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A Novel Heuristic for Handover Priority in Mobile Heterogeneous Networks

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ABSTRACT Handover (HO) is designed to facilitate user mobility and ensure quality of service in mobile networks. In multiple base station (eNodeBs) scenarios, the HO priority process is a problem that has been studied in many surveys, as neglecting the use of priority-based schemes can result in high amounts of HO and, consequently, a decrease in the quality of services provided. This paper presents a Heuristic for Handover based on AHP-TOPSIS-FUZZY (H^2ATF), which generates a priority ranking of eNodeBs from the use of (a) the analytical hierarchical process (AHP) to define the weights of the criteria; (b) the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank the selected target cells; and (c) the use of an adaptive hysteresis calculated through a fuzzy inference system based on parameters that directly impact the HO process. Through this proposal, it was possible to define the best time and, together, the best antenna to perform the HO. The results demonstrate a decrease of up to 43% in HO ping pong (HPP), a widely used metric in the literature to evaluate HO heuristics.

INDEX TERMS Handover, priority, heterogeneous networks, mobile networks, AHP-TOPSIS, fuzzy logic.

I. INTRODUCTION

In 2021, the global traffic in mobile networks will reach the 49 exabytes per month mark, approximately half of the annual zettabyte, an increase of 700% compared to the year 2016 [1]. Prospecting the amount of traffic becomes a major planning issue for mobile operators in the market [2]. In other words, obtaining high data rates and Quality of Service (QoS) combined with a lower cost are the main issues of concern for operators of mobile networks.

To meet this traffic volume, several solutions have been proposed in the literature. Among such solutions, the densification of the mobile network through the joint installation of massive BSs, such as macrocells and SmallCells (SCeNBs), known as heterogeneous networks (HetNets), stands out. These are considered an inevitable part of future cellular networks and have received focused attention from the 3GPP group's standardization work [3].

SCeNBs may have different sizes (such as micros, picos and femtos). Their common feature is that they are low power and low height nodes used for data offloading [4]. In addition, SCeNBs provide increased coverage and discharge of macrocells, thus relieving the mobile network that was not initially designed for high data traffic.

The densification of mobile network scenarios makes the process of handover (HO) extremely difficult to handle, as LTE-Advanced, developed by 3GPP [5], supports UE speeds up to 139 m/s, which influences the accuracy and efficiency of mobile networks and consequently the performance of the HO process. The HO is one of the strategies allowing the UE connected to the evolved NodeB (eNodeB) to transfer to the next eNodeB without session disconnection [6]. The HO process is desirable for users to be able to move between wireless data and cellular networks employing different technologies [7]. HOs are generally categorized as horizontal, vertical and diagonal HOs by the research community [8], [9].

It is realized, then, that the HO procedure must be fast and frequent, and the data transfer must not be delayed and lost [10], [11]. Thus, meeting such connection requirements when developing HO strategies between network cells becomes the main objective to be achieved, aiming to guarantee the Quality of Experience (QoE) of users.

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Efficient HO strategies aim to minimize the number of HO ping pong (HPP) and HO failures (HOF). The ping pong effect occurs when the UE repeatedly switches between two access nodes, which can reduce the quality of the user's connection and increase the number of handovers; in turn, this increases the network load which most of the time affects performance. During the handover process, the service eNodeB sends a handover command to the user equipment. If the UE does not receive the HO command, an HOF occurs and the UE is disconnected from the network, so it must reconnect to the network, which results in a service disruption and affects the user experience, incurring additional signaling overhead and wasted network resources [12]. A nonpriority scheme results in higher HO call dropping probability with the highest channel utilization [13].

In this paper, a Heuristic for HO based on AHP-TOPSIS-FUZZY (H^2ATF) is presented, which is based on multicriteria analysis for setting antenna priorities in a handover process. The results are the amount of handover, HOF rate, HPP rate and data rate. The approach presented preforms decision making based on multicriteria methods: (A) AHP (analytical hierarchical process) for defining the weights of the criteria (SINR, RSRP, RSRQ and speed); (B) TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) for ranking the cells selected as targets; and (c) use of a hysteresis computed using fuzzy values to define dynamic favoring of the current cell.

The main contributions of our proposal are the use of a heuristic based on analytical methods, fuzzy logic for dynamic hysteresis, and a reduction in the amount of handover and HPP that generates a reduction of signaling in the network and mitigates the unnecessary exchange of antennas.

