



A New Approach for Sum Rate Enhancement in Heterogenous Networks

Agbon E. E, Aliyu D. U, Yaro A. S, Bello H, Sani, S. M.
Department of Telecommunications Engineering,
Ahmadu Bello University, Zaria.

ABSTRACT

The massive increase in capacity and coverage demands pose serious interference and energy management problems on present day cellular mobile Heterogeneous Network (HetNet) bandwidth, which necessitates the need for cellular networks to migrate towards ultra-dense networks. Notably, network densification comes with complex interference management challenge. The interference challenge usually stems from the tight coupling between the control and data planes. A lot of researchers have attempted solving the stated challenges by using cancellation and management technique. However, these techniques were best suited for limited number of users. Consequently, the problem of interference is still inherent in cellular network which results in large decrease in network sum rate. In wake of this demand, this research developed a Sum rate Quality-of-Service Aware control and data plane SARC (QoSA-SARC) algorithm for hierarchical HetNet using D2D clustering and coordinated beamforming. In the work, various interference parameter values of 0.001, 0.01 and 1 were used in the network interference analysis at varying cell user transmission Bits (B). Here, D2D clustering is a communication technique where D2D users are grouped into clusters based on their defined cost functions. While beamforming is a method of antenna transmission that ensures that antenna beams are directionally transmitted toward a defined destination or perimeter. When the interference parameter (α) was 0.001, the QoSA-SARC scheme showed a sum rate improvement of 27.78%, 17.24%, 17.82% and 10.70% when B was 18, 12, 6 and 0 respectively when compared with the work of Saini and Kuchi, (2018). Also, when α was set to 0.01, the developed scheme showed an improvement of 28.00%, 33.90%, 8.39% and 13.89% when B was 18, 12, 6 and 0 respectively when compared to the Saini and Kuchi, (2018). Furthermore, when α was changed to a value of 1, the QoSA-SARC scheme showed an improvement of 28.00%, 33.90%, 8.39% and 13.89% when B was 18, 12, 6 and 0 respectively over the work of Saini and Kuchi, (2018).

INTRODUCTION

Today's third generation (3G) and fourth Generation (4G) cellular networks are majorly designed based on cell-centric or network-centric mode with a focus on peak rate and spectral efficiency improvements. In the 5G era, dense deployment of Heterogeneous Network (HetNet) architecture will shift towards user-centric model to deliver a uniform connectivity experience [4].

Hence, both 4G and 5G networks will require advanced algorithms to cater for network challenges such as interference and large energy consumption [3]. To further cater for energy and interference challenges, Hierarchical Heterogenous Network (H-HetNet) was introduced. H-HetNet is a type of HetNet that is categorized into different tiers such as device-to-device tier and cellular tiers. The existing cellular networks are designed in such a way that the

ARTICLE INFO

Article History

Received: June, 2020

Received in revised form: July, 2021

Accepted: October, 2021

Published online: November, 2021

KEYWORDS

SARC, QoS, Sum rate, CSI, D2D, CAT and Interference



control and data planes are coupled together. This conventional architecture was designed to conform to the main objectives of ensuring ubiquitous coverage and spectrally efficient voice-oriented homogeneous services. Research has shown that another rising issue in future ultra-dense HetNet is the interference management. The major limiting factor in achieving the optimum capacity and system efficiency is intra/inter-cell interference in the network. However, intra-cell interference in present cellular networks has been partially addressed by applying Radio Resource Management (RRM) and Orthogonal Frequency Division Multiple Access (OFDMA) technology. It is good to note that the provision of underlay co-existing networks (e.g., device-to-device (D2D), Machine-to-Machine (M2M)), in ultra-dense environment will once again introduce intra-cell interference along with existing inter-cell interference (Mustafa *et al.*, 2016).

The existing interference management techniques looks into mitigation, cancellation, and coordination concepts. The first two techniques are best suited to a single cell environment, whereas for multicell scenarios, coordination techniques comprising Inter-Cell Interference Coordination (ICIC), Coordinated Beamforming (CB) and enhanced ICIC (eICIC), are more promising to provide homogeneous Quality of Service (QoS) with small infrastructural changes over the area (Marsch *et al.*, 2006). This work developed QoS aware SARC for H-HetNet using D2D clustering and coordinate beamforming. The work was able to solve the problem of selecting appropriate Cluster Head (CH) node for D2D communication in H-HetNet. Also, this research solved the problem of sharing the beamformers to the corresponding dBSSs via asymmetric backhaul links during beamforming in the cBS which usually results in inter-cell interference and low spectral efficiency by cell edge users in the dBs cell range. To solve these problems, this work developed a new Coordinate Aided Transmission model (CAT) and a new CH selection model for D2D cluster users in the data plane was developed to improve network mean sum rate.

