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Hybrid Genetic Algorithm and African Buffalo Optimization (HGAABO) Based Scheduling in ZigBee Network

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Abstract

In Wireless sensor network (WSNs) unstable battery consumption is a major challenge to overcome these sensors should be active for a preferred duration so the network's lifetime should be essentially prolonged with less power consumption. While processing the data, the PAN coordinator transmits the beacon frame to its cluster coordinators and the sensor nodes receive the beacon frames from cluster coordinates periodically. During this process collision occurs, it results in poor performance. Various meta-heuristic optimization techniques have been proposed to resolve the optimization problems. The aim of this paper is to analysis the performance of mobility models in IEEE 802.15.4 ZigBee MAC using NS2.34.The proposed method HGAABO is a hybrid new algorithm that combines the genetic algorithm (GA) and African Buffalo Optimization (ABO) to optimize the path selection in the network. The main conclusions of this research include two parameters that were energy and delay. The algorithm is used to identify a set of routes that can satisfy the delay constraints and then select a reasonably good route through the proposed algorithm. The proposed approach is compared against the original GA and GWO on problems in terms of a set of performance metrics. The simulation results showed that the proposed approach demonstrated a better performance than the compared algorithms.

Keywords: African Buffalo Optimization, Genetic algorithm, Wireless sensors, Zigbee protocol.

INTRODUCTION

Wireless sensor networks (WSNs) [1] are not reliable because of external interference and multipath transmission. In WSN sensor nodes have limitations with battery life, memory space, and limited computing capability. To create a wireless sensor network more energy efficient, metaheuristic algorithms [17] has been used to resolve many optimization issues in WSNs. The need for the development of more efficient search optimization techniques led to the design of heuristics and metaheuristic algorithms. Two important features for metaheuristic algorithm are their abilities to make use of global search mechanism and local mechanism in course of a search. Energy usage is the indicator of network lifetime [3]. Collisions may occur during packet transmission leads to a time overlap between packet receptions. The problems of packet collision are packet loss, packet retransmission, decreasing throughput, increased delay/latency and increased wasted energy consumption. A MAC protocol based on IEEE 802.15.4 [14] was developed to solve the packet collision problem.

The GA and Grey Wolf Optimization (GWO) algorithms exposed several flaws ranging from early meeting complicates

fitness function, the use of several parameters [2], and complex implementation strategies [4]. These issues tend in the development of the African Buffalo Optimization algorithm (ABO) [20]. In targeting applications, the IEEE 802.15.4 is selected as standard protocol due to its effectiveness in on-going real time data flow. It is selected because it provides energy efficient and improves the network lifetime. For real time guarantee the protocol's beacon mode is synchronized with the duty cycles and time slots to provide collision free transmissions. To avoid the collision problem, it is necessary to configure the power utilization in terms of scheduling of clusters. In addition to the collision and lifetime problems, this research focused on spatial reuse problems, which occurs at the condition "occurrence of collision due to multi node [24] transmission at simultaneously". Hence, for optimization and function evaluation the research is extended to apply the African Buffalo Optimization algorithm and compare the specifications with genetic algorithms.

This paper proposes a new meta-heuristic approach of Hybrid Genetic Algorithm and African Buffalo Optimization algorithm (HGAABO) to solving numerical and graph-based problem ABO is updated frequently with position of buffalo to solve the problem of pre-mature convergence or stagnation and in the case where the best buffalo location is not improved in a number of iterations, the entire herd is re-initialized. Tracking the best position and speed of each buffalo ensures sufficient exploitation of the search space and into the occurrence of other buffalos as well as that of the best buffalo enables the ABO to achieve adequate exploration where ABO provides quick meeting with its use of very few parameters. Genetic algorithm (GA) [18], [24] is one of the most popular methods. the proposed algorithm is more effective in terms of node lifespan and packet delivery ratio.

The remainder of this paper is organized as follows. Section 2 gives literature review of existing approaches In section 3, the problem is stated by comparing the survey. In section 4, the methodology chapter is discussed with traditional genetic algorithm and African buffalo optimization algorithm as proposed design. The detailed implementation of the GA AND ABO method will be explained in Section 5. In Section 6 the experimental results and discussions of the proposed approach are presented. Finally, the conclusions are summarized in Section 6.

