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Low Cost Handover using Enhanced Ant Lion Optimizer (EALO) for 5G networks

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Abstract: In 5G networks, the Handover (HO) operations may result in increased cost and latency. In order to overcome these issues, in this paper, a low latency and low cost optimized HO technique in 5G network is proposed. In this technique, Enhanced Ant Lion Optimizer (EALO) algorithm is used with ants and antlions as search agents. The updated position of antlions in ALO algorithm is enhanced by applying the Whale Optimization Algorithm (WOA) algorithm. The fitness function of EALO is formed using the key performance indicator (KPI) function which is derived from the Loss and Gain functions. The loss function is derived from the HO cost and HO delay whereas the gain function is derived from coverage probability (CP) and average throughput. Then the fitness function is maximized by optimizing the HO margin (HOM) and time-to-trigger (TTT) parameters. By simulation results, we show that the proposed technique reduces cost and latency.

Keywords: *algorithm, technique, operations, time-to-trigger (TTT), antlions*

1. Introduction

A new wireless network generation (5G) was proposed by the 3GPP (3rd Generation Partnership Project) in order to address the numerous issues that existing networks were experiencing due to the exponential growth of the Internet of Things (IoT). 5G is now being utilised to address a number of issues, including network coverage, bandwidth capacity (and thus latency) and data speed. Conversely, a 5G mobile network would take use of the massive quantity of mm - wave spectrum if traffic increased significantly (mmWave). Considering this into consideration, a heterogeneous network is created by utilising several types of base stations, such as macro base stations (MBS), micro base stations (mBS), and femtocells (HetNet). Coverage, Handoff, and cost deployment are all addressed in a variety of studies. In this paper, stochastic geometry is presented to improve the downlink coverage of mmWave cell networks. [2]. If you're going to deploy the 5G architecture, you're going to have many networks with various technologies sharing the same infrastructure and overlap picocells [3].

Cellular networks rely on the Handover (HO) procedure to facilitate user mobility. The performance of HO was widely studied in the literature on cellular networks. For cloud based HetNets and two-tier networks, HO signalling overhead reduction methods have been presented [4].

New generation NodeB, or gNB, are used to configure 5G network measurements, same like in LTE. There has been a lot of study done on reducing the time it takes to do a handover, such as RACH-less handover, but very little research has been done on reducing the time it takes to prep for a handover. [5].

The main objective of this work is to design an optimization technique to reduce the cost and latency involved in the HO operations. In this paper, a low cost handover technique using enhanced ant lion optimization (EALO) algorithm is proposed.

2. Related Works

RAN, core network, and cache are three major solution areas that Imtiaz Parvez et al [6] have examined in depth to minimize the delay in communications. They also gave an overview of 5G cellular networks, which include SDN, NFV, caching, and MEC (mobile edge computing), all of which can satisfy the main criteria of 5G networks.

For heterogeneous integrated networks, Xiaonan Tan and colleagues [7] have developed a unique vertical handover algorithm that uses multi-attribute and based on biological. They have defined the network environment with resources by changing the target network among UMTS, GPRS, WLAN, 4G, and 5G. The metrics SINR, user mobility and packet loss rate are utilized as reference objects for defining the input neurons of BPNN and the training and learning process of successive n neurons. All five wireless networks are analysed to

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determine which one should be selected for vertical handover decision-making based on performance.

A research by Suzan Basloom et al. [8] examined the issue of mobile node handover failure and distributed-handoff latency in an SDN-based IEEE802.11 network. A hybrid K-means clustering algorithm to accelerate the scanning process of the mobile users by reducing the number of APs that need to be scanned for HO. The results reveal reduced delay and fewer handoff failures as compared to the unclustered network.

Po-Chiang Lin et al [9] studied how to improve HO in 5G networks. They introduced a data-based handover optimization (DHO) technique to address mobility difficulties such as too-late or too-early handoffs, HO to the inappropriate cell, ping-pong handovers, and wasted handovers (data-driven handover optimization). The KPI is calculated based on weighted average ratios of various mobility concerns (Key Performance Indicator). The DHO technique gathers the data from the mobility trace information and has a model for assessing the link between the KPI and the properties of the gathered data.

