CBRA: A Novel Game Theory, Cell-Degree based Resource Allocation Mechanisms in WiMax Wireless Network

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Abstract—Now-a-days, WiMax becomes one of the hottest broadband wireless technologies. Resource allocation plays a vital role in IEEE 802.16, which enhances cell degree and overall throughput of the system. In this paper work, a novel game theory, cell-degree based resource allocation (CBRA) methodology is proposed. The User/Base Station (BS) assesses the data rate, and the QoS parameter such as bandwidth, latency, jitter, cell loss ratio, cell error ratio. Subsequently, the comparison of BS by User Equipment (UE) is scrutinized to estimate the cell degree with the high value of BS. The degree of user SINR dispersion is introduced as the major parameter for allocating the resource. Also enhanced the fairness of the users, by acquiring a fair share of system resource along with the relay station (RS). The experimental analysis depicts that the proposed CBRA algorithm which incorporates the network throughput, user fairness and game theory. This accomplishes higher network throughput to bandwidth consumption ratio than the existing greedy approaches.

Index Terms— WiMax, Base Station (BS), Relay Station (RS), User Equipment (UE), Cell Degree (CD), Resource Allocation (RA), Game Theory, Throughput, User Fairness.

I. INTRODUCTION

WIMAX or IEEE 802.16 is a standard version of wireless communication to provide the service of broadband access to customer premises in the cost-effective way. The operation of WiMax is similar to WiFi (IEEE 802.11), which is based on wireless MAN technology. It is optimized for the distribution of IP centric services over a wide area network. The working group of IEEE 802.16 improves standards that address two usage models, namely, a fixed usage model (IEEE 802.16-2004) and a portable usage model (IEEE 802.16e). Using single station, WiMax can cover several miles to maintain easily and also delivers more reliable coverage. WiMax supports:

- Extraordinary data rates,
- High sector throughput,
- Numerous handoff mechanisms,
- Power-saving mechanisms for mobile devices,
- Advanced Quality of Service (QoS),
- Low latency,
- Advanced functionality of authorization, authentication, and accounting (AAA).

TABLE I
Comparison of Mobile Telephony Generations

Public Name	Family	Major Usage	Technology
LTE	3GPP	General 4G	OFDMA/MIMO/SCFDMA
WiMax rel 1	802.16	WMAN	MIMO/SCFDMA
WiMax rel 1.5	802.16-2009	WMAN	MIMO/SCFDMA
WiMax rel 2	802.16m	WMAN	MIMO/SCFDMA
WiFi	802.11 (11n)	Mobile Internet	OFDM/MIMO

Table I explain the comparison of mobile telephony generations with respect to the family, major usage and technology. The basic architecture of WiMax wireless networks and a network scenario with multiple relay stations and user equipment units are described in the Fig.1. Relay transmission plays a major communication among several units, which is similar to the collaborative communications. RS assists to transmit the information of user from adjacent user equipment or mobile station to a local eNode-B or base station. This provides an effective outcome by extending the signal and better coverage. It also improves the overall throughput of a wireless network.

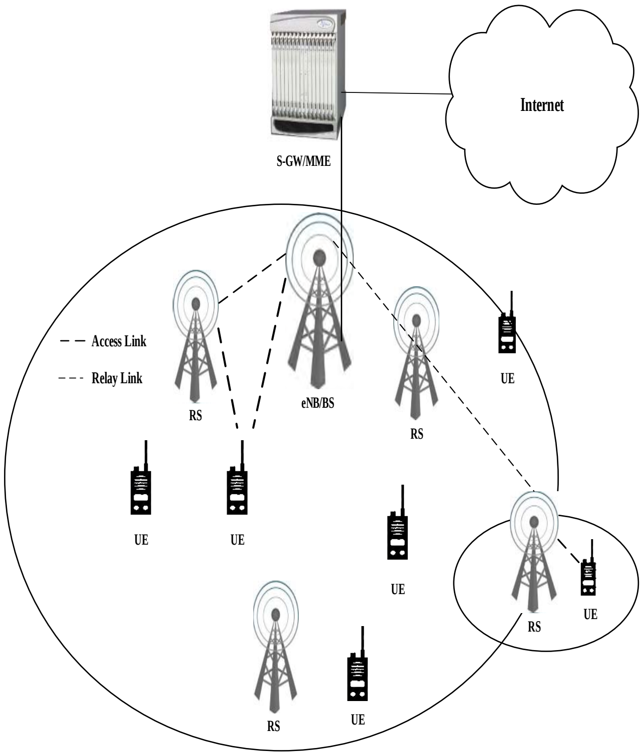

Fig.1. Architecture of WiMax IEEE 802.16 wireless network, the scenario of network with several Relay Stations (RSs) and User Equipment (UE) units.

