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Original Article

Optimal Cell Selection with Load Balancing and Handover Optimisation in LTE-Advanced Networks

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***Abstract* - *The handover process takes an important role in seamless connectivity in the network, Long Term Evolution Advanced (LTE-A). Due to more number participation of User types of equipment (UEs) in a cell, the performance of the handover technique is degraded. So, to solve this issue, this research work focuses on selecting the optimal target cell or evolved Node B (eNB). For optimal cell selection, MWOA is presented. In this algorithm, the target cell is chosen, derived from multi-objective functions RSRQ (Reference Signal Received Quality), RSRP (Reference Signal Received Power), and uplink SINR (Signal to Interference plus Noise Ratio). After selecting eNB, UE from the loaded cell would give up to the optimal target eNB. Simulation outcomes depict that the recital of the anticipated handover scheme improved by reducing handover failure, Call Dropping Ratio (CDR), handover ping-pong, Call Blocking Ratio (CBR), and increasing the throughput and energy efficiency. It has been observed that call blocking probability and call dropping probability is reduced by more than 17% and 1%, respectively and energy and throughput increased by more than 11% and 2%.*

***Keywords* - *Handover, HPP, HFR, LTE-A, Multi-objective Whale Optimisation Algorithm (MWOA), Optimal cell selection.*

1. Introduction

LTE is a remote communication technology designed by 3GPP in Release 8 with the target of the spectral efficiency of the cellular network and expanding the limit. LTE-A results from Release 10 of the 3GPP standard created with different specialised enhancements contrasted with Release 8[1] [2]. The base station of LTE is termed the eNodeB, which is liable for radio transmission among UE and eNodeB. It includes different capacities, for example, Admission control, Radio Resource Management (RRM), Dynamic Resource Radio conveyor control and scheduling. The significant elements of the eNodeB are management of handover, which assumes a significant role in offering consistent and uninterrupted services to the client [3-6].

The fundamental design aim of cell networks, a consistent and secure handover is a must without fail. In light of the occurrence of two various potential sorts of base stations, the 4G-LTE remote networks' handover plots have confounded. A standard BS is referred to as eNB (eNodeB) in the correspondence structure of LTE. Expanding the complexity of the framework implies different kinds of base stations. For example, the HeNB (Home eNodeB) doesn't straightforwardly impart to the eNB. The handover situations, including a HeNB, can prompt complex handover methods in LTE networks [7] [8]. Moreover, the absence of reverse security is discovered because of the utilisation of key chains in the handover processes. Furthermore, to fulfil the high information needs of future cell networks, an ultra-densification strategy has been introduced to compress the BS inclusion and improve the recurrence reproducibility [9] [10].

MLB balances cell traffic with appropriate CIO values based on UE mobility, while MRO optimises handover success rates with optimal hysteresis [11]. It also increases handover success rates compared to typical MRO algorithms [12]. To reduce mobility issues such as handover latency, early handover, incorrect target cell selection and frequent handover using data-driven handover optimisation [13]. The suggested D-HCPs method surpasses other existing algorithms in terms of HCP optimisation [14].

An enhanced handover scheme for improving the quality of service and coverage for users is proposed in [15]. An improved handover algorithm for lessening the number of unwanted handovers and call blocking probability is presented in [16]. New and effective detection of self-optimising handover and execution of handover and decision parameter optimisation techniques depend upon Reinforcement Learning [17]. An approach appropriate for the level of HOM which permits the UE to continue the connection for better eNB is discussed in [18]. Also, that is used to avoid unwanted handover due to the outcomes of the high velocity of UE. The presented model outcomes provide an upgrade to the LTE network's performance by means of decreasing resource blocking and signalling load [19]. Accompanied by a centralised controller in the LTE-advanced networks' framework with the issue of muting, the coordinated scheduling is inspected [20]. According to 3GPP R10 eICIC (enhanced Inter-Cell Interference Coordination), the novel approach was the integration of dynamic ABS (Almost Blank Subframe) and dynamic CRE (Cell Range Expansion) which is proposed in [21].

LTE-A network permits UE clients to wander among remote networks of LTE-A. Because LTE-A relies only on hard handover, it runs the risk of causing disconnection if the transport mechanism is inadequate. When LTE comes to performing HO, this gives an extraordinary issue to the organisation, for instance, crease handover. To achieve seamless handover, optimal cell selection is important to be presented. So, the following contribution is presented in this paper.

- To perform a section of optimal eNB, the parameters used for handover, for instance, RSRP, RSRQ, SINR and fading factor, are considered and used as objective functions.
- On the other hand, the target eNB has been chosen with the support of the proposed Multi-objective Whale Optimization Algorithm (MWOA). Objective functions are taken as a fitness function in this algorithm.
- The algorithm is evaluated regarding handover ping-pong, failure during handover, probability of call dropping, probability of call blocking.
- The algorithm is also evaluated throughput along with energy efficiency.