The remainder of this paper is organized as follows. Section II presents the related articles in the literature and the differential of this proposal with those found in the state of the art. Section III shows the problem and the proposed heuristic. Section IV presents the criteria and methodology used to evaluate system performance. Section V analyzes the results obtained from the simulations performed. Finally, Section VI draws the conclusions.

II. RELATED WORKS

In the HO process, there are three main parameters discussed in the literature, according to [14]. The first of these parameters is the modification of the hysteresis, followed by the modification of time-to-trigger (TTT) and the alteration of A3 event detection in the HO process. Optimizing these parameters in the mobile network environment will lead to a reduction in the total number of HOs, HOFs, HPPs and packet loss. In addition to these research points, other studies are aimed at increasing the data rate, capabilities and costs for users [14].

The [15] article presents an evolution of the previous work presented in [16], with modifications and extensions of the STHA algorithm focusing on fuzzy logic integrated with the conventional decision of handover through a dynamically adjusted hysteresis. This article accounts for the levels of eNodeBs' target power signals and the actual, being placed in the context of dynamic hysteresis margin, which is the output of the fuzzy logic-based system. The system is a fuzzy inference scheme adapted for handover optimization purposes. This inference scheme derives the hysteresis margin dynamically according to the actual UE speed and radio channel quality. The proposal demonstrates superior performance in the handover process when compared with state-of-the-art handover algorithms, showing a reduction in ping pong and failure rates. The paper discusses the results about users' data rate, as well as the number of users discovered.

In [17], the focus is on finding optimal triggering points such as time-to-trigger and hysteresis so that HOFs that are too early and too late, and the HPP effect can be minimized. For this purpose, the AHP and TOPSIS methods are used when considering the RSRP, RSRQ, eNodeB resources blocks (RB), SINR, and UE's movement and location. With multicriteria methods it is possible to obtain the UE's rank, and according to the order of this rank, the UEs are allocated to the best eNodeBs, also organized by AHP-TOPSIS. To obtain the optimal triggering point values and hysteresis margin, Q-learning is used. The algorithm reduces HPP by 33% and 35%, and approximately 25% and 28% in HRF when compared to the existing conventional method and the fuzzy multiple-criteria cell selection (FMCCS) scheme [18]. Despite making use of various parameters for HO decision making, the work omits the random speed of the actual scenarios in its strategy.

The FMCCS algorithm [18] uses Fuzzy-TOPSIS, where alternative scores and decision criteria weights are defined as linguistic variables. FMCCS is an HO optimization scheme for choosing the best macrocells, taking into account user movement while maintaining their Quality of Service (QoS) requirement. The variables chosen by the author are RSRP, resource blocks (RBs) and SINR (Signal-to-Interference-plus-Noise-Ratio). The simulation shows that FMCCS outperforms both the conventional method and the cell selection scheme (CSS) by reducing the ping pong rate by approximately 27% - 23% and reducing the HOF rate by 19% - 15%, respectively. The work leaves a gap in the lack of SCeNBs and lacks a truly random UE mobility as in real scenarios.

The HO process directly affects QoS/QoE metrics on mobile networks, a statement discussed and worked on in the [19] article. In this article, we present the SER (service, experience, and radio) algorithm, which is an algorithm that uses AHP to deliver video content about HetNets with QoS/QoE support. The SER algorithm takes into account the AHP multicriteria method to assign different degrees of importance to each criterion (RSRQ, PDR and pMOS) according to network conditions and to calculate the quality of each cell during the HO decision to select the best alternative that the UE should connect to. Simulations were made in NS-3 to evaluate the performance of the SER algorithm when spreading videos across HetNets compared to existing HO algorithms. Based on the simulation results, the SER

TABLE 1. Related works.

