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RESEARCH ARTICLE

Load-Aware Greedy Dynamic CoMP Clustering Mechanism for DPS CoMP in 5G Networks

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Abstract
Cooperative communications offered by the Coordinated Multipoint (CoMP) technique have been introduced and become an important technique in the 5G mobile networks to support very high system capacity and improve the end-user service quality, especially for the cell-edge users via the dynamic coordination of transceivers at different geographical sites. One major issue driving the performance of CoMP operation is the decision on the coopering clusters or the cluster formation strategies. In this work, an approach of CoMP clustering has been studied and proposed, the so-called load-aware greedy dynamic CoMP clustering mechanism. Our proposed CoMP clustering technique is deployed on top of the actual traffic-based load-aware Dynamic Point Selection CoMP (DPS CoMP) mechanism, which is our previously proposed mechanism. The approach is aimed at maximizing spectral efficiency with appropriate cell coordination based on well-balancing cell loads within the coordinating area of the 5G networks. System performance is numerically studied and observed for the 5G Non-Orthogonal Multiple Access (NOMA) systems embedded with our proposed mechanisms for the realistic scenarios, i.e., homogeneous network and Heterogeneous Network (HetNet) cases. Numerical results illustrate the benefit brought by our approaches in comparison with others CoMP clustering techniques as well as the potential for further improvement.

Keywords Dynamic CoMP clustering · 5G network optimization · Load-aware resource allocation · Dynamic point selection

1 Introduction

Future mobile communication networks are expected to support the demand for massive data traffic with a very fast response driven by future applications. The key features of 5G include ultra-Reliable Low Latency Communications (uRLLC), massive Machine Type Communications (mMTC), and enhanced Mobile Broadband (eMBB). By default, an Ultra-Dense Network (UDN) deployment of small cells in Heterogeneous Networks (HetNets) needs to be implemented for the improvement of network capacity, data rate, latency, and the Quality of Service (QoS) in the 5G networks and beyond.

To enhance the network capacity by performing a massive deployment of small cells in the HetNet, the network performance could be degraded due to the Inter-Cell Interference (ICI) issue, which directly affects the service quality of users, especially the cell-edge users. The concept of Coordinated Multipoint (CoMP) transmission has been introduced in 3GPP release 11 [1] for the LTE Advanced (LTE-A) system with the deployment of the multi-cell cooperation concept [2]. The technique was proposed to enhance the interference management technologies previously proposed, e.g., Inter-Cell Interference Coordination (ICIC) [3] and enhanced ICIC (eICIC) [4].

The coordination schemes of the CoMP concept for downlink transmission can be categorized into two main categories including Coordinated Scheduling/ Coordinated Beamforming (CS/CB) and Joint Processing (JP) [5]. For

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CS/CB, the combination of CS and CB techniques provides scheduling and beamforming decisions among multiple coordinated sectors, enabling a user at the cell-edge area to get signals from different base stations without interference using the different scheduling schemes and beamforming designs. In this case, data of a particular User Equipment (UE) are located at a single cell site. On the other hand, JP provides joint processing by sharing all available users' data among multiple cooperating base stations also called Transmission Points (TPs).

JP can be further divided into two schemes, i.e., Joint Transmission (JT) and Dynamic Point Selection (DPS). The JT CoMP scheme provides the simultaneous transmission ability for multiple TPs to provide services to a single user in order to improve the received signal quality and throughput of the UE in a time–frequency resource. In other words, the data can be jointly transmitted among the multiple cooperating base stations simultaneously. This approach could offer high system capacity at the expense of high computational requirements and signaling overhead.

DPS is a simpler CoMP scheme, in which the serving TP for a specific user at a certain time can be dynamically changed to the other TPs at the subframe level based on the availability of radio resource, the channel quality indicated by the Channel State Information (CSI), and other related parameters according to the realistic traffic conditions within the networks. In other words, the data of the DPS scheme can be transmitted by a single base station and switched to others automatically according to cell load and channel conditions.

The CoMP techniques have been studied and proposed in many aspects. For example, the study of a proactive framework of CoMP is discussed in [6]. The work contributes a resource management scheme that can be implemented to support the diverse requirements in the 5G network and beyond by providing an efficient coordination strategy and appropriated clustering scheme in the particular network scenario. The study of JT CoMP with Non-Orthogonal Multiple Access (NOMA) in the HetNet is presented in [7]. The studies of DPS CoMP with the consideration of the traffic load conditions using the average value of Proportional Fairness (PF) and the current number of active users (UEs) as a cell selection criterion are discussed in [8–10]. Among those studies, our previous work presented in [11] proposes the approach called the actual traffic-based load-aware DPS CoMP, in which a cell selection criterion is based on the actual traffic load of cells and the signal quality indicator of the active users to efficiently optimize resource among cells to enhance the overall system performance. The proposed scheme [11] offers LTE-A overall system performance enhancement, especially in imbalanced cell load scenarios. The mechanism will be presented in section two.

Even though the cell cooperation concept of CoMP can improve system capacity, cooperation complexity can be very high, especially for the large group of cooperating cells, also called cooperating clusters. As a result, the performance of CoMP implementation is limited by the complexity of associated cell coordination, signal processing, the requirement of additional overhead and backhaul bandwidth, and the need for precise synchronization. To overcome the limitation of CoMP implementation and enhance the network performance, optimal CoMP clustering should be implemented. In section three, a short review of the CoMP clustering strategies previously proposed will be given followed by our proposed CoMP clustering technique so-called load-aware greedy dynamic CoMP clustering mechanism, which offers the cluster formation on top of our previously proposed DPS CoMP mechanism presented in [11].

The system model used in this study to observe the performance of our proposed CoMP clustering mechanism will be illustrated in section four along with the realistic test scenarios used in this work. The numerical results obtained from our study will be presented and discussed in section five. Finally, the conclusion and future plan will be discussed in section six.

2 Actual Traffic-Based Load-Aware DPS CoMP

As mentioned in the previous section, the principle of CoMP is the network coordination operation developed for the overall system performance enhancement as well as the cell-edge users' performance improvement by mainly coping with the inter-cell interference in the LTE-A network and enhancing spectrum efficiency. The technique was later included as one of the 5G key technologies.

DPS CoMP is one of the CoMP techniques under the concept of the JP CoMP method enabling autonomous decision-making to select the best-serving cells of users based on the availability of radio resources, the channel quality, and other related parameters. In general, the DPS CoMP scheme can be categorized into two main categories consisting of the traditional DPS CoMP schemes and the load-based DPS CoMP schemes.

2.1 Traditional DPS CoMP Scheme

The traditional DPS CoMP scheme decides on the current serving cell using the criterion based on the highest received SINR achieved by the user and the minimum path loss in the wireless channel. The users can dynamically switch and select the best-serving cell to perform the data transmission in each time slot. The switching metric of the data transmission in the traditional DPS CoMP scheme can be defined as:

$$S_k^{s,t} = \frac{r_k^t}{r_k^s} \tag{1}$$

where r_k^t and r_k^s are the throughputs of user k that are served by the transmission point t (TP_t), and the transmission point s (TP_s), respectively.

2.2 Load-Based DPS CoMP Scheme

In the load-based DPS CoMP scheme, the DPS algorithm is performed with the criterion based on the channel quality identified by the CSI report from active users and the cell load conditions. The switching metric of the data transmission in the load-based DPS CoMP scheme can be defined as:

$$S_k^{s,t} = \frac{\left(\frac{r_k^t}{\rho_t}\right)}{\left(\frac{r_k^s}{\rho_s}\right)} \tag{2}$$

where ρ_t and ρ_s represent the cell load of TP_t and TP_s, respectively. References [8–10] present the study of DPS CoMP with the consideration of the traffic load conditions and the actual number of active users as a cell selection criterion.

Under this category, a further study of the DPS CoMP technique with a cell selection criterion based on an actual traffic load of each cell and the Channel Quality Indicator (CQI) of all active users in the LTE-A system has been proposed in our previous work presented in [11]. The cell load calculation method proposed in [11] is based on the actual use of the radio resource in realistic network scenarios. In the experiment, the video streaming traffic model has been used with a constant rate of 512 kbps. In the proposed work, the cell load can be defined as:

$$\rho_c = \frac{\sum_{u|X(u)=c}\left(\frac{D_u}{R \bullet SINR_u}\right)}{N_{tot}} \tag{3}$$

where ρ_c is the actual traffic load of each cell, D_u is the required data rate for each user, $R \bullet SINR_u$ is the data rate per one Physical Resource Block (PRB) that is defined by user u, and N_{tot} is the total number of PRBs (each cell). The studies show that the proposed mechanism provides an effective approach for the overall system throughput enhancement, especially, in scenarios with imbalanced cell load distribution within the coordinated CoMP clusters. Hence, better performance of the LTE-A system can be achieved.

