5G Downlink Throughput Enhancement by Beam Consolidation at Vacant Traffic

Ali Othman Mohammed Al Janaby

***Abstract*—The 3GPP release for 5G (R15) assigns each User Equipment (UE) a radio beam by employing Massive Multi User Multiple-Input Multiple-Output (MU-MIMO) technology. Each beam carries, at the downlink, a data with a rate according to the Modulation and Coding Scheme (MCS) assigned by the base station (BS). For the limited existence of active UEs and during vacant traffic, all UEs are not active or standby, the assigned beams will be transmitted, but not to any UE. This paper proposes a new scheme that consolidates vacant beams of inactive UEs, to the adjacent beam of the active UE or UE at the cell edge to duplicate the bandwidth of the new beam. The proposed scheme increases the level of desired MCS to a higher scheme (e.g. from Quadrature Phase Shift Keying (QPSK) to Quadrature Amplitude Modulation (QAM)), and hence enhances the spectral efficiency (SE) of the 5G mobile networks. The BS consolidates (combines) multiple radio beams along with the assigned beam during vacant traffic. More than two beams are consolidated in particular to the active UE to increase the bit rate by assigning higher MCS. The simulation evaluation depicts that the performance of beams consolidation provides a gain of 3.5 dB above than the state before beam consolidation. Moreover, more than 40 % improvement in UE throughput is achieved.**

***Index Terms*—5G, Cell Edge, MU-MIMO, Throughput.**

I. Introduction

In existing wireless systems, a number of antennas is increased at the base station (BS) with the User Equipment (UE) to improve the performance of the networks. Multiple-input and multiple-output (MIMO) was originally intended for Orthogonal Frequency Division Multiplexing (OFDM). Multi User-MIMO (MU-MIMO) is a set of MIMO technologies for wireless communication, in which a set of UEs, each with one or more antennas, communicate with each other [1]. MU-MIMO has been investigated since the beginning of research into multi-antenna communication [1]. Massive MIMO will be considered as another technology candidate for 5G systems because it increases the system capacity and facilitates the increase of the number of sub-channels [1].

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Massive MIMO systems use a few hundred antennas array at each BS to simultaneously serve a huge number of the wireless narrowband or broadband UEs and machine-to-machine (M2M) [1]. This technology allows attaining high resolution beamforming, with high gain and low side-lobes [1].

Multiple transmit antennas at the BS can be used for transmit diversity and different types of beamforming. The main target of beamforming is to improve the received signal-to-interference-and-noise ratio (SINR) and, eventually, improve system capacity. The Massive MIMO techniques may bring an additional enhancement in throughput by aggregating the spectral efficiency (SE), when utilizing the same bandwidth and deployment of BSs compared to the MIMO techniques [1]. If the same resource allocation concepts would be applied in Massive MIMO systems, with tens of UEs at each of the thousands of subcarriers, the complexity would be huge. Massive MIMO techniques can be accomplished by providing the BSs with spatial multiplexing (SM), which is a transmission technique in MIMO wireless communication technologies to transmit independent and separately encoded data signals, and will reduce the complexity [2]. The system counts the number of UEs every Transmission Time Interval (TTI) and assigns, according to the 5G standard, a radio beam, and modulation and coding scheme (MCS) to every UE [3]. There were different trends towards UE throughput enhancement. As mentioned before, MIMO techniques enhance the network throughput as well as the SM schemes to achieve throughput enhancement [4].

The main contribution of this paper can be explained as follows: when the traffic is vacant for a beam (no active users), the vacant beam is consolidated to its adjacent beam to produce a new beam, wider than the previous beam, to assign the UE a desire MCS at the downlink. However, none to the best of the author' knowledge has considered the consolidation of beams on the previous long-term evolution (LTE) and fifth generation (5G) systems in the context of massive MIMO implementation. The paper compares the proposed scheme with the standard single beam assignment at low traffic.

The rest of this paper will be organized as follows; Section II reviews the related work. Section III presents an overview of 5G system. Section IV presents the proposed scheme. Finally, section V concludes the simulation evaluation.

