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DCRS: A DYNAMIC CONTENTION RESOLUTION SCHEME FOR WIMAX NETWORKS

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Abstract
IEEE 802.16e has received wide attention as it supports high data rates and incredible pervasive connectivity with high Quality of Service (QoS) capabilities. To support QoS, many Bandwidth REQuest (BW-REQ) mechanisms are suggested in the literature for resource reservation in mobile WiMAX networks. There are chances for performance degradation with increase in the number of requests. QoS can be ensured if a contention resolution scheme is designed for sending BW-REQs to the Base Station (BS). To improve the efficiency of the random access mechanisms in the standard, a new mechanism called Dynamic Contention Resolution Scheme (DCRS) is proposed for IEEE 802.16e networks. DCRS groups the requests based on their service types and dynamically calculates the number of Contention slots based on the Arrival Rate (λ) of requests.

Keywords:
Broadband Wireless Access (BWA), IEEE 802.16e, Bandwidth Requests (BW-REQ), Contention Window, Quality of Service (QoS)

1. INTRODUCTION

Over the last decade, an explosive growth of wireless internet users and broadband applications has been witnessed. The rapid growth of high speed multimedia services for residential and small business customers has created an increasing demand for last mile broadband access. Mobile Worldwide interoperability for Microwave Access (WiMAX), standardized by IEEE 802.16e is a promising option for Wireless Metropolitan Area Networks (WMANs). It meets the convincing requirements of Broadband Wireless Access (BWA) networks [1, 2].

1.1 AN OVERVIEW OF WIMAX STANDARD

Two operational modes are specified in WiMAX: a mandatory Point-to-Multipoint (PMP) mode and Mesh mode. In the PMP mode, a centralized BS broadcasts to a set of Subscriber Stations (SSs). In the Mesh mode, the SSs are organized in an ad hoc way. In this paper, PMP mode is used as it is the main choice of WiMAX operators.

1.2 LAYERS IN WIMAX

The PHYsical (PHY) and the Medium Access Control (MAC) layer (Fig.1) are defined in the WiMAX Standard.

1.2.1 PHYsical (PHY) Layer:

The PHY Layer deals with establishing physical connections on both sides, often in both the directions (Uplink and Downlink). It is responsible for transmission of bit sequences. It defines the type of the signal used, the kind of modulation and demodulation, the transmission power and also other physical characteristics. The 802.16 standard considers 2 – 66 GHz frequency band.

This band is divided into two parts:

- The first range is between 2 and 11 GHz and is destined for Non-Line-Of-Sight (NLOS) transmissions. This is the only range presently included in WiMAX.
- The second range is between 11 and 66 GHz and is destined for Line-Of-Sight (LOS) transmissions.

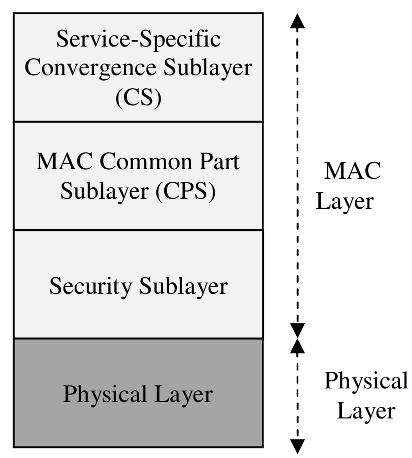

Fig.1. Layers in WiMAX

1.2.2 Medium Access Control (MAC) Layer:

The MAC layer is divided into three Sub-layers namely Security Sublayer (SS), Common Part Sublayer (CPS) and Convergence Sublayer (CS).

1.2.2.1 Security Sublayer (SS):

The MAC Sublayer consists of a separate Security Sublayer for providing

- Authentication
- Secure key exchange
- Encryption
- Integrity control

An authentication protocol - the Privacy Key Management (PKM) protocol provides secure distribution of keying data from the BS to the MSS. Through this secure key exchange, the BS synchronizes with the keying data. The basic privacy mechanisms can be strengthened by adding digital certificate based MSS authentication to the key management protocol.