Proposal	Decision Strategy	Parameters	Focus
[15]	Fuzzy Logic	RSRP, RSRQ and Speed	HO, HPP and HFF
[17]	AHP-TOPSIS and Q-learning	RSRP, RSRQ, RB, SINR, speed and UE location	HPP and HFF
[18]	Fuzzy-TOPSIS	RSRP, RB and SINR	HPP and HFF
[19]	AHP	RSRQ, PDR e pMOS	QoS and QoE
[20]	Parameters Otimization	RSRP and TTT	HPP and HFF
[21]	Fuzzy logic and Q-learning	Number of HO, CBR and CDR	HO, CBR and CDR
[22]	RL	RSRP, HO margin and TTT	HFF, CDR and HPP
Our Proposal	AHP-TOPSIS and Fuzzy Logic	RSRP, RSRQ, SINR and Speed	HO, HFF, HPP and DR

algorithm delivers videos with QoE 12% better than the classic algorithms analyzed. The work does not present in its results a comparison with new HO strategies proposed in the literature, as well as an analysis of the HPP and HFF.

In [20], a dynamic HO control parameter algorithm (D-HCP) is proposed for HO parameter optimization (HPO) based on the HO types (early HO, late HO and wrong HO). D-HCP aims to reduce HOF and HPP probability in HetNets scenarios. The HO control parameters used in this article are the HO margin (HOM) and time-to-trigger interval values.

In [21], an algorithm for load balancing and HO optimization in long evidence evolution (LTE) networks is proposed. This algorithm is based on a fuzzy system that adjusts HO parameters at the cell adjacency level to improve network performance. The fuzzy system is optimized by the Q-learning algorithm, which directs the selection of the most appropriate action, whether for load balancing or HO optimization reasons. The decision of what action the fuzzy system should take depends on past actions that were taken by the fuzzy system, whose impact on network performance was measured using key performance indicators (KPIs). The article does not take into account user speed, a fundamental attribute for HO analysis.

The article [22] proposes the algorithm entitled handover detection self-organizing handover parameter (HD-SOHP) for eNodeB systems. The algorithm uses reinforcement learning (RL), and the solution uses Markov decision process (MDP) methodologies. As decision making parameters, the strategy uses RSRP, HO margin, and TTT. To benchmark HD-SOHP with other algorithms in the literature, the HOF rate, call-drop rate and HPP rate are used. The strategy achieves good results when compared to other algorithms but does not use a random velocity for its users in its simulation and does not address the concept of SCeNBs.

Table 1 summarizes the main works found in the literature on the proposed theme. In general, the articles listed partially use characteristics implemented in this proposal, as follows: (i) analytical methods for decision making; (ii) fuzzy logic for dynamic hysteresis; (iii) random speed as a parameter; and (iv) reducing the amount of HO, HPP, HOFs and exposing results not commonly addressed in the literature, such as the data rate. Thus, this work differs from the others by considering the main features that are pointed as important in the state of the art.

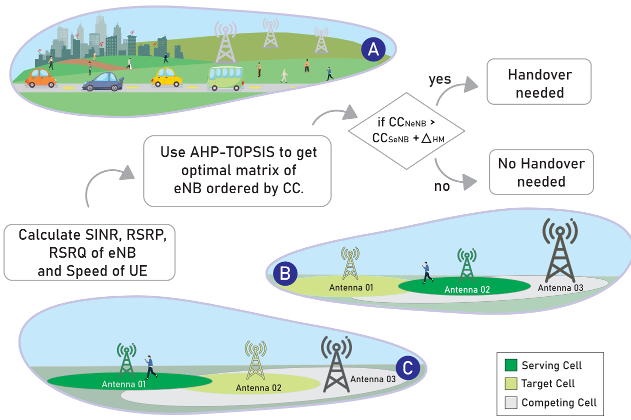

FIGURE 1. Flowchart of the proposal.

III. SYSTEM DESIGN

As detailed in [23], it is possible to characterize HO in three phases: initialization, decision and execution. The data related to the antennas and users are collected in the initial phase of the process, and the following data are used in this work: RSRP, RSRQ, SINR and user speed. The decision phase traditionally uses RSRP as the fundamental parameter for comparison between eNodeBs [24], as shown in equation (1):

$$RSRP_{NeNB} > RSRP_{SeNB} + \Delta_{HM} \tag{1}$$

where $RSRP_{NeNB}$ and $RSRP_{SeNB}$ are the power values of the neighboring eNodeB and the current eNodeB, respectively; and $Delta_{HM}$ (hysteresis) can be understood as a safety margin, the purpose of which is to avoid HPP. When this condition is met, a new connection is established with the neighboring eNodeB, thus terminating the execution of the HO. Part A of Fig. 1 presents a typical mobile network scenario; in this example there are three base stations, two SCeNBs (antenna 01 and 02) and one macrocell (antenna 03), and the various user profiles arranged in an urban area, highlighting the various forms of locomotion of users and having different speeds.