II. Related Work

This section briefly reviews the research related to throughput enhancement, beamforming and adaptive modulation schemes as well as different schemes utilized in 5G networks: In [5], the authors proposed triple novel similarity procedures for user groupings, clustering methods, and hierarchical cluster with a dynamic user scheduling scheme to enhance the system throughput once the user groups are formed. In [6], the authors implemented a framework of Network-Coded Multiple Access (NCMA) employing high-order modulations. Simplification of the existing NCMA decoding algorithm, designed for the binary phase shift keying (BPSK) caused throughput degradation. In [7], the authors investigated several constrains such as bandwidth, latency and complexity on the design of 5G. The authors evaluated the impact of spatially multiplexing more UEs on performance within a massive MIMO system to improve spectral efficiency of 5G system. In [8], the authors provided a Coordinated Multi-Point (CoMP) clustering framework and introduced a scheme for effective CoMP clustering to maximize the CoMP gains. The CoMP clustering differs from beam consolidating in that the clusters come from different evolved nodes base station (eNBs), while the approach proposed in this paper is the use of the vacant beams to enhance the UE data rate. In [9], the authors proposed a concurrent transmission for single-user multi-beams for mm-Wave networks with multiple reflected paths which improved the achievable throughput. In [10], the authors focused on a comprehensive overview of the most promising modulation, and multiple access schemes to provide enhanced throughput and massive connectivity with improved spectral efficiency for 5G system. In [11], the authors investigated the possible performance gains for coordinated beamforming. They revealed the key factors that influenced the throughput of the UEs. In [12], the authors proposed a joint fixed beam forming and Channel State Indicator (CSI)-based precoding scheme for the 5G Massive MIMO system. They showed that the proposed system with 256 transmitter antennas can achieve the higher throughput than the conventional MIMO with 16 transmitter antennas, and that the required SNR to achieve the throughput of 20 Gbps can be reduced by 13 dB. In [13], the authors modeled non-line-of-sight (NLOS) mmWave channels utilizing the stochastic geometry combined with image theory by stating channel parameters as combined parameters of antenna beam pointing direction, and antenna half power beam width. In [14], the authors presented a 50 GHz multi-user MIMO platform utilizing 32 phased-array antennas at both sender and receiver. They showed that the frequency-selective scheme can capably cancel inter-user's interference by enabling SM in interference limited scheme and doubling up the throughput compared to a Single-Input Single-Output (SISO) technique. In [15], the authors proposed an efficient design of beamforming codebook sequences solved by a Butler matrix to permit unique channel direction for single-path channels. Finally, the authors in [16] proposed an integration of Non-Orthogonal Multiple Access (NOMA) and generalized space shift keying (GSSK), called NOMA-GSSK, to increase the throughput and SE by exploiting the spatial domain. From the proposed scheme perspective, the [8] can be considered a starting point for the research conducted to enhance the throughput.

III. An Overview of 5G Systems

In this section, an overview of 5G system, in specific, massive MIMO is given with beam forming, and multi users (MU) MIMO communications.

A. *Massive MIMO Technique*

Additional arrays focusing the signal energy into narrow beams provide improvements in the UE throughput, particularly, when combined with simultaneous resources scheduling to numerous UEs [17]. The more the BS antennas utilized, the more beams will be added to serve more UEs within enhanced data rate [17]. Moreover, massive MIMO utilizes a suitable usage of beamforming methods to reduce fading which increases the SINR that reflects high Channel Quality Indicator (CQI) and reduces latency [17]. The CQI indicates the MCS that will be assigned to each user according to its SNR [17]. When the number of BS antennas exceeds the number of UEs, the throughput will increase [18]. The channel quality per antenna will improve as the number of BS antennas increases, especially in the presence of a high correlation between antennas [19]. A higher number of BS antennas reduces the noise effects and reduces the radiated power [19].

B. *MU-MIMO Communications*

The spectral efficiency of a single-input single-output (SISO) wireless communication channel, from a transmitter to a receiver, is upper limited by the Shannon capacity that has the form $\log_2(1+\overline{SNR})$ bit/s/Hz for additive white Gaussian noise (AWGN) channel. The SISO scheme capacity is thus a logarithmic function of the SNR. To expand SE, it is necessary to receive higher SNR, which corresponds to increasing the power of the transmitted signal. As an example, suppose to have a system that operates at 2 bit/s/Hz and you would like to double its SE to 4 bit/s/Hz, then this corresponds to improving the SNR by a factor 5, from 3 to 15. The next doubling of the SE, from 4 to 8 bit/s/Hz, involves additional 17 times more power.