The remaining sections of this article have been categorised into pursues. Section 2 shows the methodology. Section 3 proposes optimal cell or eNB selection using the MWOA technique. Section 4 demonstrates the proposed approach results. Section 5 summarises the findings of the study.

2. Methodology

The proposed technique has introduced selection methods for multiple cells in an optimised manner. This technique support Handover Optimisation along with Load Balancing. Before starting the handover process, handover parameters like Reference Signal Received Quality, Reference Signal Received Power, and Signal to Interference plus Noise ratio are computed in every eNB. Hence the parameters are considered an objective function, and the objective eNB is selected with the whale optimisation algorithm. Because of the selection of target eNB, the handover process would be performed efficiently. Fig. 1 displays the proposed work overall flowchart.

The LTE network model is shown in Fig. 2. As shown in Fig., the system model has 7 macrocells User pieces of equipment (UEs), serving evolution Node B termed SeNBs and target eNBs termed TeNBs. For communication, the User pieces of equipment terminal are used. The mobile phone is controlled by eNB in each cell. UEs forward the service request in the cell to the consequent eNB; The eNB estimates the load factor of the cell based on service requests received by using the X2 interface, the communication between each neighbouring eNB in the cell. The load status of the cell is swapped among neighbour cells by the X2 interface. For example, the maximum load of users in a cell contain 4 users. However, the middle cell or SeNB has 5 User types of equipment numbers. Therefore this cell is deliberated loaded cell. Because of the load, the SeNB in the cell was unable to service the new UE. Thus it has chosen the TeNB with minimum load. MWOA is presented to choose optimal TeNB. To this chosen TeNB, the service request of user types of equipment from SeNB is transferred.

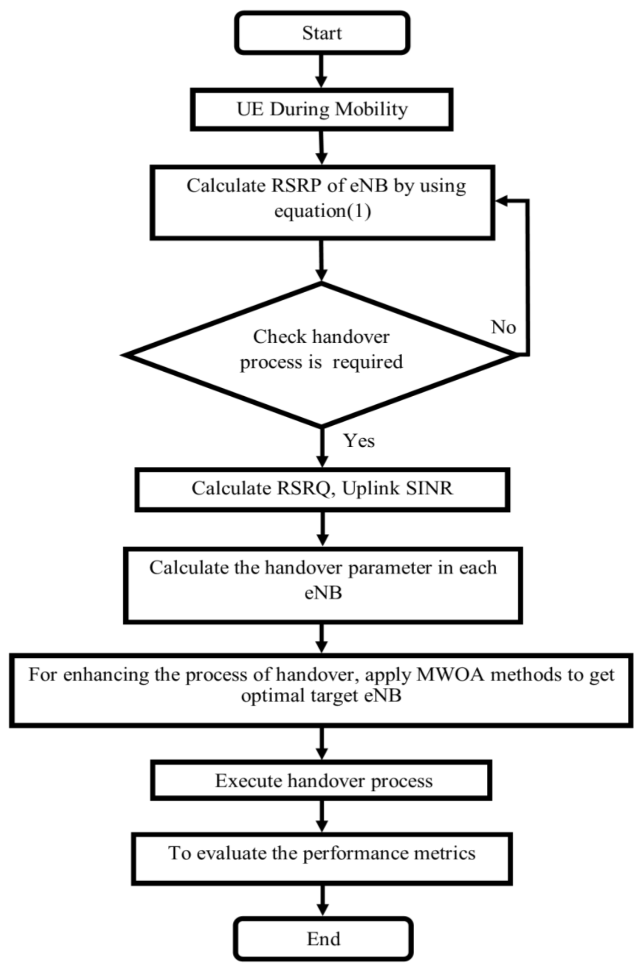

Fig. 1 Flowchart of proposed work

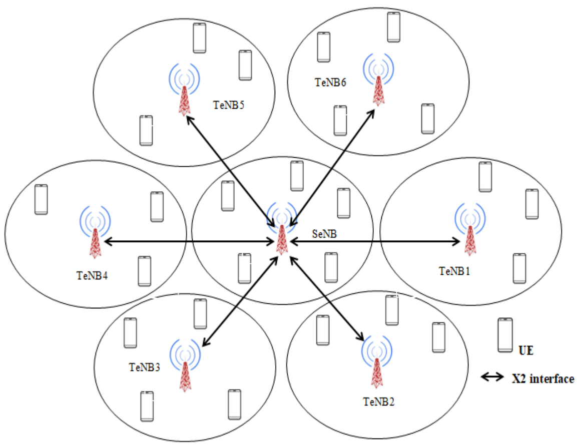

Fig. 2 System model

Shipping details can control the shipping process. According to traditional methods [9], the transition begins with confirming the energy obtained, the time taken during waiting, and the value in case of signal hysteresis. Also, you need to consider some aspects while choosing the best eNB. The following ideas describe the basic concepts of the program:

2.1 Reference Signal Received Power (RSRP)

This denotes the signal's power in the case of a particular ENB. Reference signal received power has been taken as measurement channel and is termed, Drone Link. The previous mechanism that decided on transmission considered only the Reference signal received power.