2.3 Actual Traffic-Based Load-Aware DPS CoMP for NOMA Systems

The achievement of overall system performance enhancement in the LTE-A system has been demonstrated through the deployment of our proposed DPS CoMP mechanism presented in [11]. As a result, the actual traffic-based load-aware DPS CoMP mechanism has been further studied in this work to migrate the proposed DPS CoMP mechanism with an appropriate configuration into the 5G system model with the deployment of the NOMA technique. The deployment of NOMA in the 5G networks as a multiple access technique has the spectral efficiency enhancement purpose. As a result, network performance and spectral efficiency performed by the 5G NOMA that is embedded with the proposed DPS CoMP can be further enhanced to support the demands of users in the 5G networks effectively with the benefits of the network coordination concept and NOMA technique. The workflow of the actual traffic-based load-aware DPS CoMP mechanism for NOMA systems can be illustrated through the flowchart as shown in Fig. 1.

Since the actual traffic-based load-aware DPS CoMP mechanism is deployed here in the 5G NOMA system, the configurations and other related parameters according to the NOMA technique in the system model should be set appropriately. For this reason, a further study has been pursued here on the related parameters that have an impact on the deployment of the 5G NOMA system. The impact of user pairing on the 5G NOMA systems that are embedded with the proposed DPS CoMP mechanism is also studied in this work to identify a suitable user pairing threshold level in the used system model configurations for system optimization purpose.

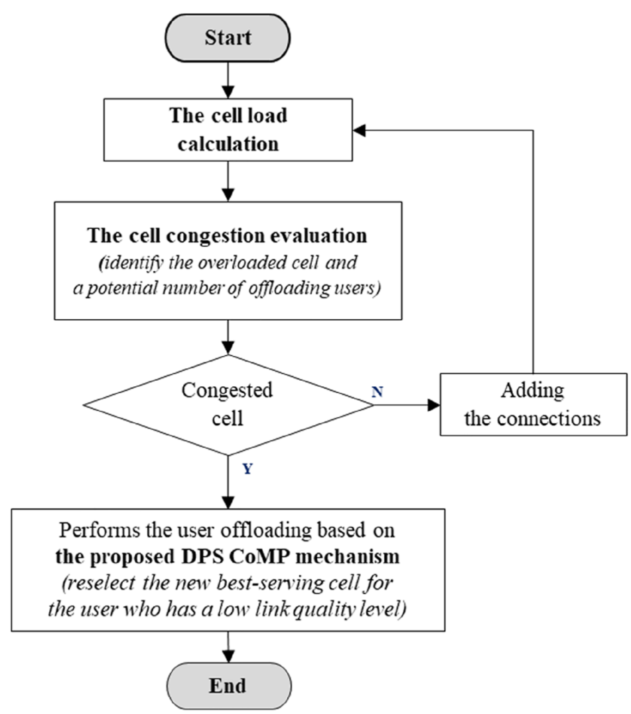


Fig. 1 Actual traffic-based load-aware DPS CoMP algorithm's flowchart

As a quick summary, the proposed DPS CoMP mechanism can be deployed in the LTE-A and 5G networks for network performance enhancement purpose. However, the performance of CoMP techniques has been limited by the efficiency of associated cell coordination. Therefore, the main focus of this work is to propose a CoMP clustering mechanism to further enhance the system performance beyond the limitation of the CoMP mechanism.

3 Proposed Load-Aware Greedy Dynamic CoMP Clustering Mechanism

3.1 Coordinated Multiple Clustering (CoMP Clustering)

The study of CoMP clustering has been introduced in [12] as an approach to form an optimum cluster of coordinating cells to perform a well-balanced spectral efficiency, energy efficiency, backhaul limitations, and load balancing in the 5G networks and beyond. CoMP clustering algorithms can be categorized into three main CoMP clustering types as follows.

- ***Static Clustering***

In static clustering, the coordinated clusters are formed statically, providing a simple solution for the CoMP clustering scheme with less complexity and less signaling overhead requirement. The existing works under the concept of static clustering have been proposed from many angles. For example, the authors of [13] have proposed a static clustering deployed on a hexagonal grid layout for SINR improvement. In [14], static CoMP clustering with the orthogonal frequency reuse technique has been deployed in HetNets to identify locations for small cell deployment to fill the dead-spots area. And in [15], a static clustering scheme was presented on the overlapped patterns solution to maximize mean SINR or minimize SINR outage at user locations.

Although static CoMP clustering has been introduced as an attractive approach for the initial CoMP clustering solution with its less complexity, the performance gains are limited since this method does not respond to the change of the network situation, i.e., user locations and required data transmission.

- ***Semi-Dynamic Clustering***

Semi-dynamic clustering scheme is an attempt to enhance static clustering, where several layers of static clusters are formed and employed more dynamically to avoid the effect of inter-cluster interference and improve the potential CoMP gains.

Under the semi-dynamic clustering concept, the authors of [16] have proposed a solution to enlarge the static clustering topology with the seven layers of static clustering deployment to provide a more dynamic clustering solution. In [17], static clusters are formed with multiple shifted cluster patterns to be allocated into different sub-channels. Moreover, further enhancement of the full-shifting clustering pattern has been proposed in [18] to reduce the inter-cluster interference and maximize the CoMP gain by allocating different frequency bands on the shifted clusters.

In summary, semi-dynamic clustering has been proposed as an improved version of static clustering with higher scalability. However, this method cannot fully and dynamically respond to the changes in network elements and user profiles.

- ***Dynamic Clustering***

This dynamic CoMP clustering scheme has been proposed as a cluster formation scheme that dynamically responds to changes in the network conditions and user profiles, for example, the changing number of available base stations, sleeping cells, loads, etc. The dynamic CoMP clustering consists of three main categories based on the network elements as follows.

A) Network-Centric Clustering

Under the network-centric clustering approach, cells are formed as a cluster (cluster formation), where all users located within the serving area of the clustered cells will be served by all coopering cells within the cell cluster. Figure 2 illustrates a simplified version of a network-centric clustering scheme.

This approach provides a dynamic clustering solution with less complexity by grouping cooperating cells into several groups and serving to all users (UEs) located within the serving area of each cluster. However, the users located at the cluster edge can suffer from inter-cluster interference. Hence, a dynamic network-centric clustering scheme has been introduced as an approach used to minimize the effect of cluster-edge interference by dynamically moving the cluster boundary. Examples of proposed algorithms are as follows:

1.1) Greedy Clustering Algorithm

Cluster formation algorithms under the concept of greedy mechanism have been widely used for cluster cooperation. With this scheme, clusters are formed iteratively with a randomly chosen cell at the beginning of the cluster formation stage. Then, the possible clusters of the chosen cell will be evaluated in terms of the sum rate. The cluster that provides

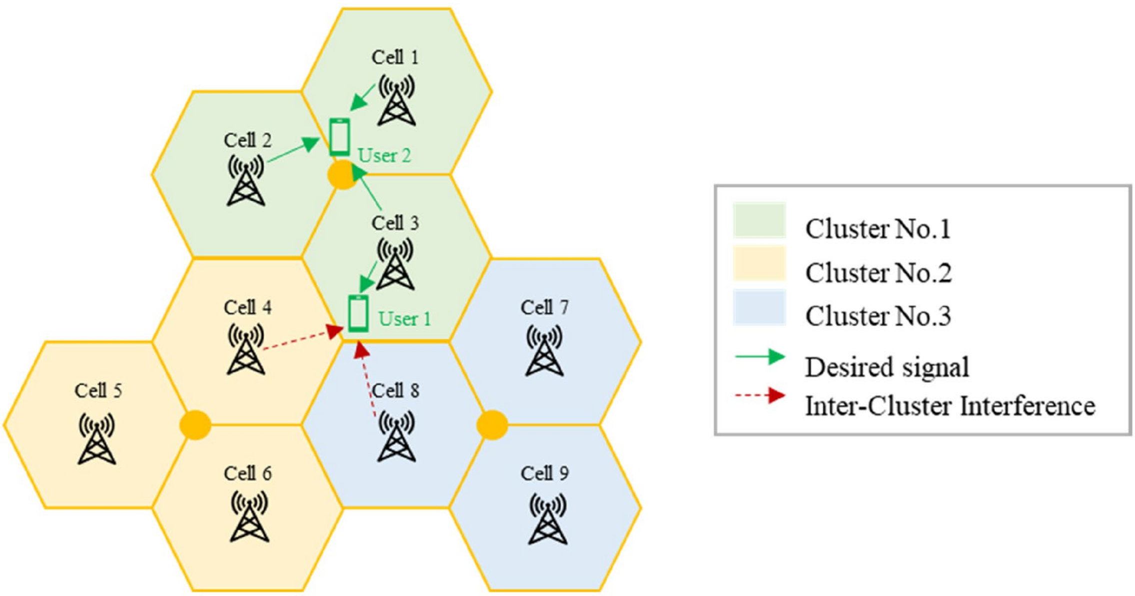


Fig. 2 Network-centric clustering

the highest sum rate will be formed. Then, the next cell will be randomly chosen until all clusters are formed. The work in [19] has studied the concept of the greedy algorithm to maximize the spectral efficiency in the uplink transmission. Also, the authors of [20] have proposed a dynamic clustering solution with a greedy algorithm concept, which dynamically provides the cluster size in the uplink Multi-User Distributed Antenna System (MU-DAS).