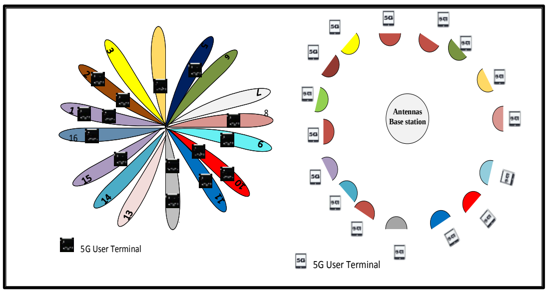

Fig.1. The DL (left) and UL (right) transmission in a MU-MIMO [1].

In other words, the logarithm of the SE expression requires that the transmit power to be increased quickly to attain a linear increase in the SE of the SISO channel. This is clearly a very inefficient way to improve the SE, and the approach also breaks down when there are interfering transmissions in other cells that scale their transmit powers in the same manner. Therefore, it is necessary to identify another way to improve the SE of cellular networks [20]. An effective way to improve the SE of the wireless network is to have several parallel beams transmission as shown in Figure 1. In massive MIMO system, the number of transmit array elements is larger than the active UEs which diminish the signal processing complication as well as accomplish higher data rates than the basic MIMO [20] [21].

IV. The Proposed Scheme at Vacant Traffic

A. System Model Assumption

The system model consists of a single BS and a set of UEs moving at 5km/h distributed randomly in the cell. Each UE provides its SNR at the Uplink to the BS to determine the position and CQI. In this work, the downlink transmission uses MU-MIMO technique where the number of UEs is U. At the BS, a two-dimensional planar array model uniformly spaced is represented by (M, N), where M is the number of array elements with the same polarization in each column and N is the number of columns. In the recent evaluation, a total number of 64 antennas (M=8 and N= 8) for the configuration has been considered [22].

Denoting an effective channel with all Tx/Rx antennas and vertical tilting by $\boldsymbol{H}$, the signal received by the UE for a MU-MIMO scenario is given as:

$$\boldsymbol{Y} = \widetilde{\boldsymbol{H}}\boldsymbol{x} + \boldsymbol{n} \quad (1)$$

where x is an input signal vector, $\boldsymbol{x}= [\boldsymbol{x_1}, \boldsymbol{x_2}, \boldsymbol{x_3}, \ldots, \boldsymbol{x_k}]^T$, of rank u, of the input covariance given by $\sum = E[\boldsymbol{x}\boldsymbol{x}^H]$, $\boldsymbol{n}$ denotes the noise including interference from other BSs. In this proposed scheme, the noise and interference are not taken into consideration. Also, a single data stream per user is considered.

Now, let V denote a set of UEs that are arranged for MU-MIMO transmission (|V|= **u**). Furthermore, let $w_u \in W$ and d_u, u denotes a UE (u= 1, …, u, u ϵ V), denote a beamforming vector and a data symbol for a UE, respectively. Assuming an equal power distribution to all UEs served by the specified BS with transmit power of P, the detected signal for the UE is assumed as:

$$y_u = \sqrt{P/_k} \cdot \left(H_u W_u d_u + \sum_{j\in u V \setminus u} H_u W_j d_j \right) + n \quad (2)$$

Moreover, the SNR for each UE is represented as:

$$SNR_u = \frac{|g_u H_u W_u|^2}{K\sigma_u^2 + ||g_u H_u W_u||_F^2} \quad (3)$$

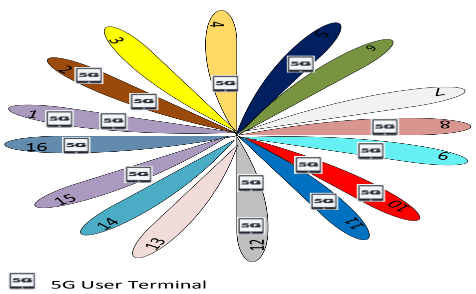

Fig. 2. The distribution of UEs in the cell beams

where $\sigma_u^2 = |g_u|^2 \sigma_n^2 / \rho$, W_u denotes a precoding matrix which excludes the uth precoding vector (W_u=[w_1,.. w_{u-1}, w_u]) and $\boldsymbol{g}_u$ is a Minimum Mean Square Error-Interference Rejection Combining (MMSE-IRC) filter and equalizer assuming AWGN used with the 5G multiuser detector and receiver.

