by multiplying the data rate and the hop count before the current handover.

In Inter handover, the remaining bandwidth is compared with the requested bandwidth if available allocate the bandwidth, or else check for the data rate of the MSS before and after the handover. Calculate the remaining bandwidth after the allocation to the MSS. In intra handover process, the Hop count is checked. If it is greater than the new hop count then bandwidth allocation is performed similar to Inter handover. After allocating the bandwidth, the MSS is now free to trigger handover easily.

V. SELF-SCANNING BACKOFF (SSB) SCHEME

In the SSB scheme, missing of ranging response messages can be reduced by sending a ranging request in early frames of a scanning interval. Scanning without association scheme and the SSB scheme have a higher collision probability of a ranging request than the scanning with association scheme.

This is because both schemes can reduce the duration of the association process, and more ranging attempts occur in a shorter association period. The SSB scheme can reduce overall ranging failure and the association latency. The improvement is derived mainly from the property of the SSB scheme performing the back off countdown process while staying connected with the serving BS.

VI. DYNAMIC QOS BASED BANDWIDTH ALLOCATION ALGORITHM ($DQBA^2$)

In the $DQBA^2$ algorithm, bandwidth is allocated dynamically based on the demand of the MSS. Bandwidth Allocation Factor (BAF) and Call Dropping Time (CD_{TIME}) are considered for scheduling the packets. The queue of the arriving packet should have sufficient bandwidth to accept the call or else the HCDP will be high.

A. Scheduling

When packets arrive, they are classified into high, medium, normal and low priority queues. The scheduler decides the queue and the packets that should be transmitted. The order in which the scheduler selects the packets to process can affect network performance. The scheduler serves the high priority queue first.

B. Bandwidth allocation

There must be sufficient bandwidth to support the call when a user handoffs to the new BS. In such a case either the call will be dropped or suffer bandwidth degradation.

The main parameters considered in this paper are

1) *New Call Blocking Probability (NCBP)*: NCBP is the probability of the new call being rejected.
2) *Handoff Call Dropping Probability (HCDP)*: HCDP is the probability of the accepted call terminated before the completion of its service.

Bandwidth Allocation module

- Assigns a threshold for the call dropping time.
- Selects the MSS that is to be dropped
- Allocates the requested bandwidth to the MSS at the instant the MSS moves to the next BS, if sufficient bandwidth is available.

In the $DQBA^2$ algorithm, when the user requests for a new connection, the new call is initiated. The call should be handed off to another BS, when an active user moves from one coverage area to next.

This algorithm performs the following steps for each service type 'i' such that its time complexity is O(n), where n is the number of service types in the WiMAX network.

The reduction of HCDP is an important issue in WiMAX networks while efficiently maintaining between utilization.

Based on the following factors the MSS that has higher HCDP is given priority.

Bandwidth Allocation Factor (BAF)

$$\mathrm{BAF} = \frac{\mathrm{BW_{AVAIL}}}{\mathrm{BW_{REQ}}} \quad (1)$$

where,

'BW_{AVAIL}' denotes the Available Bandwidth and 'BW_{REQ}' denotes the requested bandwidth.

Handover Call Acceptance Factor (HAF)

$$\mathrm{HAF} = \mathrm{HCDP} + \mathrm{BAF} + \frac{1}{\mathrm{TRAFFIC_{PRIORITY}}} \quad (2)$$

Handoff Call Dropping Probability (HCDP)

$$\mathrm{HCDP} = (\lambda - \mathrm{threshold}) + \frac{\mathrm{DISTANCE} + \mathrm{SNR}}{\mathrm{RSSI}} \quad (3)$$

where,

λ = Call Arrival rate
SNR = Signal to Noise Ratio
RSSI = Received Signal Strength Identity

To reduce the HCDP, the priority is given to the traffic with high BAF. The Bandwidth Utilization (BU) is the ratio of the bandwidth used by serviced calls to the total bandwidth capacity.

The performance metrics are plotted as a function of the offered load (Call Arrival Rate). The Bandwidth Adaptability Ratio (BAR) of a Service flow depends on the number of calls in that priority level (BW_i).

BW_{ALLOC}, Total allocated bandwidth for all active users at all priority levels is given by,

$$BW_{ALLOC} = \sum_{i=1}^{n} x_{ALLOC}^{i} \, BW_{ALLOC}^{i} \quad (4)$$

where 'x_{ALLOC}^{i}' is the number of current users that are allocated level 'i' and 'BW_{ALLOC}^{i}' is the bandwidth allocated for level 'i' users.