Greedy algorithms provide an approach for dynamic cluster formation with low complexity. However, this algorithm is limited by the sub-optimal clusters issue at the later stages of the algorithm. As a result, the greedy algorithm can be improved by employing coalitional game theory for cluster formation based on the merge and split rules to provide less signaling overhead requirements.

1.2) Game Theoretic Clustering Algorithm

This algorithm applies the coalitional game theory to design self-organized with distributed cooperative clusters [21]. The utility function has been deployed as a mathematical function to formulate the trade-off between the CoMP gain and cost function, which is deployed to limit a dynamic cluster size for cluster formation. The deployment of the utility function has been used in [22] to propose a dynamic network-centric clustering method within a fixed cluster size for maximizing the second best-serving cells for the cell-edge users within the same cluster. In [23], the dynamic scheme for cluster formation has been studied and proposed by cell merging based on spectral efficiency improvement.

Although the game theoretic clustering algorithm offers better performance in cluster formation and provides higher spectral efficiency compared with the greedy algorithm, the algorithms under the game theory concept provide higher computational complexity. Hence, the game theoretic clustering algorithm may lack scalability due to the limitation of cluster formation complexity with a larger cluster size.

B) User-Centric Clustering

In this approach, all users are allowed to select the serving cells by allocating the cooperating cells cluster individually based on their requirements, such as the required SINR, throughput, etc. Figure 3 illustrates a simplified version of a user-centric clustering scheme.

Authors of [24] have studied the macro-diversity of CoMP by employing dynamic user-centric clustering concepts in random and hexagonal network topologies. In [25], user-centric clustering has been studied for inter-cell interference mitigation purposes in the downlink coordinated beamforming system. The approach provides the ability to form a cluster by the individual user. Although this clustering approach provides better performance in terms of SINR improvement, the higher complexity and additional backhaul bandwidth are required due to the unlimited boundary of clusters and the higher number of cooperating cells. This aspect limits the deployment of a user-centric approach. Therefore, a suitable network scenario for deploying a user-centric clustering approach is a small area implemented by a small number of cooperating cells within the network.

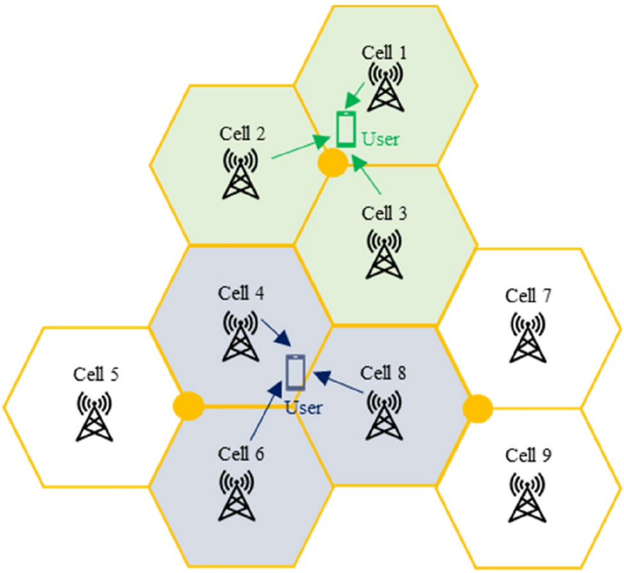


Fig. 3 User-centric clustering

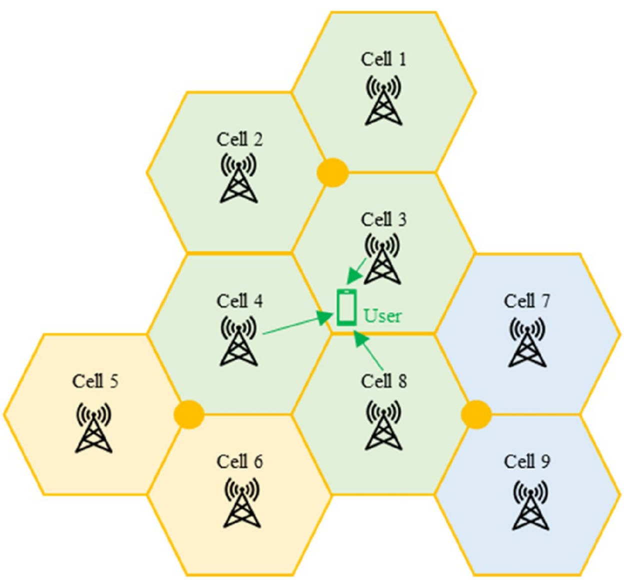


Fig. 4 Hybrid clustering

C) Hybrid Clustering

Hybrid clustering offers the trade-off between network-centric and user-centric clustering solutions to provide an optimal solution for the cluster formation method. This clustering scheme allows users to allocate their serving cells cluster within a limited group of cooperating cells or network-centric clusters individually. Figure 4 illustrates the hybrid clustering scheme.

The authors of [26] have proposed a simple downlink user-centric clustering, where users coordinate with two best-serving cells within a static cluster. Additionally, a hybrid clustering method with the deployment of a joint scheduling algorithm has been studied in the downlink single-user CoMP (SU-CoMP) system to propose a dynamic clustering scheme with low complexity [27]. The hybrid clustering approach can dynamically respond to the change of network conditions and user profiles within their cluster and give an efficient solution for the cluster formation with better performance and meet the network objectives, i.e., spectral efficiency, energy efficiency, backhaul optimization, load balancing, etc.

However, an optimal dynamic clustering scheme with appropriate cluster size and the ability for inter-cluster interference mitigation are still the major research challenges.

3.2 Proposed Load-Aware Greedy Dynamic CoMP Clustering Mechanism

In this work, the study of the CoMP clustering concepts is carried out to develop and propose an optimal cluster formation solution integrated on top of our previously proposed mechanism, the actual traffic-based load-aware DPS CoMP mechanism, to further enhance the spectral efficiency in the 5G network with the deployment of the NOMA system.

As the clustering scheme, the greedy algorithm is one of the promising dynamic CoMP clustering approaches deployed to maximize spectral efficiency and is attractive for the initial deployment of the dynamic cluster formation with low complexity. As a result, the improved version of the greedy algorithm has been proposed in this work as a dynamic cluster formation solution with the criterion based on spectral efficiency and cell load conditions. In this work, several criteria have been set and used in our cluster formation solution and user offloading scheme described as follows.

- ***Cell load calculation method***

Deployed in this work, the cell load calculation is shown in Eq. 3 [11] to calculate the cell load of each serving cell within the 5G network.

- ***Cell congestion evaluation method***

A criterion of the cell congestion evaluation method uses the actual traffic load level for the user offloading scheme. The overloaded cell will distribute users with low link quality levels, who locate within its serving area, to other cells with lower traffic load. In this work, seventy percent of the actual traffic load is set as a threshold to identify the congested cell, which will be selected for performing the user offloading. This threshold value has been studied and proposed in [28].

- ***The Criterion for the proposed CoMP clustering mechanism***

In this work, an improved version of the greedy algorithm is developed and proposed to be used as a cluster formation solution. The criterion is based on the spectral efficiency and cell load conditions. The details of spectral efficiency can be described as follows.

The cluster formation scheme used in this work is adapted from the greedy algorithm presented in [19]. The approach performs a cluster formation scheme by maximizing spectral efficiency, which can be defined as follows;

$$Spectralefficiency = log_2(1 + SINR_k) \tag{4}$$

where $SINR_k$ is the SINR of the cell with its associated users of k users. The evaluation matrix used in this work is the system sum rate that can be defined as follows;

$$R^{(G)} = \sum_{\mathcal{V} \epsilon G} \sum_{k \epsilon \mathcal{S}(\mathcal{V})} log_2(1 + SINR_k) \tag{5}$$

where $\mathcal{V}$ is the group of cooperating antennas and $\mathcal{S}(\mathcal{V})$ is the group of associated users served by the $\mathcal{V}$ group of cooperating antennas. The target of the cluster formation scheme used in [19] is defined as:

$$C_{max} = \max_{G \in g} [R^{(G)}] \tag{6}$$

Figure 5 illustrates the working procedure of our proposed load-aware greedy dynamic CoMP clustering through the algorithm flowchart. As mentioned, the proposed CoMP clustering mechanism has been adapted from a greedy dynamic CoMP clustering mechanism based on spectral efficiency and cell load conditions. The mechanism starts by selecting a single cell with high load conditions and forming a cluster of two cells. Note that the possible cells to form a cluster with the chosen cell need to be its neighboring cells in this work. The cluster is formed by considering a pair of cells that provides the maximum system sum rate and satisfies the cell load condition. The complete cluster formation will be employed and then used in the traffic offloading process until the next cluster formation interval.