LITERATURE REVIEW

A variety of works has been done to improve the quality of service of users using

cellular networks. Some of such research works include the work of [3] that designed an energy efficient resource allocation scheme for control and data plane separation architecture that was based on heterogeneous cloud radio access networks. From the work, the proposed scheme had a heterogeneous fronthaul that was set between the cBS and the dBSSs. A power consumption model for the designed scheme was developed and an optimization problem was formulated with constraint of the total network capacity of the fronthaul. The authors estimated the power allocation and resources assignment by using fractional programming method and lagrangian dual decomposition method. A closed form optimal solution was used to verify the performance of the designed scheme. Simulation result showed that the proposed scheme increased the energy efficiency of the SARC when compared to the conventional network. However, the lagrangian method that was adopted in the work has a lot of computational processes in achieving an accurate power allocation solution. This extended computational complexity resulted in high processing energy consumption by dBSS users in the data plane. Hence, data plane users expended high energy in applying the proposed algorithm. Therefore, the overall network energy efficiency would have been better if the computational complexity of the solution-oriented algorithm was considered in the work. Also, the cBSs used in their work would not be able to distribute CSI appropriately to serving UE as no asymmetric backhaul was used. This introduced a significant error in the network that led to a reduction in the general system performance. An efficient radio access network model with separated control and data plane functions was developed by [5]. In the work, the out-of-bound signalling parameters related to mobility management in a CD-SARC were investigated by making use of the relaxed constraints made available by cellular network SARC. In order to tackle the active state handover process in dBSS, two predictive dBSS handover signalling schemes was proposed which showed limited latency during data transmission. The schemes included a history-based predictive dBSS handover scheme that predicts the handover activities of a dBSS user in the future, and a context aided predictive dBSS



handover scheme that was based on measurement. The prediction outcome in both schemes was utilized to engage the process of handover in dBs radio access network. Simulation result showed that the developed schemes can greatly reduce the handover signalling latency in dBs when compared with traditional handover scheme. The drawback of the developed predictive scheme was in fact that they did not consider the effect of interference in the network during attempted handover process between cells. The problem of interference resulted in poor network performance as most of the handover process initiated were not efficient during communication. Hence from the result, this mitigated the quality of service of the users as compared to the expected performance proposed by the researchers.

[1] analyzed a decoupled user and control plane architecture in small cell of 4G LTE-A (Long Term Evolution-Advanced). In the analysis the, it was recorded that the coverage of small cells can be increased by deploying huge amount of small cells. An increase in the number of small cells would increase the number of high frequency bands in the network. In the work, the manner of small cell deployment on the separation/decoupled architecture (SARC) was seen to be based on the network traffic requirement. The mode of operation of small cells assumed a turn ON/OFF process with the major aim of saving the energy of the network devices. From the research, it was concluded that the deployment of small cells in SARC improved network density and throughput of the network. However, researchers didn't take into consideration the inherent inter cell interference in SARC which affected the system throughput and the processing energy of network devices.

The process of traffic retransmission led to extra energy consumption in the network, which was not captured in the developed model. In order to improve the sum rate of HetNet, [6] developed an optimized power allocation scheme to maximize sum rate using Coordinated Multi-Point (CoMP) with limited channel state information. In the work, the author considered the optimization of power because users at the cell edge required more attention than the user located at the center of the cell. The work showed that the estimated

power gave exponential diversity for both high and low SNR. A compression feedback method was adopted and analyzed to provide multi-cell spatial channel information. Results showed that the adopted method improved the feedback efficiency and throughput. The rows and columns of the channel matrix were compressed using Eigenmode of the user and codebook-based scheme specified in LTE specification. The main drawback of this scheme is that spectral efficiency was achieved with the cost of increased overheads for feedback and evolved NodeB (eNB) which led to a drop-in measured user sum rate. Other factor challenge is the complexity of eNodeB which led to high transmission latency.

[9] proposed a multi-beam transmission and dual-band cooperation for control and data plane decoupled wireless area networks. A station (STA) was designed to receive signals from its surrounding Access Points (APs). This was done in order to take advantage of the multiple numbers of APs in the network. Furthermore, an assumption was made such that the STAs and APs are fully equipped with high rate of multiple antennas. Hence, a STA could connect multiple directional APs in a serving set of APs using multiple directional beams in the high frequency. Hence the work developed a data plane and control plane separation wireless area network architecture that supported both low frequency and high frequency where the central control manages all the AP and STA through the control plane in the low frequency. In the research, all APs provided millimetre wave communication service for all STAs using the data plane in the high frequency. The proposed scheme was able to improve the throughput and reliability of millimetre wave communication. However, the considered millimetre wave suffered from severe path loss and penetration loss which greatly affected the communication range of the proposed scheme.