3. Proposed Solution

3.1 Overview

In this paper, a low cost handover technique using EALO algorithm is proposed. The key performance indicator (KPI) function is derived from the Loss and Gain functions. The loss function is derived from the HO cost and HO delay whereas the gain function is derived from coverage probability (CP) and average throughput. Then the HOM and TTT parameters are optimized to maximize the KPI. The EALO algorithm is used for optimization with the KPI as the fitness function.

3.2 Derivation of Key Performance Indicator (KPI)

The HO Cost (HC) is defined in terms of normalized HO delay as [4]:

$$HC = \min(HR * d, 1) \tag{1}$$

where d is the delay per HO and HR is the HO rate per unit time, given by

$$HR = HO_{len} * S \tag{2}$$

where HO_{len} is the number of HO attempts per unit distance and S is the speed of the mobile user.

Outage Probability (OP) is the probability that the immediately measured SINR level is less than a minimum threshold level $SINR_{min}$.

$$OP = 1 - P[SINR > SINR_{min}] \tag{3}$$

Coverage Probability (CP) is the probability that the SINR measured by the user becomes greater than the threshold R. It is given using the following equation [4]:

$$CP = \Pr\left\{\frac{P w_1 M_1^{-\delta}}{\sum_{i \in \emptyset \setminus s_1} P w_i M_1^{-\delta} + \gamma^2} > T\right\} \tag{4}$$

Where s_1 is the nearest BS, M is the distance between the user and BS, w is Rayleigh distribution with unit variance and δ is loss component

Average Throughput (AT) indicates the relationship between the HO cost and capacity gain as given by

$$AT = B * E\,(1 - HC) \tag{5}$$

Where B is the overall bandwidth and E is the spectral efficiency given by

$$E = e\,(\ln(1 + SINR)) \tag{6}$$

The KPI function is derived from the Loss and Gain functions.

The loss function (LF) is derived from the HO cost and OP as

$$LF() = h1.HC + h2.OP \tag{7}$$

Where h1 and h2 are normalization weight values between 0 to 1.

The gain function (GF) is derived from the CP and AT as

$$GF() = g1.CP + g2.AT. \tag{8}$$

Where g1 and g2 are normalization weight values between 0 to 1.

Then the KPI() is derived from the gain and loss functions as

$$KPI() = GF() - LF() \tag{10}$$

3.4 Optimized HO Parameters

The factors HOM and TTT are defined as follows [9].

i. HOM is defined as the difference in SINR of the current and target cells, which is the threshold of the HOM. If the target cell's SINR is greater than the serving cell's SINR, therefore the condition is met.
ii. TTT is the time period in which the HO condition must be fulfilled. HO requests are made when the HO requirement is met for a specific TTT.

HOM and TTT values are more stable when they are large, but they may postpone the HO choices excessively, which might lead to issues. HOM and TTT values that are too little may create superfluous and/or repetitive HO requests, and also ping-pong HO. Increasing the KPI() is the best way to improve these parameters' effectiveness.

3.5 Enhanced Ant Lion Optimizer (EALO)

In this section, the EALO algorithm is presented for maximizing the KPI. The fitness function of EALO is formed using the KPI function. EALO is an enhanced version of traditional ALO algorithm in which the updated positions of antlions are enhanced using the Whale Optimization Algorithm (WOA).

3.5.1 Ant Lion Optimizer (ALO)

The ALO algorithm's fundamental operations are briefly described in this section. Stochastic search algorithm ALO [11] resembles the antlion hunting strategy in nature. Ants and antlions are offered as search agents in this innovative strategy, which comprises a random walk, the construction of traps, trapping of ants in the traps, the capture of prey, and the re-construction of the traps.

According to ALO's mathematical model, this appears like this.