In this paper, the system bandwidth is variable. So, the subcarriers are variable too. The throughput for each user, which depends on bandwidth efficiency, will be variable too. The above equation (3) indicate that when the adjacent beams consolidate into single beam, the new SNR will be increased.

This paper assumes that the downlink of a single-cell BS is equipped with M-antennas serving the **u** UEs as each is equipped with a single antenna.

To evaluate the performance of the proposed scheme, simulation utilizes the Vienna link-level simulator for the 5G system. Vienna 5G link level simulator is the main branch of the Vienna simulators software suite. The simulator is currently available under a non-commercial, academic use license [23]. The proposed model is adopted for the 5G-Vienna simulator with some modification. The modification is done at the example of how to simulate a multi-user heterogeneous network consisting of many BSs and different UE types. The modified code will run through MATLAB to get the evaluation results. The model considered is two UEs located at some beams as indicated in Figure 2 which shows, also, that some beams has only single UE, while few beams has no UE at all. To perform well, the UE at the uplink, informs the BS where each UE sends every TTI the reference signal (RS) indicating its SNR. The SNR signal depends on the distances between the UE and the BS that adapts according to the mapping scheme of MCS to each UE. For far UEs, the SNRs are very low, and the BS assigns low MCS (QPSK). The UEs throughput at the cell edge will be very low compared to those UEs near the BS.

B. The Proposed Scheme Flowchart

In MU-MIMO systems, existing resources, subcarriers and beams must be assigned among UEs. The UEs may be located, randomly, near or far from the BS or located in radial distribution. This paper proposes a new scheme for the traffic is very low, some transmitted beams cover no UEs that cause energy to get wasted. This leads to the proposed scheme to enable the BS to decide to consolidate more than one beam to the UE (especially for far users or users at the cell edge) in the same radial direction of the inactive UE. Depending on the measured SNR for each UE or UEs at each beam, the proposed scheme can be explained as follows:

The simulation starts, as the algorithm shown in Figure 3, by initiating the main and system parameters according to the setting listed in Table I. In details, the following steps explain the proposed scheme;

Step 1: Start the simulation and main parameters initialization for UEs and antennas (U, M).
Step 2: Start the TTI.
Step 3: Check the number of arrays M (beams) with the number of UEs U. For M larger than U, then construct the matrix [M x U]. While, for the state when the number of UEs (U) is larger than M, the system schedulers the resources basically.
Step 4: Find the non-zero elements in each row and column.

For non-zero elements, the system schedules the resources basically.

Step 5: For the zero elements, check the adjacent elements in the row and the adjacent elements in the column (these checking must run simultaneously).

a. The adjacent elements in the row.
b. The adjacent elements in the column.

Step 6: When one of the two adjacent elements is zero, the adjacent beam consolidates to double the beam in width.

According to the proposed scheme depicted in the flow chart, at vacant duration, more than one beam will be consolidated to create a new beam having a wider bandwidth enhancing the MCS to switch to higher scheme of modulation. The two beams consolidating into wider single beam are shown in Figure 4.

The proposed scheme comprises two steps. First, the measurement of CQI for each UE and send, as a feedback signal to the BS. The CQI value reported every TTI through UL to the BS; its role is to assign the appropriate MCS that the UE can handle. This approach assumes that when the CQI is high, the SINR is high, the UE is near the BS, then the BS will assign better MCS to the UE. If the CQI feedback to the BS is low, the assigned MCS is low (BSK or QPSK). Second, the system constructs a matrix. At the UL, in MU-MIMO, the BS receives UEs signal according to the number of antennas and the scheduling scheme. Suppose the number of antennas is larger than the number of UEs, all UEs signal will be received at the same time whether the beam composed of single or more than one UEs.