To illustrate the operation of the proposal, in part B of Fig. 1, UE moves to coverage intercession area between antennas 01 and 02. The covered cell represented by the dark green color represents the serving cell, while the cell with coverage displayed in light green represents the best HO candidate cell elected by the H^2ATF. It is noted that in a first moment, in part B of Fig. 1, the user is connected consuming data from antenna 02. In a second moment in part C of Fig. 1, the data collection is performed again by the H^2ATF, and with the user's locomotion (as well as the movement of other users), antenna 01 becomes the serving cell.

Our proposal integrates the AHP and TOPSIS analytical methods with four attributes: SINR, RSRP, RSRQ and user speed. Fuzzy logic has three inputs to fuzzification: RSRP, RSRQ, and user speed. These parameters are collected for the decision in the HO process. The following points describe such input parameters:

- Signal-to-Interference-plus-Noise-Ratio (SINR): The SINR can be defined as the ratio between the received signal strength and the sum of the average interference power of other cells and background noise. The SINR is rated as excellent (signals greater than 12 dB), good (10 to 12 dBm), moderate (7 to 10 dBm), and weak (less than 7 dBm).
- Reference Signal Received Power (RSRP): Considered as the sole parameter for decision making in conventional HO [17], RSRP is a metric belonging to the downlink channel. RSRP is characterized by 3GPP and has a minimum and maximum value of −160 dBm and −20 dBm, respectively. Three states are considered: weak (−160 to −95 dBm), moderate (−100 to −73 dBm) and strong (−80 to −20 dBm).
- Reference Signal Received Quality (RSRQ): This attribute is considered complementary to power values, providing additional information when and where only RSRP is not reliable for decision making in the HO process. RSRQ is carrier-over-interference (C/I) and represents the quality of the received signal. RSRQ is characterized by 3GPP and has a minimum and maximum value of −60 dB and 20 dB, respectively, and has divisions of poor (−60 dB to −18 dB), good (−22 dB to −12 dB), very good (−14 dB to −6 dB) and excellent (−10 dB to 20 dB).
- Velocity The speed of movement of users strongly influences the HO process. When users move at high speeds, the amount of HO will increase, especially in scenarios with the presence of many SCeNBs, directly impacting network performance and increasing failed HOs. The adopted speed range is divided into three categories: slow (1 m/s to 4 m/s), moderate (2 m/s to 14 m/s) and high speed (10.5 m/s to 22.2 m/s).

To use the AHP method, the first action is to decide the criteria that will be compared to encourage the choice of alternatives; these are defined by an expert. After establishing the criteria, the pairwise comparison matrix is constructed, taking into account the basis suggested by [25]: the matrix is filled by comparing the criteria in the left column against the attributes in the row higher.

After defining the weights by the AHP method, TOPSIS obtains the criteria values; in the case of H^2ATF, these criteria are the SINR, RSRP, RSRQ and the user speed. Subsequently, the normalized decision matrix is obtained using the following equation (2):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{2}$$

where r_{ij} is the normalized matrix, x_{ij} the attribute performance of all alternatives, and m the number of alternatives.

The next step is the weighting of the attributes obtained by multiplying them by the weight values established by the AHP and determining the highest value (ideal, positive situation) for each of the evaluated items (column), which can be represented by the A+ symbol. The same procedure is adopted for choosing the lowest value (nonideal, negative situation), represented by A−.

Once A+ and A− are defined, the next step is to calculate the deviation from each assigned value and sum them according to equations (3) and (4).

$$S_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^+)^2} \tag{3}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \tag{4}$$

Finally, the closeness coefficient (CC) results in positive and negative situations, using equation (5):

$$S_i^+ = \frac{S_i^+}{(S_i^+ + S_i^-)} \tag{5}$$

With the CC values of all alternatives the TOPSIS cycle ends, resulting in the CC values of all ranked antennas resulting in the range 0 to 1. The next calculated value is the dynamic hysteresis obtained by means of a fuzzy system.