1.2.2.2 Common Part Sublayer (CPS):

The Common Part Sublayer (CPS) resides in the middle of the MAC layer. It is the core of the MAC protocol and is responsible for:

- Bandwidth allocation
- Connection establishment
- Maintenance of the connection between the two sides.

The 802.16-2004 standard defines a set of management and transfer messages. The management messages are exchanged between the SS and the BS before and during the establishment of the connection. When the connection is established, the transfer messages can be exchanged. The CPS receives data from various CSs through the MAC Service Access Point (SAP) classified to particular MAC connections. The CPS includes many procedures for frame construction, multiple access, bandwidth demands and allocation, scheduling, radio resource management, QoS management, etc.

1.2.2.3 Convergence Sublayer (CS):

The services specific Convergence Sublayer (CS), often known as CS is just above the MAC CPS Sublayer. The CS uses the services provided by the MAC CPS via the MAC SAP. The CS performs the following functions:

- Accepts higher layer PDUs.
- Classifies and maps the MSDUs into appropriate CIDs (Connection Identifiers).
- Processes the higher layer PDUs based on the classification.
- Delivers CS PDUs to appropriate MAC SAP and receives CS PDUs from the peer entity.
- PHS (Payload Header Suppression), the process of suppressing repetitive parts of payload headers at the sender and restoring these headers at the receiver. It is optional.

1.3 TYPES OF SERVICES

The IEEE 802.16e Media Access Control (MAC) layer provides different QoS for five classes of services- Unsolicited Grant Service (UGS), real-time Polling Services classified into extended real-time Polling Service (ertPS) and real-time Polling Service (rtPS) classes and non-real-time services classified into non-real-time Polling Service (nrtPS) and Best Effort (BE)services classes.

- **UGS**: It is designed for Constant Bit Rate (CBR) real-time traffic such as Voice over Internet Protocol (VoIP) without silence suppression. The main QoS parameters are Tolerated Jitter, Maximum Sustained Rate (MSR) and the Maximum Latency.
- **ertPS**: It is designed to support VoIP with silence suppression. It has the same QoS parameters as UGS. However, MSR is assigned only during active periods.
- **rtPS**: It is designed to support real-time applications with Variable Bit Rates (VBR), such as MPEG videos. The QoS parameters of rtPS services include MSR and Minimum Reserved Rate (MRR).
- **nrtPS**: It is designed for applications without any specific delay requirements but with minimum bandwidth requirements such as a FTP.
- **BE**: It is designed for delay tolerant applications that do not require a minimum amount of bandwidth. Bandwidth is granted only after allocating to other service classes.

1.4 CHANNEL ACCESS METHODS

Channel access methods allow several terminals connected to the same multi-point transmission medium to transmit and share the capacity. It is based on a multiplexing scheme that allows several data streams or signals to share the same communication channel or physical medium. There are various methods of channel access schemes available for WiMAX networks as discussed below.

1.4.1 Frequency Division Multiple Access (FDMA):

FDMA is based on Frequency Division Multiplexing (FDM) which provides different frequency bands to different data streams.

1.4.2 Code Division Multiple Access (CDMA):

CDMA is based on spread spectrum, where a wider radio spectrum, broader than the data rate of each of the transferred bit streams is used. Several message signals are transferred simultaneously over the same carrier frequency utilizing different spreading codes.

1.4.3 Space Division Multiple Access (SDMA):

SDMA is based on creating parallel spatial pipes next to higher capacity pipes through spatial multiplexing and/or diversity by which it offers superior performance in radio multiple access communication systems.

1.4.4 Time Division Multiple Access (TDMA):

TDMA is a digital transmission technology that allows a number of users to access a single radio frequency channel without interference by allocating unique time slots to each user within each channel. In this paper, TDMA scheme is used as the channel can be used by various stations in unique time slots. Fig.2 shows the TDD frame structure for IEEE 802.16e network.