4 System Model and Scenarios

The system model deployed in this work has been adapted based on the Vienna 5G Downlink System Level Simulator by the Telecommunications Institute of the Vienna University of Technology (TU Wien) [29]. Two network models have been deployed. First, one Macro Base Station (MBS) with tri-sector directional antennas and three Small Cells (SCs) with omnidirectional antennas located in the coverage area of the MBS have been deployed in the 5G Heterogeneous Network (HetNet), as shown in Fig. 6. It is assumed that the perfect backhaul links have been used as a communication channel to exchange the Channel State Information (CSI) data between MSB and all SCs within the same CoMP co-operating cluster. The inter-site distance of 500 m is used. For this first model, the three different load distribution scenarios have been deployed for the studies observing the performance of a 5G NOMA system embedded with actual traffic-based load-aware DPS CoMP, in which the test results will be presented in Sect. 5.1. The test scenarios include (1) the random users' distribution with normal traffic level, (2) the traffic load imbalanced case with all three hotspot SCs, and (3) the traffic load imbalanced case with hotspot MBS. Figure 6 depicts the first system model, the heterogeneous network case.

The second network model includes 19 MBS with tri-sector directional antennas or serving cells of 57 sectors deployed in the 5G homogeneous network, as shown in Fig. 7. This network model has been used in the performance evaluation of the proposed load-aware greedy dynamic CoMP Clustering Mechanism. The three different load distribution scenarios are deployed for the study including two scenarios of four hotspot locations with 3-cell hotspots located in different locations and one large hotspot case with 7-cell hotspots.

To make sure that the traffic demand of users represents realistic scenarios, the video streaming traffic model with the constant rate of 512 kbps has been developed and used in the system model. More details related to the system configurations and parameters are given in Table 1.

In the HetNet test cases shown in Fig. 6, the number of attached users per cell of hotspot case in MBS and SCs is 50 and 70 users, respectively. For the normal traffic situation, 20 and 10 associated users per cell are deployed in the uncongested MBS and SCs, respectively. Meanwhile, 10 and 50 users are set for the normal traffic and hotspot in the homogeneous network model, respectively. The overview of all HetNet and Homogeneous network tested scenarios deployed in this work is given in Tables 2 and 3, respectively.

5 Numerical Results

The numerical results achieved from our study will be presented in this section. The first set of studies focuses on the performance evaluation of the 5G NOMA system embedded with the actual traffic-based load-aware DPS CoMP along with the observation of the user pairing effects. The second set of studies is the observation of performance gain from our proposed mechanism, the load-aware greedy dynamic CoMP clustering technique. The performance is observed in terms of the overall system throughput and fairness in

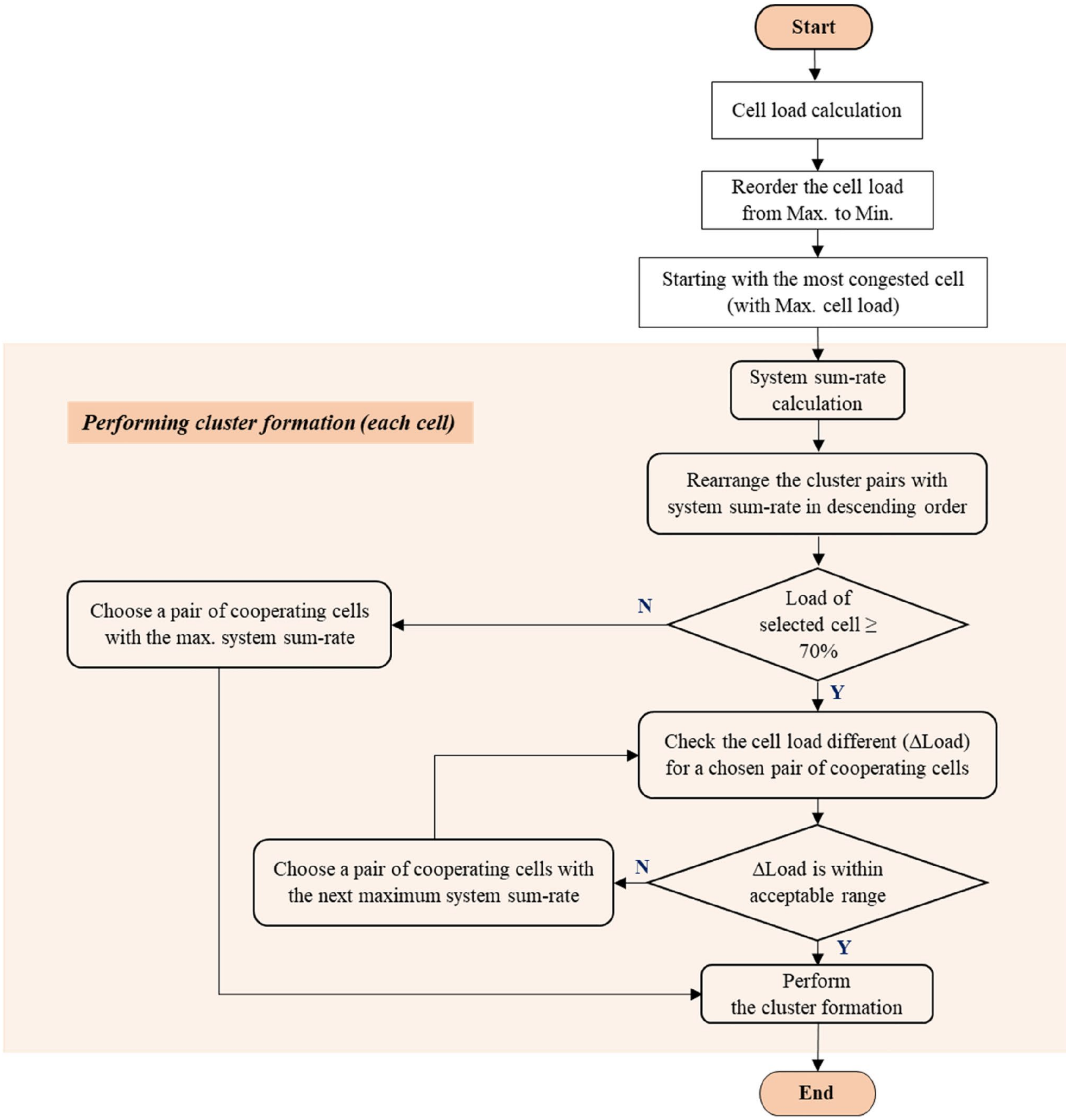


Fig. 5 Algorithm flowchart of the proposed load-aware greedy dynamic CoMP clustering mechanism

comparison with the ordinary 5G NOMA system and the system deploying other CoMP clustering techniques, i.e., fixed CoMP clustering and dynamic CoMP clustering using the traditional greedy mechanism.

In terms of system throughput performance, the total number of required data rates obtained from all active users within the network has been observed using an empirical Cumulative Distribution Function (eCDF) to provide a numerical result of system behavior at the observation point. The evaluation of system throughput performance includes:

- the peak throughput, calculated by the eCDF function identifying the 95th percentile of user throughput obtained from the entire simulation period,