The fuzzy logic method proposed by [26] has been used as a modeling tool for complex systems that can be controlled by humans but are difficult to define precisely. The main feature of fuzziness is grouping into classes that do not have well-defined boundaries. Because of its large-scale use and group expertise, this work uses fuzzy logic to define dynamic values that favor the current cell (hysteresis).

In our proposal, we used triangular functions, where the minimum and maximum intervals of the records observed for each variable were previously defined. The Mamdani inference method was used. Fig. 2 presents the linguistic variables with the corresponding degrees of input membership functions: velocity, RSRP and RSRQ. Expert analysis resulted in 36 fuzzy rules, determined by combining all states of the input variables.

The inference engine is used to combine these three inputs and then transform them into the output of the fuzzy system represented by Δ_{HM}. The output variable, which has the membership function described in Fig. 3, is defined from four sets of triangular functions to obtain reasonable granularity in the output space: very low (from 1 to 0.115), low (from 0.08 to 0.22), average (from 0.19 to 0.30), and high (from 0.27 to 0.4).

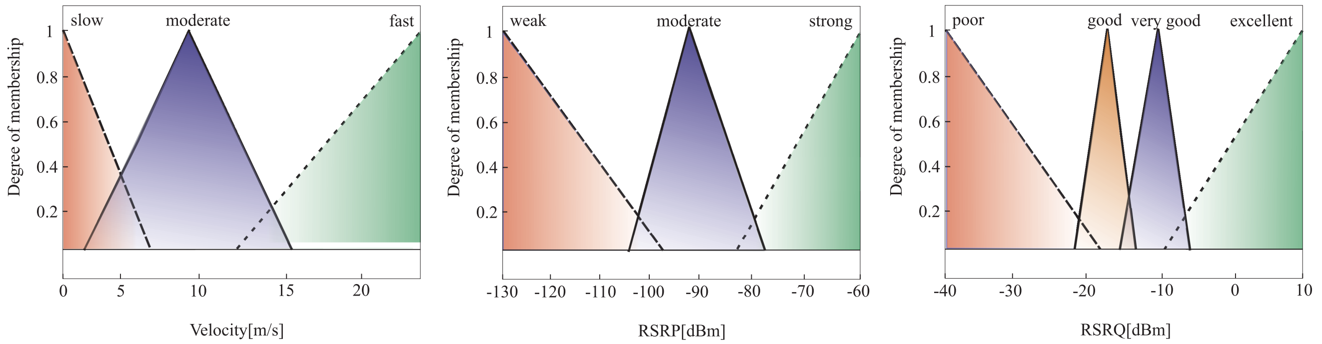

FIGURE 2. Membership functions of the input variables: VEL, RSRP, and RSRQ.

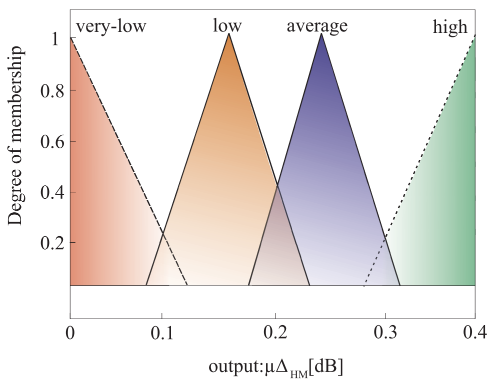

FIGURE 3. Output membership function.

IV. PERFORMANCE EVALUATION

In this section, the parameters of the proposed modeling are discussed. The results of the comparative algorithms used in this work are presented in section 5.

A. EVALUATION METRICS

The evaluation metrics used are as follows: average HO number, HOF ratio, HPP ratio and data rate. The failure ratio is the number of HOF in relation to the total number of HOs (successful HOs and failed HOs). The HOF ratio is represented in equation (6):

$$HOF(\%) = \frac{N_{HOF}}{N_{AmountHOAttempted}} \tag{6}$$

When a UE makes an HO from its current cell to another and reconnects to the same previous cell before the time-to-trigger expires, that HO is counted as the HPP. The HPP rate is the amount of HPPs relative to the total amount of HOs (HPP, successful HOs, and HOFs). Eq (7) demonstrates the rate of HPP.

$$HPP(\%) = \frac{N_{HPP}}{N_{AmountHOAttempted}} \tag{7}$$

Along with the metrics already presented in this paper, the average data rate values are analyzed to verify the quality of the user's connection.