In this paper, a novel game theory, cell-degree based resource allocation (CBRA) is introduced. Initially, the parameters of user or base station is estimated. Subsequently, the BS is compared with user equipment for evaluating the cell degree. If the cell-degree value is high, then the resource is allocated using game theory. Otherwise, it will check for other user or base station.

The rest of the paper is systematized as follows: Section II briefly overview the related works in the resource allocation in WiMax wireless networks. Section III involves the detailed explanation about the proposed method. Section IV describes the implementation details. Section V summarizes with a brief conclusive remark.

II. RELATED WORK

This section deals with the related work based on WiMax wireless networks. This also describes the resource allocation methodologies in WiMax. *Kim et al* focused on the difficulties of resource allocation in 802.16j based networks. This was enhanced with non-transparent relay stations (RSs). Initially, an optimal scheme for two-hop relaying networks was proposed. This scheme maximizes the throughput of the cell and also provides lower outage performance [1]. *Awan et al* introduced the Channel Based Resource Allocation Mechanism (CBRAM) algorithm. This offers tool for parameters such as SNR, QoS classes. It also provides better QoS and maximizes the resource utilization of the system [2]. *Tarhini et al* introduced a new density-based admission control scheme. A novel QoS-oriented resource allocation approach was utilized to reduce the higher dropping rate. It was the combination of streaming (for instance voice) and elastic (data) flows in IEEE 802.16e mobile WiMax. These flows were more tolerant to delay [3].

Ng et al suggested the design of resource allocation and scheduling for orthogonal frequency division multiple access (OFDMA) decode-and-forward (DF) relay networks. A distributed resource allocation algorithm was proposed for secrecy and channel outage [4]. *Jha et al* discussed the analysis of location based resource allocation for WiMax. This was employed to enhance the overall throughput of the system [5]. *Afolabi et al* proposed channel-aware multicast scheduling and resource allocation (MSRA) technique. This also explained the formation of the multicast group. This technique was processed for downlink multicast services in ODFMA systems. It maximizes the throughput and better performance [6]. *Ng et al* addressed the scheduling difficulty in multi-cell OFDMA systems with DF relaying. A time slot strategy was integrated to alleviate the interference. It provides higher computational complexity and also signaling overhead using semi-distributed algorithm [7].

Li et al introduced a novel proximal optimization algorithm. It also addressed the difficulty of joint multi-path QoS routing and scheduling in wireless mesh network. It solved the subproblem of routing and scheduling using dual decomposition [8]. *Lu et al* studied the impact of relay station (RS) placement on IEEE 802.16j WiMax network. An effective heuristic algorithm was introduced to describe (a) the resource allocation schemes, (b) location of RS deployment. The RS placement problem was formulated using an Integer Linear Programming (ILP) model. It attains higher throughput [9]. *Karimi et al* proposed a two-level scheduling mechanism which was an integration of Priority Queuing (PQ), Weighted Round Robin (WRR), and First come, First served (FCFS). It provides better performance for best effort (BE) service class. Also accomplish high throughput of the network [10].

Huang et al presented a novel opportunistic layered multicasting (OLM) which was a joint user scheduling and resource allocation methodology. It also contributed the formulation for efficient multicasting of layered video over mobile WiMax. It was applicable to 4G technology based on OFDMA in the downlink distribution [11]. *Font-Bach et al* proposed a multi-antenna WL communications testbed, namely, Generic hardware demonstrator for multi input multi output (MIMO) systems (GEDOMIS). This estimates the formation of the whole PHY-layer of a real-time MIMO mobile WiMax receiver [12]. *Zubow et al* designed an SDMA-OFDMA Greedy Scheduling Algorithm (sGSA) for WiMax networks. A new complexity algorithm was described to predict the signal-to-interference-plus-noise ratio (SINR). It decreases the overall computational load [13].

