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Venue Cast User Prioritized Round Robin Scheduling Algorithm

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Abstract: ***The demand for video services such as live video streaming, video on demand etc., over mobile broadband has been growing rapidly in recent years and is expected to increase in near future. If the mobile networks consider unicast transmissions to every user accessing live video streaming applications then it may lead to inefficient resource utilization and reduced fairness among users. In order to support these high data rate video service users, Long Term Evolution (LTE) network has adopted mobile broadcasting and multicast mechanism for efficient utilization of the available spectrum. Mobile broadcasting is a mechanism that efficiently delivers same content using common resources to many users. The design of resource allocation strategies for broadcast and multicast services is required to achieve high performance in terms of both total service throughput achieved and fairness among all the users. Hence in this paper, Venue Cast User Prioritized Round Robin (VCUPRR) Scheduling Algorithm is proposed to enhance throughput and fairness of venue cast users accessing same venue specific content. The performance of proposed scheduling algorithm is evaluated using QualNet 7.1 network simulator by considering aggregate throughput, average delay and average jitter as performance metrics.***

Keywords: LTE, Round Robin, Scheduling, Venue cast users.

I. INTRODUCTION

The growing demand for mobile video services such as live and on-demand video streaming services in Long Term Evolution (LTE) network pose new challenges in the design of scheduling algorithms to improve the overall system capacity [1]. With the introduction of evolved Multimedia Broadcast and Multicast Service (eMBMS) in LTE [2], users in venue specific areas can be delivered with same multimedia content using a Single-Frequency Network (SFN) mode. However to perform optimal resource allocation in eMBMS, a number of mechanisms such as multicast coding scheme, resources allocated to unicast users and multicast group, the number of groups and their membership, etc., needs to be considered [3].

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Resource allocation strategies for broadcast and multicast services are not standardized and new techniques are designed to achieve high throughput performance and fairness among users. Many system designers consider the channel condition experienced by users in resource allocation [4], which maximizes the throughput performance of users in good channel condition. However, the users with bad channel condition may not be serviced leading to reduced fairness among users and inefficient spectrum utilization [1].

Hence in this paper, a novel Venue Cast User Prioritized Round Robin (VCUPRR) scheduling algorithm is proposed in which venue cast users are identified and grouped during resource allocation to enhance overall system throughput and fairness. Performance of the proposed VCUPRR scheduling algorithm is evaluated using QualNet 7.1 network simulator by considering aggregate throughput, average delay and jitter as performance metrics.

The rest of this paper is organized as follows. Section II describes the existing Round Robin (RR) scheduling algorithm for LTE Networks. Section III describes proposed VCPURR scheduling algorithm. Simulation results and discussion are presented in Section IV, followed by conclusion in section V.

II. ROUND ROBIN (RR) SCHEDULING ALGORITHM

In Round Robin (RR) scheduling algorithm, the number of available RBs (N_{PRB}) is estimated using channel bandwidth. The available RBs are divided into Resource Block Group (RBG) and the number of RBs in each group (RBG size) varies depending on the channel bandwidth as given in table I. Fig. 1 shows the representative scenario for RR scheduling algorithm with 5MHz channel bandwidth consisting of three unicast and three venue cast User Equipments (UEs).

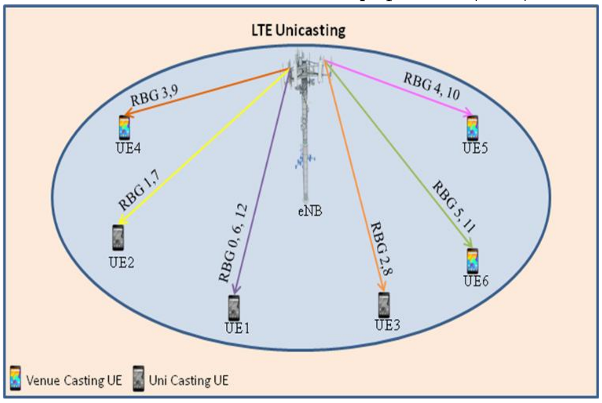

Fig. 1.Representative scenario with 5 MHz channel bandwidth for RR scheduling algorithm