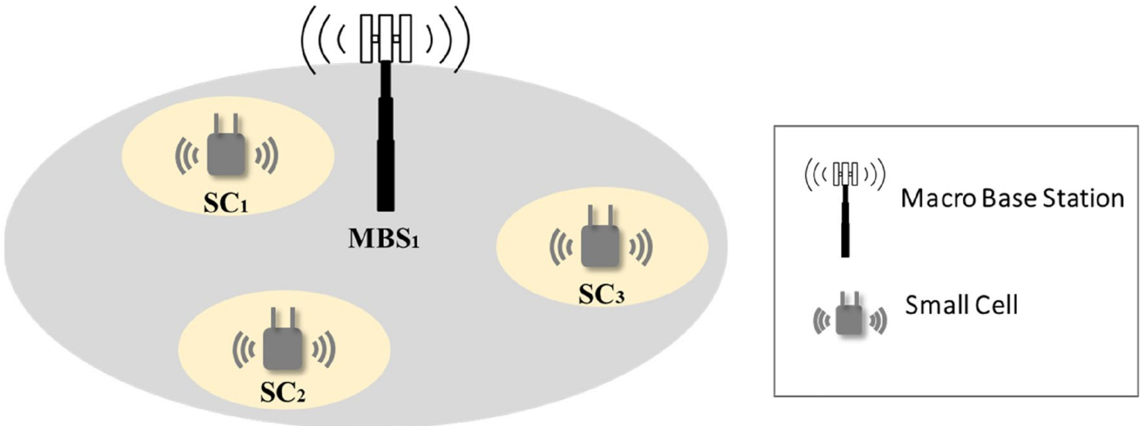


Fig. 6 Heterogeneous network test case

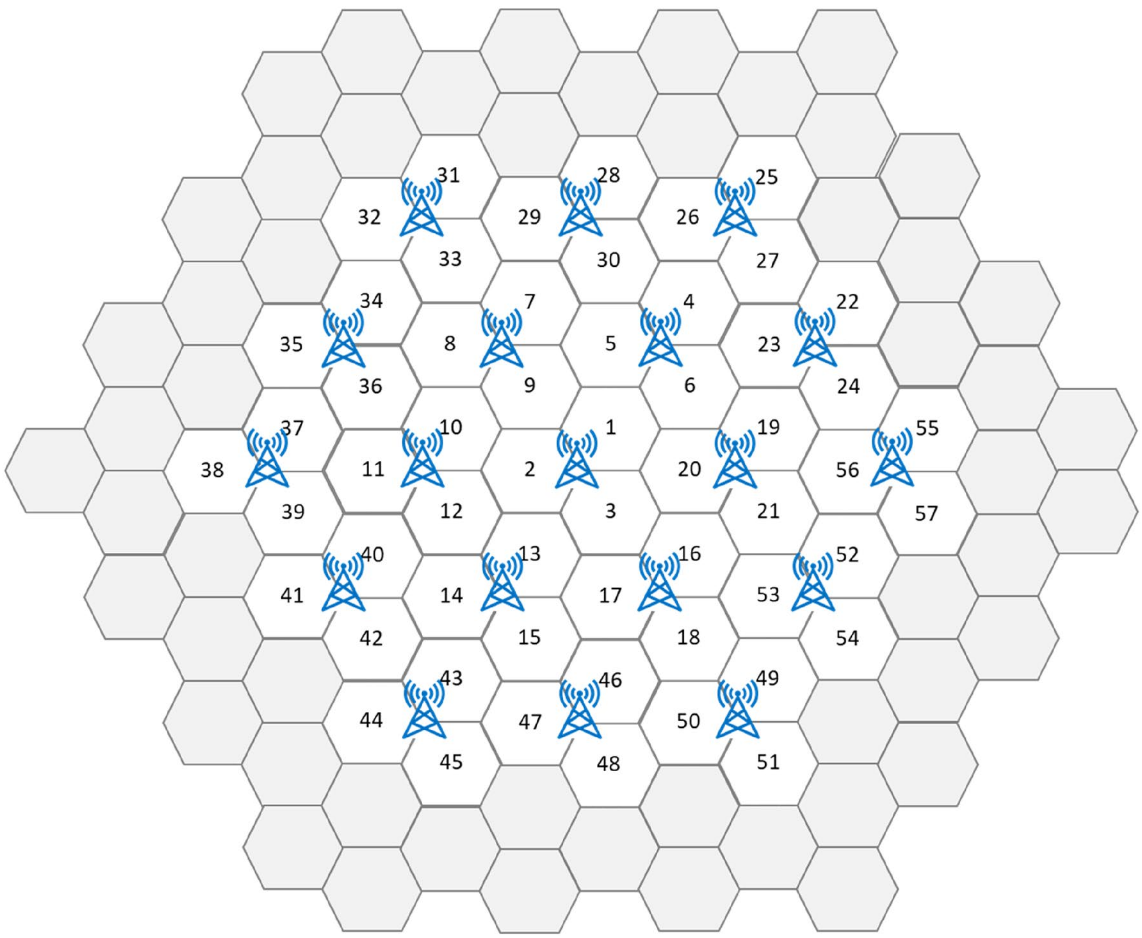


Fig. 7 Homogenous network test case

- the average throughput identifying the average throughput level of all users obtained from the entire simulation period, and

Table 1 System Model Configuration and Parameters

Parameter	Value
TTIs or slots	1000 slots
Time slot duration	1 ms
Carrier frequency	2.1 GHz
Bandwidth in MHz	15 MHz
Pathloss model	3GPP Macrocell (3D Urban Macrocell) with an inter-site distance of 500 m
Channel model	Pedestrian A
Traffic model	Video streaming traffic model with a constant rate of 512 kbps
Antenna configuration	2×2 MIMO
Number of users	Heterogeneous network: 20 users (MBS with normal traffic load) 10 users (SCs with normal traffic load) 50 users (Hotspot case of MBS) 70 users (Hotspot case of SCs) Homogeneous Network: 10 users (MBS with normal traffic load) 50 users (Hotspot case of MBS)
User pairing threshold level (Δ)	12, 15, 18
Speed of user	3 km/hr

- the cell-edge throughput or edge throughput, calculated by the eCDF function identifying the 5th percentile of user throughput obtained from the entire simulation period.

To measure the equality of resource allocation, the fairness index's calculation has been deployed in this work to demonstrate the equality of obtained system throughput of all active users within the network. The equation of the fairness index calculation [30] that has been used here to evaluate the fairness of resource allocation among traffic flows can be defined as;

$$f(x) = \frac{\left[\sum_{i=1}^{n} x_i\right]^2}{n\sum_{i=1}^{n} x_i^2} \quad (7)$$

where $f(x)$ is the fairness index, x_i represents the data rate (each user), and n represents the number of all users.

5.1 Actual Traffic-Based Load-Aware DPS CoMP for NOMA System with the Study on User Pairing Effects

In this work, the actual traffic-based load-aware DPS CoMP mechanism has been implemented in the 5G HetNet system based on three main traffic distribution scenarios, including random users' distribution with normal traffic level, all three hotspot SCs with traffic load imbalanced, and hotspot MBS with traffic load imbalanced (see Table 2).

The system performance has been evaluated via the system model mentioned earlier for the conventional OMA (Orthogonal Multiple Access) systems, the OMA system embedded with our proposed DPS CoMP mechanism, the conventional NOMA system, and the NOMA system embedded with our previously proposed DPS CoMP mechanism. For the NOMA system, the user paring threshold has also been varied in three levels, consisting of 12, 15, and 18. The range of user pairing threshold or Δ threshold implemented in this study is based on the default value of the user pairing threshold recommended in the system model.

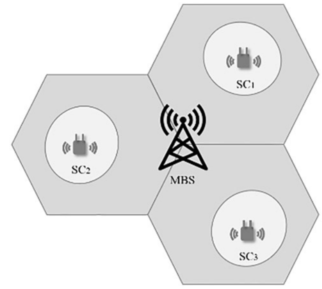
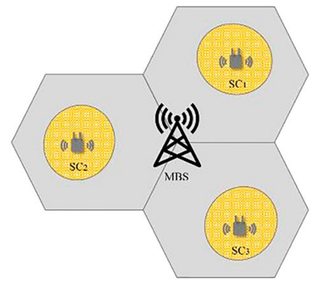
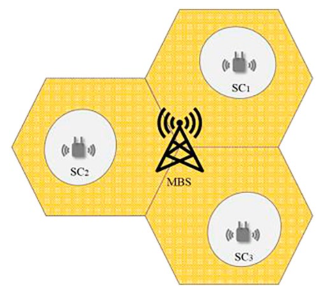
The results achieved from this study can be used to evaluate the performance of the proposed work from two angles. The first angle is the performance of our proposed DPS CoMP mechanism, known as the network coordination technique that is used for network capacity enhancement and inter-cell interference mitigation purposes. The second angle will demonstrate the impact of user pairing deployment, since the NOMA technique has been deployed in the 5G networks for spectral efficiency enhancement. Note that the Fixed power allocation NOMA (F-NOMA) is implemented in this work, which deploys the conventional near-far user pairing scheme.

As stated, the peak throughput performance has been used to represent the 95th percentile of the user throughput and the obtained results are illustrated in Fig. 8.

The results in the angle of the proposed work's performance have demonstrated that all obtained peak throughput performances obtained from all test systems have achieved the guaranteed bit rate level of 512 kbps for all test scenarios both in the normal traffic case (scenario 1) and the imbalanced load cases (scenario 2 and 3). Hence, the impact of user-pairing cannot be detected from the peak throughput performance since all test systems have performed well and the peak throughput performances are satisfied for all scenarios.

The average throughput represents the average throughput of the system achieved from all user throughput within the network. The numerical results of the average throughput performance achieved from all test systems for all three test scenarios are illustrated in Fig. 9. As scenario 1 has been used to represent the normal traffic load case, the results obtained from all test systems in scenario 1 can be seen that the obtained average throughput performance of all test systems achieves the guaranteed bit rate level of 512 kbps, since all cells in this scenario are not overloaded. While in the imbalanced load cases in scenario 2 and scenario 3, the results show that a slight enhancement of average throughput performance can be offered by the implementation of the DPS CoMP mechanism compared with systems that do not deploy the CoMP mechanism for both the OMA

Table 2 HetNet test scenarios

HetNet model	Scenario
HetNet Scenario 1 Random user distribution with normal traffic level	
HetNet Scenario 2 Load imbalanced case, where the three SCs are hotspots (overloaded)	
HetNet Scenario 3 Load imbalanced case, where the MBS is hotspot (overloaded)	

and NOMA systems. In addition, the best enhancement of average throughput is offered by the use of the DPS CoMP mechanism deployed in the NOMA system for all hotspot scenarios, i.e., scenario 2 and scenario 3.