Sheu et al presented a bounded greedy weighted algorithm (BGWA), which prevent redundant bandwidth allocation. It minimizes computational complexity and maximizes the throughput of the network and satisfied users [14]. *Esmailpour et al* proposed the Radio Resource Management (RRM) methods in WiMax. It also introduced two WiMax QoS metrics (fairness and utilization). It provides better performance [15]. *Hwang et al* suggested a new adaptive downlink bandwidth allocation method (DBAM). It also introduced the hierarchical priority queuing with weighted round robin (HPWRR) scheduling algorithm. It attains greater resource utilization and also improves the multicast traffic [16].

Yousefi et al proposed a multicast interference-aware scheduling mechanism for WiMax mesh networks. It leads to a better throughput and delay which supported by the spatial mini-slot [17]. *Lawal et al* investigated the distributed QoS-oriented model. It improvises the performance of network for fixed WiMax. Also develop the system of point-to-point and point-to-multipoints [18]. *Huang et al* addressed the sleep scheduling problem in IEEE 802.16j networks. To tackle this problem, an energy efficient sleep scheme was introduced [19]. Chang et al proposed an effective relay placement mechanism. It minimizes the number of relay stations, improves the network throughput, and minimize the cost of deploying BS [20]. *Chen et al* presented the new DL (Downlink) and UL (Uplink) Alignment (DUAL) scheme. The effect of energy conversation was improved using DUAL [21].

III. The Proposed Game Theory, Cell-Degree based Resource Allocation (CBRA) Methodology

This section presents the detailed explanation about the resource allocation based on the cell degree. Fig.2 describes the overall flow of the proposed game theory, cell-degree based resource allocation (CBRA) mechanisms along with the parameters of the user / base station (BS) in WiMax IEEE 802.16 wireless network.

As mentioned in the fig.1, the downlink two-hop infrastructures are discussed in the relay based architecture of a WiMax network. There are several user equipments (UEs) that distributed randomly and consists of two serving nodes, namely, one evolved Node B (eNB) and set of relay stations (RSs). Both eNB and RNs is considered as radio access points (RAP). This is determined by the size of the user’s signal-to-interference-plus-noise ratio (SINR) values and the signal during transmission. To differentiate the relay user with normal users, the following algorithm is described.