FUNDAMENTAL CONCEPT

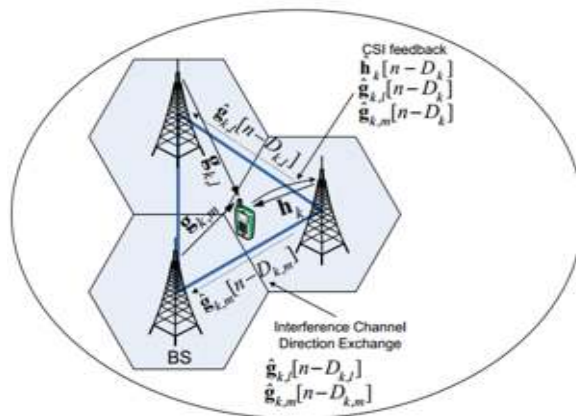
Coordinated Beamforming

This is a transmission concept whereby the BSs cooperate with each other and share CSI between each other to enable limited inter-cell interference. This process is termed multi-cell coordinated beamforming. It is good to note that this level of coordination demands optimal

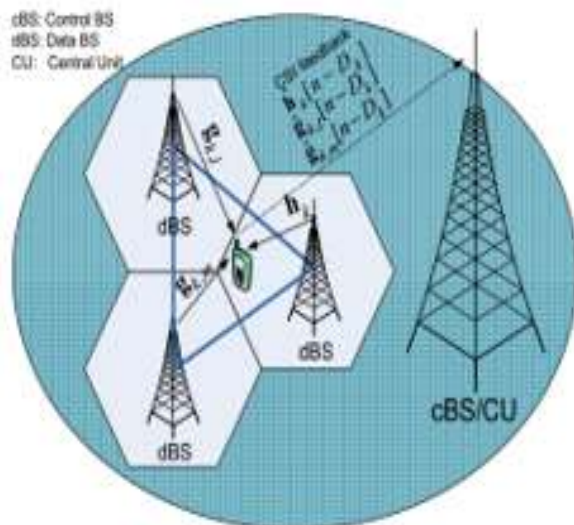
backhaul capacity which makes it favourable for usage especially in 5G cellular communication [10]. Coordinated beamforming is a transmission concept that takes into consideration the desired and interfering CSI of a given network. In this type of transmission, each BS in the coordinated set shares their CSI to each other. In CARC, the channel state of reference BS (serving BS) and neighbouring BS is measured by UE. The reference BS has the sole duty of sorting out the ICI of participating BS and shares this information amongst the BSs. However, the participating BS experiences a delay in the reception of interference information via the backhaul and thus chooses efficient beamformer [4]. Transmission process in the traditional multicell CARC experiences two major drawbacks which include; occurrence of backhaul delay during the exchange of CSIs amongst participating BS and the imperfect removal of the interference at neighbouring cells due to CSI perturbation [4]. Figure 1 is the system model of three cells that

shows the exchange of interfering channel and the desired channel for both CARC and SARC. In CARC and SARC, all BS are assumed to be equipped with N_t number of antennas with each UE having the ability to support a single received antenna. The channel that relates to the UE desired channel between k^{th} BS and k^{th} UE is given by $h_k[n] \in \mathbb{C}^{N_r \times 1}$ at n^{th} defined discrete time. Following the same process, the UE interfering channel is given as $g_{k,x}[n] \in \mathbb{C}^{N_r \times 1}$ for $k \neq x$ [2]. In this work, the desired and interfering channels will be modelled by using identically distributed Rayleigh fading channel model which has an entry that is a unit variance complex Gaussian function. It can be seen from the Figure 1 that the uplink/downlink desired and interfering channels at the UE are giving as h_k and $g_{k,x}$ respectively where

$$x \in \{l, m\}.$$



(a) Conventional Architecture (CARC)



(b) Split Architecture

Figure 1: Comparison of Desired and Interfering Channel of CARC and SARC [4]

During transmission process, the BS/dBS normalizes and then quantizes these channels to

$\hat{h}_k[n]$ and $\hat{g}_{k,x}[n]$ respectively. In order to have limited system feedback, the UE sends the channel direction to the service BS. In the serving BS, multi-antenna beamforming (when considering a single cell scenario) and CB (when considering a multi-cell scenario) vectors are selected in such a pattern that null space of interference channel direction is assured to aid inter-cell interference cancellation [2]. During the channel state estimation, B_T total number of bits can be utilized by a UE for feedback purposes

where $B_{k,x}$ and B_k are used to quantize $\hat{g}_{k,x}[n]$

and $\hat{h}_k[n]$ respectively at each coherence time.

When each BS has received channel CSI, all BS has the duty of segregating and forwarding

ICI information to individual BS through the backhaul. The feedback delay that is related to the CSI is given as D_k . The forwarding of ICI through the backhaul result in more delay which is

represented as $D_{k,x}$. During network transmission the value of $D_{k,x} \geq D_k$. Thus, the total network delay during transmission is given as [4]:

$$D_{bh} = D_k + D_{k,x} \quad (1)$$

Also, the BS/dBS has desired received signal to noise ratio ρ_k and interfering signal to noise ratio $\alpha_{k,x}\rho_k$. The interfering signal strength is defined as [2]:

$$\alpha_{k,x} = \frac{L_k}{L_{k,x}} = \frac{\frac{E_s}{\gamma_k}}{\frac{E_s}{\gamma_{k,x}}} \quad (2)$$

where: L_k is the path loss of the desired signal, $L_{k,x}$ denotes the path loss of the interfering signal, $\alpha_{k,x}\rho_k$ is an element of 0 and 1, E_s represents the BS/dBS transmitting energy,