Moreover, the impact of user-pairing can be detected according to a varying configuration of user-pairing threshold level deployment. The slight enhancement of average throughput performance is offered using a lower level of user pairing threshold level. This is because a smaller user pairing threshold allows a higher number of user pairs, which leads to increasing compensation among users. As a result, the overall system throughput can be enhanced with the benefits of an optimal user pairing threshold deployment.

The cell-edge throughput performance achieved from all test systems based on three different network scenarios has also been used to represent the 5th percentile of user throughput as shown in Fig. 10.

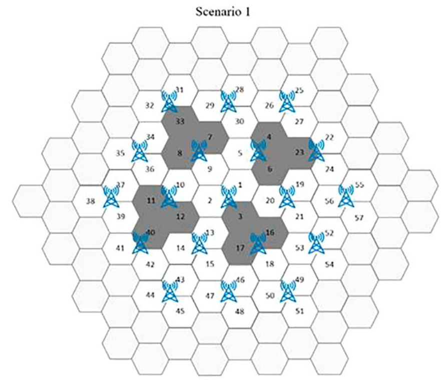
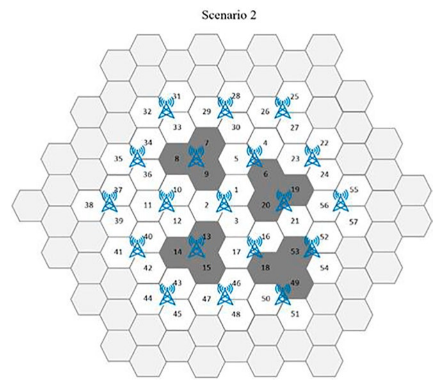
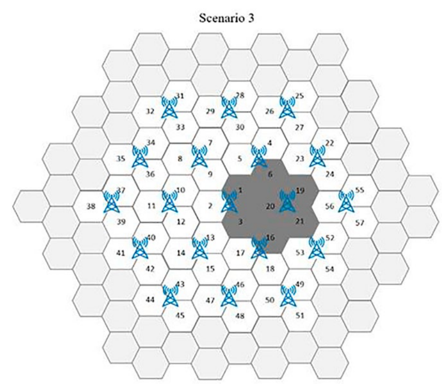
The results of edge throughput in the normal traffic case that is represented in scenario 1 illustrate that all obtained edge throughput of all test systems have reached the guaranteed bit rate level, since all cells in this scenario are not overloaded. In contrast, the results in the imbalanced load cases (scenario 2 and scenario 3) show that the edge throughput performance can be further enhanced with the DPS CoMP mechanism deployment in both the OMA and NOMA systems, especially in scenario 3. This is because the cell-edge throughput performance can be compensated due to the DPS CoMP mechanism implementation by offloading the cell-edge users of the congested cells to other neighboring cells with lighter traffic loads.

In addition, further enhancement of the edge throughput performance can be obtained by the impact of user-pairing threshold level configuration deployed in the 5G NOMA system. The more suitable user-pairing threshold level has been set, the more overall system throughput performance has been further enhanced.

System fairness performance can be evaluated by the fairness index achieved from the simulation results of all test systems based on the three different load distribution scenarios as shown in Fig. 11.

The results of system fairness performance of all test systems based on the normal traffic load scenario (scenario

Table 3 Homogenous network test scenarios

HetNet model	Scenario
Homogenous network scenario 1 Four hotspot locations, each hotspot consists of three cells *Note that the cells with a dark gray shade are the hotspot cells*	
Homogenous network scenario 2 Four hotspot locations, each hotspot consists of three cells *Note that the cells with a dark gray shade are the hotspot cells*	
Homogenous network scenario 3 One large hotspot area consisting of seven cells *Note that the cells with a dark gray shade are the hotspot cells*	

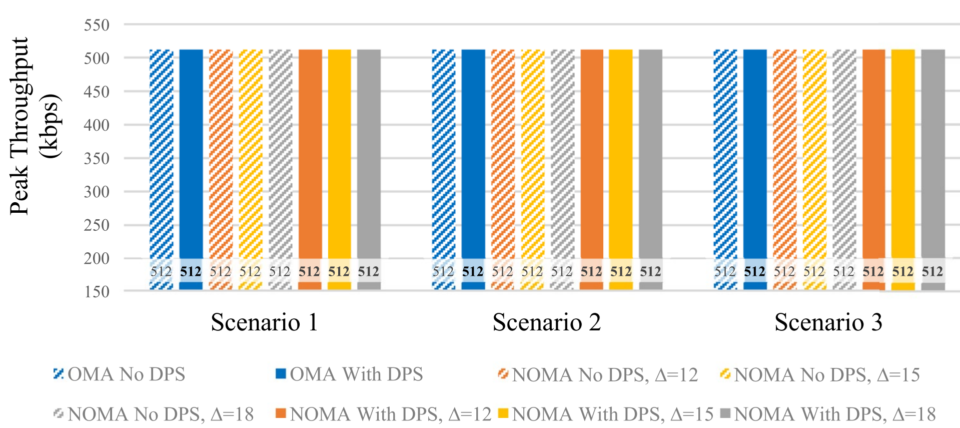


Fig. 8 Peak throughput from the study of DPS CoMP for OMA and NOMA system

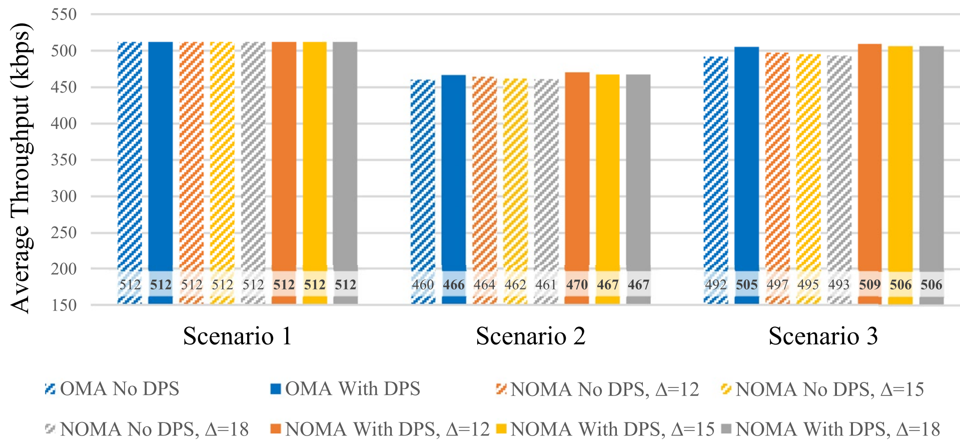


Fig. 9 Average throughput from the study of DPS CoMP for OMA and NOMA system

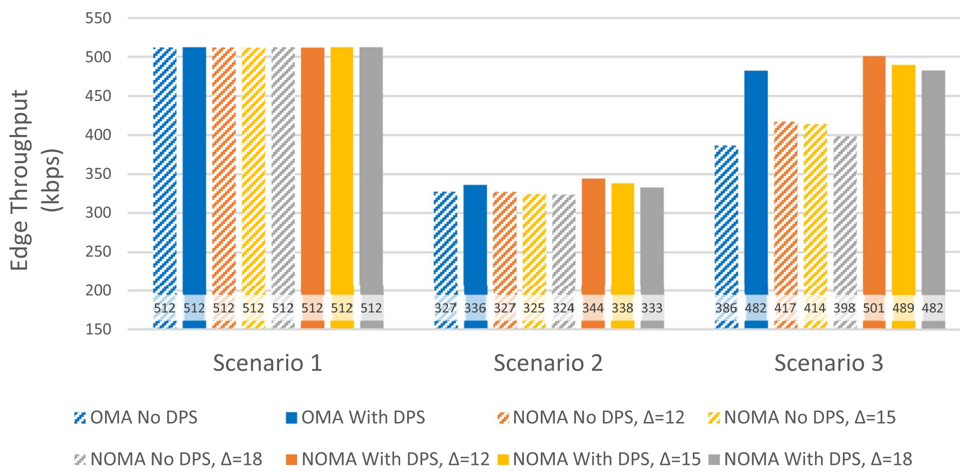


Fig. 10 Edge throughput from the study of DPS CoMP for OMA and NOMA system

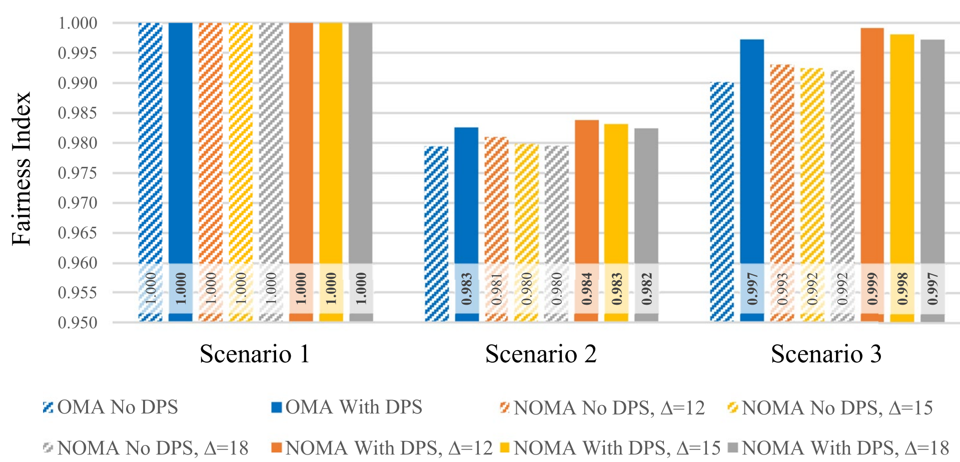


Fig. 11 Fairness from the study of DPS CoMP for OMA and NOMA system

1) show that all results of the fairness index have reached the work's expectation by illustrating the results of 1. Meanwhile, the fairness index in the imbalanced traffic load cases in scenario 2 and scenario 3 can be enhanced with the use of the DPS CoMP mechanism implementation in both the OMA and NOMA system.