TABLE 2. eNodeB ranking obtained by applying TOPSIS.

UE	BS	SINR	RSRP	RSRQ	Speed(m/s)	ranking
16	43	13,5476	-95	9	0,3	1
16	36	0,0071	-116	-12	0,3	0,0189
16	38	0,0028	-120	-16	0,3	0,0173
16	29	0,0022	-121	-17	0,3	0,0169
16	37	0,0013	-124	-19	0,3	0,016
16	48	0,0002	-131	-27	0,3	0,0129

B. NUMERICAL ANALYSIS

With the weight vector already defined by AHP that is set to calculate different moments of HO choice, taking into account the attributes, the ranking of the available antennas for each user in TOPSIS is defined. The pairwise comparison matrix used in AHP for weighting criteria analysis is presented below in equation 8.

$$PCM = \begin{bmatrix} 1 & 4 & 8 & 1 \\ 1/4 & 1 & 2 & 1/4 \\ 1/8 & 1/2 & 1 & 1/8 \\ 1 & 4 & 8 & 1 \end{bmatrix} \tag{8}$$

From the calculations presented in the section, the weights for eNodeB selection are obtained: 0.4215, 0.1054, 0.0516 and 0.4215, respectively, for SINR, RSRP, RSRQ and speed. To validate the application of weights, the consistency ratio (CR) was verified. The proposal presented a CR of less than 1, which is a satisfactory degree of consistency and which, according to Saaty [25], meets the validation criteria defined for AHP.

The values of the weight vector are fixed; however, the values of the matrix that will be used to apply the TOPSIS model are obtained continuously, whenever a calculation for the priority definition of BSs is required. An example of the resulting ranking is shown in Table 2, where the BS in the first row of the Table is chosen for the next antenna selection for HO.

Note that in Table 2, the values obtained at a given moment are the parameters used in H^2ATF. By applying the required calculations (section III) of the TOPSIS model, the ranking column is updated, making the antenna priority list possible for the HO to occur.

TABLE 3. Simulation parameters.

Parâmetros	MacroCell	Small Cell
Quantidade	2	50, 100, 150 e 200
Potência de transmissão	43 dBm	33 dBm
Banda	20Mhz	18Mhz
Frequência	3.5Ghz	2.4Ghz
Alcance	700 m	150 m

C. SIMULATION SCENARIO

Once the performance evaluation metrics were defined, a simulation was carried out with different SCeNBs and fixed macrocells to verify the efficiency of the proposed heuristic.

The SUI (Stanford University Interim) model, terrain A, was used as a propagation model for SCeNBs and macrocells cite hari2003channel. The speed adopted by users changes from 0 to 80 km/ h to characterize the various user profiles, as already explained in Section ref system. The simulation was performed in MATLAB 2017b, and the essential parameters are presented in Table 3.

The number of macrocells for the test scenarios is fixed, as are the transmit power, bandwidth and frequency of the two antennas, respectively, at 43 dBm, 20 MHz and 3.5 GHz. The difference in each scenario is the number of SCeNBs (50, 100, 150 and 200), and seeks to evaluate the behavior of HO strategies in scenarios with small numbers of SCeNBs to scenarios with a larger number of cells. SCeNBs have transmit power, bandwidth and frequency of 43 dBm, 20 MHz and 3.5 GHz, respectively. The range of the antennas is taken into consideration in the proposed HO strategy, with macrocells in the range of 700 m and SCeNBs of 150 m, as this variable is responsible for choosing the HO target antennas in the strategy H^{2}ATF. The chosen simulation time was 1000 seconds, an amount of time considered satisfactory for the simulation to achieve a stable performance.

The proposed scenario has a size of 1000 m x 1000 m (Fig. 4), where the placement of SCeNBs (black axes) is fixed and users (blue asterisks) are randomly placed at the beginning. The users' displacement is based on the random waypoint [27] mobility model, and the macrocells (red triangles) are positioned to provide greater coverage of the stipulated area.

V. RESULTS

H^{2}ATF is compared with two algorithms to demonstrate the effectiveness of the proposal. The intention is to compare it with the classic state-of-the-art algorithm (best connection - BC) that uses only the RSRP metric as the target eNodeB selection parameter. In addition, the second algorithm, the STHA [15], was chosen because it uses fuzzy with dynamic hysteresis, making it ideal for analyzing the number of HOs, HPP, HOF and data rate in the HO process. The STHA in [15] was previously compared to the FMCSS [18], LTE conventional [28], and BC algorithm.