Ants travel stochastically when hunting for food, hence the optimization process defines a random walk as follows:

$$X_i = [0; r(1); r(1)+r(2);,,,,,; \sum_{j=1}^{T-1} r(j); \sum_{j=1}^{T} r(j)$$

(11)

Where *i = 1,..., dim, dim* is the size of ant or antlions , *T* is the maximum iterations, $X = [X_1; \ldots ; X_{dim}]$, X_i is a $(T+1) \times 1$ *matrix*, and *r(j)* is a function which is defined as:

$$r = \begin{cases} 1 & if rand > 0.5 \\ -1 & if rand \leq 0.5 \end{cases}$$

(12)

Here rand denotes a random number that is created in the range [0, 1].

According to lower and higher limits, ants' random travels need to be translated to their actual position in the searching space. Equation (3) may be used to determine it:

$$Y_i = \left(\frac{X_i - a_i}{d_i - a_i} \right) X (d_i - c_i) + c_i$$

(13)

For any dimension X_i,c_i, and d_i, we have the upper and lower bounds which are given as a_i and d_i, respectively.

Antlions' traps restrict the ants' ability to move. In layman's terms, this is known as

$$c = c' + Antlion, d = d' + Antlion$$

(14)

Where c' and d' are the current iteration's lowest and maximum altering limit, Antlion is the antlion's location as determined by the fitnesses of the Roulette wheel.

The more fit an *antlion* is, the more likely it is to develop a trap. Sliding process with decreasing radius of ants happens as soon as antlions are aware that their prey is captured. Equation (15) is used to update c' and d'.

$$c' = \frac{lb}{10^w x(t/T)}$$

$$d' = \frac{ub}{10^w x(t/T)}$$

(15)

Where lb and ub are the lower and upper bounds and W is a constant based on the iteration number.

Each ant's current location is determined by the Roulette wheel and an elite group of ants doing random trips around an antlion. It can be determined as:

$$Ant = \frac{R_A + R_E}{2}$$

(16)

where R_A is the random walk around an *antlion*, and R_E is an elite walk and Ant is the new position.

In the process of catching prey, if the ant's new place crosses the boundary, it should be re-adjusted. Unless ant reaches the bottom of the hole, the antlion should assume the role of leader.

The catching prey step can be defined as

$$Antlion = Ant, iff(Ant) < f(Antlion)$$

(17)

Where f (.) is the fitness function.

3.5.2 Whale Optimization Algorithm (WOA)

WOA [12] is an optimization algorithm which is inspired from the natural behaviour of humpback whales. These whales are mostly depending on the hunting process for surviving. The unique characteristic of the WOA is the capability to use an optimum agent in the searching space to get the prey. In addition, it has the capability to produce bubble-net attaching techniques of the humpback whales by means of spirals.

The main functions of WOA are

1. Prey encircling.

2. Hunting using Bubble net.

3. Prey searching.

Spiral updating position: Let (X,Y) be the whale and (X∗, Y∗) be the prey. Then the distance between these two is calculated in this method. In order to simulate the movement of humpback whales, a spiral position is determined between the position of whale and prey:

$$\vec{X}(t+1) = \vec{D}.e^{bl}.\cos(2\Pi l) + \vec{X}(t) \tag{18}$$

Where $\vec{D} = |\vec{X}^*(t) - \vec{X}(t)|$ represents the distance, b denotes the shape of the spiral, l is a random number in the range [-1,1] and . is an element-wise multiplication operator.

Humpback whales swim across the regions of prey in the shapes of small circle and spiral, simultaneously. There is 50% chance for applying the shrinking encircling operations or the spiral swim to update the positions of whales to optimize the solutions. It is also possible for humpback whales to hunt prey without the aid of a bubble net.

$$\vec{X}(t+1) = \begin{cases} \vec{X}^*(t) - \vec{A}.\vec{D} & if p < 0.5 \\ \vec{D}.e^{bl}.\cos(2\Pi l) + \vec{X}^*(t) & if p \geq 0.5 \end{cases} \tag{19}$$

where p is a random number in [0,1].

After performing the bubble-net sorting process, the random prey searching process is applied.

