

Integrated Grey Rational Analysis-Standard Deviation Method for Handover in Heterogeneous Networks

Mohanad Alhabo, Naveed Nawaz, Mahmoud Al-Faris

Abstract—The dense deployment of small cells is a promising solution to enhance the coverage and capacity of the heterogeneous networks (HetNets). However, the unplanned deployment could bring new challenges to the network ranging from interference, unnecessary handovers and handover failures. This will cause a degradation in the quality of service (QoS) delivered to the end user. In this paper, we propose an integrated Grey Rational Analysis Standard Deviation based handover method (GRA-SD) for HetNet. The proposed method integrates the Standard Deviation (SD) technique to acquire the weight of the handover metrics and the GRA method to select the best handover base station. The performance of the GRA-SD method is evaluated and compared with the traditional Multiple Attribute Decision Making (MADM) methods including Simple Additive Weighting (SAW) and VIKOR methods. Results reveal that the proposed method has outperformed the other methods in terms of minimizing the number of frequent unnecessary handovers and handover failures, in addition to improving the energy efficiency.

Keywords— Energy efficiency, handover, HetNets, MADM, small cells.

I. INTRODUCTION

THE extensive growth of the number of mobile user equipments (UEs) connected to the network has led to a capacity shortage [1]. The current deployed macrocell (MC) suffers from high congestions and poor coverage in some places. The small cells (SCs) technology, which are small base stations with low transmit power and coverage area, has been introduced to tackle this demand [2]. However, the dense SCs deployment has caused new challenges in the network such as interference, handover failure and unnecessary handovers. Thus, low QoS is delivered to the end user [3]. There have been a number of research works in the literature that aim to solve the problems associated with dense SCs deployment in HetNets. In [4], we presented a handover (HO) method to minimize the number of SCs and minimize the unnecessary HOs in HetNet. A neighbour cell list (NCL) of the SCs is built by deploying the distance between a UE and a SC and the UE angle of movement. Very high speed UEs are not permitted to access the SCs. Results show that the NCL has been minimized and the unnecessary HOs have been reduced. Authors in [5] presented a HO method

to limit the unnecessary HO and HO failure. An estimated time of stay (ToS) is deployed to exclude SCs, which could result in unnecessary HO or HO failure, from NCL. The UE switches to a SC with the highest signal to interference plus noise ratio (SINR) and has a proper remaining capacity. A time threshold along with the SINR are deployed to obtain a compromise between the unnecessary HO and HO failures where the results reveal a reduction in both. Another HO method for load balancing in HetNets is proposed in [6]. The impact of interference and estimated time of stay (ToS) are taken into account to offload the traffic from an overloaded MC to a SC. A HO margin that is based on the serving cell load and interference is derived to perform offloading. Results reveal that this method has limited the unnecessary HO and outage probability in addition to throughput enhancement. Authors in [7] [8] presented methods to obtain high resource block efficiency in the network by mitigating the interference. According to the required QoS, resources are distributed dynamically. Results reveal a mitigation in the interference and an improvement in spectrum efficiency. In [9], authors presented an energy efficiency scheme for HetNets. SCs are cooperating according to a game theory strategy to obtain an optimal subframe and power configurations. Results reveal an improvement in the energy efficiency and maintaining capacity at maximum level. Authors in [10] presented a HO method for load balancing HetNets. The influence of interference is taken into account to offload the UEs from the overloaded cells. The proposed method utilizes a modified A3 HO triggering event considering the cell load and the interference. Results show a good performance in load balancing and throughput enhancement. Multiple attribute decision making (MADM) is considered as one of the most deployed strategies that deals with the choosing of best alternatives, which are classified according to multiple attributes. Thus, MADM techniques can be used as good solution to model the HO decision problem. In this paper, four HO metrics, the downlink SINR, capacity of the target cell, ToS and the UE transmit power with respect to the target cell. The interference is very high in HetNets with dense deployment of SCs. For this reason, this paper deploys the downlink SINR as one attribute for HO decision. Additionally, the UE transmit power with respect to the target cell is deployed to ensure that the HO is performed to the cell that requires less power in uplink, this reduces the power consumption and improves the energy efficiency. Cell capacity is also deployed to reduce HO failure and manage the load balance in the network. Fast UEs pass the SC and stay for

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a short time resulting in signalling overhead as a result of unnecessary HO. Therefore, GRA-SD method deploys the estimated ToS for the UE in a target cell to minimize the unnecessary HOs.