Table- I: Number of available RBs (N_{PRB}) and RBG in Channel bandwidths

Channel bandwidth [MHz]	1.4	3	5	10	15	20
Number available RBs (N_{PRB})	6	15	25	50	75	100
Number of RBG	6	7	13	17	19	25
RBG size	1	2	2	3	4	4

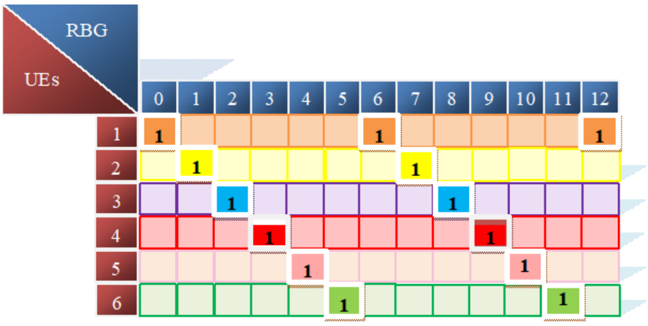

Fig. 2.Representative bitmap of UEs for 5 MHz bandwidth for RR algorithm

In every Transmission Time Interval (TTI), eNB considers UEs from a list of connected UEs for which it has data to communicate as target UEs and prepares a list of target UEs. The number of UEs that can be served among the list of target UEs is determined based on number of RBGs and number of target UEs whichever is minimum. eNB schedules these UEs one after the other in cyclic order [5][6]. For each UE, when a RBG is allocated, a bit corresponding to the allocated RBG in the bitmap of the UE is set (fig. 2).

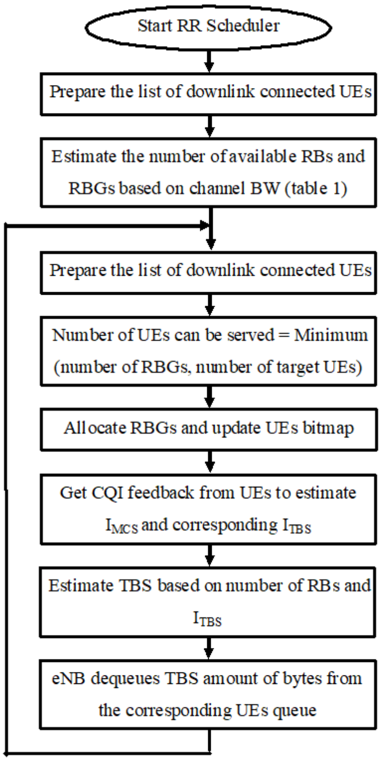

Fig. 3.Flowchart of RR Scheduling Algorithm

At the end of current TTI, eNB determines Modulation and Coding Scheme index (I_{MCS}) based on Channel Quality Indicator (CQI) values retrieved from UE and then estimates the corresponding Transport Block Size index (I_{TBS}) [7]. Further, eNB dequeues Transport Block Size (TBS) amount of bytes, estimated based on number of RBs allocated (N_{RB}) and I_{TBS}, from the corresponding UE queue. Fig. 3 shows the flowchart of RR scheduling algorithm.

III. PROPOSED VENUE CAST USER PRIORITIZED ROUND ROBIN (VCUPRR) SCHEDULING ALGORITHM

The users accessing venue specific contents such as live video coverage, software updates, departure and arrival information at the airport, special offers available at the mall etc., over LTE network are increasing rapidly. If such users accessing the same content are considered as unicast users then there is an increase in the resource (RB) requirement as the cell load increases. Hence, to service the users accessing venue specific contents, venue casting mechanism is adapted at eNB where same content are delivered to many users using common resource blocks.

