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Leader-Bird Selection for Energy Optimization for Device-to-Device Communication in 5G Networks

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ABSTRACT:

With the advancement of technology, more and more user devicesare being added to communication networks every day. Although with the introduction of 5G technology more devices can communicate in a network, westill require a method to efficiently distribute energy and signals throughoutthe network. To manage this immense load of devices optimization algorithms, need to be developed. To this end, we propose a Leader-Bird Selection for Energy Optimization algorithm for device-to-device communication in 5G networks. In our algorithm, we select one device with a high amount of energyand signal capacity as the leader. This leader can sustain other devices connectedto it. When this first leader loses its strength a second leader is chosenbased on its proximity and signal strength. We observed a decrease in overconsumption by 20 % and an increase in the throughput by 55 Mbps. The energy also remained constant throughout all the devices in the device- to evice communication. Our algorithm can be used to improve the energy efficiency of the device- to device communications in 5Gnetworks

Keywords: *-Device to device Nature-inspired algorithm Bird-swarm 5G networks*

I. INTRODUCTION

We propose a novel Leader-Bird Selectionfor Energy Optimization (LBS- EO) algorithm that optimizes device-to-device communications. This algorithm mimics the migrating behaviour of the birds. The birds when migrating choose one leader that leads the formation of the birds. For the purpose of our algorithm, we consider that this leader bird is decided on the basis of its strength.

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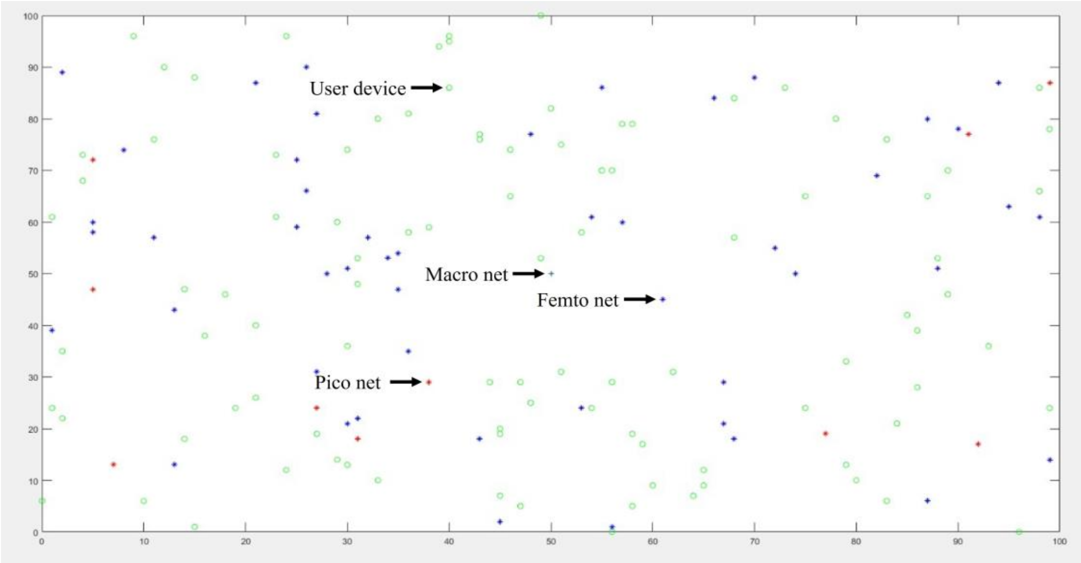