γ_k is the received signal power by the desired

signal., $\gamma_{k,x}$ stands for the received signal power by the interfering signal

The received signal at the BS/dBS is given as [2]:

$$y_k[n] = \sqrt{\gamma_k} h_k^*[n] f_k[n] s_k[n] + \sum_{\substack{x=1 \\ x \neq k}}^K \sqrt{\alpha_{k,x} \gamma_k} g_{k,x}^*[n] f_x[n] s_x[n] + v_k[n] \quad (3)$$

where: ρ_k is the desired received signal to noise ratio by the BS/dBS, $\hat{h}[n]$ denotes the received

desired CSI by the BS/dBS, $f_k[n]$ is the beamforming vector at k th BS/dBS, $f_x[n]$ represents the interfering beamforming vector at k th BS/dBS, $s_k[n]$ is the normalised desired symbol transmitted from k th BS/dBS, $s_x[n]$ denotes the interfering normalised symbol transmitted from k th BS/dBS, $g_{k,x}^*[n]$ is the received CSI of the interfering channel by the BS/dBS, $\eta_k[n]$ represents the auto-correlation function of the desired channel.

The quantized CSI estimated by the UE is given as [2]:

$$\left. \begin{aligned} \hat{h}_k &= Q \left[h_k / \|h_k\| \right] \\ \hat{g}_{k,x} &= Q \left[g_{k,x} / \|g_{k,x}\| \right] \end{aligned} \right\} \quad (4)$$

where: $Q[\cdot]$ is the quantization function, $\|h_k\|$ represents the Frobenius normalization of h_k ,

$\|g_{k,x}\|$ stands for Frobenius normalization of

$g_{k,x}$

The Gauss-Markov auto-regressive model is used to show the relationship between present and delayed CSI and ICI. The Markov model that shows slowly time varying channel properties is given as [4]:

$$\hat{h}_k[n] = \eta_k \hat{h}_k[n - D_k] + \sqrt{1 - \eta_k^2} e_{h_k}[n] \quad (5)$$

$$\hat{g}_{k,x}[n] = \eta_{k,x} \hat{g}_{k,x}[n - D_{k,x}] + \sqrt{1 - \eta_{k,x}^2} e_{g_{k,x}}[n] \quad (6)$$

where: $e_{g_{k,x}}[n]$ is the interfering channel error

vector, $e_{h_k}[n]$ represents the desired channel error vector, η_k denotes the auto-correlation function of desired channel, $\eta_{k,x}$ is the auto-correlation function of the interfering channel.

D2D CLUSTERING

Social relationship based D2D clusters: The social relationship based D2D clustering targets to meet a relatively more realistic scenario of content dissemination, where the degree of D2D device social influence is used to model realistic D2D communication links. Here, content dissemination amongst D2D devices considers the degree of social influence of all D2D devices which will be grouped into different levels of social impact by taking advantage of the history of device activity in the network. In a network, there is possibility that some users may have a history of limited degree of social influence based on the degree by which they assist the network in disseminating contents [7]. This type of D2D device will fall in the group of ad-hoc mode or cellular mode. However, there are also possibilities that D2D users may be involved in high participation of helping the network in content dissemination. This type of device falls in the clustered D2D communication. An illustration of this concept is shown in Figure 2. From the Figure, it can be observed that the establishment of D2D links is achieved by considering different decision parameters. As a result of this, different network users will be allocated different degree of social influence. The social influence of a node can be evaluated using the measure centrality parameter [8].

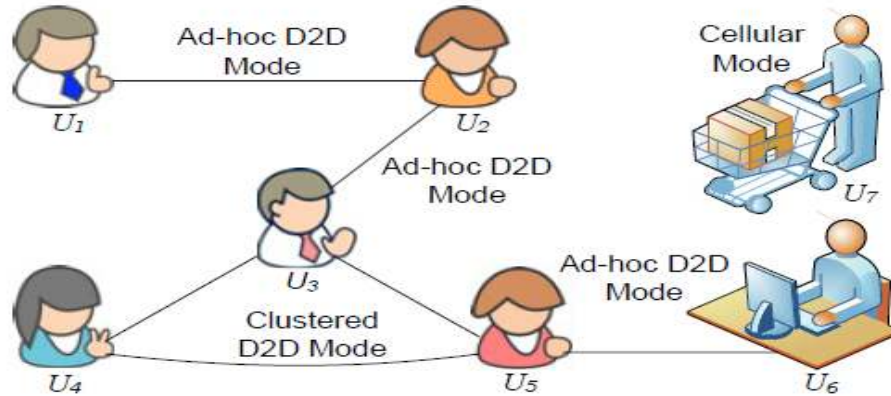


Figure 2: Network Modes Base on Social Network Influence [4]

The degree of closeness centrality (shortest distance between a reference node and other devices) can be used to estimate the closeness of D2D users which will now be used to assign weights to users. The closeness of centrality is given by [4]:

$$C_c(U_a) = \frac{\left[\sum_{b=1}^N d(U_a, U_b) \right]^{-1}}{N-1} \quad (7)$$

where: N is the total number of network nodes, $d(.)$ is the shortest distance between reference node and all other nodes, U_a is the reference node, U_b can be any other node.