LITERATURE REVIEW

In a multi-hop fashion, the position of the PAN coordinator has several performance impacts, hence, it affects the network energy for both topology formation and data routing. So, it is necessary to develop the efficient self-configuring, self-managing and self-regulating protocols for the election of the node. The node coordinating and managing the IEEE 802.15.4/ZigBee [15] wireless sensor network is still an open Election (PANEL) to self-configure IEEE 802.15.4/ZigBee by electing a suitable PAN coordinator in a distributed way. Ahmed et al., (2016) compared a performance evaluation between IEEE 802.11 and IEEE 802.15 zigbee Medium Access Control (MAC) protocol. They have analyzed the mobility of Reference Point Group Mobility Model (RPGM), Random Way Point Mobility Model, Freeway Mobility Model and City Section Mobility Model. For simulation, Network Simulator (NS-2) [37] is used, the simulation made with a specification of 25 mobile nodes and 10sec to 80 sec with total simulation time of 100 sec. They have made various performance metrics like throughput, end to end delay, and packet delivery ratio and data loss.

Hassan and et.ll [10] proposed a combination of genetic algorithms (GA) and African Buffalo Optimization algorithm in WSN for extended energy and lees delay in networks. The major algorithms include Elishet.al achieved the prediction accuracy in software maintenance by using the Tree Net model using stochastic gradient boosting. Shi Y. and R. Eberhart discussed a modified particle swarm optimizer. Khanafer et al., (2014) [13] made a survey about beacon-enabled IEEE 802.15.4 MAC protocols, to improve a diverse field of applications. The book representing the performance analysis of the IEEE 802.15.4 MAC layer with its applications are mentioned by Palattella et al., (2014) [9], [14]. In a multi-hop fashion, the position of the PAN coordinator has several performance impact, hence, it affects the network energy for both topology formation and data routing. So, it is necessary to develop the efficient self-configuring, self-managing and self-regulating protocols for the election of the node. The node coordinating and managing the IEEE 802.15.4/ZigBee. Hence, cuomo et al., (2013) [17],[19] proposed a standard-compliant procedure named as PAN coordinator ELection (PANEL) to self-configure IEEE 802.15.4/ZigBee by electing a suitable PAN coordinator in a distributed way.

In addition to that the proposed algorithms balance the trade-off between the aggregated data and interference. Ding et al., (2013) made a new traffic scheduling algorithm for real-time (Industrial applications) data transmission through guaranteed time slots (GTSs). It concentrates on time-critical industrial periodic messages and determines the values of network and node parameters for GTS. Based on the network traffic conditions it provide guarantee requirement in terms of tens to hundreds of milliseconds. It improves the scalability and energy efficient of network. The Collision Free Multichannel Superframe Scheduling (CFSS) has proposed by Jin et al., (2014) for IEEE 802.15.4 cluster–tree networks.

PROBLEM STATEMENT

The energy conservation is one of the main challenge, in IEEE 802.15.4 nodes the lifetime of nods is directly depends upon the energy consumption. The prevailing literatures are not supposed to provide a solution to both power efficient and co-channel interference. In some cases, the delay and reliability is addressed separately. From the survey it is analyzed that various methods are used for scheduling. Since, the problem is exists in any one of the form such as by reframing the scheduling it lacks in flexibility, in another case if number of nodes or devices interfaced with single standard protocol, it results in interference. Likewise delay is the major factor due to the fixed number of formats, while deploying the nodes in randomly the coverage problem also exists due to lagging in distance. In default 802.15.4 standard, there is only one type of Guaranteed Time Slots (GTS). If an end device requests GTS, then the coordinator checks whether it has GTS resource or not. If it has resource then it allocates the requested size of GTSs to the corresponding end device. In rare cases, the end device only has a small data packet to send that may result in under-utilization of Contention Free Period (CFP). In order to overcome these issues it is necessary to construct cluster-tree and propose a new scheduling algorithm that overcome both energy and bandwidth utilization issues.