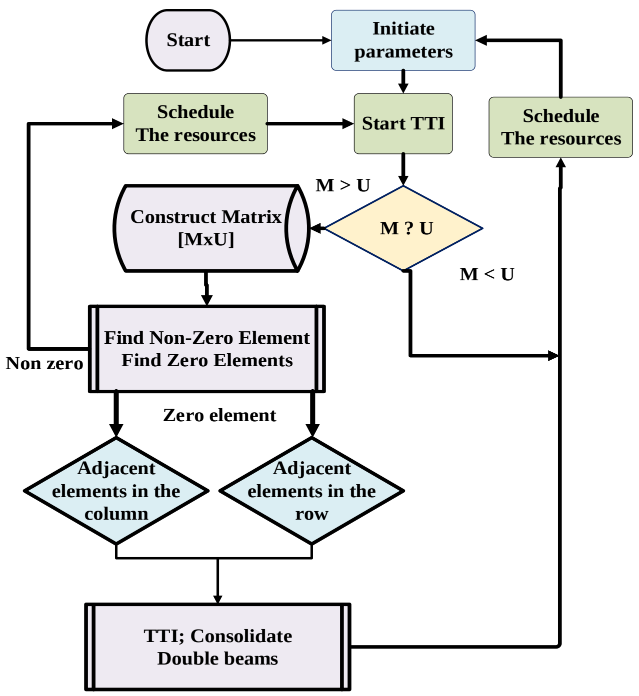

Fig. 3. Flowchart of the proposed scheme

The UEs-antennas matrix produced by the proposed approach can help to decide consolidation of adjacent beams or not. Every TTI, a matrix can be available to discover the UE at the beam.

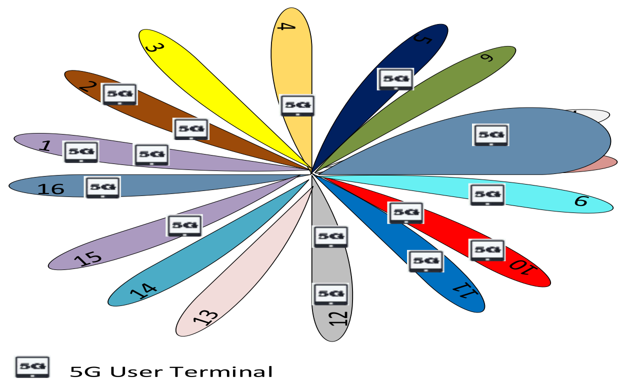

Fig.4. UEs distribution after beams consolidation.

TABLE I
MAIN SIMULATION PARAMETERS

Parameter	Setting
Carrier frequency	2.5 GHz
System bandwidth	Variable Bandwidth
Number of subcarriers	Variable
Subcarrier spacing	15 KHz
Transmitted power for base station	30, 40 dBm
Path loss	80 dBm
Layer mapping mode MIMO model	5 G Custom
UE speed	5km/h
Modulation waveform	Filer Bank Multi Carrier (FBMC)
Channel estimation method	Approximation-perfect
Number of frames	5000 frames

V. SIMULATION RESULTS

To evaluate the effectiveness of the proposed scheme, a single cell BS is considered in a scenario serving as a reference starting point to define the simulation setup. The cell is equipped with multiple (M) antennas with each antenna having a beam transmitted radially. Some beams are intended to serve a single UE while other beams serve two UEs. The Vienna 5G link level simulator code v1.1 is modified to accomplish the proposed scenario [23].

To illustrate the advantage of the proposed scheme at the down-link, the simulation evaluation gives the performance of the UE as throughput and bit error rate (BER) using the main parameters as listed in Table I shows the general and main simulation parameters setting for two users.

The simulation setup assumes the 5G system having a single cell composed of U UEs has a range of SNRs extending from -15 to 45 dB [23] distributed in the cell according to the proposed scheme explained in IV. The simulation examines the occupancy of the UE resources at subcarriers to evaluate the impact of the availability of UEs at vacant traffic on the performance in terms of the throughput. The user performance in terms of BER versus SNR for both states (without and with beam consolidation) is shown in Figure 5, which reveals an improvement in the performance.