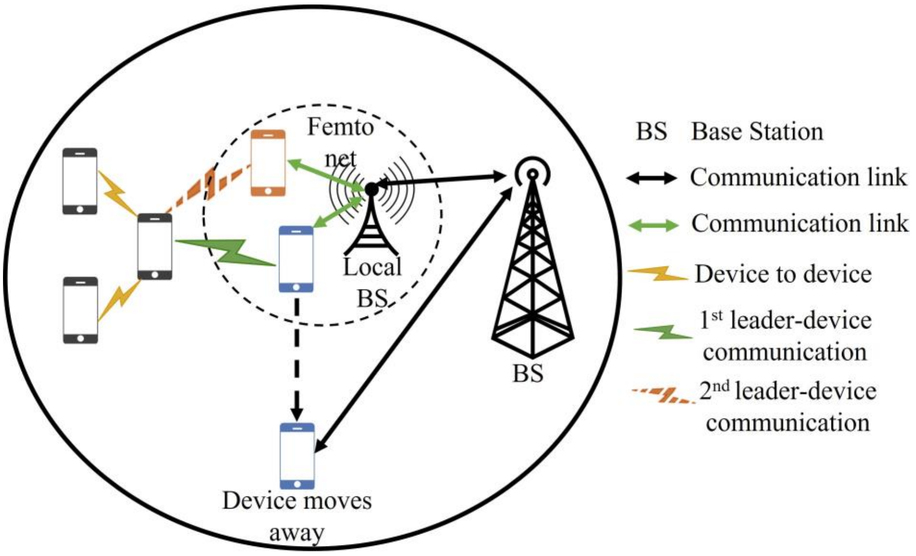

Fig. 1 Concept diagram of the proposed Leader-Bird Selection for Energy Optimization (LBS-EO) algorithm. The two devices denoted by orange and blue are inside a Femto net connected to a local base station connected to the main base station. Initially, since the blue device has higher signal strength and is in proper range the other device outside the Femto net connects to the base stations via that device. Thus, the strength of the outer devices depends upon the blue device. Eventually, the blue device moves out of range, and in this case, the outer devices choose the orange device as the leader as it is the next best device with good signal strength. Thus signal strength of all the devices is maintained

Fig. 2 A network architecture was developed using code in MATLAB. The architecture comprises user devices denoted by green circles and base stations of different subnetworks such as piconet, Femto net, and Macro nets. The piconet, Femto net, and macro net stations are given by red asterisks, blue asterisks, and black plus sign respectively.

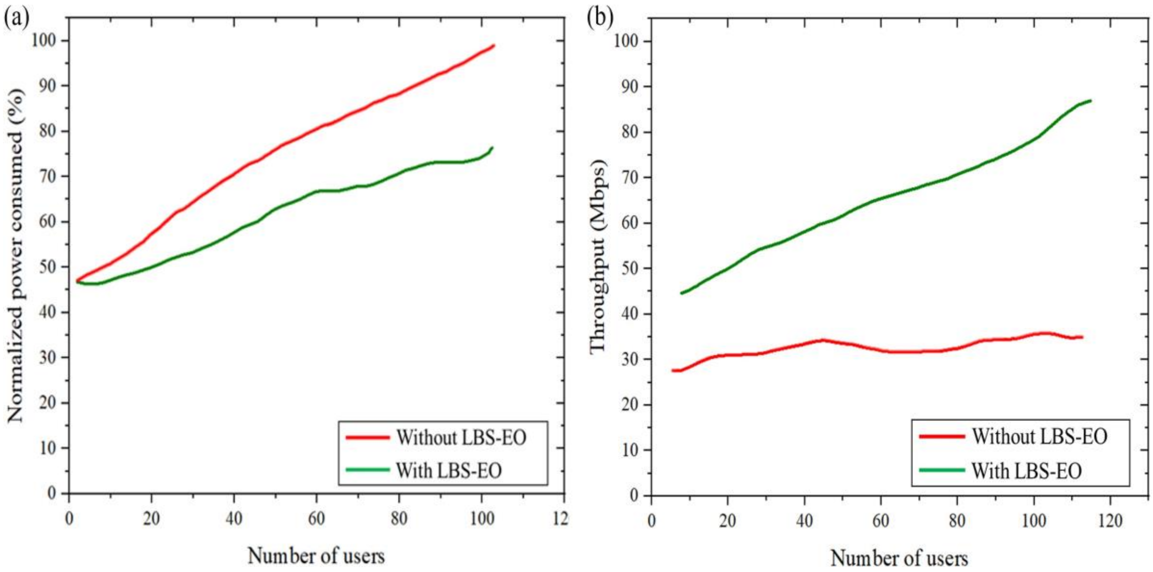

Fig. 3 (a) Graph of the number of users versus normalized power consumed in percentage throughout the network. It shows a comparison in power consumption in the network with and without our proposed algorithm, LBS-EO. It is observed that with our proposed algorithm the power consumption decreased by almost 20 %. (b) Graph of the number of users versus throughput in Megabits per second (Mbps). The throughput of the network increased by almost 55 Mbps when LBS-EO was applied to it as compared to when the network was without LBS-EO**.**