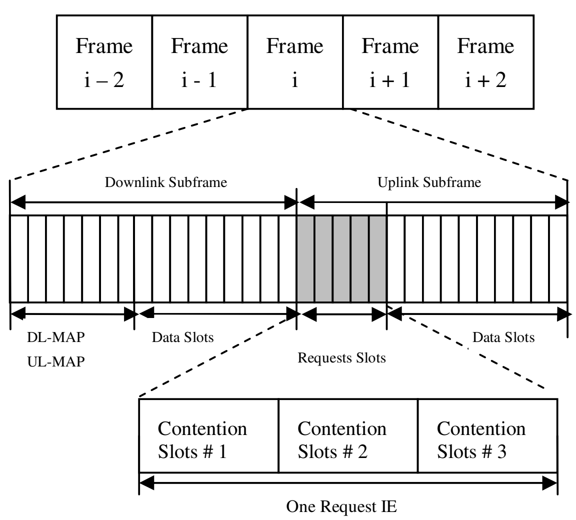

Fig.2. TDD frame structure of IEEE 802.16

1.5 BANDWIDTH REQUESTS AND GRANTS

In the DL sub-frame, two management messages (DL-MAP and UL-MAP) are transmitted which indicate the bandwidth allocation for data transmission in both the DL and UL directions respectively. UL-MAP messages are used by the BS to control the UL transmissions from the SSs to the BS.

At the MAC layer, the BS schedules the resources of the UL channel for initial ranging, Bandwidth Request (BW-REQ) and data transmissions. The BW-REQ messages may be aggregate or incremental.

- **Aggregate:** An aggregate BW-REQ indicates the total amount of bandwidth that a MSS requires.
- **Incremental:** An Incremental BW-REQ indicates that some additional amount of bandwidth is needed in addition to its existing allocation.

A MSS may establish multiple connections with a BS, where each BW-REQ request should be per-connection based. Two basic mechanisms are suggested in the WiMAX standard for BW-REQ transmission:

- **Contention-based random access mechanism:** In case of contention-based random access, a MSS transmits a BW-REQ during a slotted time duration known as contention period, the duration of which is within a repetitive WiMAX frame and consists of slots.
- **Contention-free based polling access mechanism (unicast polling):** When polling-based BW-REQ allocation is chosen, the BS maintains a list of registered SSs and polls them based on this list. Each SS is allowed to transmit the BW-REQ message only after it is polled.
- **Grouping mode:** Besides the above two mechanisms, the random access mechanism may work in combination with polling which is referred to as the grouping mode. When a group is polled, the MSSs within the group compete for BW-REQ transmission. This grouping mechanism is suggested for situations when available bandwidth is insufficient for a BS to individually poll many SSs.

In WiMAX, no explicit Acknowledgement (ACK) frame is sent to indicate whether a BW-REQ message is successfully transmitted or distorted. If a grant is not awarded within timeout, the MSS decides that the BW-REQ must be corrupted and starts a resolution process. On the other hand, on receiving a grant within the timeout, the MSS uses the allocated bandwidth for UL transmission of data packets or to piggyback additional requests if any.

2. RELATED WORK

The existing researches on WiMAX contention resolution focus mainly on modeling and performance evaluation. Few researches discuss about improving the performance of contention resolution in IEEE 802.16.

Markov model proposed in [3] analyzes both backoff and waiting states.

In [4], Ni et al. has proposed a model for analyzing the performance of collision probability, throughput, and mean delay under different traffic and channel conditions.

Lin et al. has used a 3-D Markov chain to model the backoff process of initial ranging [5]. A cross-layer analytical model is used for finding the optimal size of the contention period in an IEEE 802.16 Broadband Wireless Access (BWA) system with various classes of services.

In [6], a scheme for contention window size assignment at the BS is proposed. The size of the contention window is dynamically updated based on the Arrival rate of BE traffic and the number of subordinate MSSs that have encountered transmission collision while handling BW-REQs.