Furthermore, with a more suitable setting of user-paring threshold level configuration, i.e., a lower level of user pairing threshold deployment, the further enhancement of system fairness performance can be offered in the 5G NOMA system both in the systems implemented with and without the actual traffic-based load-aware DPS CoMP mechanism.

This could be concluded that identifying the suitable user pairing threshold level and power allocation scheme in the F-NOMA system can be another factor strongly affecting the 5G system performance.

5.2 Proposed Load-Aware Greedy Dynamic CoMP Clustering Mechanism

In this section, the performance of our proposed load-aware greedy dynamic CoMP clustering mechanism will be given. The system performance has been evaluated by comparing it with the other two CoMP clustering mechanisms, implemented with our previously proposed load-aware DPS CoMP mechanism. The two other CoMP clustering schemes consist of the 2-cells fixed clustering and the greedy dynamic CoMP clustering. Our proposed CoMP clustering mechanism is the improved version of greedy dynamic CoMP clustering for a cluster size of two cells as mentioned in Sect. 3. In the case of the fixed CoMP clustering mechanism, Fig. 12 illustrates a fixed clustering pattern deployed in this work.

In this study, the three different load distribution scenarios have been investigated as given in Table 3 and the system performance is observed in terms of the overall system throughput and fairness index. Referring to the test scenarios given in Table 3, the three cases consist of three different imbalanced traffic load distribution scenarios, in which the first and second scenarios include four hotspot areas in different locations and each hotspot covers three macrocells. The last test case includes only one large hotspot area covering seven macrocells.

As shown in Fig. 13, the numerical results for the peak throughput performance are illustrated for the 5G NOMA system without the implementation of CoMP and the 5G NOMA system employing the three different CoMP clustering mechanism, i.e., the 2-cells fixed clustering, the greedy dynamic CoMP clustering, our proposed load-aware greedy dynamic CoMP clustering mechanism.

It can be seen that all results of the peak throughput performance achieved the guaranteed bit rate level of 512 kbps for all test scenarios. This is due to the fact that all three test cases include cells with normal traffic load

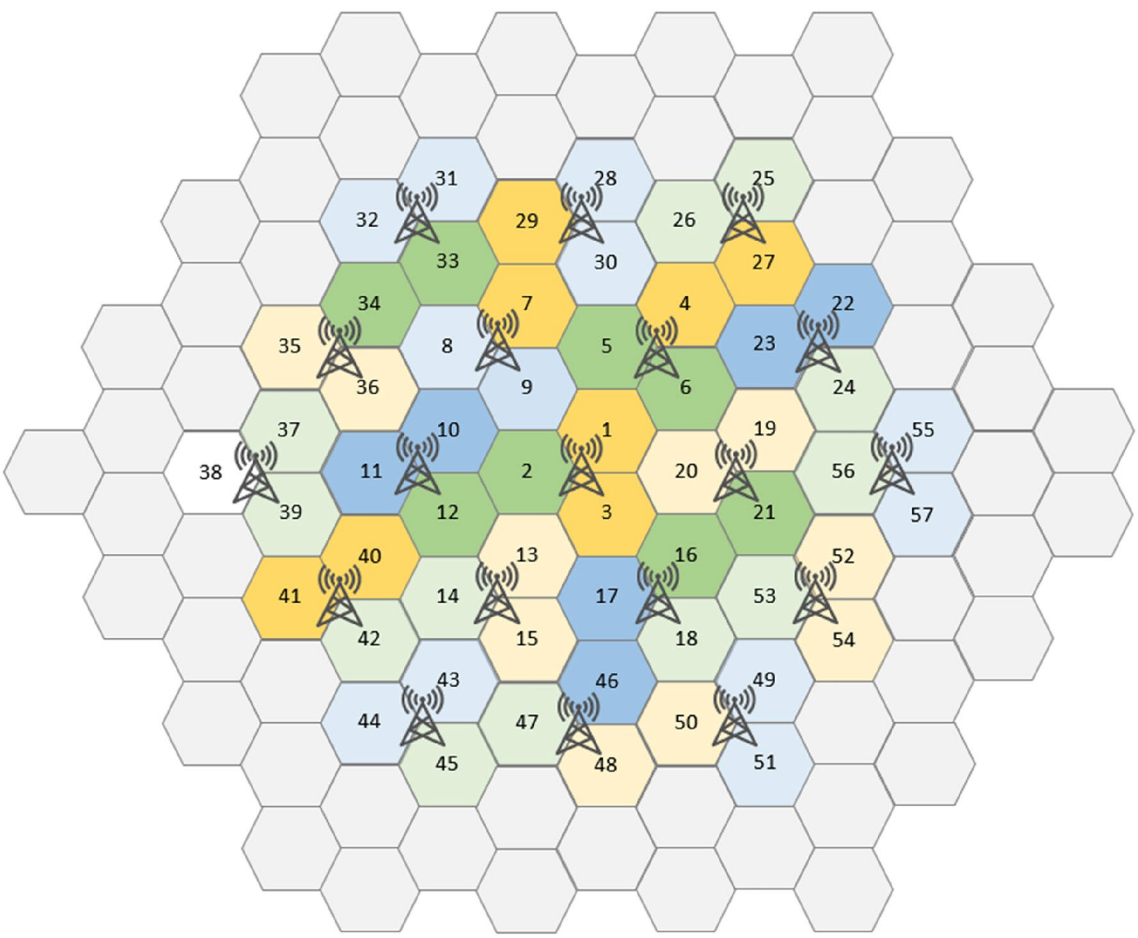


Fig. 12 Fixed CoMP clustering pattern for a 2-cell fixed clustering mechanism

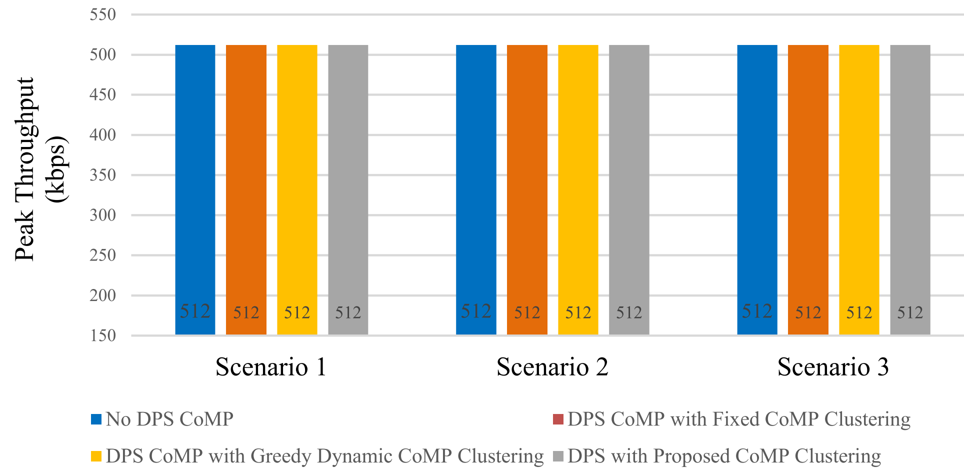


Fig. 13 Peak throughput from the study of the proposed comp clustering mechanism

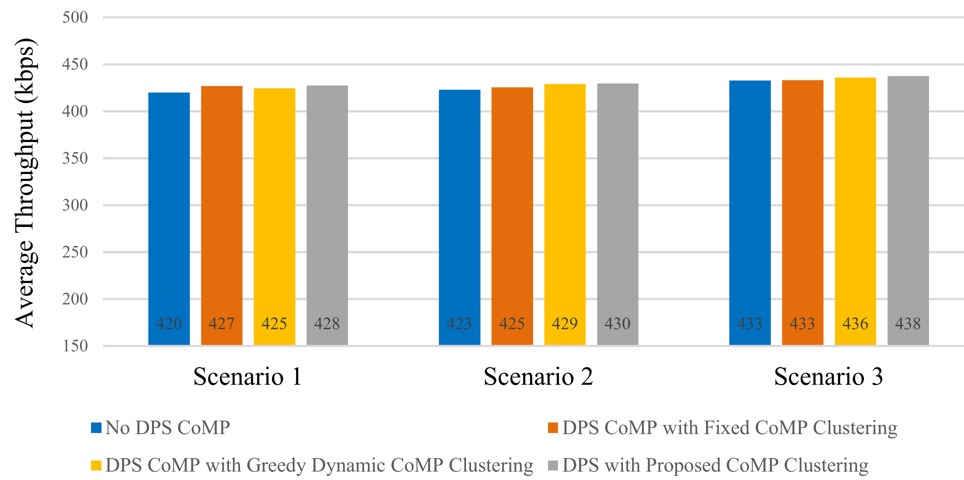


Fig. 14 Average throughput from the study of the proposed CoMP clustering mechanism

situations leading to the well-available resources to support demand in those normal-load cells.