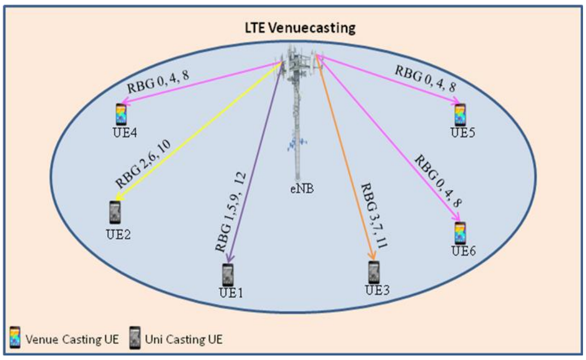

Fig. 4.Representative scenario with 5 MHz bandwidth for the proposed VCUPRR scheduling algorithm

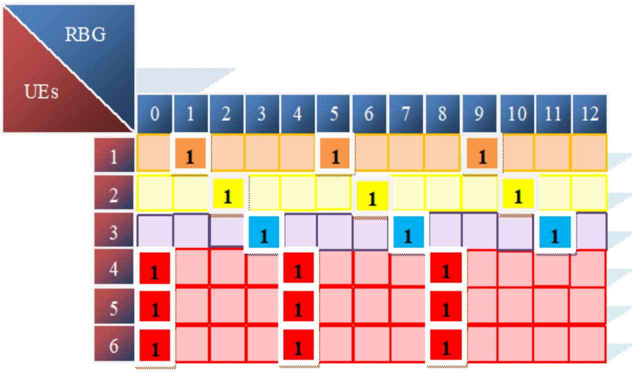

Fig. 5.Representative bitmap of UEs with 5MHz Bandwidth for VCUPRR scheduling algorithm

In the proposed VCUPRR Scheduling Algorithm, the number of available RBs (N_{PRB}), RBGs and UEs to be served are estimated as per the RR scheduling algorithm. Further in the proposed scheduling algorithm, the users accessing same streaming content are identified among the UEs to be served and grouped as venue cast users.

From the group of venue cast users, A UE experiencing the lowest CQI value is identified and its MCS index and corresponding Transport Block Size achievable with a single allocated RBG is estimated. The total number of RBGs (N_{RBG}) required to suffice Quality of Experience (QoE) of the corresponding venue casting UE is obtained by (1)

$$N_{RBG} = \frac{\text{Total buffer size of the UE}}{\text{TBS achieved with single RBG}} \qquad (1)$$

The same N_{RBG} RBGs are allocated to all venue cast users in the group by setting the bit corresponding to RBGs in bitmap of each venue cast UE (fig. 5) thereby allowing them access the venue specific content through same RBGs. Further, the remaining RBGs are allocated to unicast UEs among the list of target UEs as per RR scheduling algorithm [8]. Fig. 4 shows the representative scenario for proposed VCUPRR scheduling algorithm consisting of three unicast (UEs 1,2,3) and venue cast UEs (UEs 4,5,6) with 5MHz channel bandwidth. The flowchart of the proposed VCUPRR algorithm is shown in fig. 6.

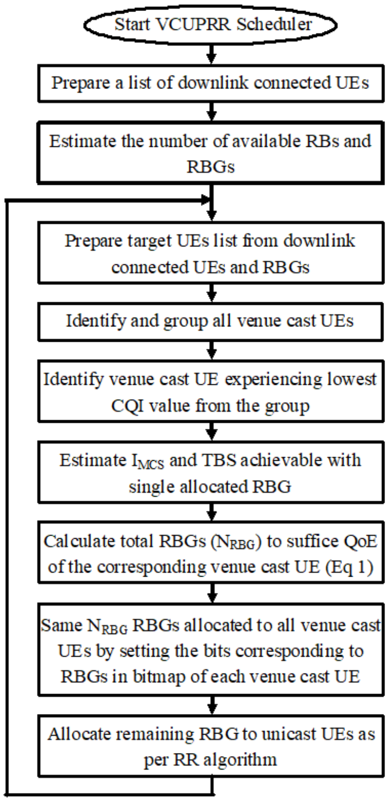

Fig. 6.Flowchart of Proposed VCUPRR Scheduling Algorithm

IV. SIMULATION AND RESULTS

The performance of proposed algorithm is evaluated using QualNet 7.1 network simulator by considering single cell scenario in a simulation area of 5Km x 5Km. Two ray path loss model with lognormal shadowing is considered for the simulation studies. The remaining simulation parameters are listed in table II. The snapshot of the scenario designed for simulation study using QualNet 7.1 network simulator is shown in fig. 7.