The GRA is considered as one of the most important parts of the grey system theory. The theory of grey system targets information uncertainty. The system is called white if all of its information is known otherwise it is named a black system. Systems with partially known information is called grey system [11]. The GRA is a good technique that can be used to solve the HO problem. To get the grey relationship between HO attributes, the grey relational coefficients (GRC) is computed. Then, the GRC are ranked and the alternative index with the highest rank is chosen as a HO cell. Therefore, the proposed method integrates GRA and SD techniques. The SD technique gives the weights for all HO attributes then the GRA chooses a target HO cell by ranking the candidate cells. The advantages of GRA deployment can be listed as: the results depend on the original value of the HO attributes gathered during the measurement report by the UE, the calculations are simple and it is suitable for multiple complicated relationships between alternatives [12]. A fairness comparison and dimensional attributes are ensured by normalization [13]. Ranking abnormality is the phenomena of reversal ranking which means that the ranking of alternatives changes when removing any of the lowest ranked alternative [11]. This phenomena can cause high number of unnecessary HOs. The enhanced max-min normalization technique is deployed in this paper to avoid ranking abnormality. To this extent, the contributions of this paper can be listed as:

- The selection of multiple HO attributes such as SINR, UE transmit power, cell capacity and ToS.
- Using the SD technique to obtain the weights of HO attribute.
- Deploying the GRA method to rank the cells for HO purpose and select the cell with the highest rank as HO target.
- Deployment of the enhanced max-min normalization, in which the benefit and cost attributes are dealt with differently to limit the impact of ranking abnormality, and hence, minimizing the unnecessary HOs.
- Integrating the SD and GRA in a (GRA-SD) method for dense SCs HetNet scenario.
- Implement, evaluate and compare the GRA-SD method with the traditional MADM methods including SAW and VIKOR where results reveal a better performance for GRA-SD method compared to the other two methods in terms of minimizing the unnecessary HO and HO failure, in addition to improving the energy efficiency.

The rest of the paper is organized as follows. Section II gives the related work. The system model is illustrated in Section III. The proposed method procedures are given in Section IV. The

performance and results analysis are presented in Section V. Finally, the conclusion is drawn in Section VI.

II. RELATED WORKS

Generally, MADM techniques have been widely adopted to control the complicated decision making such as network selection. Simple Additive Weighting (SAW) is considered as one of the simplest MADM techniques. Authors in [14] presented a HO method based on SAW. The source cell is responsible for alternative selection targeting to extend battery lifetime for the UE. The HO attributes utilized in their work are bandwidth and cost. However, one of the disadvantages of SAW is that a low value of one HO attribute can negatively be affected by high value metric, e.g., when an alternative has low throughput with an affordable cost, it can be selected over a slightly costly alternative with a much better throughput. Another MADM method is the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) which depends on the concept of choosing the alternative, which is close to the positive ideal solution and far from the negative ideal solution [15]. Authors in [16] deployed TOPSIS with Analytical Hierarchy Analysis (AHP) to rank the alternatives. The AHP is utilized to get the attribute weights and TOPSIS is then deployed to rank the alternatives. Multiple attributes are utilized in their work such as packet delay, bandwidth, jitter, packet loss and security. In [17], authors presented two modified weighted TOPSIS methods for the purpose of HO management. The first method deploys the entropy weighting strategy for HO attributes weighting. The second method uses a standard deviation weighting technique for HO attributes weighting. Results reveal that the proposed methods have minimized the number of unnecessary HOs and failure probability, in addition to enhancing the UE throughput.