The adaptability ratio is calculated as follows:

$$BAR = 1 - \frac{BW_{ALLOC}}{C} \quad (5)$$

where 'C' is the total capacity of each cell (bbu).

Based on the Call Arrival Rate, it is found that the Average Residence Time of a new call is given by 'RT_{AVG}^{NC}' and the Average Residence Time of a handoff call is given by 'RT_{AVG}^{HC}'.

$$RT_{AVG}^{NC} = \frac{8*R*\lambda\left[\frac{1}{s}\right]}{3\pi} \quad (6)$$

$$RT_{AVG}^{HC} = \frac{\pi R}{2\lambda[S]} \quad (7)$$

where 'R' in the radius of the cell and 'S' the average speed of a mobile in the cell. Therefore, the handoff rate (H_{RATE}^{NC}) of new calls and handoff call (H_{RATE}^{HC}) is

$$H_{RATE}^{NC} = \frac{1}{RT_{AVG}^{NC}} \quad (8)$$

$$H_{RATE}^{HC} = \frac{1}{RT_{AVG}^{HC}} \quad (9)$$

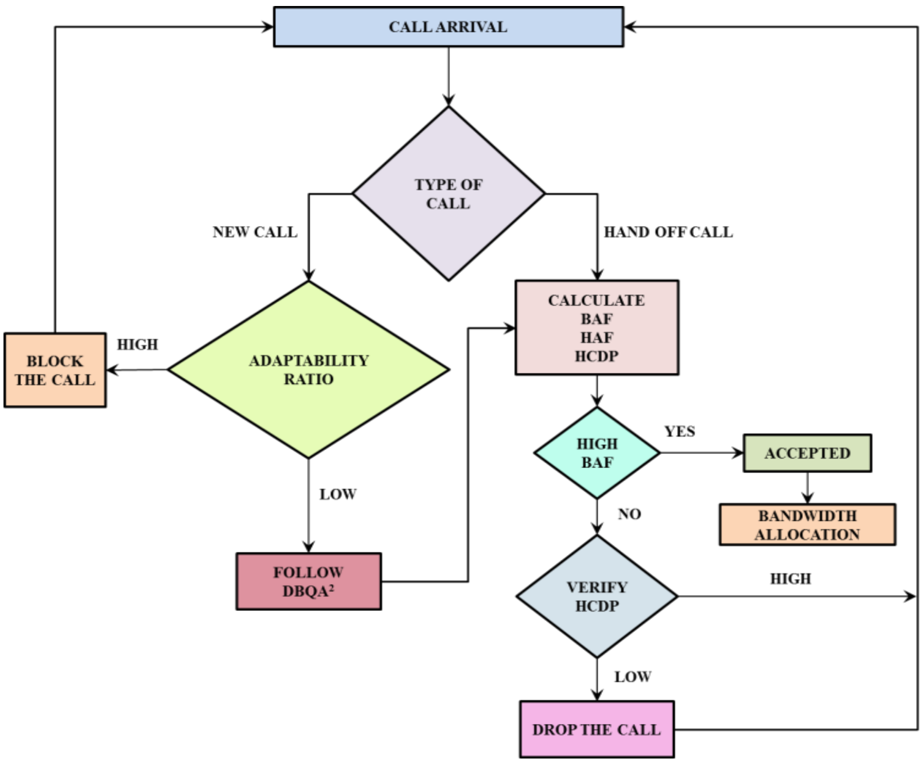

Fig. 1 Flowchart

VII. IMPLEMENTATION

In the following section, simulation results obtained from ns2 simulator are discussed by assuming that an MSS may pause communication with the serving BS and scan the neighbouring BSs before conducting handover. The packets are buffered temporarily in the serving BS during scanning intervals. During interleaving intervals, extra radio resources are allocated to transfer the buffered packets to the MSS.

Therefore, ertPS and rtPS service classes, which are able to request extra resources, are used for delivering real-time communication services. Simulation parameters are listed in Table I.