In it, the P_{TX} shifts the current to the eNB. It computes the value of path loss from one eNB to the other. On the other hand, FSF is a blurred shadow. It is 3 decibels. Reference signal received power is computed as presented in Equation (1).

$$RSRP = P_{TX} - P_{PL} - P_{SF} \tag{1}$$

2.2 Reference Signal Received Quality (RSRQ)

RSRQ introduce to quality of the interference mediator (C / I) and the strength of the received signal. Reference Signal Received Quality provides additional information that is not sufficient in case of safe transmission.

Received signal strength indicator termed as RSSI specifies signal along with noise. Received signal strength indicator measurement deviation number N and computation as shown in (2).

$$RSRQ = \frac{N * RSRP}{RSSI} \tag{2}$$

2.3 Uplink Signal-to-Interference Plus Noise Ratio (SINR)

eNB has no comparison with the downlinks due to the limitation of ONU; moreover, it has a limited capacity to transport. It has been observed that all EU coverage is not similar. Thus [4] considers signal to interference plus noise ratio uplink to allow communication in a better way. The calculation for Uplink signal to interference plus noise ratio has been computed in Equation (3);

$$SINR = \frac{P}{IT_{ul} + N} \tag{3}$$

In the above Equation, P shows the signal captured by *eNB*, and N shows noise in the background. Besides, IT_{ul} is showing the upper link Interference over Thermal. It could be computed by Equation (4).

$$IT_{ui} = 10 \log_{10} \left(\frac{IT_m + N}{N} \right) \tag{4}$$

Where ITm is showing interference that is macro cell-to-macro cell.

3. Selection of Enb using Mwoa Algorithm

Overloaded eNB handovers user to target eNB after calculating the handover parameters in every eNB as eNB is having. Minimum handover failure. To enhance the handover process, the target eNB is selected optimally with the support of the proposed MWOA.

MWOA is a delayed planned meta-heuristic motivated by the hunting behaviour of humpback whales [23]. MWOA shows uncommon chasing conduct with humpback whales, whereas whales try to circle their prey (units of fish) close to the outside of the water while making bubbles form as a circle. Humpback whales jump roughly 12 meters descending and begin to create spiral bubbles around the prey and swim to the surface, derived from a bubble-net hunting technique. The phases of optimal cell selection using the MWOA algorithm have been described as follows:

3.1 Initialization

The candidate solutions or the positions of whales are initialised. In this approach, a number of eNBs are considered as the candidate solution. The initialisation can be defined as follow:

$$S = \{S_{i,j}\} \tag{5}$$

Whereas S denotes the number of solutions or number of eNBs in the network,

3.2 Fitness

For preliminary solutions, fitness values are premeditated to calculate the optimal solution. Equation (6) defines the function of Fitness,

$$Fit_k\,(t) = Max(w_1(RSRP) + w_2(RSRQ) + w_3(SINR)) \quad (6)$$

Here, w1, w2 and w3 represent the parameters for weight in the range [0, 1]. The maximum Fitness valued solution is selected as the optimal solution or eNB. Otherwise, every solution will be reorganised unless the optimal result is available.

3.3 Update the Solution

Along with the fitness calculation for every solution, it will be updated using the following behaviour of whales.

3.4 Encircle the prey

Initially, Humpback whales detect the position of prey (groups of fish) and encircle them. MWOA algorithm considers target prey as the closest candidate solution to the correct answer. Once the best hunting agent is delineated, search operators for other whales will try to reorganise their localisation to the best hunting agent. In optimisation, the following equations are proposed to give a mathematical form to the surrounding mechanism.

$$\vec{D} = \left| \vec{M}.\vec{S}^{*}(t) - \vec{S}(t) \right| \quad (7)$$

$$\vec{S}(t+1) = \vec{S}^{*}(t) - \vec{B}.\vec{D} \quad (8)$$

$\vec{S}(t)$ is the position of the current iteration's vector, $\vec{B},\vec{M}$are coefficient and the optimal solution's position vector, and $S*$ is the position of the current iteration's vector. In this example, * is the multiplication of constituents by constituents. It must be revealed here $S*$ is supposed to update during every iteration with the best solution. Coefficient vectors $\vec{B},\vec{M}$ are premeditated as pursues;

$$\vec{B} = 2\,\vec{a}.\vec{r} - \vec{a} \quad (9)$$

$$\vec{M} = 2\vec{r} \quad (10)$$

During iterations (both exploration and exploitation stages), the elements decrease in a straight line from 2 to 0, whereas r is a vector with a random value within [0, 1]. Equation 8 tolerates some search agents for updating their location within the current best solution area and surrounding prey.