3.5.3 EALO Algorithm

Let a be the minimum of all variables for i^{th} antlion

Let b be the maximum of all variables for i^{th} antlion

The steps involved in this algorithm as follows:

EALO Algorithm

---

1. Randomly initialize the population of ants and antlions.
2. Estimate the fitness function using the KPI function (explained in section 3.3 and 3.4)
3. Detect the best antlions and assign them as Elite.
4. For each ant,
5. Select an antlion using Roulette wheel method
6. Update a and b using Eq. (14)
7. End for
8. Generate a random walk and normalize it using Eq (11):
9. Compute the fitness function of all ants.
10. Replace an antlion with its associated ant if it is fitter.

$L_j = P_i$ if $f(P_i) > f(L_j)$

Where L_j is the position of selected j^{th} antlion at t^{th} iteration

11. The position of ant and antlion is updated using the spiral position update technique (12):

$$L(t+1) = \overrightarrow{g'}.e^{vl}.cos(2\pi l) + \overrightarrow{L'(t)}$$

$\overrightarrow{g'} = |\overrightarrow{L'(t)} - \overrightarrow{L(t)}|$ = distance of ith antlion to ant

v denotes the shape of the spiral

l is a random number in [−1,1],

. is an element-wise multiplication operator

12. If an antlion becomes fitter than the elite
    Update elite using Eq. (18) and (19) of WOA

13. If the stopping criterion is met,
    Return the Elite
    Else
Return to Step 4.

---

4. Simulation Results

4.1 Simulation settings

The proposed LCH-EALO algorithm is implemented in NS2 and its performance is compared with Coverage, Handoff and Cost optimization (CHCO) technique [2] and the following metrics are analyzed such as HO delay, data delivery probability, HO cost and Throughput.

Table 1 shows the simulation settings.

Number of Macro cells	6
Number of small cells	12
Area size	500 X 500m
Bandwidth	100Mbps
Cell Range	Macro cells- 5 km small cells – 25m
Number of users	6 users per cell
Load	10 to 20Mb
IoT Traffic models	Constant Bit Rate (Non real-time), Exponential (real-time) and TCP (Text)
Transmit power	0.4 KW
Receive power	0.6 KW
Idle power	0.03 KW
Initial Energy	20 Joules

Table 1 Experimental settings

4.1 Result Section

A. Based on No of Handoffs

In this experiment, the number of HO attempts is varied from 1 to 5.

Number of HOs	CH-CO (ms)	LCH-EALO (ms)
1	5.31	4.89
2	5.38	4.91
3	5.47	4.93
4	5.5	4.97
5	5.62	5.15

Table 2 Handoff Delay for No.of Handoffs

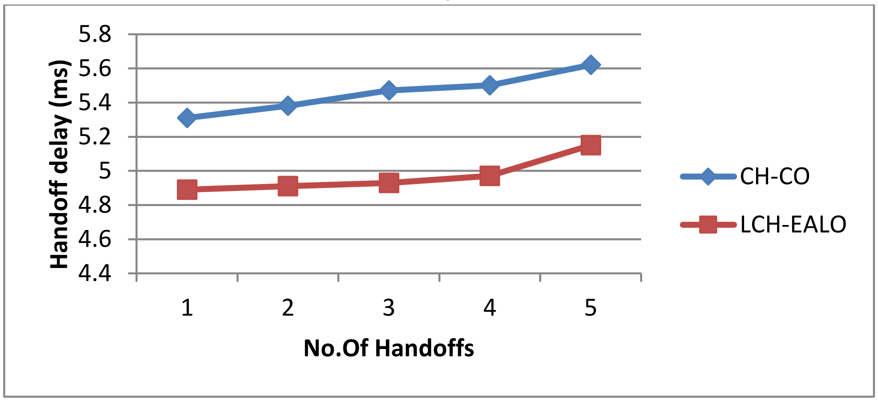

Fig 1 Handoff delay for No. of Handoffs

Table 2 and Figure 1 shows the results of HO delay for the HO attempts. It can be seen that the HO delay of LCHEALO is 9% lesser than CHCO technique.