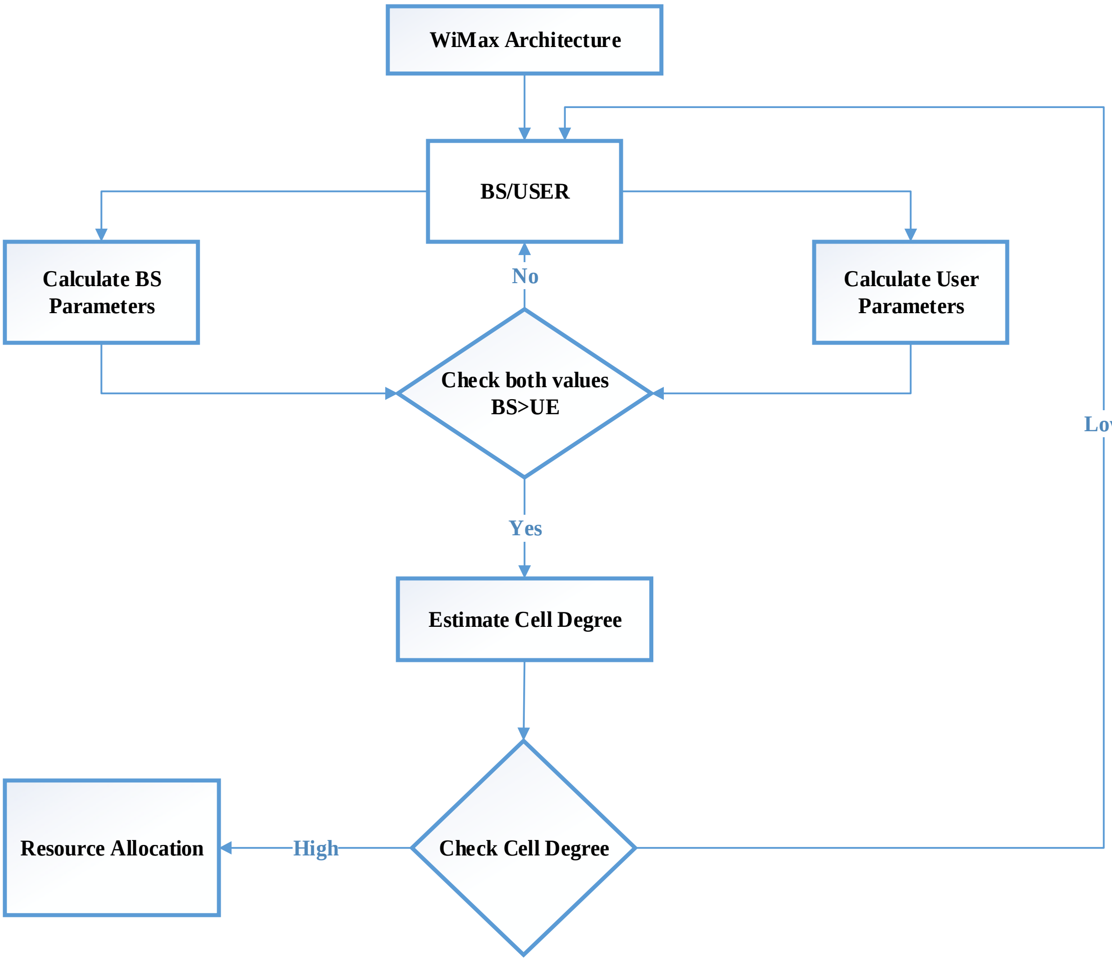

Fig.2. The overall flow of the proposed game theory, cell-degree based resource allocation (CBRA) mechanisms along with the parameters of the user / base station (BS) in WiMax IEEE 802.16 wireless network.

Algorithm to differentiate the normal and relay users

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1. Select the Relay Station (RS) // Nearest RS for the user in the cell.
2. Estimate the user's SINR value from eNB.
3. Determine the chosen RS to the user.
4. Pick destination node // Node with the larger SINR value.

$$DN = \max \{SINR_{RS}, SINR_{MS}\} \quad (1)$$

where $SINR_{RS}$ and $SINR_{MS}$ are the SINR values from RS and MS.

A. User SINR Dispersion (USD)

Assume *N* users in a cell, which composed of a radio network, the maximum value of SINR is termed as *max S*, the *max S* were splited into *K* segments. The USD is estimated as follows:

$$USD_i = \frac{1}{K}\sum_{n=1}^{N}\left(\sum_{j=1}^{K} USD\left(C_{n,j}\right).j - usd\right)^2 \quad (2)$$

$$usd = \frac{1}{N}\sum_{n=1}^{N}\sum_{j=1}^{K} USD\left(C_{n,j}\right).j \quad (3)$$

where $USD(C_{n,j})$ denotes the value of SINR is dispersed in the segment j (1≤ j ≤K). If the above statement satisfies, $USD(C_{n,j})$=1 or else 0. Herein, USD_i denotes the USD of microcell i, which mentions the change about quality of channel for various users among the micro-cell. This offers a significant reference to guarantee user fairness. Fig.3 depicts the Cumulative Distribution Function (CDF) curves of user's SINR.

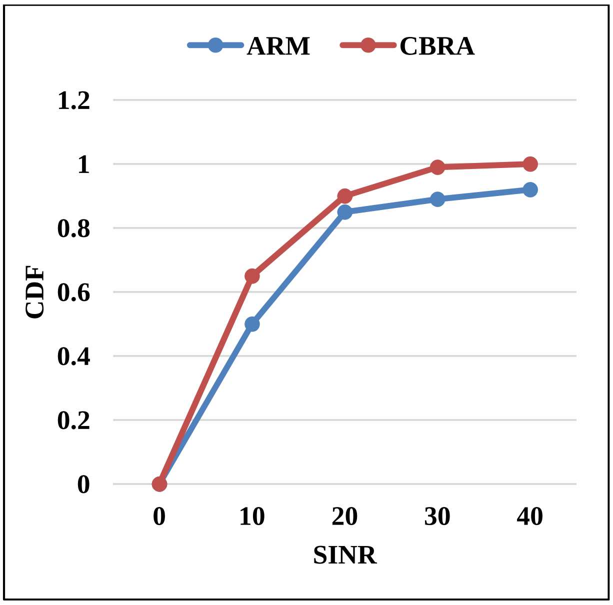

Fig.3. The CDF curves of users SINR with the existing ARM and the proposed CBRA methodology.