Note that in Fig. 5, there is an increase of SCeNBs in the 50 to 100 SCeNBs scenarios for all algorithms. In scenarios of 150 and 200 SCeNBs, this behavior was not repeated. The H^{2}ATF is superior to all strategies used for comparison, and in the scenario of 200 SCeNBs, the H^{2}ATF presents the largest difference in the amount of HO compared to the comparative algorithms, reaching an improvement of 46% and 49% compared to STHA and BC, respectively.

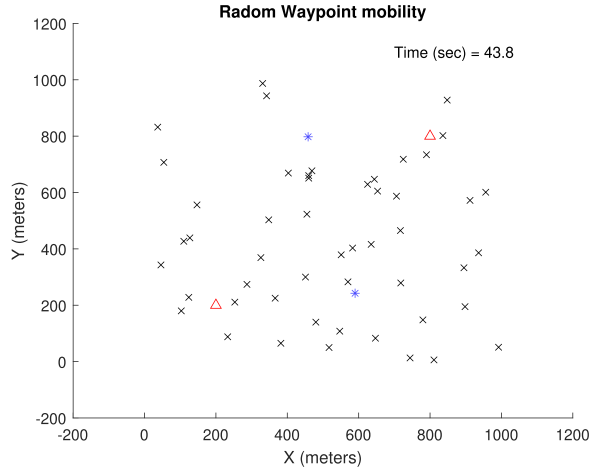

FIGURE 4. Simulation scenario.

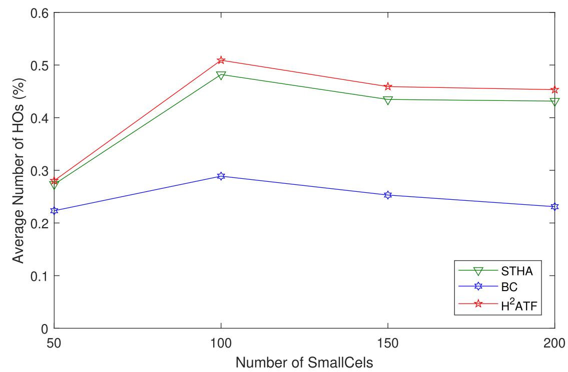

FIGURE 5. Average number of HOs.

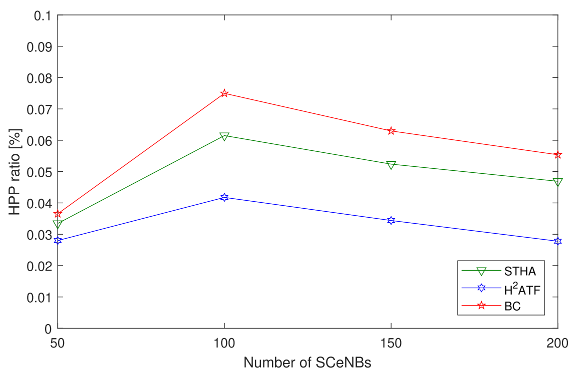

FIGURE 6. HPP ratio.

It is noted from Fig. 6 that the effect of HPP on BC is higher. As BC only uses RSRP, unnecessary transfers are performed, thereby increasing the load on the signaling network and consequently wasting resources. The HPP effect on

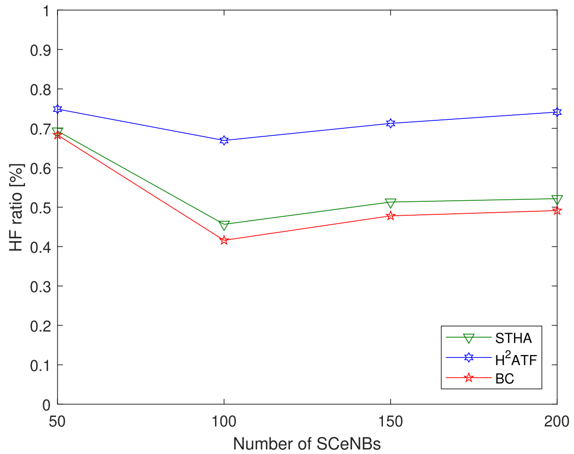

FIGURE 7. HOF ratio.