3.5 Bubble Net Attacking Strategy (Exploitation Period)

In revealing the numerical Equation for aggressive activities of humpback whales with bubble nets, two approaches have been designed as pursues:

3.5.1 Shrinking Encircling System

This method can be attained through lessening the linear value of $\vec{a}$ from 2 to 0 through (9). Using $\overrightarrow{\ }$ this, the range of $\vec{B}$ fluctuations is significantly reduced. If you want to be exact, you may think of Vector $\vec{B}$ as a random number between [-a, a] where A decreases from 2 to 0. The new localisation of the search agent might be classed anywhere from the initial localisation to the currently best agent by setting $\vec{B}$ randomly in [-1, 1].

3.5.2 Logarithmic Spiral Updating Position

Prey is primarily sought out by humpback whales, and the distance to that prey is estimated. After that, humpback whales move in logarithmic conical spiral motion for attacking the fishponds. Every single humpback whale is proposed to reorganise their localisation based on the spiral flight path. Mathematically, the following behaviour may be described as follows:

$$\vec{D}' = |\,\vec{S}^{*}(t) - \vec{S}(t) \quad (11)$$

$$\vec{S}'(t+1) = \vec{D}'.\,e^{bl}.\cos(2\pi l) + \overleftarrow{S}^{*}(t) \quad (12)$$

Whales and prey are separated by a distance of$\vec{D}' = |\,\vec{S}^{*}(t) - \vec{S}(t)$, which is random number in range of [-1, 1], * is constituent-by-constituent multiplication and b is constant on delineating logarithmic spiral shapes.

While hunting pods of fish, humpback whales must be spotted swimming in a conical logarithmic spiral pattern around their prey. For ease, It supposes humpback whale positions to get reorganised by (8) and (12), all with a 50% chance, which is expressed mathematically given below:

$$\vec{S}(t+1) = \begin{cases} \vec{S}^{*}(t) - \vec{B}\,.\vec{D}\ if\ p < 0.5 \\ \vec{D}'.\,e^{bl}.\cos(2\pi l) + \vec{S}^{*}(t)\ if\ p > 0.5 \end{cases} \quad (13)$$

p is a number with a random value within the range [0, 1]. Besides the bubble-net strategy, humpback whales have been further exciting probing behaviour of prey randomly. This is followed by a mathematical model of whale search behaviour.

3.6 Search for prey (Exploration Period)

Humpback whales, on the other hand, look for food at random while their locations are aligned. Search agents should be told to avoid the reference whale at this point, so they may focus on trustworthy areas of the search location. When scanning for prey, the vector is used to aid in exploration since its value ranges between 1 and -1. Unlike the exploitation period, the status of the search agent will be updated during the study period based on a roughly selected search agent rather than the best agent ever found. It uses

$|\vec{B}|$>1to impose a scan within the MWOA algorithm for establishing the global optimum as well as evading the local optimum optimally. Mathematically model is expressed as pursues;

$$\vec{D} = |\vec{M}.\vec{S}_{rand} - \vec{S}| \tag{14}$$

$$\vec{S}(t+1) = \vec{S}_{rand} - \vec{B}.\vec{D} \tag{15}$$

While $\vec{S}_{rand}$ is selected within a current generation and specifies a random position vector. Common MWOA steps could be summarised within pseudo-code publicised in Algorithm 1.

3.7 Termination

The above-mentioned steps last until an optimal solution is calculated. The procedure stops after getting an optimal solution.

Algorithm 1: MWOA algorithm

Input: Number of eNBs $\boldsymbol{S_i}$
Output: Target eNB
Whale population initialized $\boldsymbol{S_i(i = 1, 2, \ldots, n)}$
Fitness calculation of every SA
Search Agent (SA)
$S^* = best\ SA$
Loop1 $(\boldsymbol{t < max_i tearation})$
Loop 2 SA
Set a, B, M, l, and p
Condition 1$(\boldsymbol{p < 0.5})$
Condition 2 $(|\boldsymbol{B}| < \boldsymbol{1})$
Set position of present SA using (6)
else Condition 2 $(|\boldsymbol{B}| \geq \boldsymbol{1})$
Select a random SA $(\boldsymbol{S_{rand}})$
Set position of present SA by (13)
Condition 2
else Condition 1$(\boldsymbol{p \geq 0.5})$
Set position of present SA using (10)
end Condition1
end loop2
Verify if any SA is going beyond search space and changing it
Fitness calculation of every SA
Update $\boldsymbol{S}^*$ if there is the better solution
$\boldsymbol{t = t + 1}$
end loop1
return $\boldsymbol{S}^*$

3.8 Performance of Handover

Fig. 3 shows the handover process after the selection of the target eNB. After selecting the target eNB, serving eNB forwards handover requests to the selected target eNB. Destination eNB service sends the response to the eNB along with the values of the handover parameters. Then, the service sends the values to the UE in the eNB measurement control message. The UE generates the measurement information and forwards it to the serving eNB. According to the information sent by UE, the eNB server performs the handover. Target eNB sends Handover Request Ack to serving eNB. After this completion, the target eNB forwards the handover result to the serving eNB.