III. SYSTEM MODEL

The network system model in this work takes into account the two-tier HetNets which consists of a number of SCs, N_{sc} , deployed under the coverage area of a single MC, which covers a 500m radius. The SCs are randomly distributed based on a uniform distribution with a coverage radius of 100m each. The minimum distance restriction is considered to guarantee the overlapping between cells. MC to SC distance is set to 75m and SC to SC distance is set to 40m [2]. Users are uniformly distributed and follow a Gauss mobility model, the Gauss mobility model is a widely adopted model to represent the mobile user movement, particularly for medium to high speeds (e.g., vehicular speed) [18], which can be defined using UE velocity, V_{ue_k} , and UE direction, θ_k . The two mobility metrics are expressed as Gaussian distribution and are updated accordingly [19]

$$V_{ue_k} = \mathcal{N}(v_m, v_{std}), \quad (1)$$

$$\theta_k = \mathcal{N}(\theta_m, 2\pi - \theta_m \tan(\frac{\sqrt{V_{ue_k}}}{2}\Delta t)), \quad (2)$$

where v_m is the mean speed of the UE, v_{std} characterises the standard deviation of the UE speed, θ_m is the former direction of the UE, Δt is the period between two updates

of the mobility model, and $\mathcal{N}(x, y)$ is a Gaussian distribution with mean x and standard deviation y . Let N_{bs} be the set of all cells in the network, $N_{bs} = \{0, 1, 2, \dots, N_{sc}\}$, where 0 represents the MC, and U_i is the set of UEs served by cell i . To preserve service continuity, users should obtain a minimum signal strength of $RSRP_{th}$ and to retain the ongoing service quality, it should have a minimum uplink SINR of γ_{th}^{up} .

The following subsections explain the HO attributes utilized in the proposed GRA-SD method.

A. Downlink SINR Attribute

The downlink reference signal received power (RSRP) of cell i in dBm can be given as

$$P_{i \rightarrow k}^r = P_i^t \cdot h_{i \rightarrow k}, \quad (3)$$

where $P_{i \rightarrow k}^r$ is the downlink RSRP of cell i received at UE k , P_i^t is the transmission power of cell i and $h_{i \rightarrow k}$ is the channel gain between the UE and cell i considering the path loss and shadowing effects [20]. The propagation model between the MC and UE is expressed as

$$\delta_{m \rightarrow k} = 128.1 + 37.6 \log_{10}(d_{m \rightarrow k}) + \xi, \quad (4)$$

where $d_{m \rightarrow k}$ is the distance between the UE and the MC in kilometres, and ξ is a Gaussian distribution random variable with zero mean and 12 dB standard deviation [21].

For SC, the path loss is expressed as

$$\delta_{sc_i \rightarrow k} = 38 + 30 \log_{10}(d_{sc_i \rightarrow k}) + \xi, \quad (5)$$

where $d_{sc_i \rightarrow k}$ is the distance between the UE and SC i in metres. The downlink SINR attribute is considered to incorporate the impact of interference in HO decision. The downlink SINR for UE k received at cell i in dBm can be measured as

$$\gamma_{i \rightarrow k}^r = \frac{P_{i \rightarrow k}^r}{\sum_{bs \in N_{bs}, bs \neq i} P_{bs}^t \cdot h_{bs \rightarrow k} + \sigma^2}, \quad (6)$$

where σ^2 is the noise power and the term $\left(\sum_{bs \in N_{bs}, bs \neq i} P_{bs}^t \cdot h_{bs \rightarrow k}\right)$ is the summation of the downlink power from the neighbouring cells apart from cell i i.e., the interfering cells.