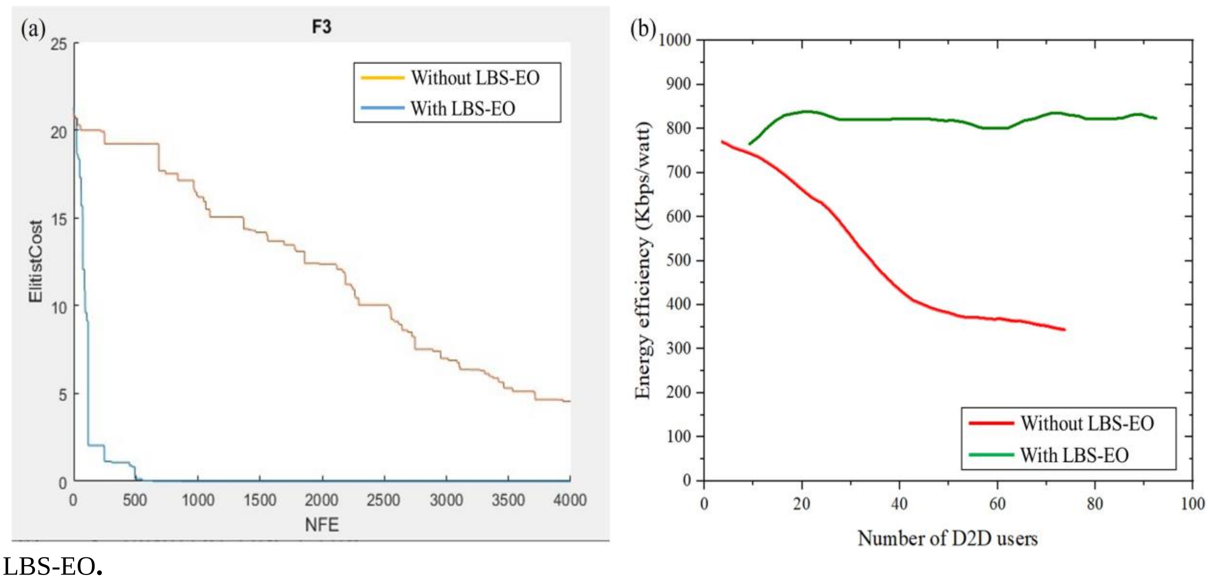

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Fig. 4 (a) The graph number of finite elements versus network cost. The number of finite elements stands for the number of network devices. It can be observed that with the application of our proposed algorithm, LBS-EO, the overall cost of the network has dropped significantly. (b) The graph of the number of d2d users versus energy efficiency in Kilobits per second per watt (Kbps/watt). When LBS-EO was applied to the network the energy efficiency is seen to be constant at around 800 Kbps/watt for all the devices in the network but without our algorithm, the energy efficiency drops steadily as the number of devices increases.

To better illustrate the algorithm, imagine that there are 2 devices (birds) A and B connected to a leader device C. Device C is chosen as the leader because it could be connected to the strongest base station. There could be a few devices connected to devices A and B that are in turn connected to devise C creating a shape the migrating birds make as shown in Fig. 1. Now, if device C which is the leader, moves away from the current network and loses it strength or its battery goes down the signal strength of all devicesconnected to it goes down. Then the other device A and B start searching for a new leader. In this time, if a new device D with better signal strength than A and B comes into the network then all devices connect to that and consider that device as the leader. Eventually, the strength of either A or B will match or increase that of the new device D and this will again cause a change in leadership for the devices closest to the strong device. This ensures that the receiving signal strength and the communication range of the devices always stay maintained.

Switching of leader devices also causes the path of transmission to change. Device C could be connected to a base station in one network and device Dcould be connected to another. This will cause a change in the path so that the signal strength is always maintained.