METHODOLOGY

The IEEE 802.15.4/ Zigbee protocol is selected as standard protocol due to its effectiveness in on-going real time data flow. The wireless sensors are deployed in the chosen region according to the area of interest so that it can continue sensing for a long duration. The African Buffalo Optimization is, therefore, an attempt to complement the existing algorithms with the aim of solving some of the perceived weaknesses of the earlier algorithms, especially the problems of delay and inefficiency. In the proposed approach, genetic algorithm (GA) was adopted to generate the diversified initial positions. This algorithm combines the advantages of both GA and ABO algorithms.

A. Genetic Algorithm

Genetic Algorithm (GA) is a search-based optimization technique based on the principles of Genetics and Natural Selection. A Genetic Algorithm is a biological system proposed in Charles Darwin's evolution theory. It is a high level simulation. The GA starts with a set of solutions (represented by chromosomes) called population. This process is repeated until some condition is satisfied such as achievement of best solution. Hence the population is improved over generations to accomplish the best solution. The GA uses three main cycles at each step to create new population. The operator selects the individuals in the population called parents to contribute in the next generation is shown in the Fig 1. Crossover combines two parents to form children for the next generation. Mutation helps in randomization of individual parents to form children.

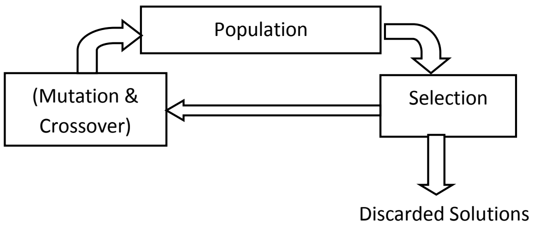

Figure. 1: Genetic Algorithm Evolutionary Cycle

1. Start: Generate random population of n chromosomes strings
2. Evaluate the fitness f(x) of each chromosome x in the entire solution space.
3. Create a new population by repeating following steps until the new population is complete
4. Select two parent chromosomes (strings) from a population according to their fitness (the better fitness, the bigger chance to be selected)
5. With a crossover probability cross over the parents to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents.(tree Construction, power configuration)
6. With a mutation probability mutate new offspring at each locus (GTS).
7. Place new offspring in a new population (valid tree construction)
8. Use new generated population for a further run of algorithm
9. If the end condition is satisfied, stop, and return the best solution in current population
10. Go to step 2

Figure. 2: Algorithm for Genetic Algorithm

The above are general steps implemented when using GA algorithms first it generate a random initial population and create the new population by applying the selection operators to select pairs. The number of pairs will be the population size divided by two, so the population size will remain constant between generations. By applying the crossover operator to the pairs of the s of new population and apply the mutation operator to each pair in the new population. Suppose if the selection is not fitted than the go to step two processes.

The reproduction selects the two chromosomes and combines them with characteristics of strings. In normal this implementation the genetic algorithm uses weighted roulette wheel method to select the chromosome strings with better fitness. The mutation process is considered with a random perturbation to reproduce the strings. The value which is chosen randomly out of $\omega_{ij}s, PW_i s, BI_k s, SD_k s, and\ GTS_k^i s$ and modify these process with a randomly generated value.

Step 1: Valid tree Construction represents in $\omega_{ij}s, 1 \le i \le m, 1 \le j \le m$ to represent a valid tree

Step 2: Each node has a parent node N_i, and formulated as $\sum_{j-1}^{m} w_{ji} \le 1, \forall_i \in \{1,2,..,m\}$

Step 3: Add up all the child nodes for all nodes, it should be always *m-1*,it is formulated as

$$\sum_{i-1}^{m}\sum_{j-1}^{m}\omega_{ij} = m-1$$

Step 4: represent the obvious constant as,$\omega_{ii} = 0, \forall_i \in \{1,2,\dots,m\}$.