TABLE I

SIMULATION PARAMETERS

Parameters	**Values**
MAC protocol 802.16	2 Mbps
Threshold Bandwidth (BAC)	0.5 Mbps
Data Rate	512 kbps
Routing protocol	DSDV
Transmission Range	250 – 400 M
Queue Length	50
Queue Type	Priority Queue
Simulation time	100 Sec
Drop-threshold	2dB
Default handover-threshold	4dB
Speed range	1-40 m/s
Frequency	5G

The simulation results reveal that the missing probability of a ranging response is unaffected by the number of MSSs competing for ranging opportunities, and it is determined by the lengths of a scanning interval, an interleaving interval, and the delay of the neighbouring BS responses to the ranging request.

The following graphs show the delays of $DQBA^2$ and QoS Adjustment algorithm for various types of traffic (Fig. 2 to Fig. 5). The proposed scheme involves less delay when compared to the QoS Adjustment Scheme.

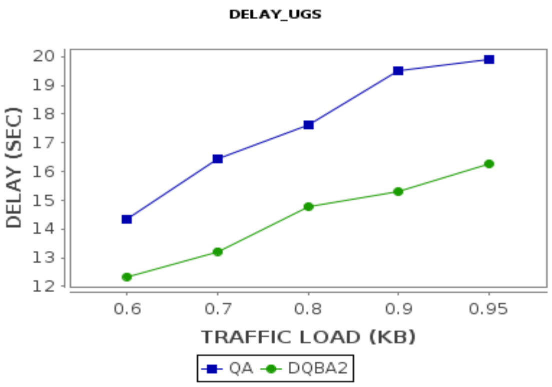

Fig. 2 Delay of UGS traffic

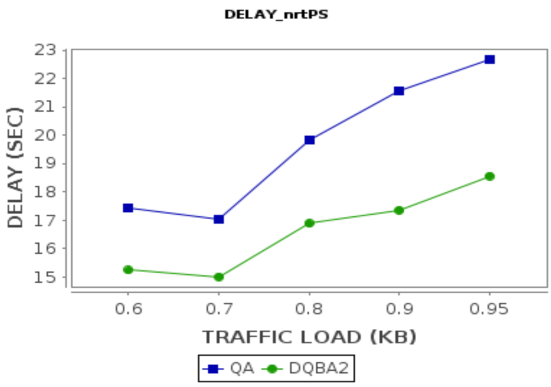

Fig. 4 Delay of nrtPS traffic

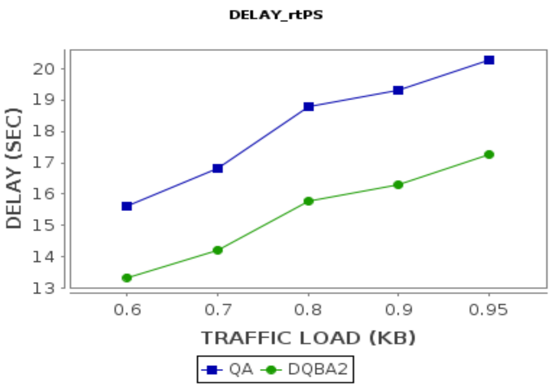

Fig. 3 Delay of rtPS traffic

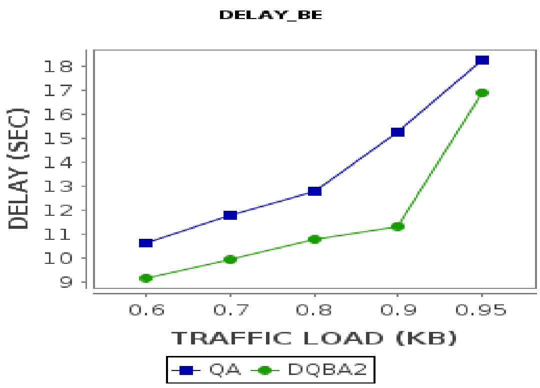

Fig. 5 Delay of BE traffic

The following graphs show the Packet Loss Ratio (PLR) of DQBA^2 and QoS Adjustment algorithm for various types of traffic (Fig. 6 to Fig. 9). The PLR of QoS Adjustment algorithm is more when compared to the proposed DQBA^2.