METHODOLOGY

1. Development of a Coordination Aided Transmission (CAT) beam forming model for Control and Data plane separation architecture (CD-SARC) the following steps was carried out:
 - i. cBS and dBS are deployed using Poisson Point Process (PPP)
 - ii. Implementing sample three-cell network deployment using PPP
 - iii. All dBS send their location information to neighboring dBSs
 - iv. All dBSs estimate their coverage area based on reference dBSs and restrict the radiation range of each dBS based on the estimated coverage transmission area
 - v. Exchange of CSI/ICI between cooperating set of dBSs to the cBS

2. The development of a user eligibility and cluster formation algorithm for D2D communication in SARC was actualized using the following steps:
 - i. Formation of D2D tier in SARC
 - ii. Setting-up the user eligibility criterion for cluster head based on distance using the closeness model
 - iii. Setting-up node selection condition for content dissemination-based node energy and transmits power.
3. The implementation of steps (1) and (2) on hierarchical HetNet
 - i. Activating the developed cluster formation algorithm and CAT model on SARC of HetNet.
 - ii. Analyzing the performance of the implemented hierarchical HetNet in terms of network sum rate.
 - iii. Comparative analysis of the developed algorithm with the work of Saini and Kuchi, (2018) using network mean sum-rate as performance metrics.

Coordinate Aided Transmission (CAT) Model

The estimation of restricted dBS cell coverage area will help in defining the area of transmission of individual cooperating cells. To achieve this, a CAT model took into consideration the positions of dBS in estimating the coverage area of serving dBS to aid efficient coherent beamforming. In this work, an assumption was made that three dBSs are cooperating by defining their transmission area to make the processes of

sharing beamformers by the cBS to dBSs efficient. The use of cBS in SARC ensures that the entire beamformers for the participating dBSs in the network are accurately designed coherently. Despite the possibility of coherent beamforming in SARC, the problem of sharing the beamformers to individual dBSs through asymmetric backhaul link is still a challenge. However, the problem was solved as the participating dBSs can adjust their transmissions area to aid coherent beamforming. Therefore, the coverage probability of the cBS can be improved for better network performance due to improvements in the system SINR. Thus, in this work, the dBSs adjusted their transmission area based on Coordination Aided Transmission (CAT) model that will be discussed shortly. The serving BS of the UE will adjust its transmission area in order to aid coherent beamforming. In CAT model, the radiation pattern of the antennas in the dBS will be such that their energy will not radiate out of the estimated coverage perimeter which also helped against perturbations. A three hexagonal

cell network was used in this work with each cell having a dBS as depicted in Figure 3.1. The CAT model will take into consideration the positions of dBS in estimating the coverage area of serving dBS to aid efficient coherent beamforming. Also, the effective radiated power of the dBSs will be based on the estimated transmission area of serving cell. The CAT model was able to improve coherent beamforming, ensure an optimum transmit power for dBSs and ensure better quality of service to cell edge users as discussed in the result section.

The coordination transmission architecture for the CAT model that will aid the serving dBSs to adjust their transmission area in order to ensure appropriate sharing of beamformers to participating dBSs for better network energy and spectral efficiency is represented in Figure 3. Here, the coverage area adjustment by the three network scenarios discussed during transmission process is shown.

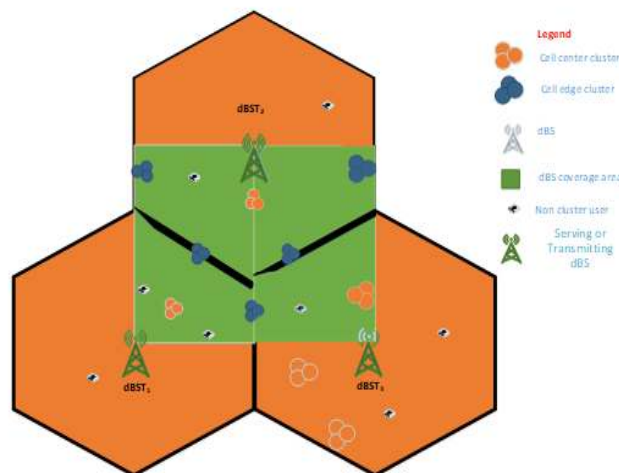


Figure 3: Developed Network Coverage Architecture for CAT Model

It is good to note that the use of the CAT model will help in mitigating interference from other signal sources. The CAT model will help in restricting the radiation region of dBSs and as such, the effective radiated power of dBSs antennas will improve user network experience and will also ensure efficient utilization of dBS

transmit power (P_t) in a given cell. The flowchart for the CAT model is depicted in Figure 5. Hence in this work, the dBS channel power gain will be expressed as h_{CAT} . The flowchart for the CAT model is given in Figure 4.