Table II: Simulation Parameters

Property		Value
Simulation-Time		30sec
Simulation-Area		5Km X 5Km
Downlink-Channel-Frequency		1.85GHz
Uplink-Channel-Frequency		1.75GHz
Pathloss model		Two-ray
Propagation-Model		Statistical
Fading Model		Ricean
Ricean K factor		4.0
Shadowing mean		4dB
Channel-Bandwidth		10MHz
Antenna-Model		Omnidirectional
eNB	PHY- Tx-Power	46dBm
	PHY- Num-Tx-Antennas	1
	PHY- Num-Rx-Antennas	1
	Antenna-Height	15m
UE	MAC- Scheduler-Type	Simple-Scheduler
	PHY- Tx-Power	23dBm
	PHY- Tx-Antennas	1
	PHY- Rx-Antennas	1
	Antenna-Height	1.5m

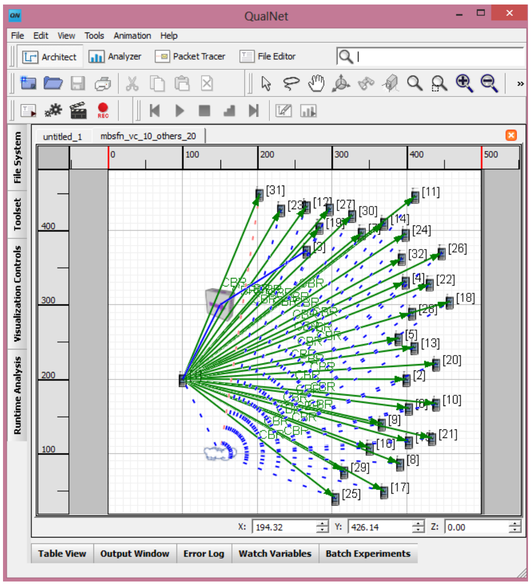

Fig. 7.Snapshot of the scenario designed for performance evaluation RR and VCUPRR scheduling algorithms

A. Scenario 1

In this scenario, an eNB with 10 venue cast UEs & 20 unicast UEs are considered in a single cell environment. A downlink Constant Bit Rate (CBR) connection of 512Kbps is established between eNB and each UE. Simulation is carried out for the proposed VCUPRR scheduling algorithm for channel bandwidth of 1.4 MHz and total number of users served, number of unicast and venue cast users served and aggregate throughput of unicast and venue cast users are recorded. Also, simulation studies are repeated for data rates of 1Mbps and 2Mbps.

Further, the simulation experiments are carried out by increasing the number of venue cast UEs from 10 to 50 in steps of 10 UEs.
Similar set of simulation experiments are repeated by setting the channel bandwidth to 3MHz, 5MHz, 10MHz, 15MHz and 20 MHz. Also, simulation studies are repeated for existing RR algorithm. The results recorded are tabulated in table III.

Table- III: Total number of users served, number of unicast and venue cast users served, aggregate throughput performance for different bandwidth and data rates

BW (MHz)	Data rate (bps)	Total users served		Unicast users served	Venue cast users served	Aggregate Throughput (Mbps)	
		With Basic RR	With VCUPRR			Unicast user	Venue cast user
1.4	512K	6	11	1	10	2.74	5.11
			21		20	2.76	10.23
			31		30	2.76	15.35
			41		40	2.76	20.47
			51		50	2.78	25.59
	1M	6	11		10	2.07	9.96
			21		20	2.07	19.92
			31		30	2.07	29.94
			41		40	2.07	39.94
			51		50	2.08	49.9
	2M	6	11		10	1.49	18.17
			21		20	1.56	37.44
			31		30	1.55	57.59
			41		40	1.53	77.38
			51		50	1.75	94.09
3	512K	7	13	3	10	7.6	5.11
			23		20	7.66	10.22
			33		30	7.67	15.35
			43		40	7.65	20.46
			53		50	7.74	25.59
	1M	7	13		10	6.99	9.92
			23		20	7.06	19.95
			33		30	7.05	29.93
			43		40	7.06	39.96
			53		50	7.14	49.87
	2M	7	13		10	6.37	17.63
			23		20	6.55	35.99
			33		30	6.49	56.77
			43		40	6.56	75.70
			53		50	6.69	92.54
5	512K	13	18	8	10	9.88	5.03
			28		20	9.61	10.16
			38		30	9.94	15.28
			48		40	10.13	20.41
			58		50	9.87	25.51
	1M	13	18		10	10.93	9.80
			28		20	10.91	19.81
			38		30	11.05	29.83
			48		40	10.74	39.81
			58		50	11.17	49.71
	2M	13	18		10	10.31	15.77
			28		20	10.81	34.99
			38		30	10.93	53.02
			48		40	10.49	74.33
			58		50	10.94	85.93
10	512K	17	22	12	10	10.1	5.06
			32		20	10.12	10.19