The issues of improving the performance of the contention-resolution process in IEEE 802.11 and IEEE 802.16networks are well studied in [3, 7].

In [8], Cali et al. has dynamically calculated the size of the backoff window based on the number of active nodes. However, the number of active MSSs cannot be precisely estimated.

Vinel et al. has proposed a model to analyze the capacity of reservation based random access systems and estimated the upper and lower capacity bounds [9].

Cheng et al. has discussed about the fairness of different scheduling algorithms of WiMAX networks and has optimized the bandwidth allocation process of UGS flows [10].

A fixed amount of bandwidth is given to UGS connections while all connections in other scheduling classes make BW-REQs by unicast polling [11]. Connections of ertPS, nrtPS, and BE classes can request bandwidth by contention resolution process.

In [12], the SS sets a timer when transmitting BW-REQs. Once the SS is granted slots, it transmits data packets at the allocated time slots; otherwise it performs Truncated Binary Exponential Backoff (TBEB) process for BW-REQ retransmission. An analytical model is developed based on contention and request collision.

In [13], two-hop contention based BW-REQ mechanism for WiMAX relay networks is investigated under ITU-R path loss models and these failure models have been suggested for single hop networks. Unique failure models are developed to set the contention window by considering the characteristics of BW-REQ mechanism and the hop at which the BW-REQ is performed.

For Contention based BW-REQ resolution, a Modified Contention based BW Resolution algorithm (MCB-BWR-Scheme) is proposed in [14].

The impact of handover parameters and an error-prone radio channel over the IEEE 802.16e CDMA-based handover procedure is studied in [15] and the parameters like minimal and maximal size of contention window, number of transmission allocations per frame, number of available CDMA ranging codes, timers and maximum retransmission limits used in the processes of ranging, basic capabilities negotiation and registration are investigated.

A Cross Layer analytical model for computing the optimal size of contention period in IEEE 802.16 BWA systems is proposed in [16] by taking into account different service classes.

A scheme called Virtual Backoff Algorithm (VBA) is proposed in [17] that adopt the sequencing technique with the aim to minimize the number of collisions and to increase the system throughput. However, the VBA scheme suffers from collisions unless the network operates under a steady state. The number of active stations is fixed as all the stations are

In the literature, however, very little work is done in reducing the contention probability and determining the number of contention slots based on Arrival Rate (λ) of requests.

2.1 TRUNCATED BINARY EXPONENTIAL BACKOFF (TBEB)

Truncated Binary Exponential Backoff (TBEB) is the mandatory contention resolution scheme for initial ranging and BW-REQ in IEEE 802.16 standards. Each MSS takes TBEB as the primary scheme to handle collisions in BW-REQ process. TBEB accumulates MSSs which failed in the last transmission and enables them to join in the next round of contention [18].

During the process of contention, if there is only one request submitted to a request slot, the request is successful. But, when there are two or more MSSs submitting their requests in the same request slot, a collision occurs and TBEB is used to resolve the contention. In particular, when sending a request at backoff state 'i', $i \geq 0$, a MSS must carry out the backoff process by randomly selecting a backoff time in the range [0, $W_i - 1$], where W_i is the contention window for backoff state 'i'. Here, the backoff time represents the number of request slots that must be passed before the request can be submitted [19].

It is observed that the TBEB scheme performs well when the number of MSSs is limited [19–21]. The performance of the system degrades when the network becomes saturated with many MSSs, wherein most BW-REQ opportunities are wasted. Each MSS always has a BW-REQ to send and the number of opportunities provided in an upcoming time frame is far fewer than the number of MSSs that want to send BW-REQs. Hence, an effective contention-resolution scheme is very essential.

In WiMAX, the backoff mechanism is carried without carrier sensing. Hence, the backoff counter is decremented without accounting the status of the channel or number of stations in the network. This increases the chance of overlapping of backoff counter among the stations that leads to a high probability of collision with TBEB. Also, the MSSs set their backoff counter to the minimum contention window size on success which leads to a high probability of collision. It occurs often when piggybacking is not carried after first successful data transmission. The setting of contention window to minimum value causes unfairness to unsuccessful MSSs as they have to wait for a long time to capture the slot.