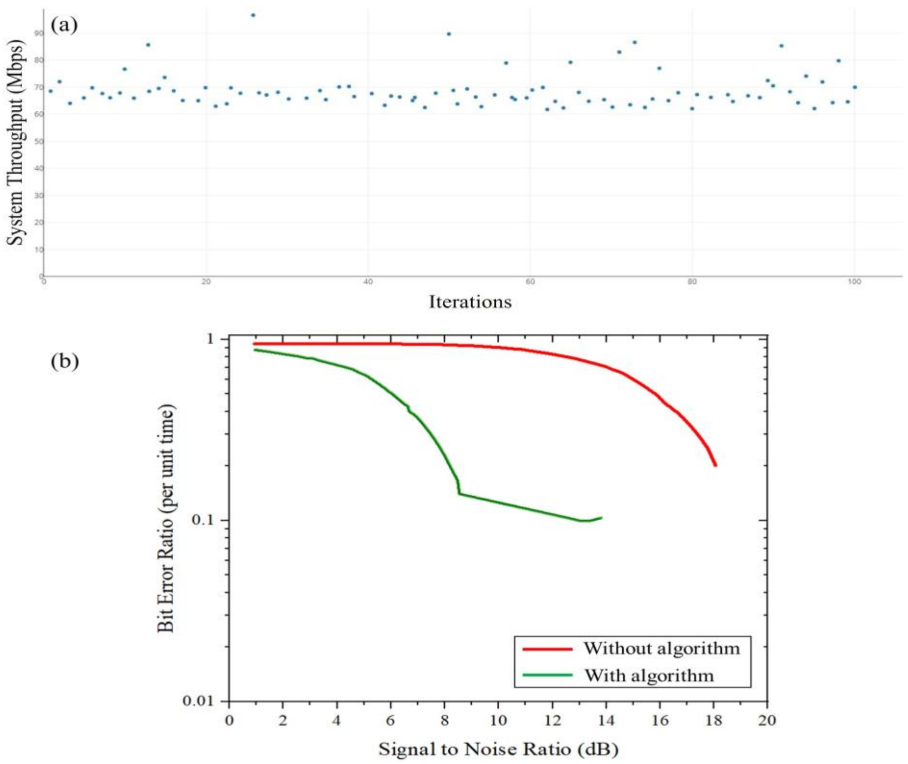

Fig. 5 (a) The graph of system throughput versus the number of iterations. It can be seen that over the 100 iterations, the throughput of the system remained well above 60 Mbps and was fairly constant around 70 Mbps.

(b) Graph of Bit Error Rate versus Signal to Noise Ratio. It is observed from the graph that when our proposed LBS-EO has applied to the network the graph for BER versus SNR reduces.

II. LITERATURE REVIEW

Huynh et al. [2] proposed a method that conserves energy during device-to-device communication. They developed an algorithm based on the Adaptive Genetic Algorithm. Their method aimed to maintain the QoS of the transmission while also conserving the energy. Vlachos et al. [7] have proposed an algorithm based on the genetic algorithm that stays aware of any interferences in the communication and allocates resources. Benbraika et al. [1] have proposed a novel bee-life optimization algorithm that tackles the problem of resource allocation due to the decreasing battery life of devices in a network. Mishra et al. [4] have developed an algorithm to increase the connecting range between devices in Device to Device (D2D) communication and also maintain the throughput. They proposed a two-part scheme where they first create an interference matrix and then use the particle swarm optimization al- algorithm. Using this they were able to reduce the interference, improve resourceallocation and thus increase bandwidth up to 2000 Kbps.

Tan et al. [6] proposed a refined particle swarm and genetic optimization algorithm to allocate devices to resource blocks n D2D communications, efficiently. The genetic algorithm could converge to the optimal path in 200 generations. the system capacity of the particle swarm optimization and genetic algorithm were 0.6 and 2 devices better than their previous algorithm called simple particle swarm optimization.

Sun et al. [5] proposed a hybrid algorithm with genetic plus particle swarm optimization along with an interference avoidance algorithm. The bio-inspired al- algorithms were used to do efficient resource allocation in D2D communication. They observed that their avoidance algorithm was able to reduce the interference by 2dB.