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			42		30	10.12	15.22
			52		40	10.13	20.44
			62		50	10.1	25.3
			22		10	15.03	9.86
			32		20	16.54	19.88
	1M	17	42		30	15.91	29.86
			52		40	15.8	39.88
			62		50	16.12	49.81
			22		10	16.58	15.67
			32		20	16.72	34.59
	2M	17	42		30	17.42	53.31
			52		40	17.87	74.11
			62		50	18.99	87.10
			24		10	10.11	5.08
			34		20	10.12	10.2
	512K	19	44		30	10.12	15.32
			54		40	10.12	20.43
			64		50	10.11	25.51
			24		10	16.11	9.91
			34		20	16.92	19.83
15	1M	19	44	14	30	17.47	29.85
			54		40	18.46	39.85
			64		50	17.78	49.74
			24		10	21.14	14.64
			34		20	22.29	32.7
	2M	19	44		30	21.79	51.97
			54		40	21.3	72.03
			64		50	23.09	82.64
			30		10	10.1	5.04
			40		20	10.1	10.17
	512K	25	50		30	10.09	15.28
			60		40	10.09	20.39
			70		50	10.10	25.48
			30		10	18.73	9.80
			40		20	19.11	19.17
20	1M	25	50	20	30	19.29	29.15
			60		40	18.34	39.19
			70		50	18.75	49.07
			30		10	19.11	12.78
			40		20	19.51	31.17
	2M	25	50		30	19.75	50.54
			60		40	20.02	68.57
			70		50	23.33	77.57

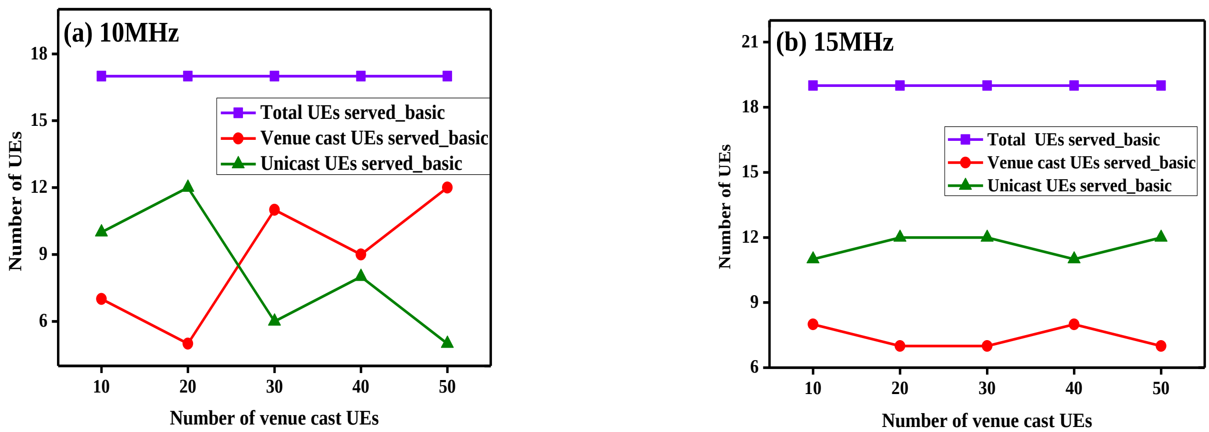


Fig. 8.Plot of total number of users, unicast and venue cast users served with increasing number of venue cast users in the representative scenario for basic RR scheduling algorithm with channel bandwidth a) 10MHz and b) 15MHz