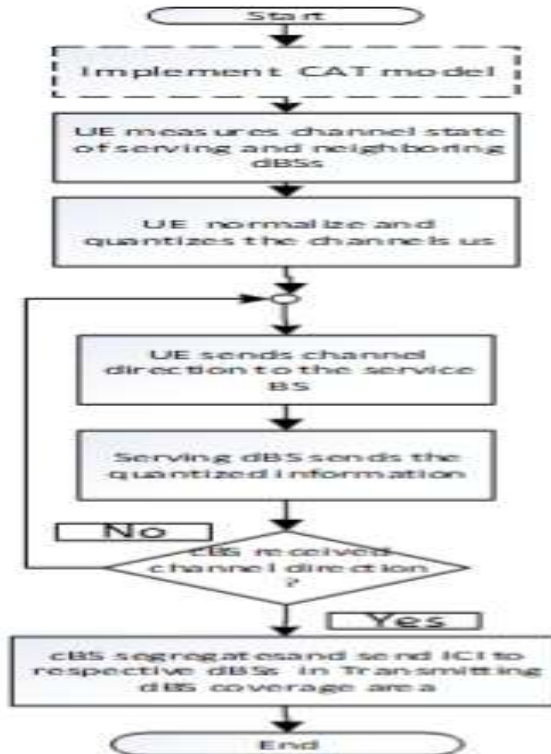


Figure 4: Developed Coordinated Beamforming Algorithm for SARC

Developed D2D Model for SARC

The closeness of centrality will be used to classify the cellular network into different hierarchy. The hierarchy will represent different groups of nodes which will assume unique mode of operation and these groups include; clustered group and the cellular group. The nodes that are not in the cluster assumes cellular mode (that is SARC) of operation. Equation (7) was used for the grouping purpose. In the group, the cellular group of nodes are modelled as those nodes that are not eligible to be part of the cluster and as such, they will be directly communicating with the dBSS for content dissemination. The energy eligibility criterion for CH selection is given as:

$$E_{N_{eligible}} = \begin{cases} E_{N_{max}} - E_{N_{min}} & \text{if } E_{N_{min}} < \frac{E_{N_{max}}}{2} \\ N & \text{otherwise} \end{cases} \quad (8)$$

The cluster nodes will transmit their data to their destination via the CH. Due to the energy constrained D2D devices in the cluster, the choice of a CH node for efficient data (content) dissemination to the dBSS is of paramount importance in D2D communication. Hence in this work, the model Equation for CH selection took into account the energy and transmit power of cluster nodes. The flowchart for the developed cluster model is given in Figure 5.

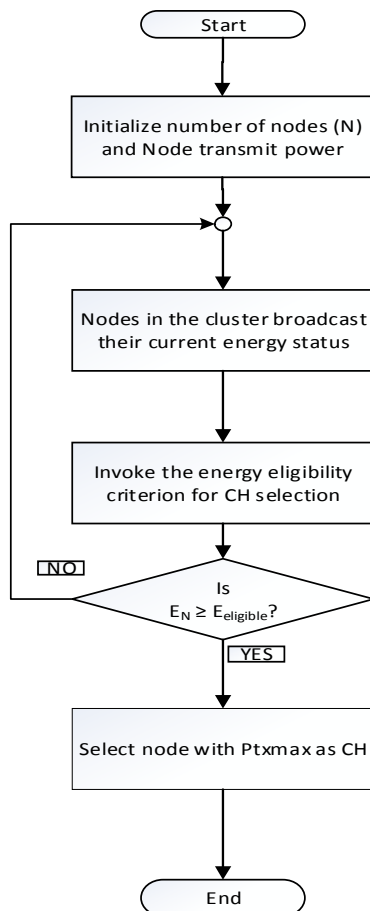


Figure 5: Developed Cluster Formation Algorithm.

RESULTS

Mean Sum Rate at Interference Parameter of 0.001

Figure 6 shows the result of performance of the work of [6] and the developed sum rate aware Quality of Service Aware Separation architecture (QoSA-SARC) in terms of network sum rate against number of network cells. In order to analyze sum rate maximization, the generalized Eigen vector Beamforming (EB) was adopted. In the analysis, the number of cell bits (B) was varied at a value ranging from 0 to 18 as it would help in analysing the network performance of cell edge and cell center users. Additionally, the EB was implemented using an interfering parameter ($\hat{g}_{k,x}^T [n]$) having an assumed value of 0.001. From the Figure, it can be observed that

an increase in the number of network cells led to a corresponding increase in the network mean sum rate. This is due to the fact that an increase in cell number leads to increase in available network resources meant for transmission purpose. Thus, an increase in the number of available bits (by increase in cell/channel number) for transmission process will efficiently serve cell edge users. This is because, cell edge user will require more transmission bit as compared to cell center user due to the effect of poor coverage. However, it can be observed that the sum rate performance of QoSA-SARC outperforms that of [6]. This is due to the advantage offered by the CAT model. Hence, in the developed scheme, packet overhead due to the coupling of the control and data plane as seen from the work of [6] was