No. of HOs	CH-CO	LCH-EALO
1	0.8761	0.9112
2	0.8442	0.8723
3	0.8205	0.8522
4	0.8011	0.8478
5	0.7983	0.8261

Table 3 Data Delivery Probability for No. of Handoffs

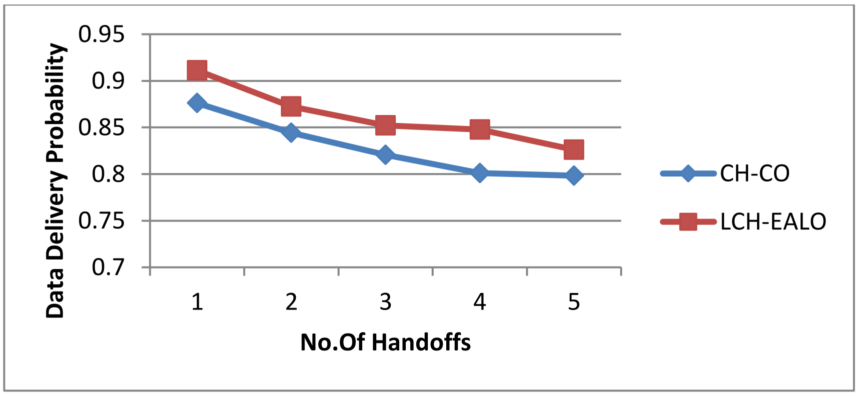

Fig 2 Data Delivery Probability for No. of Handoffs

Table 3 and Figure 2 show the results of data delivery probability for the HO attempts. It can be seen that the delivery probability of LCHEALO is 4% higher than CHCO technique.

No.of HOs	CH-CO	LCH-EALO
1	0.15	0.13
2	0.16	0.15
3	0.19	0.17
4	0.20	0.18
5	0.22	0.19

Table 4 HO Cost for No. of Handoffs

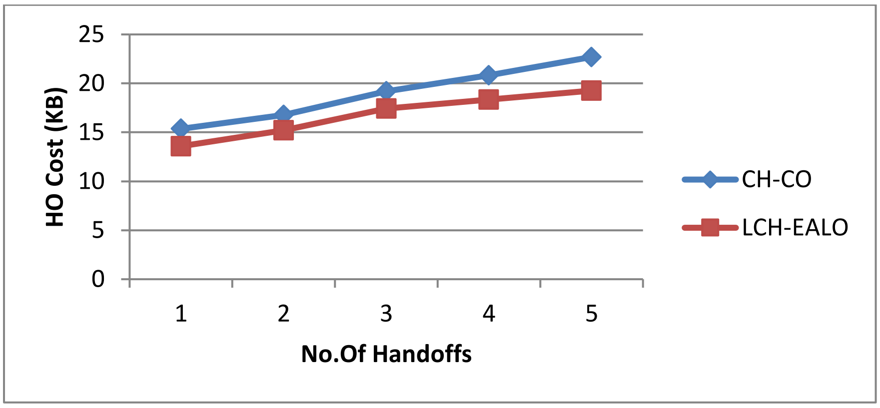

Fig 3 HO Cost for No. of Handoffs

Table 4 and Figure 3 show the results of HO cost for the HO attempts. It can be seen that the HO cost of LCHEALO is 11% lesser than CHCO technique.

No. of HOs	CH-CO (Mb/s)	LCH-EALO (Mb/s)
1	7.12	9.46
2	6.92	9.26
3	6.86	9.23
4	6.58	9.1
5	6.47	8.84