During contention resolution, the performance of TBEB degrades while modeling transmission failure. The backoff process is carried out when a collision occurs due to contention. Nevertheless, the backoff counter should be varied if transmission failure is due to unavailability of bandwidth or channel error. TBEB suffers from low contention efficiency and high access delay. Hence, an effective backoff mechanism is required to improve the performance of WiMAX networks [22].

2.2 EXPONENTIAL INCREASE AND EXPONENTIAL DECREASE (EIED)

In EIED, MSS randomly selects a backoff value within the contention window [22]. The obtained random value indicates the number of slots that the MSS will defer before transmitting. The MSS considers only the contention slots for which this

initialized with the same sequence number.

transmission is possible. The MSS transmits its BW_REQ when its backoff counter reduces to zero. If the MSS does not receive any response from the BS after a specific duration of time (response time), it assumes loss of request and starts it backoff.

If the MSS is unsuccessful in capturing the slots, the value of contention window is updated with an incremental backoff factor. The backoff process continues for every unsuccessful transmission up to 'm' backoff stages. On reaching the maximum backoff stage 'm', the MSS drops the data. Since the backoff factor in the proposed method accounts for pastcontention window size and probability of failure in every stage, the current contention window is set to avoid possible collision due to overlapping of backoff factor. However, the backoff with TBEB lacks this dynamic wrap of backoff factor.

2.3 REMAINDER BASED CONTENTION AVOIDANCE (RBCA) SCHEME

In RBCA [23], the BW-REQs of subordinate MSSs are divided into several groups according to the size of available slots in the next time frame. All MSSs send their BW-REQs during their group time. Meanwhile, the size of available slots in each time frame is adaptively configured by the BS according to the average collision probability and the utilization of slots in the last two rounds of contention resolution. When the utilization of slots and the collision probability reach certain thresholds, wherein the BS cannot receive any BW-REQs generated by MSSs and most slots are wasted, the number of MSSs that send BW-REQs is limited to a certain value.

The MSSs are divided into several groups according to the contention probability ratio between the last two time frames. All the MSSs send their BW-REQs in a round-robin fashion across groups, until all the BW-REQs blocked in the previous contention avoidance processes have successfully been transmitted and the contention probability has returned to normal. In particular, the principle of remainder is used to divide the BW-REQs of subordinate MSSs into different groups which can avoid the main problem of the TBEB scheme and improve the utilization of slots.

3. PROPOSED SYSTEM

Most of the aforementioned schemes do not work well when the number of BW-REQs reaches a certain threshold value. Slots are wasted in several rounds of contention-resolution processes. The Proposed scheme overcomes this problem by limiting the number of MSSs based on the contention condition of the former time frames and the Arrival Rate of requests.

Each MSS is assigned a fixed serial number during the initial ranging process when it joins the network. Before assigning the serial numbers, the MSSs are kept in a queue based on their type of services. The number is assigned strictly based on the priority. Weighted Fair Queuing (WFQ) and Deficit Weighted Round Robin (DWRR) scheduling algorithms are used to schedule the services.

The WFQ scheduler is used to schedule the real time services, while DWRR schedules the delay tolerant non-real time services. WFQ can easily handle the packets of variable lengths. DWRR schedules the traffic in such a way that the maximum packet size is subtracted from the packet length and large packets are held back until the next round.

Let SN_i be the assigned number of the 'i^{th}' MSS, $0 \le i \le n$. The total number of available slots, N_{CS}^{i} is a key factor in the proposed scheme and is dynamically updated in the UL_MAP by the BS for time frame 'i'. Meanwhile, all the slots in each time frame is numbered one by one.

3.1 DYNAMIC CONTENTION RESOLUTION SCHEME (DCRS)

After all the requests from the MSS are queued based on the types of services, the traffic is prioritized based on delay constraints.