From table III and fig. 8(a-b), it is evident that for existing RR scheduling algorithm, the total number of UEs (unicast and venue cast) served is limited to number of RBGs (table 1) available for a particular bandwidth, i.e., 6, 7, 13, 17, 19 and 25 UEs served for bandwidth of 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz respectively. The RR scheduling algorithm allocates one RBG to each UE, if the number of target UEs is more than the available RBGs. In the scenarios considered for simulation studies, the minimum total number of UEs including both venue cast and unicast users is 30 and is more than the RBGs available with all considered bandwidth.

Also, from the table III and fig. 9(a-b), it is evident that for proposed VCUPRR algorithm, the maximum number of unicast UEs served are almost same and equal to the number of available RBGs excluding RBGs allocated to serve venue cast UE experiencing lowest CQI value. It is also evident from the table 3 that all venue cast users in the cell are served and it is also observed that the number of venue cast users served increases with increase in number of venue cast users in the considered scenarios.

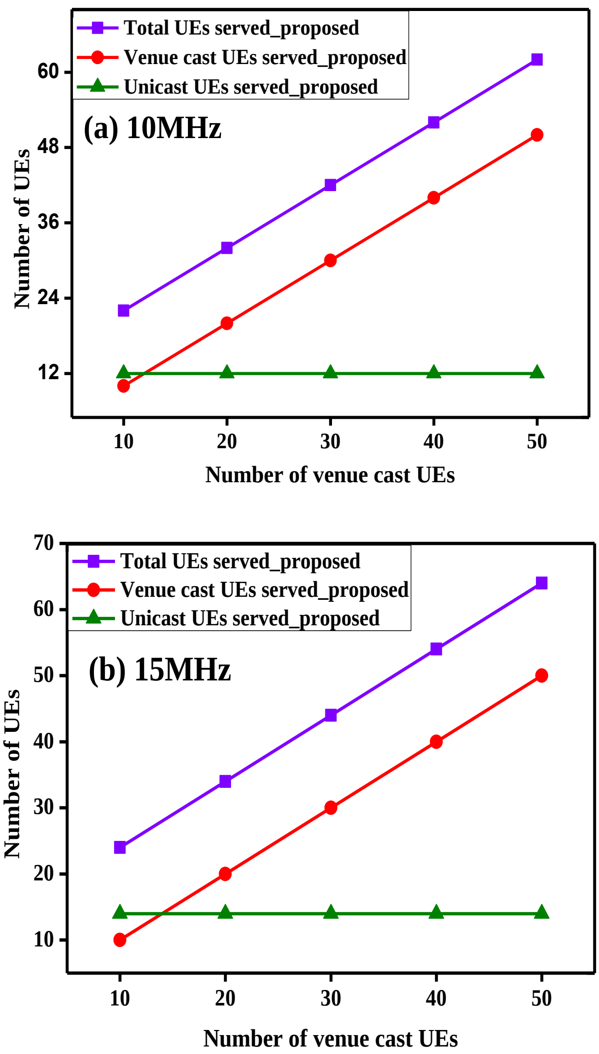


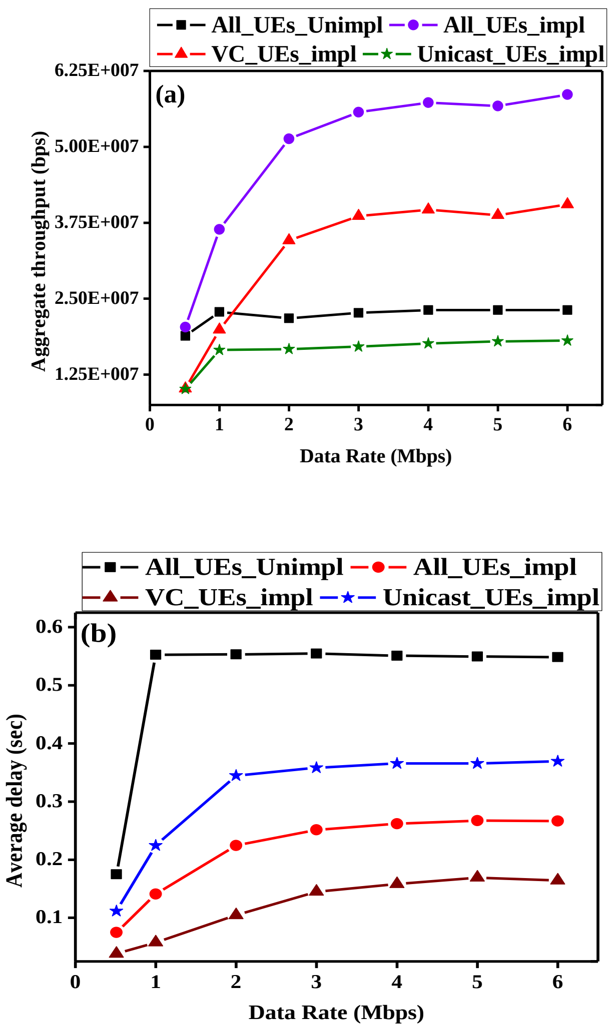
Fig. 9.Plot of total number of users, unicast and venue cast users served with increasing number of venue cast users in the representative scenario for proposed VCUPRR scheduling algorithms with channel bandwidth a) 10MHz and b) 15MHz

It is also evident from table III that aggregate throughput of unicast users is almost constant for all scenarios considered for a given data rate independent of number of venue cast users, since number of unicast users served are same. The aggregate throughput performance of venue cast users increases with increase in number of venue cast users served. The observed increase in throughput is almost equal to the product of number of venue cast users and data rate of each venue cast user.