Table 5 Throughput for No. of Handoffs

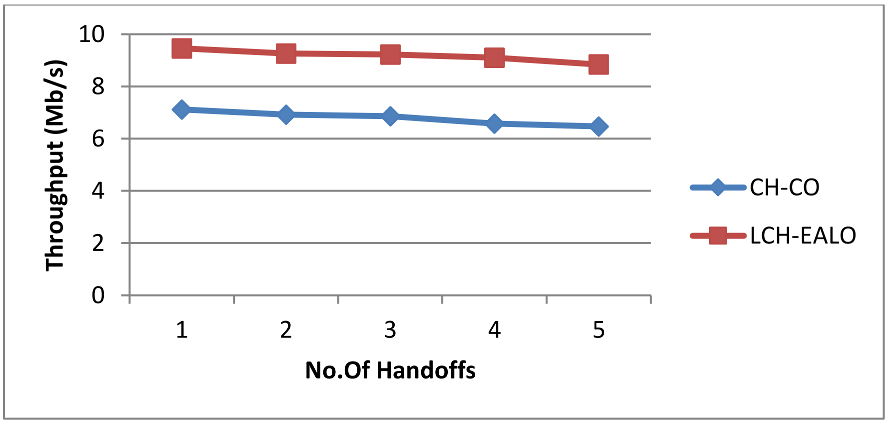

Fig 4 Throughput for No. of Handoffs

Table 5 and Figure 4 show the results of throughput for the HO attempts. It can be seen that the throughput of LCHEALO is 26% higher than CHCO technique.

B. Based on Nodes

In this experiment, the number of users is varied from 18 to 108.

No. of Nodes	CH-CO (ms)	LCH-EALO (ms)
3	4.29	3.64
6	4.4	3.86
9	4.98	4.35
12	5.08	4.61
18	5.31	4.89

Table 6 HO Delay for Cells

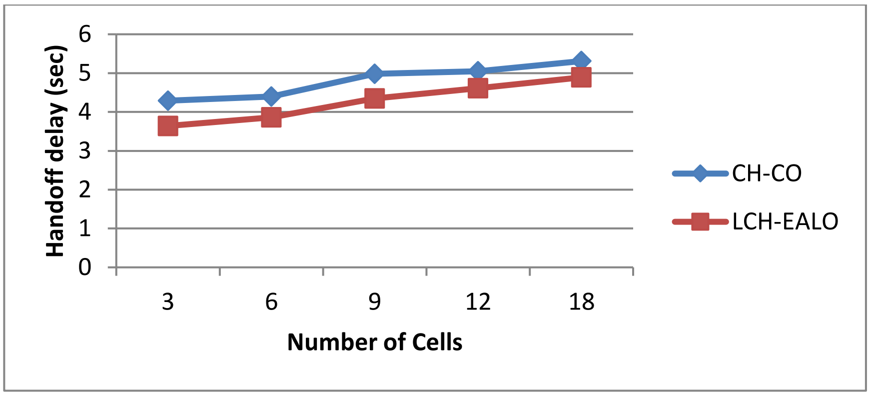

Fig 5 HO Delay for Cells

Table 6 and Figure 5 shows the results of HO delay for varying the cells. It can be seen that the HO delay of LCHEALO is 14% lesser than CHCO technique.

No. of Nodes	CH-CO	LCH-EALO
3	0.7944	0.8676
6	0.8368	0.8916
9	0.8564	0.9011
12	0.8612	0.9055
18	0.8761	0.9112

Table 7 Data Delivery Probability for Cells

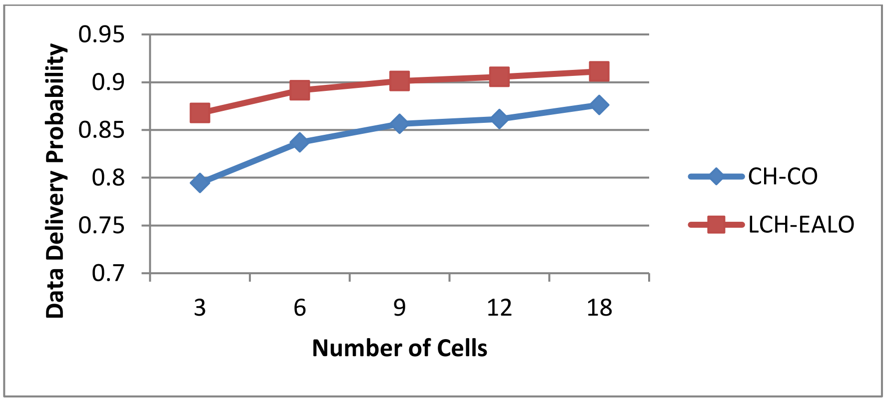

Fig 6 Data Delivery Probability for Cells

Table 7 and Figure 6 show the results of data delivery probability for varying the cells. It can be seen that the data delivery probability of LCHEALO is 7% higher than CHCO technique.