B. Cell-Degree Based Resource Allocation Algorithm

The overall performance of the WiMax system is based upon the enhancement of network throughput and also the user fairness. The proposed game theory algorithm is to enhance the throughput of network by guaranteeing user fairness. For measuring a cell's resource utilization, the basic parameters used are throughput and fairness. The cell degree is introduced to balance the connection between the system's network throughput and user fairness. The cell degree is the ratio of the normalized throughput T and the user fairness F. The system utility function (i.e., throughput of the cell and user fairness) is as follows:

$$UF(Cf_a, Ar_b, \theta) = \prod_{a=1}^{m} \prod_{b=1}^{n} (Ar_b - Rr_b) \quad (4)$$

$$s.t \ \sum_{a=1}^{m} Cf_a = \theta S \quad (5)$$

$$s.t \ \sum_{b=1}^{n} Ar_b = (1-\theta)S \quad (6)$$

where Ar_b describes the standardized actual rate of user b, Rr_b denotes the smallest required rate, Cf_a represents the degree of channel fairness of micro-cell a, which is the reciprocal of USD_i. θ is the relative between the standardized throughput T and the user fairness F, as the cell degree. S signifies the sum of standardized throughput and user fairness. *UF* comprise the T and F, which should be in equal proportion. To optimize the performance of the system, T and F should attain the greatest value. Therefore, $uf(\theta)$ is defined as follows:

$$uf(Cf_a, Ar_b, \theta) = \ln(UF(Cf_a, Ar_b, \theta)) \quad (7)$$

i.e., $$uf(Cf_a, Ar_b, \theta) = \sum_{a=1}^{m} \ln Cf_a + \sum_{a=1}^{m} \ln(Ar_b - Rr_b) \quad (8)$$

The proposed CBRA algorithm is to accomplish the best symmetry of T and F. It is based on the *USD* of micro-cells. The θ value is obtained as follows:

$$\theta = \left(\frac{\sum_{b=1}^{n} Rr_b}{S.n} + \frac{1}{m}\right) . \frac{1}{\frac{1}{m} + \frac{1}{n}} \quad (9)$$

Fig.4 shows the analysis of user fairness with regard to the average throughput of the overall system for the existing ARM and the proposed CBRA algorithm.

The Procedure of CBRA Algorithm

1) Get the parameters of UE and BS based on channel conditions.
2) Calculate the value of user's SINR and the access conditions for RSs and eNB.
3) Estimate the User SINR Dispersion USD_i of micro-cell *i*.
4) Get the parameter of Cf_a and Ar_b, produce $UF(Cf_a, Ar_b, \theta)$.
5) $uf(\theta)$ is determined to get the cell degree θ.
6) Resource Allocation is done based on the θ.

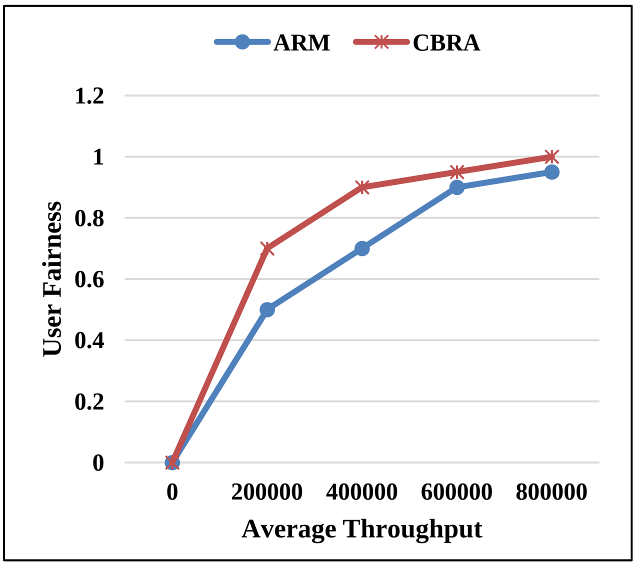

Fig.4. The analysis of user fairness with respect to the average throughput of the system for the existing ARM and the proposed CBRA methodology.

IV. Performance Analysis

In this section, the performance of proposed algorithm is estimated and compared with the existing algorithms. The analysis is based on the following metrics:

A. Amount of Bandwidth vs. Network Throughput

The network throughput is denoted as the degree of effective message delivery over a communication channel. It is measured in terms of bits per second (bps). Fig.5 represents the performance analysis of the network throughput with respect to the amount of bandwidth. It analyzes the existing methods: greedy approach, bounded greedy weighted algorithm (BGWA), call admission control (CAC), joint scheduling and resource allocation (JSRA), coverage based cell selection (CBCS), adaptive resource allocation mechanism (ARM) with the proposed Cell-degree based Resource Allocation (CBRA) methodology. The proposed approach attains higher network throughput than the existing methods.