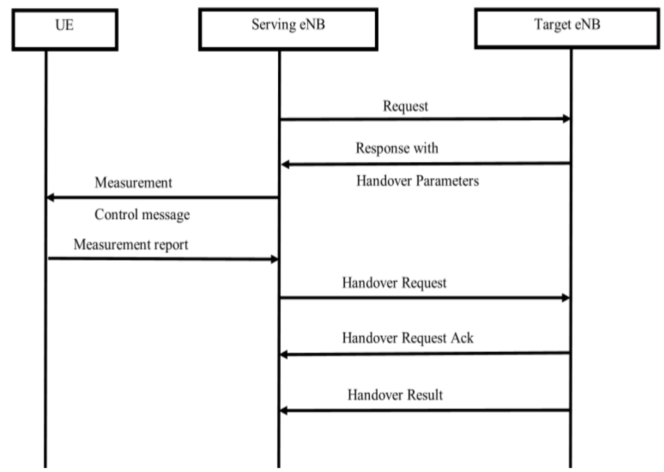

Fig. 3 The handover process

4. Experimental Results and Discussion

A. Simulation Result

In this section, experimental findings gained from that proposed method have been analysed through MATLAB R2015, along with the system having an I3 processor with 8GB RAM. Table 1 represents the simulation parameter in the case of the proposed method. Table 1 shows 100 numbers of User types of equipment and 15 numbers of eNBs are utilised in this simulation. For each UE, a random mobility direction is used. For each UE, a random mobility direction is used. The simulation process will be completed within the time of 2000ms.

Table 1. Simulation parameters

Parameters	Assumptions
Simulation time	2000ms
eNB count	15
Direction of movement	Movement is Random
Number of UEs	100
Shadow fading	Gaussian log-normal distribution
Frequency	2 GHz
Nature of Traffic	sensitive to delay and speed

The proposed handover system is investigated in terms of CDR and CBR for varying situations such as heavy load along with huge mobility. Also, the proposed scheme's working performance is evaluated in terms of handover ping-pong, handover failure. Moreover, energy efficiency and throughput are calculated to increase the efficiency of the proposed handover scheme. The proposed scheme is compared with the existing techniques such as PSO and GA. Based on the optimal values of δ and τ, which represent the variation of O and H components of the handover margin [22], the proposed handover scheme is analysed. Fig. 4 displays the CDR of the proposed system in the situation of high mobility. As shown in Fig., CDR reduces when both δ and τ has high value. But, CDR increases while δ has a high value and τ has a low value due to the high mobility of users. CBR of the proposed approach in the situation of huge mobility is shown in Fig. 5. As shown in Fig., CBR reduces when both δ *and* τ have low values due to the efficient handover signalling under the situation of the user's high mobility. But, the handover signalling is affected when δ has more value and τ has a lesser value, as publicised in Fig.5.

Fig. 6 demonstrates the CDR of the proposed approach in the situation of heavy load. As shown in Fig., CDR increases when δ less value has while it rises when δ has a high value. Because of the high-value ofδ, the H parameter can initiate the handover process without any difficulties in the situation of high load. The CBR of the proposed approach in the situation of a high load is shown in Fig. 7. As shown in Fig., the CBR reduces when δ has a high value, and τ has less value. Fig. 8 depicts the CDR of the proposed method in the situation of both high mobility and high load. As publicised in Fig., CDR reduces when both δ *and* τ have low values. CDR increases when δ increases. The CBR of the proposed scheme in the situation of both high load and high mobility is shown in Fig. 9.

Fig. 10 depicts call blocking probability performance in the case of the proposed MWOA based scheme and existing schemes. A low call blocking probability has been achieved, as seen in Fig., whereas the existing techniques such as PSO, GA and, without optimisation technique, have attained the high call blocking probability, in which the high call blocking probability has been achieved in the absence of optimisation technique. Therefore, when compared to the other schemes such as PSO, GA and, without optimisation technique, the proposed MWOA based scheme has been outperformed in terms of call blocking probability.

Fig. 11 shows the drop-out rate performance of planned along with present systems. As shown in Fig., the probability of call dropping for the proposed approach has been achieved low while compared with other techniques such as GA, PSO. The handover failure effect of proposed and existing schemes is depicted in Fig. 12. From Fig., the proposed scheme's handover failure percentage is increased up to 0.08 % at 400 sec. Then handover failure percentage is decreased to less than 0.04 %. While comparing the existing techniques, the proposed scheme has been attained a low handover failure percentage. Hence, the proposed scheme has been outperformed the handover process in LTE.

The handover ping-pong performances of proposed and existing schemes are depicted in Fig. 13. The proposed scheme has been reached less handover ping-pong percentage, whereas the PSO based scheme has been attained a handover ping-pong percentage slightly higher than the proposed scheme. But, the GA and absence of optimisation have been attained a high handover ping-pong percentage. Therefore, the proposed scheme has been better performance than existing schemes such as PSO and GA.