Step 5: Valid Power Configuration for packets to transmitted packets.

$$RF(PW_i) \ge RF_{recv}^{min} + 10_\gamma \log_{10}\big(max_{1\le j\le m}\big(\omega_{ij} + \omega_{ji}\big).d_{ij}\big) + C, \forall_i \epsilon \{1,2,\dots m\}$$

Step 6: Valid duty cycle Scheduling, by Cheikhrouhou et al. (2010) algorithm works for the example set of (BIk, SDk)s for six clusters, i.e.,

$$\{cluster_1(16,4), cluster_2(8,1), cluster_3(16,2), cluster_4(32,1),\ cluster_5(32,4), cluster_6(16,2)\}$$

Step 7: Determine the end-to-end deadline guarantee

Figure. 3: Formulation of the Constraints for Optimization

In order to solve the min max problem, the valid tree construction, end-to-end deadline guarantee and valid duty cycle scheduling is to be considered. To manage the high complexity of optimization problem shown in 3, genetic algorithm is considered. Initially, the chromosome is represented with fitness function. Chromosome string represents the possible solution for optimization problem. It is shown in the figure 3; it is a complete set of all parameters of cluster tree construction. Then the fitness function is evaluated with a quality of each solution.

B. African Buffalo Optimization

African Buffalo Optimization (A.B.O) is a simulation of the alert ('*maaa*') and alarm ('*waaa*') calls of African buffalos in their foraging assignments. The *waaa* calls is used to warn the buffalos of the presence of predators, ward off an approaching inferior, assert dominance or express the lack of pastures in a particular area and therefore urge the herd to move on to safer or more rewarding areas (exploration). Whenever this call is made, the animals are asked to be alert and to seek a safer or better grazing field. The *maaa* calls is used to encourage the buffalos to be relaxed as there are good grazing fields around, reassure an inferior and to express satisfaction about the amount of pastures cum favorable grazing atmosphere at a particular location (exploitation). With these sounds, the buffalos are able to optimize their search for food source. The ABO is a population-based algorithm in which individual buffalos work together to solve a given problem. Using the waaa (move on) signal or the maaa (hang around) signal, the animals are able to obtain amazing solutions in their exploration and exploitation of the search space.

This study is an attempt to develop a robust, fast, efficient, effective, yet simple-to-implement algorithm that has enormous capacity to explore and exploit the search space by simulating the communicative and coopertaive characteristics of the African buffalos in their search for solutions. It solves the problem of premature convergence by regularly monitoring and updating the location of the best buffalo in the herd. In a situation where the best buffalo is not updating in a given number of iteration, the entire herd is re-initialized. This helps to ensure adequate exploration. The problem of slow speed is handled with the African Buffalo Optimization's use of very few parameters, primarily the learning parameters (lp1 and lp2). The issue of adequate exploration and exploitation of the solution space is further enhanced with the democratic equation where the animals regularly communicate with one another.

The algorithm starts by initializing the population of buffalos with the function f(x). The location allocation is random within the N-dimensional space for each buffalo. After allocating, it updates the buffalo's fitness separately within the search space. The following two factors vary based on the fitness value, if the fitness is better than the individual buffalo's maximum fitness (bpmax), it saves the location vector for the particular buffalo. In another case, if the fitness is better than the herd's overall maximum, it saves it as the herd's maximum (bgmax). After completing all process the algorithm m updating for the best buffalo. If it is updating, then it moves on to validate the stopping criteria. Finally, if our global best fitness meets termination criteria, it gives the location vector as the solution to the given problem. The ABO algorithm is shown is Figure 5.

Step1. Objective function f(x) $x=(x_1, x_2, \ldots\ldots\ldots x_n)^T$

Step2. Initialization: randomly place buffalos to nodes at the solution space;

Step3. Update the buffalos fitness values by following equation

$W.k+1 = w._k + lpr_1(bg_{maxt.k} - m._k) + lpr_2(bp_{max.k} - m._k)$

Where $w._k$ and $m._k$ represents the exploration and exploitation moves respectively of the k^{th}buffalo (k=1, 2…N); lp1and lp_2 are learning factors; r_1 and r_2 are random numbers between [0, 1];

$bg_{max\ is}$ the herd's best fitness and $bp_{max,}$ the individual buffalo's best

Step4. Update the location of buffalo k in relation to $bp_{max.k}$ and $bg_{max.k}$ using $m._k+1 = \lambda\ (w._k + m._k)$. Where 'λ' is a unit of time

Step5. Check $bg_{max}$is updating or not. If yes, go to 6. else, go to 2

Step6. If the stopping criteria is not met, go back to algorithm step 3

Step7. Output best solution.