- First Priority - UGS
- Second Priority - ertPS and rtPS
- Third Priority - nrtPS and BE

The MSSs are assigned random numbers and they contend for the slots. All the MSSs are divided into several groups according to the number of slots in each time frame and the serial number of the MSSs. Each MSS sends its BW-REQ at special slots which is associated with an assigned group number. As the BS can choose the number of slots, this value is configured based on the Contention Probability, the number of slots in the previous time frame, Traffic Priority (T_p) and the Arrival Rate (λ).

Whenever a MSS wants to send a BW-REQ or enter the contention-resolution process, it will be grouped according to the type of traffics it carries. All the MSSs with the same type of traffic are assigned to group 'G_k' and they can send their BW-REQs in the slots allocated for 'k^{th}' group.

The number of contention slots for the next time frame is found by considering the Arrival Rate, the Contention Probability (P_{CT}^{i}) of the current time frame 'i' and the former time frame 'i-1'(P_{CT}^{i-1}) and the number of contention slot N_{CS}^{i} in the current time frame.

With increase in 'λ', the Contention Probability 'P_{CT}^{i}' also increases. In other words, the Contention Probability of each group increases with rise in the number of MSSs in the group. To ease the BW-REQ process, the number of contention slots 'N_{CS}^{i+1}' for the next time frame 'i+1' should be more.

The number of Contention Slots for the ensuing time frame is determined dynamically based on the Arrival Rate, Traffic Priority and the number of Contents Slots in the current time frame along with the Feedback Ratio and the Average Contention Probability in the current and the previous time frame.

For each type of traffic, the number of contention slots in time frame 'i+1' can be derived as,

$$N_{CS}^{i+1} = \frac{\lambda}{N_{CS}^{i} * T_P} * \left\lceil \frac{N_{CS}^{i}}{1-\alpha\left(P_{CT}^{i} - P_{CT}^{i-1}\right)} \right\rceil \tag{1}$$

For instance, if more number of MSSs request for real-time traffic in the current round, the number of slots to be allocated to the rtPS group in the next time frame increases. As the priority of the traffic is taken into consideration, for an Arrival Rate (λ), more number of slots will be allocated to delay sensitive real-time requests than the delay tolerant non-real-time requests.

The feedback ratio 'α' is defined using Bernoulli trial.

$$\alpha = \frac{P_{CT}^{i}}{P_{CT}^{i-1}} \tag{2}$$

The Average Contention Probability, 'P_{CT}^{i}' is the key factor for finding the size of available sots in the next time frame.

$$P_{CT}^{i} = \frac{G_M(i) * P_M(i) + G_L(i) * P_L(i)}{N_{CS}^{i}} \tag{3}$$

The number of groups G_M^{i} with more MSSs in time frame 'i' is computed as follows:

$$G_M^{i} = n - N_{CS}^{i} * \left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor \tag{4}$$

It therefore follows that the number of MSSs in a group with more MSSs is given by $\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor + 1$.

The contention probability 'P_M^{i}' of all groups with $\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor + 1$ MSSs is

$$P_M^{i} = P_i\left(\left\lfloor N_{CS}^{i} \right\rfloor + 1\right)$$

$$P_M^{i} = \sum_{k=2}^{\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor + 1} C_{\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor + 1} P^k * (1-P)^{\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor + 1 - k} \tag{5}$$

Similarly, the number 'G_L^{i}' of groups with fewer MSSs in time frame 'i' is derived as

$$G_L^{i} = N_{CS}^{i} * \left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor - n \tag{6}$$

The number of MSSs in a group with fewer MSSs is $\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor$ and the contention probability of the group is 'P_L^{i}'.

$$P_L^{i} = P_i\left(\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor\right)$$

$$P_L^{i} = \sum_{k=2}^{\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor} C_{\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor} P^k * (1-P)^{\left\lfloor \frac{n}{N_{CS}^{i}} \right\rfloor - k} \tag{7}$$

If the current Contention Probability, 'P_{CT}^{i}' is more than 'P_{CT}^{i-1}' then it means that the Arrival Rate has increased. More MSSs contend to send BW-REQs in time frame 'i+1' than in time frame 'i'. The number of contention slots is much less than the number of MSSs that send BW-REQs. More slots should be provided in the next frame. Similarly, if the 'P_{CT}^{i}' is less, then it means that more number of slots are available and can accommodate more MSSs. The number of slots, 'N_{CS}^{i+1}' in the next time frame can be reduced.