From the literature survey, we saw that nature-inspired algorithms were applied for device-to-device communications in 5G networks by very few studies. Nature-based algorithms such as bee-swarming, dragonfly, and ant colony have proven to work efficiently for 5G resource allocation. The nature-inspired algorithms have also proven to improve device-to-device communications in Long Term Evolution (LTE) networks. Our proposed algorithm provides a novel method that uses nature-inspired algorithms to achieve device to device in for optimization of 5G communication networks.

III. METHODOLOGY

One of the methods developed by Meng et al. [3] as a part of the bird-swarm optimization algorithm was based on the migrating behaviour of birds. In this, the birds were divided into two parts: producers and borrowers. The producersare those birds that have high amounts of energy reserves or the ones that find food patches to feed on when they arrive at new locations. While the borrowers simply borrow energy from the producers or feed from the food patches found by the producers rather than finding their own. The producers are always at the lead while the borrowers remain at the back. Depending upon the energy reserves the birds keep changing positions.

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The mathematical equation to denote the behavior of the producers is given by Equation 1.

$$a_{i,j}^{x+1} = a_{i,j}^{x} + rand\,[n(0,1)] \times a_{i,j}^{x} \quad (1)$$

The mathematical equation to denote the behavior of the borrowers is given by Equation 2.

$$a_{i,j}^{x+1} = a_{i,j}^{x} + \left(a_{t,j}^{x} - a_{i,j}^{x}\right) \times A \times rand\,(0,1) \quad (2)$$

Where, $t \in 1,2,3 \ldots N$ and $t \neq i$ Also, $A \in [0,2]$ this denotes that theborrowers follow the producers in serach of energy reserves.

Our algorithm takes inspiration from the bird-swarm optimization algorithm to develop a LBS-EanO algorithm. The modification in our algorithm is that there are multiple swarms spread across a network and each swarm has one leader bird that looks for new food resources and thus has the highest energy reserve. The rest of the birds in the swarm feed from the energy of the leader bird. When the position of the leader bird changes of its energy reserves depletes then the rest of the swarm changes its leader bird to another one. In our proposed LBS-EO the selection criteria for the 2nd leader-bird were based on the proximity to the neighbouring devices and the signal strength of the device. When the 1st leader bird decreased in signal strength the devices connected to that looked for another device that was well within range and had a similar signal strength to sustain their communication. The threshold for leader switching was 50 % than that of the first leader bird. If the range and signal strength of the device fell within 50 % of the first then it was chosen as the new leader. Also, the selection criteria to begin D2D communication depended on the Bit Error Rate (BER) between the device to base station communication. When the BER for D2D communication fell below the BER of the device to base station communication, the D2D communication was selected.

Figure 2 shows how a MATLAB code was used to create a network architecture. This architecture was used to deploy the proposed LBS-EO algorithm. The simulation was done in a 100 sq.m area with 1000 user devices, 100 Femtonets, 10 piconets, and 1 macro base station. The architecture is made up of user devices denoted by green circles and base stations from various subnet- works such as pico-net, Femtonet, and Macro net. Stations in the pico-net, Femtonet, and macro net are denoted by red asterisks, blue asterisks, and a black plus sign, respectively.

The network was designed by keeping all the parameters of 5G networks in mind. The values of all the parameters are listed in the table 1.

Table 1 The values of the different parameters considered while develop the optimization algorithm for 5G networks.

Systemparameters	Value
Higherfrequency	24to30GHz
Lowerfrequency	6GHz
Numberofpackets	5000
Sizeofpackets	32Bytes

Channelnoise	-20dBm
Channelbandwidth	40MHz
Devicebatterypower	5000mAh
Basestationpower	50dBm
Femtobasestationpower	24dBm
Receiverpower	-32dBm
Picobasestationpower	24dBm
Speedoftransmission	1ms

The transmission power for the small cells was considered to be 24 dBm. For the transmission towers, it was set to 50 dBm which is around 120 Watts and for the receiver station, it was -32 dBm which is around 1 micro-Watt. The equation for power consumption is given by Eq. 3.

$$P_{rx} = \frac{P_{tx}}{4\pi R^2}\frac{\lambda^2}{4\pi}G_{rx} \quad (3)$$

Where, $G_{rx}$is the receiver antenna gain.