Fig. 6 Packet Loss Ratio of UGS traffic

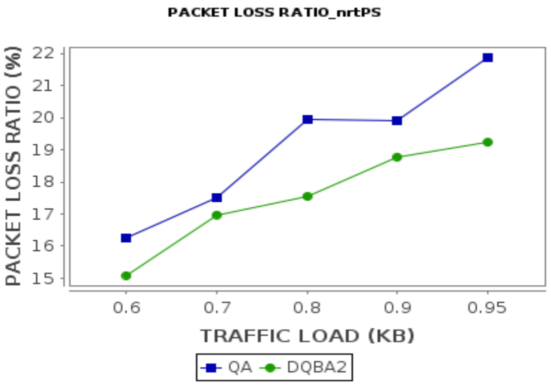

Fig. 8 Packet Loss Ratio of nrtPS traffic

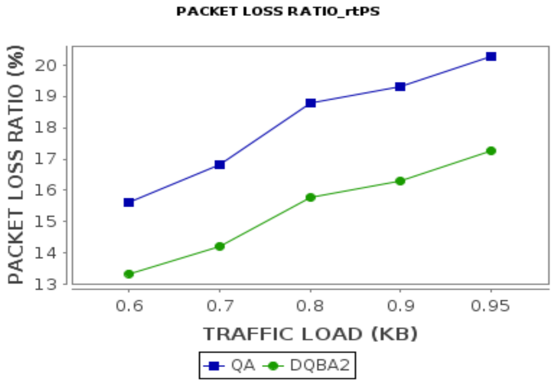

Fig. 7 Packet Loss Ratio of rtPS traffic

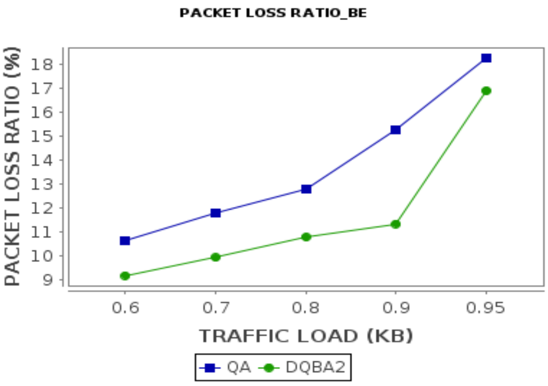

Fig. 9 Packet Loss Ratio of BE traffic

The following graphs show the throughput of DQBA^2 and QoS adjustment algorithm for various types of traffic (Fig. 10 to Fig. 13). The throughput of QoS Adjustment algorithm is less when compared to the proposed DQBA^2.