The requests from the MSSs are grouped and the Arrival Rate of each type of traffic is determined from the Schedulers. The number of time slots for the next time frame is determined from the utilization of contention slots in the current time frame (Fig.3).

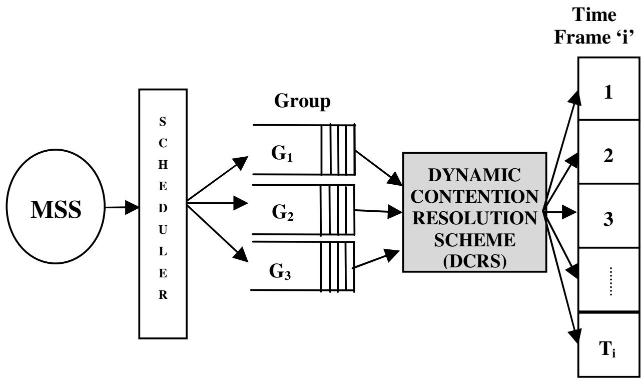

Fig.3. Dynamic Contention Resolution Scheme (DCRS)

4. PERFORMANCE ANALYSIS

The system is simulated using ns-2 and the performance is analyzed. The simulation parameters are listed in Table.1.

The simulation results show that the proposed scheme outperforms the existing system. The proposed Dynamic Contention Resolution Scheme (DCRS) based on the Arrival Rate affords better results in terms of Contention Probability, delay and throughput.

Table.1. Simulation Parameters

PARAMETERS	VALUE
MAC Protocol	IEEE802.16e
Duplexing	TDD
Routing Protocol	DSDV
Number of handover devices	2 -12
Packet Size	512 Bytes
Number of MSSs	25
Bandwidth	11MB

The Fig.4 shows that the Average Contention Probability of DCRS is better when compared to the former scheme as the number slots are determined dynamically based on the Arrival Rate. The Average Contention Probability of DCRS is 2 times better when compared to the existing RBCA scheme.

Similarly, as shown in Fig.5, the delay involved in the proposed scheme is less. The Average Delay of RBCA scheme is 2.6 times more than that of DCRS. The throughput of DCRS is better when compared to the existing scheme (Fig.6). The proposed DCRS scheme offers 1.7 times more Average Throughput when compared to RBCA.