B. User Transmit Power Attribute

The mean UE transmit power can be predicted for a candidate cell by performing the standard measurement. Assume that the channel gain is symmetric, i.e., $h_{i \rightarrow k} = h_{k \rightarrow i}$, and using (3), the uplink RSRP of UE k for the target cell i , $P_{k \rightarrow i}^r$ in dBm, can be written as

$$P_{k \rightarrow i}^r = \frac{P_k^t P_{i \rightarrow k}^r}{P_i^t}, \quad (7)$$

where P_k^t is the UE mean transmit power for cell i . Thus, the uplink SINR can be written as

$$\gamma_{k \rightarrow i}^r = \frac{P_{k \rightarrow i}^r}{I_{k \rightarrow i}}, \quad (8)$$

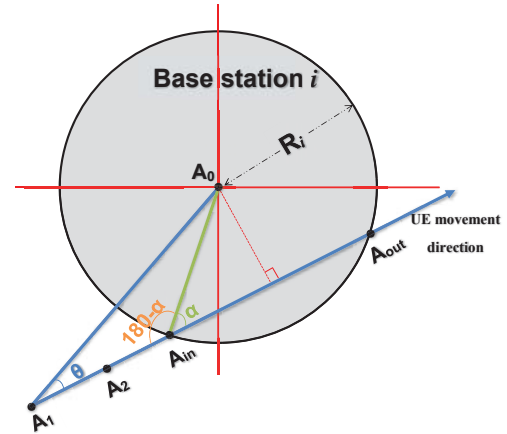


Fig. 1 Time of stay measurement

where $I_{k \rightarrow i}$ is the interference induced by users in the same cell i and the interference induced by users in the adjacent cells plus noise,

$$I_{k \rightarrow i} = \sum_{ue \in U_i, ue \neq ue_k} P_{ue}^t \cdot h_{ue \rightarrow i} + \sum_{bs \in N_{bs}, bs \neq i} \sum_{ue \in U_i} P_{ue}^t \cdot h_{ue \rightarrow bs} + \sigma^2, \quad (9)$$

where the first line of (9) is the interference from the UEs in the same cell and the second line represents the interference from the UEs in the neighbouring cells plus noise power. Given the minimum requirement for keeping quality performance γ_{th}^{up} and according to (7) and (8), we can have a prediction of the UE transmit power with respect to cell i as

$$P_k^t = \frac{I_{k \rightarrow i} \cdot P_i^t \cdot \gamma_{th}^{up}}{P_{i \rightarrow k}^r}. \quad (10)$$

Equation (10) can be deployed to estimate the power consumption of UE k , if we consider the UE transmit power as a main source to the UE power consumption. Therefore, we can deploy this attribute to reduce the UE transmit power by performing the HO to a cell that requires a lower power requirement.

C. Predicted ToS Attribute

As depicted in Fig. 1, the ToS, ToS_k , can be measured as

$$ToS_k = \frac{|A_{in} A_{out}|}{V_{ue_k}} = \frac{2R_i \cos(\alpha)}{V_{ue_k}}, \quad (11)$$

where A_{in} is the entry point of the user to base station i , A_{out} is the exit point of the user from base station i , R_i is the radius of cell i , and V_{ue_k} is the user velocity. We can obtain the following from Fig. 1

$$\frac{|A_1 A_0|}{\sin(180 - \alpha)} = \frac{R_i}{\sin(\theta)}, \quad (12)$$

where A_0 , and A_1 are respectively the location of base station i , and the previous location of the UE.

Equation (12) can be rewritten as

$$\sin(\alpha) = \frac{|A_1 A_0| \sin(\theta)}{R_i} \quad (13)$$

Therefore

$$\cos(\alpha) = \sqrt{1 - \frac{(|A_1 A_0| \sin(\theta))^2}{R_i^2}} \quad (14)$$

The angle between the UE trajectory and the base station i , θ , can be measured as

$$\theta = \arccos\left(\frac{\overrightarrow{A_1 A_0} \cdot \overrightarrow{A_1 A_2}}{|\overrightarrow{A_1 A_0}| \times |\overrightarrow{A_1 A_2}|}\right), \quad (15)$$

where A_2 is the current location of the UE. Finally, substituting (14) and (15) in (11) to obtain ToS as

$$ToS_k = \frac{2R_i \sqrt{1 - \frac{\left(|\overrightarrow{A_1 A_0}| \cdot \sin\left(\arccos\left(\frac{\overrightarrow{A_1 A_0} \cdot \overrightarrow{A_1 A_2}}{|\overrightarrow{A_1 A_0}| \times |\overrightarrow{A_1 A_2}|}\right)\right)\right)^2}{R_i^2}}}{V_{uek}} \quad (16)$$