The numerical results of the average throughput performance achieved from all test systems for all three simulation scenarios are illustrated in Fig. 14. The average throughput performance achieved from 5G NOMA systems embedded with the DPS CoMP mechanism and clustering solutions can be slightly enhanced compared with the 5G NOMA system without DPS CoMP and the clustering solution. Moreover, a slight enhancement of the average throughput performance has been offered by the use of our proposed dynamic clustering algorithm in comparison with the other two techniques. This is because the spectral efficiency enhancement based on the available spectrum resource and cell load conditions have been taken into account in the cluster formation process.

The cell-edge throughput performance achieved from the test of all test systems based on the three hotspot scenarios has been used to represent the 5th percentile of user throughput as shown in Fig. 15.

It can be concluded from the results of edge throughput performance that the 5G NOMA systems with the deployment of the DPS CoMP mechanism and clustering solutions have offered a better edge throughput performance in comparison with the 5G NOMA system that has not deployed the DPS CoMP mechanism and the clustering solutions. This is due to the ability to jointly and more efficiently manage the available spectrum resources among cells in the clusters. Comparing the results among the three CoMP clustering mechanisms studied here, the proposed CoMP clustering scheme integrated on top of the load-aware DPS CoMP mechanism highly outperforms the other two CoMP clustering methods for all three test scenarios. This is due to the ability of the proposed clustering algorithm that is aimed to enhance the cell-edge throughput performance with the ability to dynamically respond to the real traffic load situation as well as the available spectrum resources.

System fairness can be evaluated by the fairness index achieved from the numerical results of all test systems based on the three different load distribution scenarios

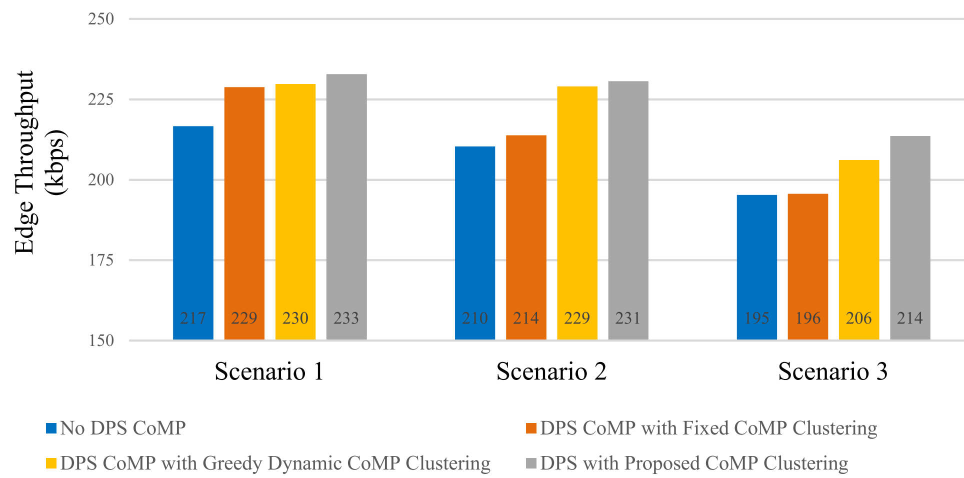


Fig. 15 Edge throughput from the study of the proposed CoMP clustering mechanism

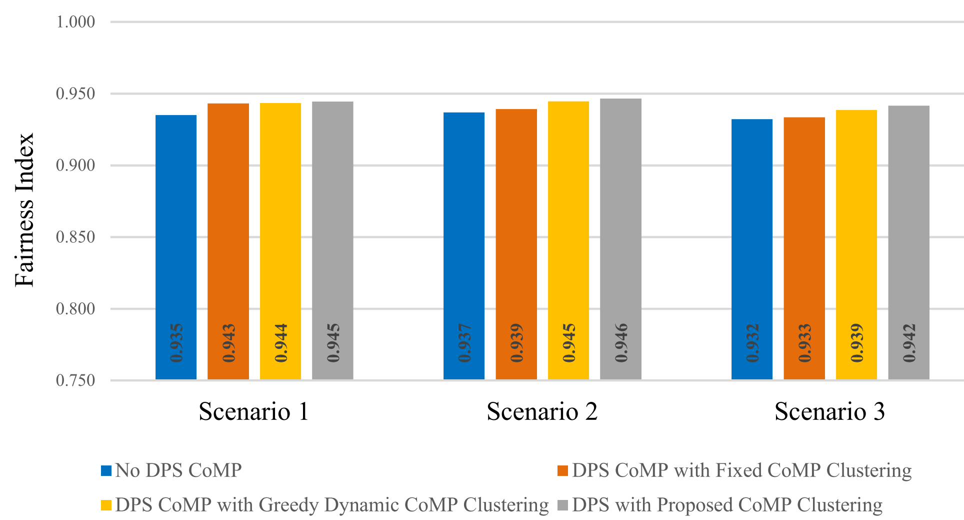


Fig. 16 Fairness from the study of the proposed CoMP clustering mechanism

as shown in Fig. 16. It can be seen that a better system fairness has been offered by the deployment of the DPS CoMP mechanism implemented with clustering solutions. The lowest system fairness is from the 5G NOMA system without the deployment of DPS CoMP. This is due to the lack of flexibility and awareness of the changes in the current network environment. On the other hand, all systems implemented with DPS CoMP offer fairness enhancement. Better system fairness can be achieved with the deployment of dynamic CoMP clustering schemes and the best system fairness has been offered by the use of the proposed CoMP clustering mechanism.

This can be summarized that the dynamic CoMP clustering mechanism proposed in this work implemented with the actual traffic-based load-aware DPS CoMP mechanism in the 5G NOMA system offers better fairness and edge throughput performance and highly outperforms the conventional 5G system without DPS CoMP implementation and the other two CoMP clustering approaches for all test scenarios.

6 Conclusion

In this work, the load-aware greedy dynamic CoMP clustering mechanism has been proposed as an efficient cell coordination strategy with the consideration of spectral efficiency and load balancing aspects. The mechanism is designed to be deployed on top of our previously proposed DPS CoMP mechanism presented in [15]. With an appropriate CoMP clustering scheme allowing an optimal cluster formation, the further enhancement of overall system performance can be achieved and this has been illustrated in terms of system throughput and fairness index obtained as the numerical results under all realistic test scenarios.

Since the DPS CoMP mechanism in our previous work has been deployed in the LTE-A system, the study has included also the deployment of the DPS CoMP mechanism in the 5G system model. This work also comprises the study of an optimal configuration of user pairing threshold level. To observe the system behaviors under realistic network scenarios, different load distribution scenarios in the 5G heterogeneous network and homogeneous network have been investigated. In this work, the video streaming traffic model with the constant rate of 512 kbps has been deployed in the ordinary 5G system (OMA system) and the 5G system embedded with the NOMA deployment to observe and evaluate the overall system performance offered by our proposed CoMP clustering technique in comparison with other techniques previously introduced in the literature.

The results achieved from the proposed works can be illustrated that the overall system performance enhancement in terms of system throughput and fairness can be offered by the deployment of the proposed CoMP clustering mechanism implemented on top of the actual traffic-based load-aware DPS CoMP mechanism in the 5G NOMA system for all tested scenarios. In other words, the objectives of network capacity enhancement and spectral efficiency enhancement based on the consideration of users' profile and cell load conditions can be served and fulfilled with the use of a network coordination approach, known as the DPS CoMP algorithm with an optimal proposed CoMP clustering mechanism in the 5G NOMA system.

As mentioned, the proposed CoMP clustering mechanism has been developed from the original version of the greedy dynamic CoMP clustering mechanism with the 2-cells cooperated CoMP cluster. Moreover, our technique also includes the consideration of spectral efficiency and cell load conditions. As illustrated, a better overall system performance has been offered by our proposed CoMP clustering mechanism compared with the other two clustering techniques. However, this still lacks scalability to respond to a variety of network conditions. In our future work, the clustering mechanism could be further enhanced with an optimal number of coordinated cells within the same cooperating cluster or with the use of other cluster formation methodologies. Furthermore, the computational and implementation complexities can become a strong impact factor and this should be considered a major challenge in this research field.

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Data availability Data sets generated during the study are available from the corresponding author on reasonable request.

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