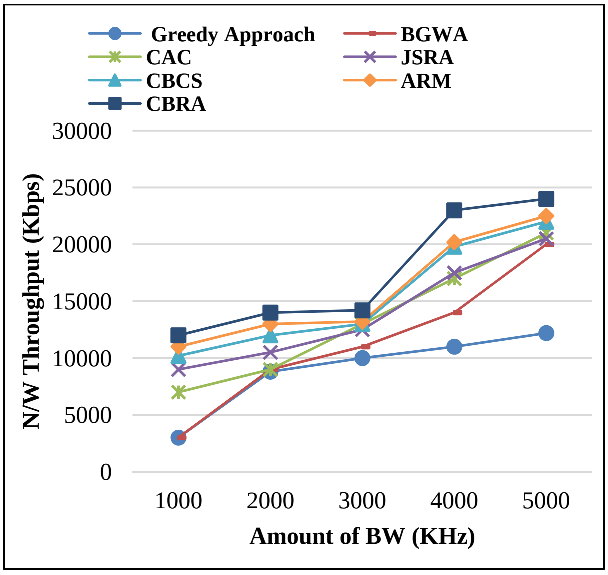

Fig.5. The result of network throughput with respect to the amount of bandwidth for existing greedy approach, BGWA, CAC, JSRA, CBCS, ARM and the proposed CBRA approach.

B. Amount of Bandwidth vs. Network Throughput to Bandwidth Consumption Ratio

The bandwidth is defined as the data rate maintained by a network connection or interface. The higher the capacity, the greater the performance. Fig.6 describes the performance analysis of the network throughput of bandwidth consumption ratio with respect to the amount of bandwidth. It analyzes the existing methods: greedy approach, bounded greedy weighted algorithm (BGWA), call admission control (CAC) joint scheduling and resource allocation (JSRA), coverage based cell selection (CBCS), adaptive resource allocation mechanism (ARM) with the proposed Cell-degree based Resource Allocation (CBRA) methodology. The proposed approach attains greater network throughput to BW consumption ratio than the existing methods.

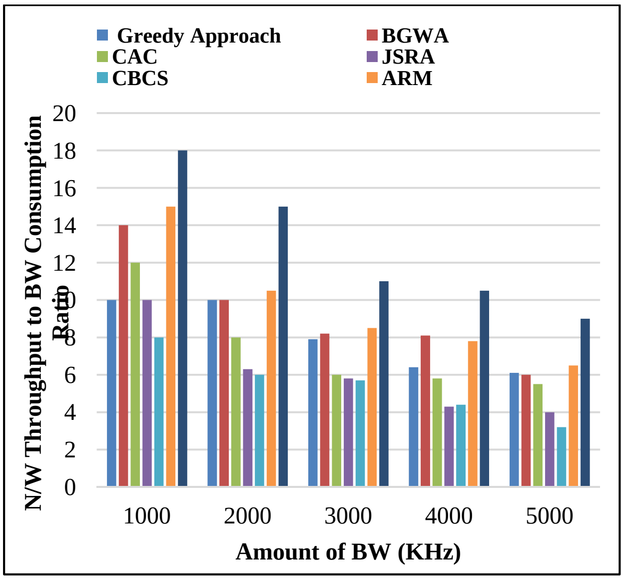

Fig.6. The result of network throughput to bandwidth consumption ratio with regard to the amount of bandwidth for existing greedy approach, BGWA, CAC, JSRA, CBCS, ARM and the proposed CBRA approach.

C. Number of SSs vs. Network Throughput

Fig.7 depicts the performance analysis of the network throughput with respect to the number of subscriber stations (SSs). It analyzes the existing methods: greedy approach, bounded greedy weighted algorithm (BGWA), call admission control (CAC) joint scheduling and resource allocation (JSRA), coverage based cell selection (CBCS), adaptive resource allocation mechanism (ARM) with the proposed Cell-degree based Resource Allocation (CBRA) methodology. The proposed approach achieves higher network throughput than the existing methods.