D. Cell Capacity Attribute

The cell capacity is an essential attribute in HO decision because it can reduce the HO failure and enhancing the QoS delivered to the end user. The cell capacity can be expressed as [22]

$$CP_i = BW \cdot (1 - R_{ue}^i) \cdot \log_2(1 + \gamma_{i \rightarrow k}^r), \quad (17)$$

where BW is the system bandwidth and R_{ue}^i is the total ratio of resources assigned to all active UEs in cell i compared to the cell's total resources, R_{total}^i , which can be expressed as

$$R_{ue}^i = \frac{\sum_{\forall j} R_{uej}}{R_{total}^i}, \quad (18)$$

where R_{uej} is the resource allocated to user j from cell i , thus the term $\sum_{\forall j} R_{uej}$ is the summation of all resources allocated to all active users in cell i .

IV. PROPOSED GREY RELATIONAL ANALYSIS STANDARD DEVIATION BASED HANDOVER (GRA-SD) METHOD

The proposed GRA-SD method integrates the GRA method with SD weighting technique for HO decision in HetNets. The deployed attributes for cell ranking include: the downlink SINR ($\gamma_{i \rightarrow k}^r$), UE transmit power (P_k^t), cell capacity (CP_i) and ToS. The HO takes place by selecting a proper alternative among the available set. The procedures of GRA-SD method can be divided into three parts. First, the attributes of all alternatives that satisfy the condition of maintaining service continuity are acquired. Second, deploying the SD technique to get the weighting vector w as explained in section IV-B. Finally, applying the GRA method for alternatives ranking to get the best one for HO as illustrated in section IV-A.

A. Cell Ranking Using Grey Relational Analysis (GRA)

The UE has an m number of alternatives, n number of attributes and a weighting vector w . The procedures of the GRA method can be explained as follows:

Step 1: a decision matrix, D , is formed by mapping the alternatives with respect to the attributes as

$$D = \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} \\ x_{21} & x_{22} & x_{23} & x_{24} \\ x_{31} & x_{32} & x_{33} & x_{34} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & x_{m4} \end{bmatrix}, \quad (19)$$

where rows represent alternatives, and columns represent their correspondent attributes, $n = 1, \dots, 4$, $m = 0, 1, \dots, N_{sc}$, x_{ij} represents the value of the j^{th} attribute for the i^{th} alternative. Thus, $x_{i1} = SINR$, $x_{i2} = P_k^t$, $x_{i3} = CP_i$ and $x_{i4} = ToS$. Thus,

$$D = \begin{matrix} & SINR & P_k^t & CP_i & ToS \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_n \end{matrix} & \begin{bmatrix} \gamma_{1 \rightarrow k}^r & P_1^t & CP_1 & ToS_1 \\ \gamma_{2 \rightarrow k}^r & P_2^t & CP_2 & ToS_2 \\ \gamma_{n \rightarrow k}^r & P_n^t & CP_n & ToS_n \end{bmatrix} \end{matrix}$$

Step 2: The decision matrix is normalized to make the attributes dimensionless in the range of [0,1] for comparability. We utilized the enhanced max-min normalization which takes into considerations both cost attributes (the smaller the better) and the benefit attributes (the larger the better). In the proposed GRA-SD method, there are four attributes, one of which is a cost attribute (P_k^t) and the other three are benefit attributes (SINR, CP_i and ToS). For cost attribute, the normalization of the j^{th} attribute for the i^{th} alternative is measured as

$$x_{ij}^n = \frac{\max_{\forall i} \{x_{ij}\} - x_{ij}}{\max_{\forall i} \{x_{ij}\} - \min_{\forall i} \{x_{ij}\}} \quad (20)$$