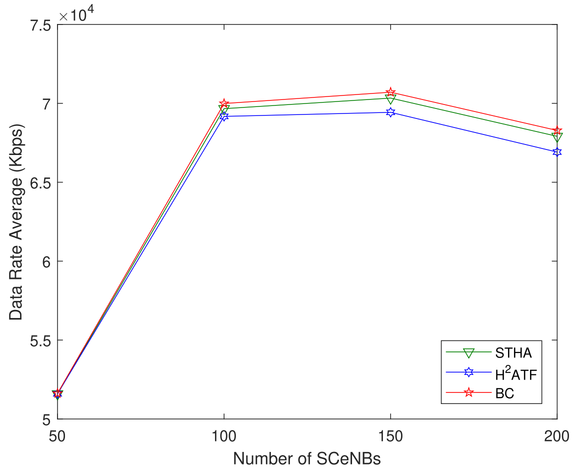

FIGURE 8. Data rate average.

STHA is higher compared to the proposed scheme, resulting in a reduction of 33% and 45% compared to STHA and BC, respectively, in the scenario with 100 SCeNBs. This finding is justified by the fact that the STHA does not consider essential parameters, such as SINR, in the decision making process. In the scenario with higher SCeNBs density, the difference between the approaches becomes more evident, decreasing by 59% and 50% in relation to STHA and BC, respectively.

Regarding HOF, Fig. 7 shows that in the scenario with 50 SCeNBs, the proposed algorithm achieves performance similar to the compared STHA and BC. However, from 100 SCeNBs, the heuristic obtains inferior results but does not considerably impact the network. This fact is attributed to the minimum connection requirements established in the simulation performed, in addition to the dynamic user speed during eNodeB selection. The large number of failures presented by the algorithms occurs because the simulation was performed with very strictly designed minimum parameters to test the strategies in more demanding scenarios.

Additionally, regarding the performance resulting from the simulation and considering the results presented in Figs. 6 and 7, the abovementioned behavior is also presented by [17], which describes the trade-off between the HOF effect and HPP. The proposed scheme minimized HPP and presented higher HOF than other competitive algorithms using specific parameters, as described in the previous section. Although H^2ATF has shown higher results compared to failures, it is important to highlight other network parameters that the related papers don't emphasize in their results. Therefore, even though there are a few more HOFs in the execution of H^2ATF, the proposed algorithm achieved the same results as the other algorithms in a satisfactory way in relation to the data rate average in the different simulated scenarios, as shown in Fig. 8.

VI. CONCLUSION

In this paper, a novel heuristic for HO priority in mobile HetNets scenario is presented. The proposed approach makes a decision based on multicriteria methods by implementing the AHP method to define the criteria weights (SINR, RSRP, RSRQ and speed) and TOPSIS to rank the target cells. A hysteresis calculated from fuzzy logic is also used to define dynamic values that favor the current cell.

Considering the average of all scenarios (50, 100, 150 and 200 SCeNBs), the results show that in the parameter number of HOs, H^2ATF exceeds STHA by 39% and BC by 42%. In the ping pong assessment, H^2ATF is lower (better) than STHA and BC by 33% and 43%, respectively. This factor is what draws the most attention because in decision making, the proposed model achieves a much lower number of HPP compared to other studies in the literature. However, for the number of failures, STHA has 31% and BC 38% less talk than H^2ATF.

Although H^2 ATF exhibits a trade-off in the last measured parameter, it is noted that the percentages in the other parameters are higher than the compared models. Moreover, the number of failures proposed here takes into account SINR, minimum RSRP and the eNodeB Channel, which are not always considered by other works in the literature, which sometimes only consider the failure of SINR. Other parameters will be studied to mitigate failure in future work.

Importantly, the proposed heuristic is generic and flexible, allowing the incorporation of other parameters and technologies not specified in this article. Thus, this approach provides new sets of decisions for various other scenario possibilities.

As future work, we intend to use new parameters for the decision, such as the direction, antenna load and flow type. In addition, another mobile network architecture may be considered as well as new computational intelligence techniques, such as clustering, a genetic algorithm and an evolutionary fuzzy approach, so that the decision making process can be further optimized.

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