mitigated which led to improvements in the network mean sum rate

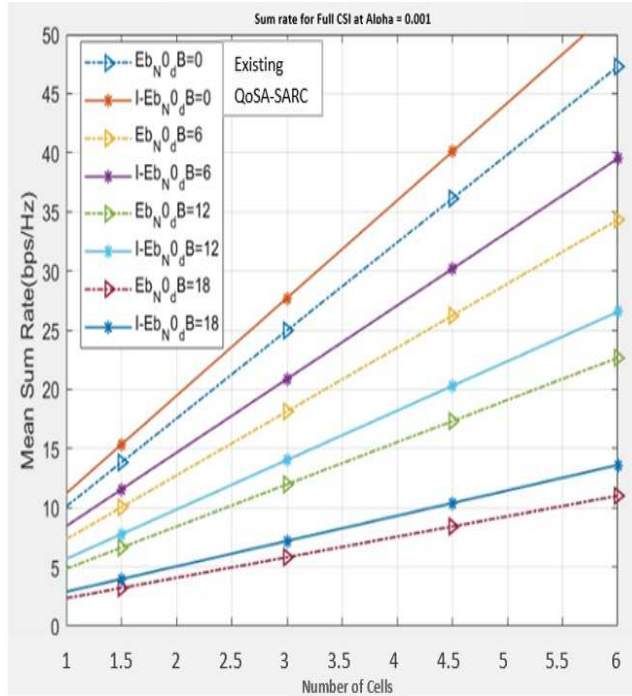


Figure 6: Plot of Sum Rate against Number of Cells at Alpha = 0.001

From the Figure, the QoSA-SARC scheme showed a percentage improvement of 27.78%, 17.24%, 17.82% and 10.70% when B was 18, 12, 6 and 0 respectively when compared with the work [6].

Mean Sum Rate at Interference Parameter of 0.01

Figure 7 shows the result of performance of the work of [6] and the developed sum rate scheme in terms of mean network sum rate against number of network cells at interference parameter of 0.01. To carry out sum rate performance analysis, the generalized Eigen vector Beamforming (EB) was also adopted. In this work, the number of cell bits (B) was varied at a value ranging from 0 to 18. In the network analysis, the EB was implemented using an interfering parameter having a value of 0.01. From

the Figure, one would notice that an increase in the number of network cells led to a corresponding increase in the network mean sum rate. This is due to the fact that an increase in cell number leads to increase in available network resources meant for users during transmission process. Therefore, to serve cell edge users, an increase in the number of available bits for transmission process is needed which improves the accuracy of CSI estimation. This is because, cell edge user will require more transmission bit as compared to cell center user due to the effect of poor coverage.

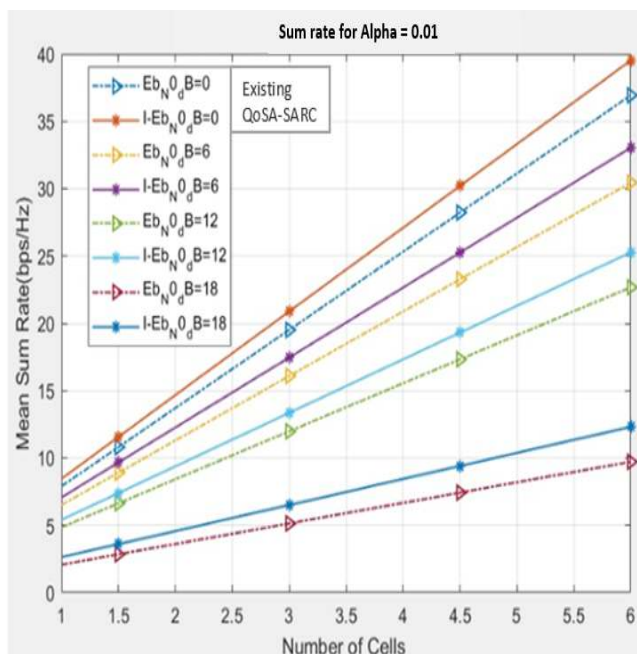


Figure 7: Plot of Sum Rate against Number of Cells at Alpha = 0.01

In the analysis, the interference parameter was increased from 0.001 to 0.01. This implies that users (especially the cell edge users) would suffer high data loss. However, it can be observed that the mean sum rate performance of QoSA-SARC is better than that of [6]. The use of D2D communication limited the effect of interference suffered by both D2D cell edge and cell center users in the network as there are less contenders for BS transmission. Thus, more successful data transmission was experienced by the network in all available channels. From the Figure, the QoSA-SARC scheme showed an improvement of 28.00%, 33.90%, 8.39% and 13.89% when B was 18, 12, 6 and 0 respectively when compared with the work of [6].

Mean Sum Rate at Interference Parameter of 1

From Figure 8, in order to analyze sum rate maximization, the generalized Eigen vector Beamforming (EB) was adopted for interference

parameter value of 1. From the Figure, it can be observed that an increase in the number of network cells led to a corresponding increase in the network sum rate. This is because, an increase in cell number leads to increase in available network resources meant for transmission purpose especially during CSI estimation. With an interference parameter value of 1, both cell edge and cell center users will require more network resources for efficient transmission. Moreover, it can be observed that the sum rate performance of developed scheme outperforms that of [6]. This is due to the advantage offered by the CAT model. Thus, this led to reduction in the occurrence of data loss during transmission process. Additionally, the use of clustered D2D transmission in the presence of high interference greatly ensured successful transmission of information amongst cell users which led to improvements in the network mean sum rate.