The benefit attributes are normalized as

$$x_{ij}^n = \frac{x_{ij} - \min_{\forall i} \{x_{ij}\}}{\max_{\forall i} \{x_{ij}\} - \min_{\forall i} \{x_{ij}\}} \quad (21)$$

Step 3: In this procedure, the definition of the ideal reference sequence is defined, whose sequence is close to the best alternative. The preferred value of the j^{th} attribute for the i^{th} alternative is 1, hence, we define the ideal reference sequence as $x_j^* = 1 \forall j = 1, 2, 3, 4$, i.e., the ideal alternative vector can be defined as [1 1 1 1].

Step 4: This procedure computes the Grey Relational Coefficient (GRC) which is used as a measure for how much is the j^{th} attribute for the i^{th} alternative, i.e., x_{ij}^n , close to the ideal sequence x_j^* . The formula for computing the GRC is expressed as

$$GRC(x_{ij}^n, x_j^*) = \frac{\min_{\forall i, \forall j} \{\delta_{ij}\} + \Psi \max_{\forall i, \forall j} \{\delta_{ij}\}}{\delta_{ij} + \Psi \max_{\forall i, \forall j} \{\delta_{ij}\}}, \quad (22)$$

where $\delta_{ij} = |x_j^* - x_{ij}^n|$ and Ψ is the distinguishing coefficient $\in [0,1]$.

Step 5: The ranking of GRCs, denoted as GRA_i , is finally obtained as

$$GRA_i = \sum_{j=1}^n w_j GRC(x_{ij}^n, x_j^*), \quad (23)$$

$$\text{subject to } \sum_{j \in n} w_j = 1, \quad (24)$$

where w_j is the j^{th} attribute weight.

Step 6: The largest grey relational coefficient grade is selected as a HO target cell.

$$HO_{\text{target}} = \arg \max GRA_i. \quad (25)$$

The procedures of the proposed GRA-SD method is illustrated in Algorithm (1).

B. Standard Deviation Attributes Weighting

The proposed GRA-SD method uses the SD technique [23] to rate the influence of the attributes for each alternative. The SD weighting technique computes the weigh of each attribute in terms of standard deviation. The SD technique assigns a small weight for an attribute if its value is identical for all alternatives. For instance, if an attribute has identical values on all available alternatives, then obviously it has no influence on HO decision and hence, its weight is null. In other words, attributes with small SD are assigned smaller weights and vice versa.

The weighting vector w represents the influence of the attributes. Thus, w_1, w_2, w_3 and w_4 are respectively the weights of SINR, P_k^t , CP_i and ToS. The weights is measured by utilizing SD technique as

$$w_j^{sd} = \frac{\sigma_j}{\sum_{k=1}^4 \sigma_k}, \quad (26)$$

$$\sigma_j = \sqrt{\frac{1}{m} \sum_{i=1}^m (x_{ij}^n - \mu_j)^2}, \quad (27)$$

$$\mu_j = \frac{1}{m} \sum_{i=1}^m x_{ij}^n, \quad (28)$$

where σ_j and μ_j are respectively the SD and mean value of the j^{th} normalized attribute.

Algorithm 1 GRA-SD Method

- 1: **Start procedures**
- 2: **Get HO attributes**, $\gamma_{i \rightarrow k}^r, P_k^t, CP_i$ and ToS_k for all alternatives with $RSRP \geq RSRP_{th}$
- 3: **Form the decision matrix D** according to the values obtained in step 2
- 4: Get the **weighting vector w** using SD technique
- 5: Apply the **GRA-SD** on the decision matrix **D**
- 6: **Rank** the alternatives obtained from step 5
- 7: **Perform HO** to the alternative with the **highest rank**
- 8: **End procedures**

V. PERFORMANCE ANALYSIS

The performance of the proposed method is evaluated in terms of complexity, number of HOs, HO failure probability and energy efficiency. The GRA-SD method is compared with the conventional SAW and VIKOR methods. Simulation parameters are given in Table I.