In the 5G network, the speed of the Femtonet transmitters was set between 100 to 900 Mbps with a bandwidth of 24 to 54 GHz. For the piconets, the speed was 1 Gbps and the bandwidth was 24 to 47 GHz. The network considers all the predefined standards of 5G New Radio (NR) and Ultra-Reliable Low Latency Communication (URLLC). In our network, for transmission, we used three error control codes namely, turbo, low-density parity check, and polar codes. In our network the Frequency Range (FR) 1 was 410 MHz and could increase up to 7125 MHz and the slot duration was 1, 0.5, 0.25 for 15, 30, 60 kHz subcarrier spacing respectively. The FR2 was set to 24250 MHz going up to 52600 MHz and the slot duration was between 0.25 to 0.625 for 240 kHz subcarrier spacing. Also, 190 MHz was the distance between the uplink and downlink for lower bands, and for extended bands it was decreased to 30 MHz For 15 kHz, the length of the cyclic prefix was 4.7 microseconds and for 240 kHz t was 0.29 microseconds.

IV. RESULTS AND DISCUSSIONS

Figure 3 (a) shows a graph depicting the number of users versus the normalized power consumed in percentage across the network. It depicts a comparison of network power consumption with and without our proposed algorithm, LBS- EO. From the graph, we can observe that our proposed algorithm reduces power consumption by nearly 20 %.

Figure 3 (b) depicts the graph of the number of users in relation to throughput in Megabits per second (Mbps). When LBS-EO was applied to the network, its throughput increased by nearly 55 Mbps when compared to when it was not.

Figure 4 (a) shows a graph depicting the number of finite elements versus network cost. The total number of finite elements represents the total number of network devices. It can be seen that by implementing our proposed algorithm, LBS-EO, the overall cost of the network has been significantly reduced.

In Fig. 4 (b) we can see the graph depicting the number of d2d users in relation to energy efficiency in Kilobits per second per watt (Kbps/watt). When LBS-EO was applied to the network, the energy efficiency was found to be consistent at around 800 Kbps/watt for all network devices. However, in the absence of our algorithm, energy efficiency decreases steadily as the number of devices increases.

In Fig. 5 (a) we see the graph that shows the relationship between system throughput and the number of iterations. The system's throughput remained above 60 Mbps and was constant around 70 Mbps throughout the 100 iterations.

In the network with the proposed algorithm the jitter was seen to be 50 microseconds, the mean opinion score was 3.5, the Bit Error Rate (BER) was 0.00001 and the packet loss was 4.2 %. From Fig. 5 (b) we can see the graph of Signal to Noise (SNR) versus BER.

Nature-based algorithms are widely used for the optimization of 5G networks. As the scope for further improvement, these algorithms can be im- implemented with other types of optimization algorithms to achieve even more energy-efficient networks. Currently, in our work, we have applied our technique only for data transmission. The speeds for data and audio transmission are different. Audio transmission occurs at a slower pace and hence we are directly focused on data transmission. But in the future, the proposed algorithm can be tested with audio transmission as the main focus. Moreover, with the release of Sixth-Generation (6G) bands, these optimization algorithms can slowly be tested out on 6G networks are well to optimize them.

V. CONCLUSION

To cope with the increase in the load of user devices in the communication networks, we developed an energy optimization algorithm for the device-to-device communication in 5G networks. The algorithm was developed by taking inspiration from the bird-swarm optimization algorithm. We named our algorithm the Leader-Bird Selection for Energy Optimization algorithm as in this we chose a leader device that had the highest amount of energy reserves and could also sustain the other devices connected to it. Our proposed algorithm was able to decrease power consumption by 20 %, increase throughput by 55 Mbps, and maintain the energy across all the devices in the D2D communication We also saw a massive drop in the network cost. Our algorithm can beused for data transmission in D2D communications in 5G networks to improve energy efficiency.

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