Fig. 14 shows the proposed and existing schemes for throughput performance. As publicised in Fig., the proposed MWOA based scheme has been attained the maximum throughput of 1690 Mbps at 2000 sec. At the same time, existing schemes such as PSO and GA have been attained the maximum throughput of 1610 Mbps and 1580 Mbps, respectively, at 2000 sec. But, in the absence of an optimisation technique, the throughput value is 1560 Mbps. From this, the proposed scheme has been outperformed by existing schemes in terms of throughput.

Similarly, the comparative analyses of the proposed and existing scheme's performance for energy efficiency are shown in Fig.15. As shown in Fig., the proposed MWOA scheme has been achieved high energy efficiency at 2000 sec, that is, 35 J. But existing techniques such as PSO and GA have less energy efficiency. While, the minimum energy efficiency has been attained in the absence of the optimisation technique, which is 28 J. Therefore, the proposed scheme has been outperformed when compared with the existing techniques in terms of energy efficiency.

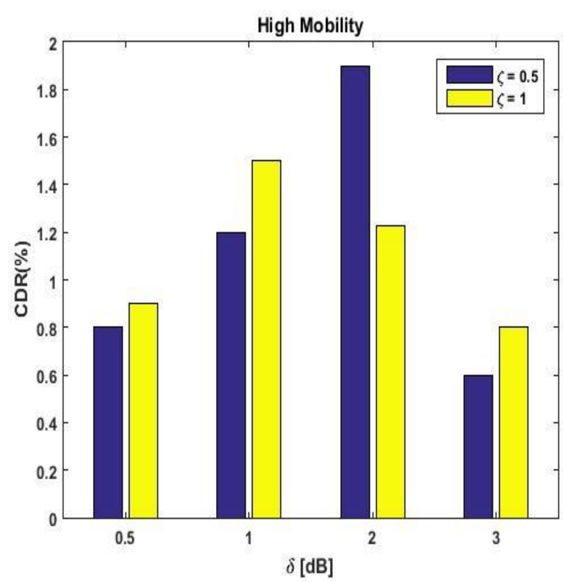

Fig. 4 CDR of the proposed approach when mobility is high

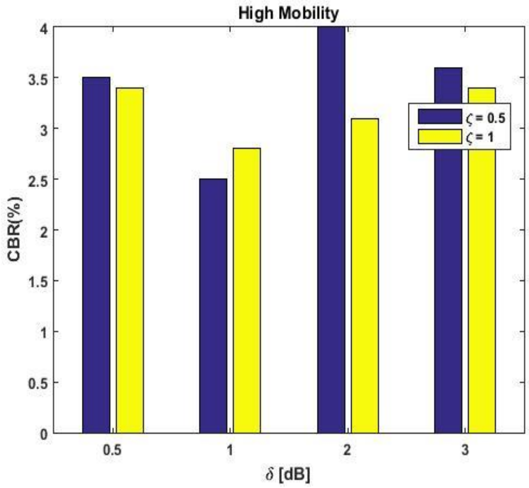