TABLE I
SIMULATION PARAMETERS [12],[17]

Bandwidth	20 MHz
Carrier Frequency	2.5 GHz
Macrocell Transmit power	43 dBm
Macrocell Radius	500 m
Small Cell Radius	100 m
Number of Small Cells	50
Maximum Small cell Transmit power	30 dBm
Minimum required signal for service continuity ($RSRP_{th}$)	-70 dBm
Uplink SINR threshold (γ_{th}^{up})	3 dB
UE transmit power	23 dBm
Mean velocity of the UE (v_m)	{1,20,40, 60,80,100} km/h
Standard deviation for UE velocity (v_{std}) [19]	1 km/h
Period between two updates of the mobility model (Δt) [19]	1 sec
Distinguishing coefficient (Ψ) [12]	0.5

A. Complexity Analysis

Fig. 2 illustrates the computational complexity of the GRA-SD, SAW and VIKOR methods. This is accomplished by evaluating the three methods in terms of the number of floating point operations (flops) with different number of alternatives. To achieve this, the Matlab function defined in [24] is deployed. Obviously, the complexity increases with the increase in the number of SCs for the three methods. The VIKOR method has the high complexity compared to the other two methods. The GRA-SD method has slightly higher complexity compared to SAW method. However, this slight difference well justified the accurate alternative selection of the GRA-SD method. The curve of the GRA-SD method increases linearly due to the slight increase in the number of SCs.

B. Number of Handovers

The number of HOs is illustrated in Fig. 3. The SAW method has the highest increase in the number of HOs compared to VIKOR and GRA-SD methods. The GRA-SD method has the lowest number of HOs particularly for low and medium speed users. This minimization can be owed to the deployment of ToS attribute. Unlike the SAW and VIKOR method, which assign a fixed weight for the attributes causing a high number of HOs, the GRA-SD method gives a proper weights to the attributes resulting in a minimization in the unnecessary HOs.

C. Probability of Handover Failure

A HO failure is declared if the HO is triggered to alternative but the downlink SINR of that alternative goes below a predefined threshold γ_{th} for a period of time (T310), which is 1 second, as defined in [25]. Fig. 4 shows the probability of HO failure. The SAW method produces higher

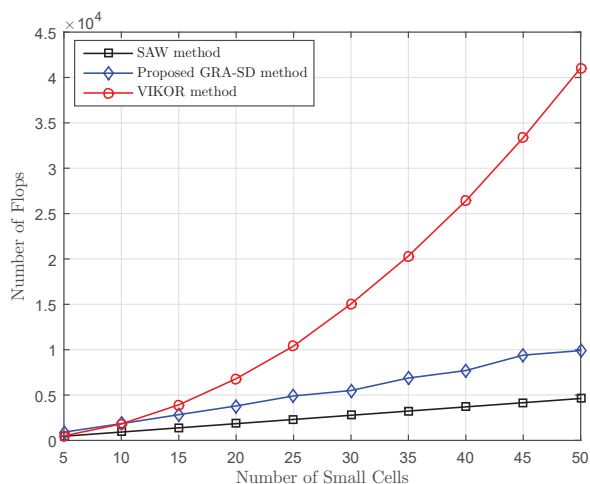


Fig. 2 Complexity analysis

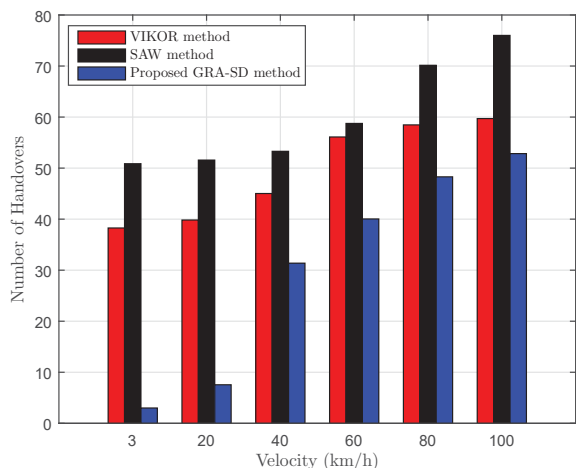


Fig. 3 Number of handovers with 50 small cells

HO failure compared to VIKOR because of its straight forward computation prior to HO, and hence, higher HO failure occurs. The GRA-SD method has the lowest HO failure because of the early HO to the proper alternative with a sufficient enough capacity. For example, when the velocity is 50km/h, the GRA-SD method has 69% and 75% reduction in HO failure compared to VIKOR and SAW methods respectively.