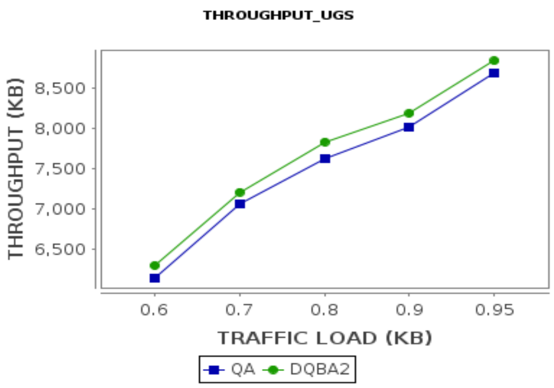

Fig. 10 Throughput of UGS traffic

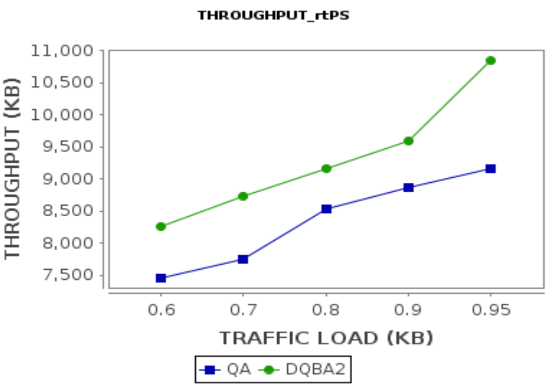

Fig. 11 Throughput of rtPS traffic

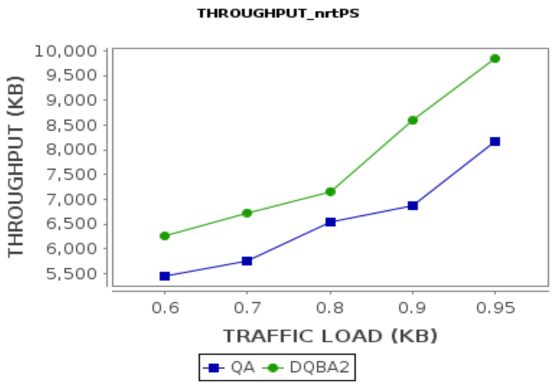

Fig. 12 Throughput of nrtPS traffic

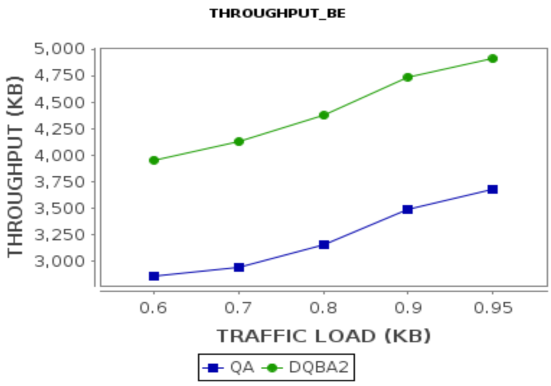

Fig. 13 Throughput of BE traffic

The following graph shows the HCDP and NCBP of the $DQBA^2$ and QoS adjustment algorithm with respect to the Call Arrival rate (Fig. 14 and Fig. 15).

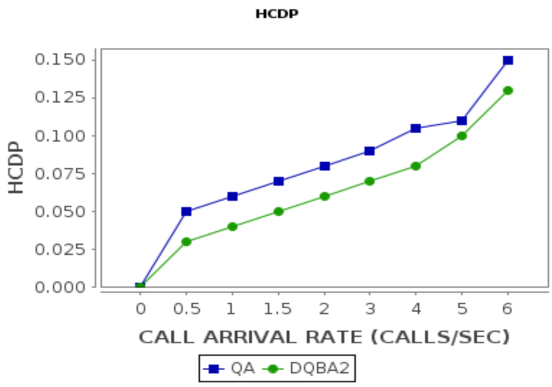

Fig. 14 HCDP

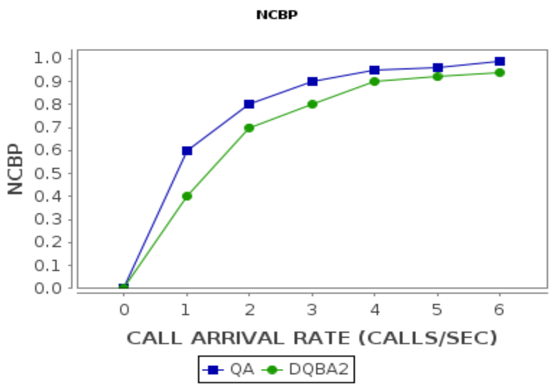

Fig. 15 NCBP

$DQBA^2$ algorithm offers 23% less HCDP when compared to QoS Adjustment algorithm. Similarly the NCBP of QoS Adjustment Algorithm is 10% more when compared to $DQBA^2$ algorithm.

The following table shows the percentage of increase in Throughput, decrease in Delay and Packet Loss Ratio of the $DQBA^2$ algorithm in comparison with QoS Adjustment algorithm for the various types of traffic (Table II).

TABLE II
PERFORMANCE ANALYSIS

Performance Analysis	**Service Classes**			
	UGS	**rtPS**	**nrtPS**	**BE**
PACKET LOSS RATIO (%)				
QA	17.16	18.16	19.10	13.76
$DQBA^2$	14.38	15.38	17.53	12.03
Performance (%)	**31.54**	**33.54**	**36.63**	**25.79**
DELAY (SEC)				
QA	17.56	18.16	19.71	13.76
$DQBA^2$	14.38	15.38	16.61	12.03
Performance (%)	**31.94**	**33.54**	**36.32**	**25.79**
THROUGHPUT x 10^3 (KB)				
QA	7.5	8.4	6.6	3.2
$DQBA^2$	7.7	9.3	7.7	4.4
Performance (%)	**2.67**	**10.71**	**16.67**	**37.5**

VIII. CONCLUSION

The Self Scanning with association scheme provides an efficient support of seamless handover management activity and is an important requirement for communication technologies that are intended to be universally accepted in next-generation communication systems. The prediction of the call blocking probability for self-scanning algorithm with arrival rate yields better performance. The future work includes the prediction based call dropping scheme with additional scanning features. The proposed algorithm yields high Throughput, low Delay and call drop.

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