Fig. 5 CBR of the proposed approach when mobility is high

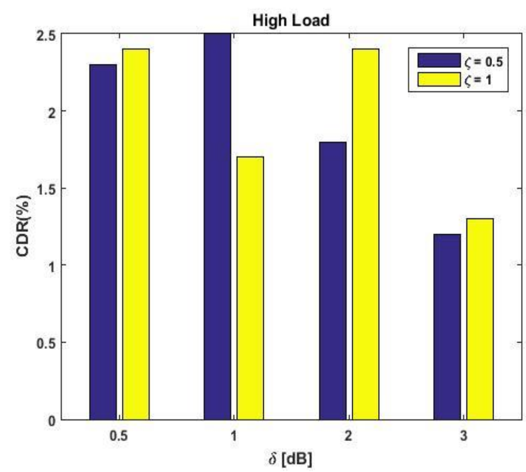

Fig. 6 CDR of the proposed approach when the load is high

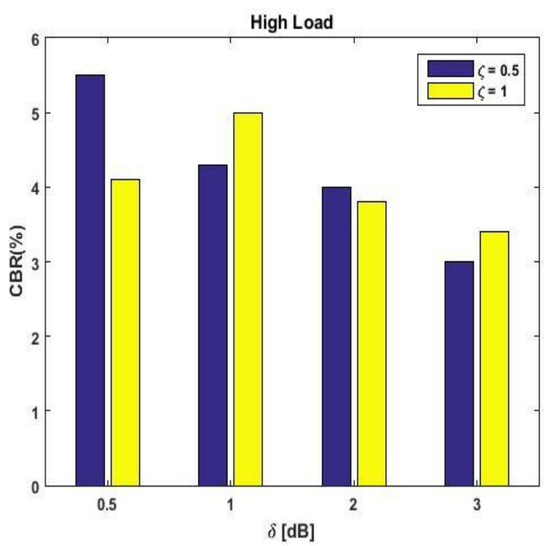

Fig. 7 CBR of the proposed approach when the load is high

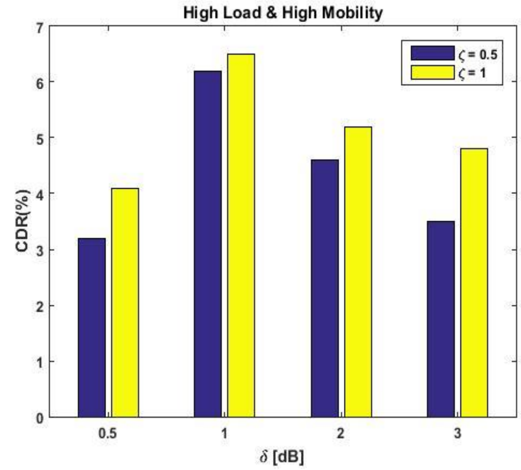

Fig. 8 CDR of the proposed approach when mobility and load are high

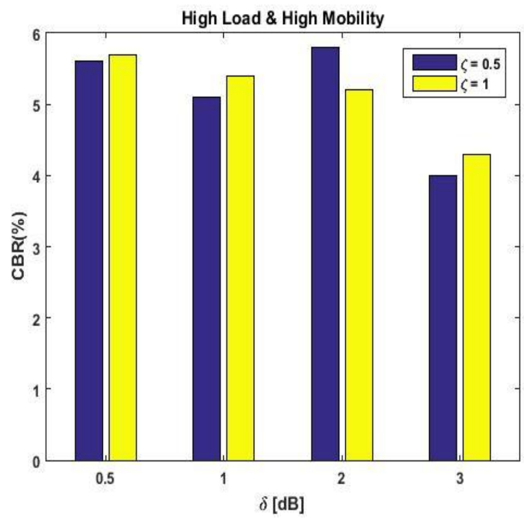

Fig. 9 CBR of the proposed approach when mobility and load are high

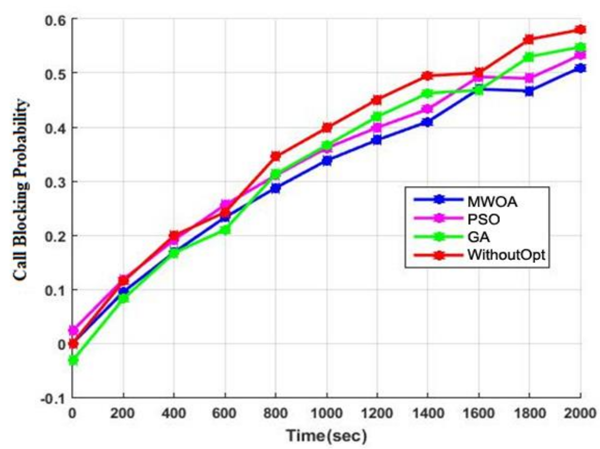

Fig. 10 Shows the performance of the current system and current schemes in terms of a selection time for eNB with UEs travelling at a velocity of three kilometres

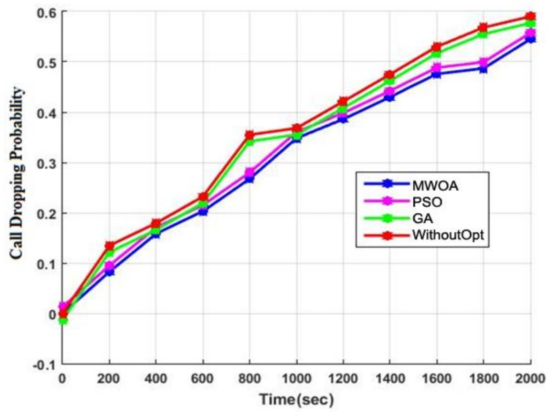

Fig. 11 For a UE travelling at a speed of 3 kilometres, the performance of probability call dropping for both the existing and current systems can be shown

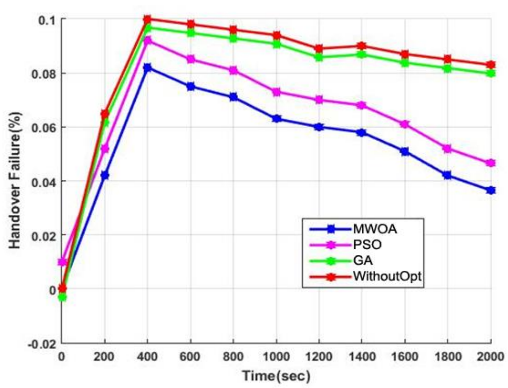

Fig. 12 According to the proposed scheme and existing schemes, the performance of Handover Failure for the existing and the current systems A distance of 3 kilometres

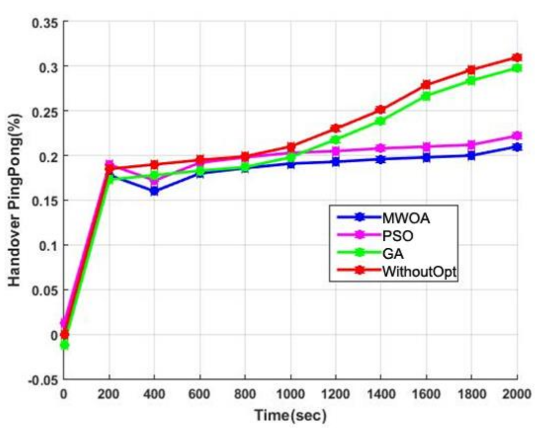

Fig. 13 UE Speed of 3 Kilometers, Performance of Ping-Pong Handover for Proposed and Existing approach.