D. Energy Efficiency

The performance of the three method is evaluated in terms of the mean user energy efficiency considering the UE transmit power consumption needed to connect to an alternative. The energy metrics defined in [26] is deployed to compute the energy efficiency

$$\text{Energy Efficiency} = \frac{\text{Channel capacity (bits/sec)}}{\text{Transmit power (watt)}} \quad (29)$$

The mean UE energy efficiency is illustrated in Fig. 5. The energy efficiency is inversely proportional to the user speed

for all methods since higher speed results in lower ToS, and hence, a lower throughput is obtained yielding a lower energy efficiency. Generally, high number of SCs produces better performance in terms of energy efficiency owing to the fact that the load generated by the UEs will be distributed among SCs yielding a lower interference caused by other UEs. This means that the UE mean throughput will be improved causing an enhancement in energy efficiency.

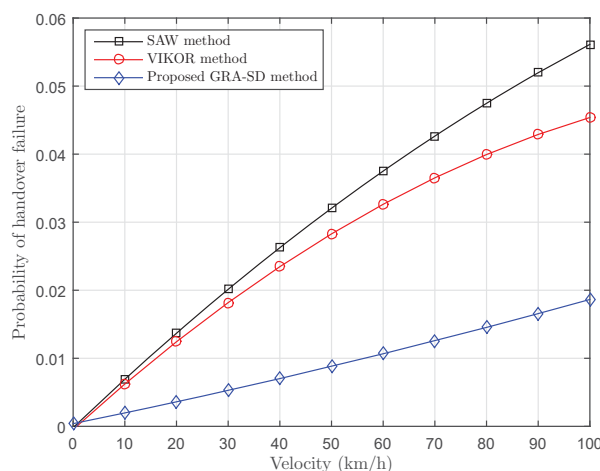


Fig. 4 Probability of HO failure

VI. CONCLUSION

This paper presents a GRA-SD HO method for HetNet which jointly considers the impact of interference, cell capacity, energy consumption and time of stay. The proposed method deploys the SD technique to give weights to the attributes then the GRA method is applied to rank the alternative and choose the best one for HO. Enhanced max-min normalization is deployed to normalize the attributes to minimize the ranking abnormality of the GRA and hence minimizing the unnecessary HO. Results reveal a good

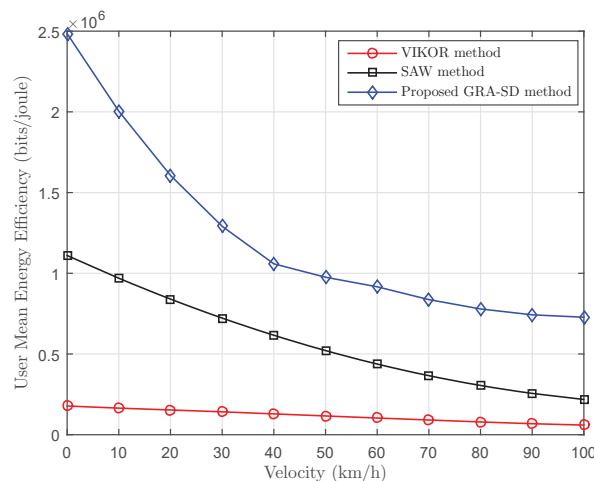


Fig. 5 User mean energy efficiency

performance for the proposed method in terms of complexity, minimizing the unnecessary HO and HO failure in addition to improving the energy efficiency compared to the conventional SAW and VIKOR methods.

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