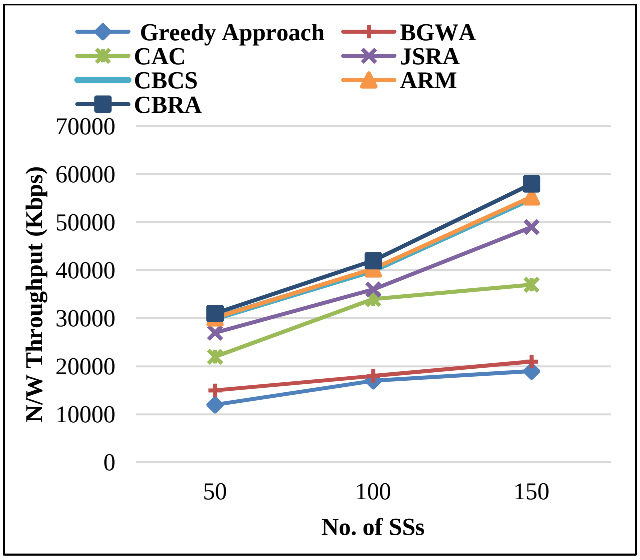

Fig.7. The result of network throughput as the number of SSs for existing greedy approach, BGWA, CAC, JSRA, CBCS, ARM and the proposed CBRA approach.

D. Number of SSs vs. Network Throughput to Bandwidth Consumption Ratio

Fig.8 shows the performance analysis of the network throughput of bandwidth consumption with respect to the number of subscriber stations (SSs). It analyzes the existing methods: greedy approach, bounded greedy weighted algorithm (BGWA), call admission control (CAC), joint scheduling and resource allocation (JSRA), coverage based cell selection (CBCS), adaptive resource allocation mechanism (ARM) with the proposed Cell-degree based Resource Allocation (CBRA) methodology. The proposed approach accomplishes greater network throughput to BW consumption ratio than the existing methods.

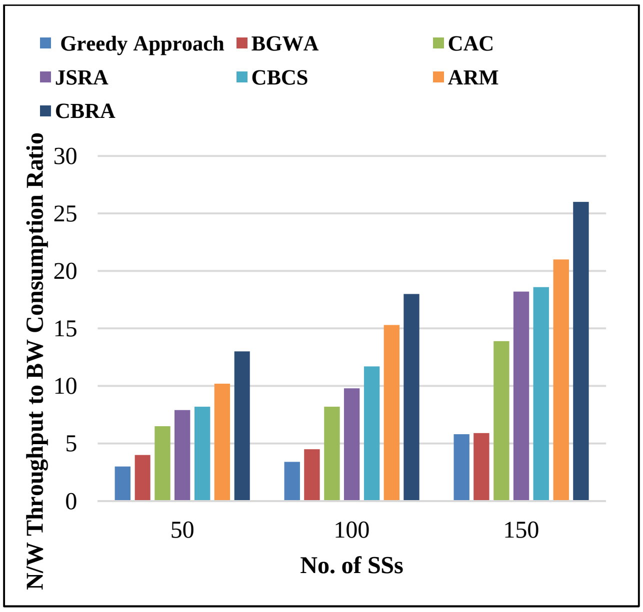

Fig.8. The result of network throughput to bandwidth consumption ratio with respect to the number of SSs for existing greedy approach, BGWA, CAC, JSRA, CBCS, ARM and the proposed CBRA approach.

V. Conclusion

In this proposed work, a novel game theory, cell degree based resource allocation (CBRA) algorithm is introduced. This accomplishes the highest network throughput and also user fairness. It enhance the cell degree of the system using the proposed methodology. At first, the user/ base station evaluates the data rate, and the QoS parameter such as bandwidth, latency, jitter, cell loss ratio, cell error ratio. If the value of BS is higher than the user equipment, then it estimate the cell degree. The SINR dispersion is employed as the major parameter for allocating the resource. The performance analysis shows the proposed CBRA algorithm that incorporates the network throughput, user fairness and game theory. This accomplishes higher network throughput to bandwidth consumption ratio than the existing greedy approaches.

REFERENCES

[1] Y. Kim and M. L. Sichitiu, "Optimal max–min fair resource allocation in multihop relay-enhanced WiMAX networks," Vehicular Technology, IEEE Transactions on, vol. 60, no. 8, pp. 3907-3918, 2011.