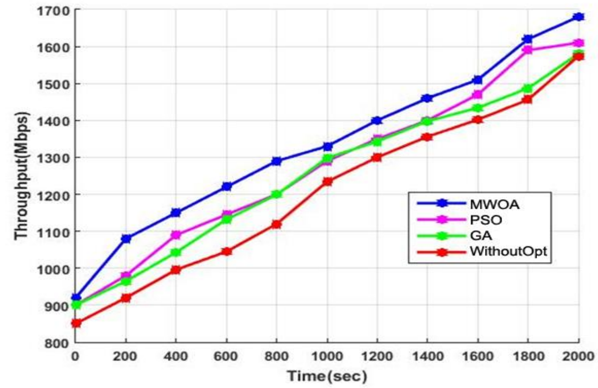

Fig. 14 Throughput for existing and proposed schemes

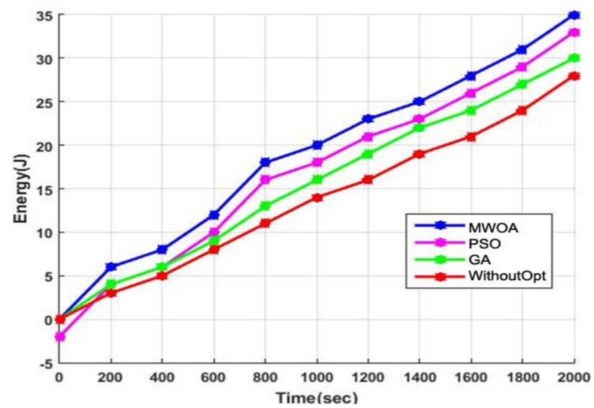

Fig. 15 Current and prospective solutions should be more energy efficient

A. Comparative analysis with existing algorithms

Comparative analysis of call blocking probability, call dropping probability, handover failure, ping pong handover performance, throughput and energy in case of simulation without optimisation, genetic algorithm, PSO, and MWOA has been shown in Table 2.

Table 2. Comparative Analysis

Average	**Without opt [7]**	**GA[25]**	**PSO [24]**	**MWOA (ProposedWork)**
Call Blocking probability(Unit)	0.4399	0.395036	0.370	0.305455
Call dropping probability (Unit)	0.381	0.375	0.370	0.366
Handover failure (%)	0.0991	0.0912	0.0721	0.0653
Ping-Pong Handover Performance (%)	0.2145	0.1589	0.2	0.1565
Throughput (Mbps)	1230	1290	1300	1320
Energy (J)	14	16	18	20

It has been observed that the call blocking probability of MWOA is 31% less than without optimisation, 23% less than the genetic algorithm, 17% less than that of PSO. Call dropping probability of MWOA is 4% less than without optimisation, 2% less than the genetic algorithm, 1% less than that of PSO. Handover failure of MWOA is 34% less than without optimisation, 28% less than the genetic algorithm, 9% less than that of PSO. Ping-pong handover of MWOA is 27% less than without optimisation, 2% less than the genetic algorithm, 22% less than that of PSO [24]. On the other hand throughput of MWOA is 7.3% more than without optimisation, 2% more than the genetic algorithm, 2% more than that of PSO, while energy is 42% more than without optimisation, 25% more than the genetic algorithm and 11% more than PSO.

5. Conclusion

To obtain seamless connectivity in the LTE-A network, Multi-Objective Whale Optimization Algorithm (MWOA) based handover optimisation has been presented in this paper. Before selecting the optimal cell, handover parameters such as RSRP, RSRQ, and SINR of each cell have been exchanged with each other. By considering these handover parameters as objective functions, the proposed algorithm has selected the optimal cell or eNB. The performance of the proposed handover scheme has been achieved better CBR and CDR under high mobility, high load and both together situations. Also, the proposed MWOA based handover scheme has been outperformed existing techniques such as PSO and GA in terms of probability of call blocking and call dropping, failure in handover, handover ping-pong. On the other hand, the impact on throughput and energy efficiency is also considered. It has been observed that call blocking probability and call dropping probability is reduced by more than 17% and 1%, respectively and energy and throughput increased by more than 11% and 2%. Future research may consider the study of handover underwater. Moreover, further influencing factors might be considered during the simulation process.

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