According to the quality of service (QoS) requirement for wireless communication systems, for BER=10^{-1} (at figure 5), the performance improved 3.5dB for beam consolidation with respect to the state before beam consolidation. This means that the BS will assign a higher MCS scheme to the active UE located at that consolidating beams.

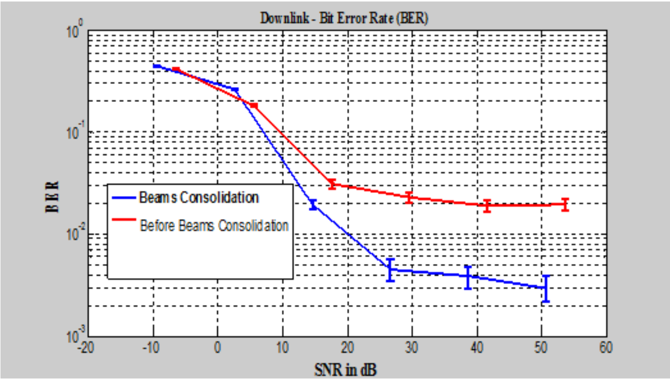

Fig. 5. BER with SNR for downlink before and after beams consolidation

Finally, Figure 6 presents the downlink UE throughput for beams (before and after consolidation) which reveals a throughput enhancement.

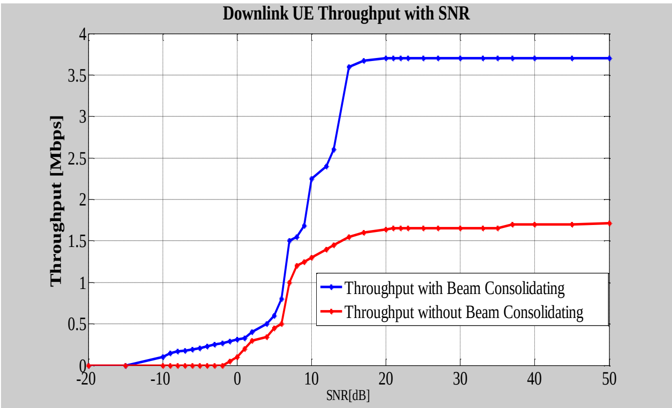

Fig. 6. User throughput SNR for downlink before and after beams consolidation

To compare the performance (figure 5 again), for 10% BER, the SNR is about 10dB, if we digitize this value on Figure 6 the throughput increased about 0.98 Mbps. The evaluation reveals more throughput increase at high SNR. For example, for 20 dB, the throughput increased about 2.05 Mbps. As a final assessment, Table II compares between user's throughput before and after beam consolidation. The table reveals that the proposed scheme for beam consolidation at vacant traffic achieve about double throughput at specific value of SNR.

TABLE II
THROUGHPUT COMPARISON FOR BEFORE AND AFTER BEAM CONSOLIDATION

SNR dB	Throughput before beam consolidation (Mbps)	Throughput after beam consolidation (Mbps)
-15	0	0
-10	0	0.15
-5	0	0.25
0	0.15	0.3
5	0.3	0.5
10	1.25	2.25
15	1.55	3.5
20	1.6	3.7
30	1.7	3.75
40	1.75	3.75

This proposed method for beam consolidation can be recommended with the 5G systems for vacant traffic as it can enhance the user's performance and throughput.

VI. CONCLUSION

This paper has presented a new scheme for exploiting vacant transmitted beams from the base station. The proposed scheme uses the vacant beams of the inactive UEs to be consolidated with the beam of the connected UE, or UE at the cell edge, to increase the level of MCS to a higher scheme and enhance the spectral efficiency of the 5G mobile networks. The simulation evaluated the proposed scheme for vacant beam consolidated with the adjacent beam improved the performance and provided a gain of 3.5 dB more than the state before beam consolidation. Moreover, more than 40 % improvement in UE throughput was achieved. As for a future work, further different simulation parameters such as beam splitting and other parameters related to uplink transmission can be selected and simulated under the condition of mobility. Also, the proposed scheme can be extended to consolidate adjacent beams in the case where different UEs are covered by adjacent beams, i.e., when more UEs are covered by one beam than by another.

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