[2] K. M. Awan, et al., "Channel Based Resource Allocation Mechanism (CBRAM) in WiMAX," Life Science Journal, vol. 10, no. 3, 2013.

[3] C. Tarhini and T. Chahed, "QoS-oriented resource allocation for streaming flows in IEEE802. 16e Mobile WiMAX," Telecommunication Systems, vol. 51, no. 1, pp. 65-71, 2012.

[4] D. W. K. Ng, et al., "Secure resource allocation and scheduling for OFDMA decode-and-forward relay networks," Wireless Communications, IEEE Transactions on, vol. 10, no. 10, pp. 3528-3540, 2011.

[5] R. K. Jha, et al., "Resource Allocation in Mobile WiMAX Network: An Optimal Approach," arXiv preprint arXiv:1211.1782, 2012.

[6] R. O. Afolabi, et al., "Multicast scheduling and resource allocation algorithms for OFDMA-based systems: A survey," Communications Surveys & Tutorials, IEEE, vol. 15, no. 1, pp. 240-254, 2013.

[7] D. W. K. Ng and R. Schober, "Resource allocation and scheduling in multi-cell OFDMA systems with decode-and-forward relaying," IEEE Transactions on Wireless Communications, vol. 10, no. 7, pp. 2246-2258, 2011.

[8] Y. Li, et al., "Optimization architecture for joint multi-path routing and scheduling in wireless mesh networks," Mathematical and Computer Modelling, vol. 53, no. 3, pp. 458-470, 2011.

[9] H.-C. Lu, et al., "Relay station placement strategy in IEEE 802.16 j WiMAX networks," IEEE Transactions on Communications, vol. 59, no. 1, pp. 151-158, 2011.

[10] R. Karimi, et al., "New Downlink Scheduling Framework for Hybrid Unicast and Multicast Traffic in WiMAX Networks," International Journal of Wireless and Microwave Technologies (IJWMT), vol. 2, no. 5, p. 69, 2012.

[11] C.-W. Huang, et al., "OLM: opportunistic layered multicasting for scalable IPTV over mobile WiMAX," IEEE Transactions on Mobile Computing, vol. 11, no. 3, pp. 453-463, 2012.

[12] O. Font-Bach, et al., "A real-time MIMO-OFDM mobile WiMAX receiver: Architecture, design and FPGA implementation," Computer Networks, vol. 55, no. 16, pp. 3634-3647, 2011.

[13] A. Zubow, et al., "sGSA: A SDMA–OFDMA greedy scheduling algorithm for WiMAX networks," Computer Networks, vol. 56, no. 15, pp. 3511-3530, 2012.

[14] J.-P. Sheu, et al., "A resource allocation scheme for scalable video multicast in WiMAX relay networks," IEEE Transactions on Mobile Computing, vol. 12, no. 1, pp. 90-104, 2013.

[15] A. Esmailpour and N. Nasser, "A Novel Scheme for Packet Scheduling and Bandwidth Allocation in WiMAX Networks," in IEEE International Conference on Communications (ICC) 2011, pp. 1-5.

[16] I.-S. Hwang, et al., "Maximizing downlink bandwidth allocation method based on SVC in mobile WiMAX networks for generic broadband services," ISRN Communications and Networking, vol. 2011, p. 5, 2011.

[17] S. Yousefi and M. Maleki, "Multicast scheduling algorithm supporting spatial mini-slot reuse for IEEE 802.16 mesh networks," Communications, China, vol. 10, no. 1, pp. 116-133, 2013.

[18] I. A. Lawal, et al., "A Distributed QoS-Oriented Model to Improve Network Performance for Fixed WiMAX," Int. J. on Recent Trends in Engineering and Technology, vol. 10, no. 1, 2014.

[19] H.-S. Huang, et al., "Sleep scheduling in IEEE 802.16 j relay networks," in Personal Indoor and Mobile Radio Communications (PIMRC), 2013 IEEE 24th International Symposium on, 2013, pp. 2951-2955.

[20] C.-Y. Chang and M.-H. Li, "A placement mechanism for relay stations in 802.16 j WiMAX networks," Wireless Networks, vol. 20, no. 2, pp. 227-243, 2014.

[21] J. Chen, et al., "A Downlink and Uplink Alignment Scheme for Power Saving in IEEE 802.16 Protocol," The Scientific World Journal, vol. 2014, 2014.