B. Scenario 2

In this scenario, the simulation parameters of scenario 1 are retained and simulation is carried out for the proposed algorithm for channel bandwidth of 10MHz and performance metrics such as aggregate throughput, average delay and average jitter are recorded. Also, simulation studies are repeated by increasing the data rate to 1Mbps and further upto 6Mbps in steps of 1Mbps.

Similar set of simulation experiments are repeated for proposed VCUPRR scheduling algorithm with channel bandwidth of 15MHz and also repeated for basic RR scheduling algorithm.



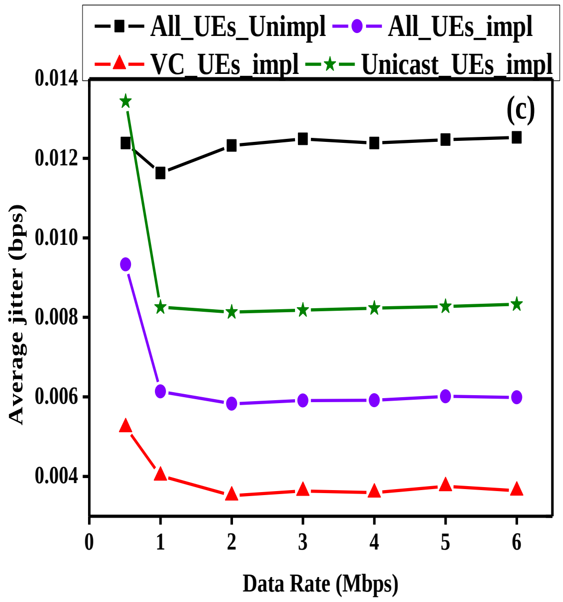


Fig. 10. (a) Aggregate throughput, (b) Average delay and (c) Average jitter performances for 10 venue cast and 20 unicast UEs with 10MHz channel bandwidth for RR and VCUPRR scheduling algorithms

Figures 10(a-c) shows aggregate throughput, average delay and jitter performances for representative scenario consisting of 10 venue cast user and 20 unicast users respectively for RR and VCUPRR scheduling algorithms with 10MHz channel bandwidth.

From the fig. 10(a) it is evident that the aggregate throughput performance increases linearly for lower data rates as sufficient number of RBs are available for all users. However, at higher data rate above 2Mbps, the throughput performance of all UEs saturates as the cell capacity is less than the number of UEs within the cell.

It is also evident from fig. 10(a) that total throughput performance of the proposed VCUPRR scheduling algorithm is better compared to the RR scheduling algorithm.