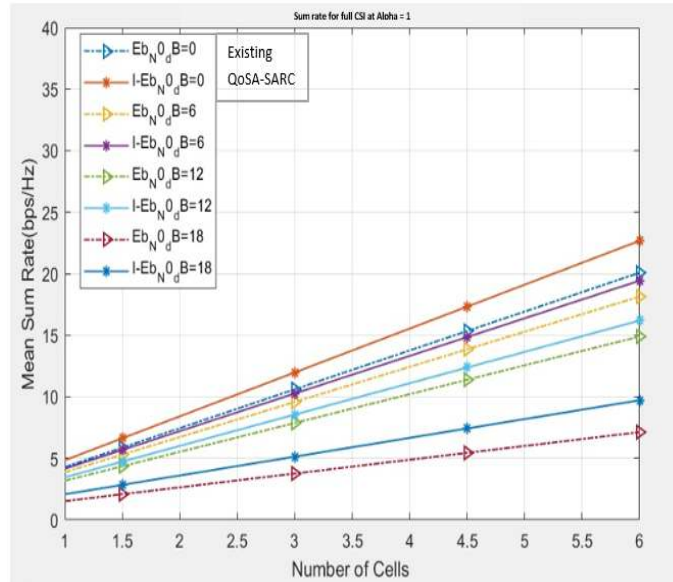


Figure 8: Plot of Control Plane Coverage Probability against SINR

From the Figure, the QoSA-SARC scheme showed an improvement of 28.00%, 33.90%, 8.39% and 13.89% when B was 18, 12, 6 and 0 respectively when compared with the work of Saini and Kuchi, (2018).

CONCLUSION

This research has developed a new approach for sum rate enhancement in HetNet using device-to-device clustering and coordinated beamforming. The developed scheme (QoSA-SARC) was able to improve the mean sum rate performance of HetNet at varying interference parameters of 0.001, 0.01 and 1. The QoSA-SARC made use of CAT model and clustered D2D to mitigate the effect of interference. Also, it's good to note that as the interfering values goes down with limited CSI, the developed scheme obtained significant mean sum rate for low as well high interference parameters. Thus, this showed that cell edge users require more bits for feedback as compare to the desired bits at the cell center to achieve the maximum sum rate.

REFERENCES

- [1] Arora, M., & Jain, P. C. (2017). Control-and user-plane splitting in small cell architecture of 4G LTE-A". In *2017 International Conference on Multimedia, Signal Processing and Communication Technologies (IMPACT)*, 3(5), 75-79.
- [2] Bhagavatula R. and Heath R, (2011) Impact of delayed limited feedback on the sum-rate of intercell interference nulling, in Proc. IEEE International Conference on Communications (ICC), 2(5), 1-5
- [3] Liu, Q., Wu, G., Guo, Y., Zhang, Y., & Hu, S. (2016, December). Energy efficient resource allocation for control data separated heterogeneous-CRAN. In *2016 IEEE Global Communications Conference (GLOBECOM)* 1(2),1-6.
- [4] Mustafa, H. A. U., Imran, M. A., Shakir, M. Z., Imran, A., & Tafazolli, R. (2016). Separation framework: An enabler for cooperative and D2D communication for future 5G networks. *IEEE Communications Surveys & Tutorials*, 18(1), 419-445.
- [5] Mohamed, A. K. A. (2016). *Efficient radio access network with separated control and data functions* (Doctoral dissertation, University of Surrey (United Kingdom). 2(4), 5-9.



-
- [6] Saini, N. K., & Kuchi, K. (2018). *Optimize Power Allocation Scheme to Maximize Sum Rate in CoMP with Limited Channel State Information* (Doctoral dissertation, Indian Institute of Technology Hyderabad).
- [7] Sugimoto C. Ni, and J. Jiang (2011), "Degree, Closeness, and Betweenness: Application of group centrality measurements to explore macro-disciplinary evolution diachronically," in Proc. International Conference of the International Society for Scientometrics & Informetrics (ISSI), 3(3), 1–13.
- [8] Yan E. and Ding Y (2009), "Applying centrality measures to impact analysis: A coauthorship network analysis," *Journal of the American Society for Information Science and Technology*, vol. 10(60), 2107–2118
- [9] Zhou, P., Fang, X., Wang, X., & Yan, L. (2019). Multi-Beam Transmission and Dual-Band Cooperation for Control/Data Plane Decoupled WLANs. *IEEE Transactions on Vehicular Technology*. 2(3), 2-15.
- [10] Li, Y., Xia, M., & Aïssa, S. (2020). Coordinated Multi-Point Transmission: A Poisson-Delaunay Triangulation Based Approach. *IEEE Transactions on Wireless Communications*.