Figure. 5: African Buffalo Optimization Algorithm Based Clustering

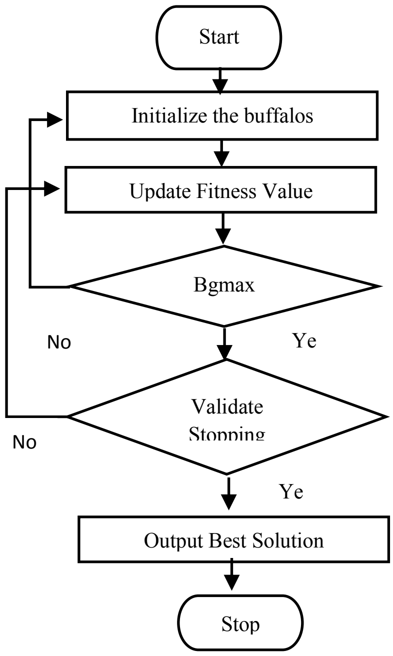

Figure. 6: Basic Flow of the ABO

It is observed that the algorithm's movement has three parts as shown in figure 4. Initially 'w.k '' represents the memory of the buffalos past location. A list of solutions represents the memory of each buffalo that can be used as an alternative for the current local maximum location. There is a probability of choosing one of the target list of solutions of the buffalo's memory instead of the present herd's maximum point.

Secondly lp1r1 (bgmaxt.k – m.k) is concerned with the Cooperative part of the buffalos and is a pointer to the buffalo's social and information-sharing experience. Finally the third part lp2r2 (bpmax.k – m.k) indicates the intelligence part of the buffalos. Hence the ABO exploits the memory and efficient caring capabilities of the buffalos in arriving at solutions.

PROPOSED HYBRID GENETIC ALGORITHM AND AFRICAN BUFFALO OPTIMIZATION (HGAABO) ALGORIHTM

The genetic Algorithm is used to solve energy problem that shown in Ahmadi scheme. This research proposed a hybrid algorithm to solve the GA problems where the GA consumes a high amount of time to get a best solution also stuck in local optima. The ABO is a response to generate the population and find out the initial solution. The GA selects two solutions from an initial solution that comes from ABO. Then, it performs the crossover and mutation process till produce the best solution for GA algorithm. Next, ABO checks the state of the solution based on the fitness. Then, it will update position of buffalos and checks the stopping criteria inorder to get an optimum solution. The steps for a proposed algorithm are given below.

Step 1: Initialization of Population is done randomly.

Buffaloes are placed at nodes in a random manner.

Step 2: Determine Fitness of population by the following equation

mk′=mk+lp1(bg – wk) + lp2(bp.k − wk) (1)

where

Lp1,lp2--learning factors

Bgmax--herd's best fitness

Bpmax--kindividual buffalo's best fitness

Wk mk--exploration and exploitation movement of kth buffalo

K=1, 2…., N.

Step 3: Repeat

Select parents from the population.

Perform Crossover on parents, creating a new population.

Perform Mutation on New population.

The ABO uses generated population to select the path based on energy of each node in the network represent as buffalo in ABO, as mentioned earlier the buffalo (node) has two types of sounds (messages) these messages are uses to indicate the energy level of each node in the networks. All nodes forward the information of energy to the source node (herd). There are different paths are discover from source to destination nodes. The fitness function of ABO evaluates the quality of paths then sorts them. Moreover, get an optimum solution from all possible solutions, the GA selects two best solutions from a list of solution that generated by ABO as parents. Thereafter perform the operation of GA (crossover and mutation), then select the best solution (path). Through this mechanism get an optimum path with less delay and highest energy level.