It also observed from the fig. 10(a) that throughput performance of venue cast users are much better than unicast users and total throughput performance of the RR scheduling algorithm.

Since in proposed VCUPRR algorithm same RBGs are allocated to all venue cast users, the remaining RBGs are efficiently distributed among the unicast users thereby increasing the overall system throughput and venue cast user throughput.

Where in RR scheduling algorithm unicast and venue cast user are not differentiated and available RBGs are used to serve all users there by reducing total throughput performance.

Further from figures 10(b and c), it is observed that the delay and jitter performances of the proposed VCUPRR scheduling algorithm is better compared to the RR scheduling algorithm. Observed better delay and jitter performance for venue cast users is due to allocation of dedicated RBGs.

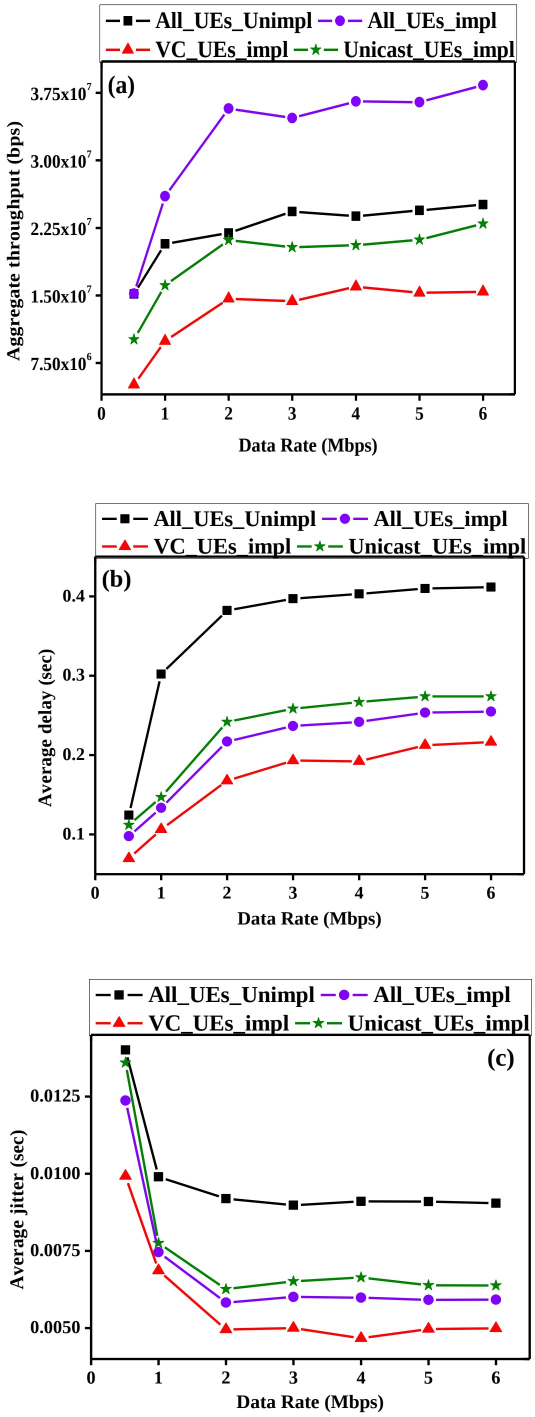


Fig. 11. (a) Aggregate throughput, (b) Average delay and (c) Average jitter performances for 10 venue cast and 20 unicast UEs with 15MHz channel bandwidth

V. CONCLUSION

LTE standard introduces evolved Multimedia Broadcast and Multicast Service (eMBMS) to support high data rate video applications over the mobile broadband. In this paper, a novel Venue Cast User Prioritized Round Robin (VCUPRR) scheduling algorithm is proposed in which venue cast users are identified and grouped during resource allocation to enhance overall system throughput and fairness.

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Performance evaluation of the proposed VCUPRR scheduling algorithm is carried out using QualNet 7.1 Network simulator by varying number of venue cast users. From simulation results, it is evident that throughput is enhanced for unicast and venue cast users without degrading overall system throughput.

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