No. of Nodes	CH-CO	LCH-EALO
3	13.59	11.05
6	14.23	11.93
9	14.79	12.82
12	15.21	13.35
18	15.36	13.58

Table 8 HO Cost for Cells

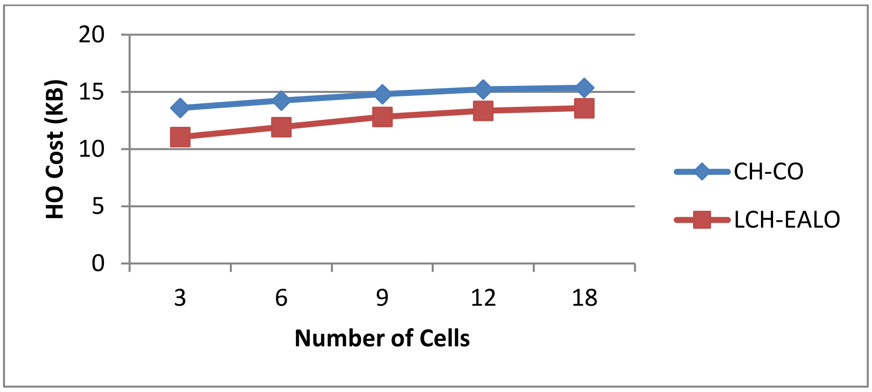

Fig 7 HO Cost for Cells

Table 8 and Figure 7 show the results of HO cost for varying the cells. It can be seen that the HO cost of LCHEALO is 18% lesser than CHCO technique.

No. of Nodes	CH-CO (Mb/s)	LCH-EALO (Mb/s)
3	8.28	10.32
6	7.77	9.8
9	7.29	9.68
12	7.20	9.55
18	7.12	9.46

Table 9 Throughput for Cells

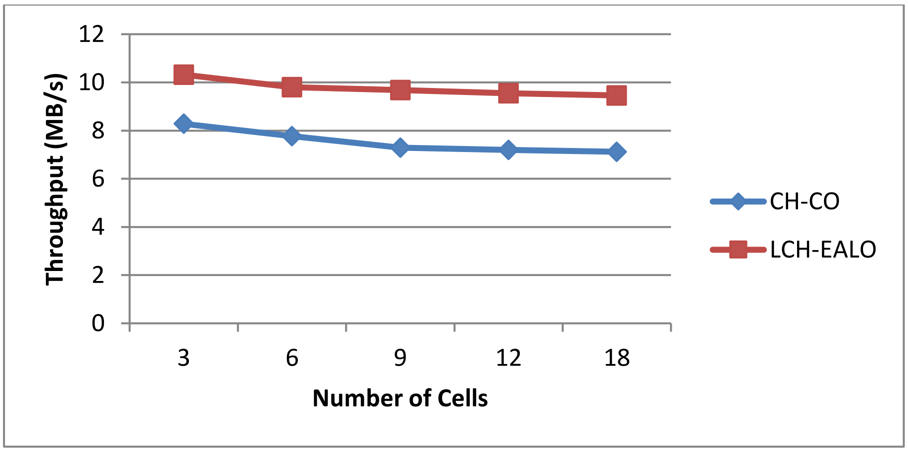

Fig 8 Throughput for Cells

Table 9 and Figure 8 show the results of throughput for varying the cells. It can be seen that the throughput of LCHEALO is 28% higher than CHCO technique.

5. Conclusion

In this paper, we have proposed a low latency and low cost optimized handoff technique in 5G network. In this technique, Enhanced Ant Lion Optimizer (EALO) algorithm is used with ants and antlions as search agents. The fitness function of EALO is formed using the key performance indicator (KPI) function. The proposed LCH-EALO algorithm is implemented in NS2 and its performance is compared with CHCO technique in terms of HO delay, data delivery probability, HO cost and Throughput. Simulation results have shown that LCH-EALO attains reduced HO delay and HO cost with increased throughput.

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