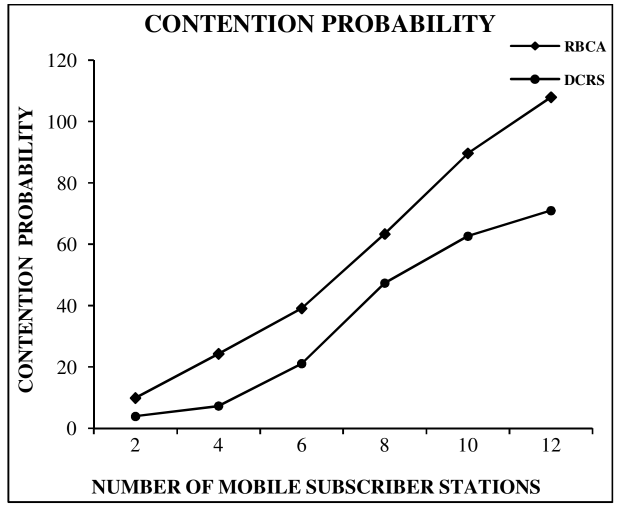

Fig.4. Average Contention Probability

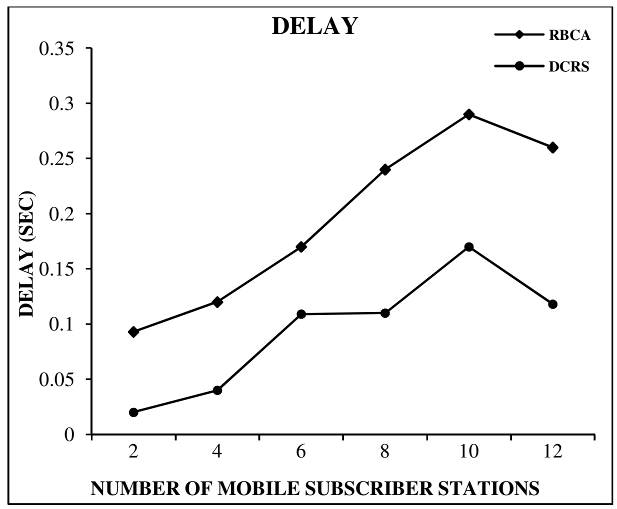

Fig.5. Delay

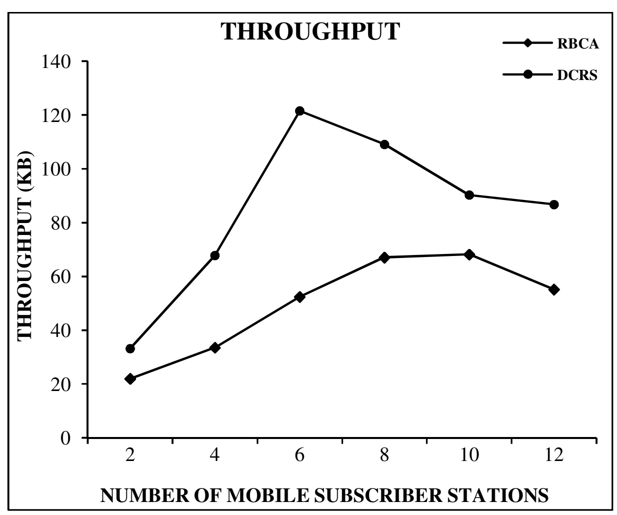

Fig.6.Throughput

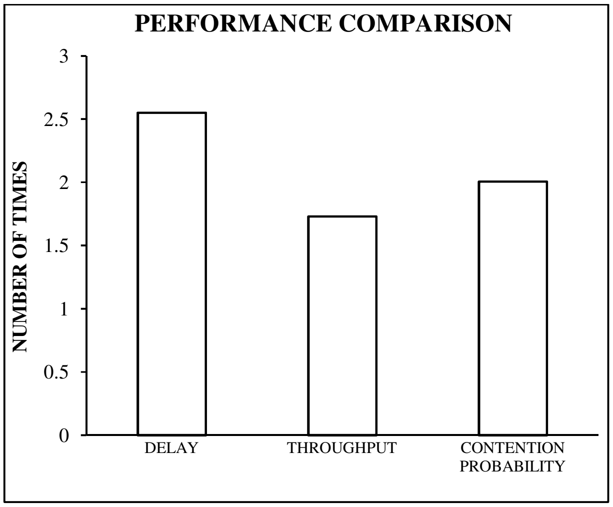

Fig.7. Performance Comparison

The Fig.7 shows the number of times, DCRS is better when compared to RBCA in terms of Average Delay, Average Throughput and Average Contention Probability.

5. CONCLUSION

A novel Dynamic Contention Resolution Scheme (DCRS) based on the Arrival Rate (λ) of requests is proposed to improve the performance of WiMAX networks with heavy traffic. In this scheme, all the MSSs which send BW-REQs form groups based on the type of traffic and the priority assigned to the traffic. The Average Contention Probabilities for the current and former time frame are calculated. As the number of Contention Slots for the next time frame is determined dynamically based on the Arrival Rate in the current time frame and Traffic Priority, the prediction is accurate. The simulation results reveal that this scheme yields better performance, especially when the number of BW-REQs is more in the next time frame.

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