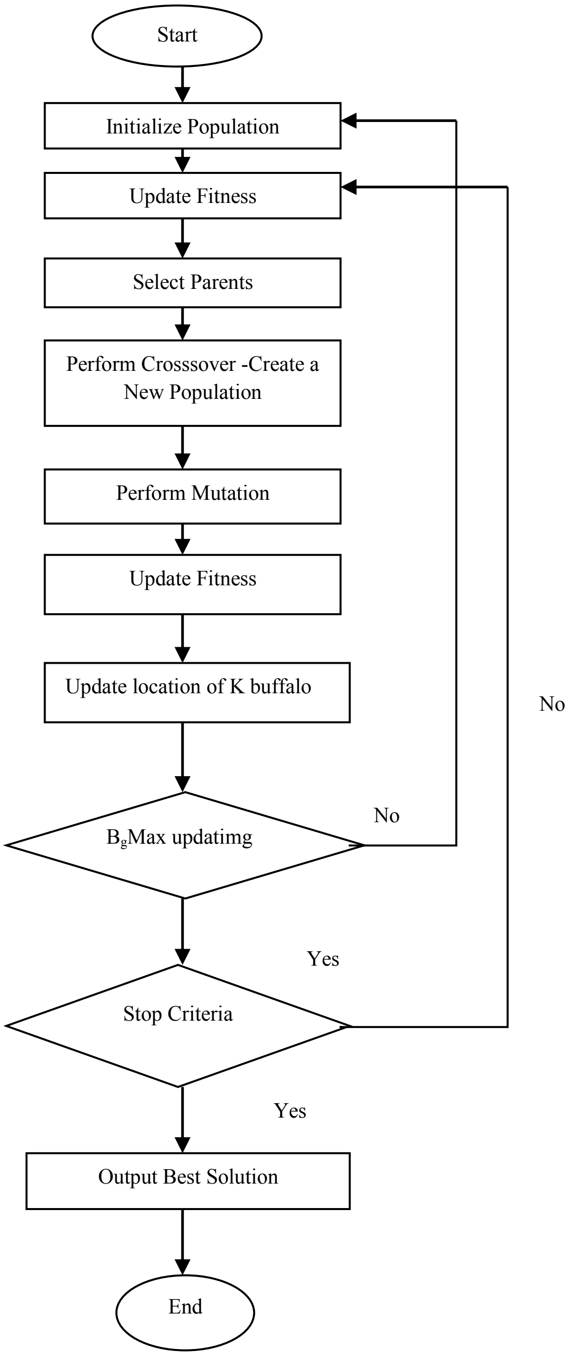

Figure. 7: Flow Chart of HGAABO Algorithm

SIMULATION RESULTS

Comparative experiments were performed between proposed HGAABO Algorithm and the other two competitive methods, including EGWO, GWO and GA, in order to evaluate the effectiveness of the proposed method for the prediction problems. The performance evaluation for Hybrid Genetic Algorithm and African Buffalo Optimization (HGAABO), genetic algorithm and African Buffalo Optimization algorithm is implemented in Network Simulator (NS-2).It evaluate the performance of frame format in IEEE 802.15.5 standard. The performance comparison is shown in table II, which made for genetic and grey wolf based approach on an IEEE 802.15.4 based cluster tree consists of 75 sensor nodes that are one hop away from a PAN coordinator (sink node). The area is about 200 x 200, with a transmission range of 14m, and its simulation time 400 seconds.

The initial energy is considered as 10 joule. To make an effective comparison the performance metrics such as end to end delay, throughput, packet delivery ratio, energy utilization factor are used to evaluate the performance of the proposed approach with traditional genetic algorithm. From the figure 8, the proposed HGAABO based algorithm attains 0.69% packet delivery ratio for 20 transmissions in the network, while genetic algorithm based scheduling attains 0.62% packet delivery ratio. Next analysis is based on delay with respect to the transmission nodes, the delay will increase when the number of transmission increases in the network. Figure 9 illustrates the end-to-end delay of real-time tasks over a number of time periods. The delay is a combination of Queuing Delay (QD), Processing Delay (PD), and Propagation Delay (PGD), it is represented as D= QD + PD+ PGD.

TABLE I

SIMULATION PARAMETERS

Parameter	Value
Area	200×200
Physical and MAC model	IEEE 802.15.4
Number of nodes	75
Transmission range	14 m
Simulation time	450s
Channel frequency	2.4 GHZ
Traffic type	CBR
Initial energy	10 joule
Transmission speed	250 kbps

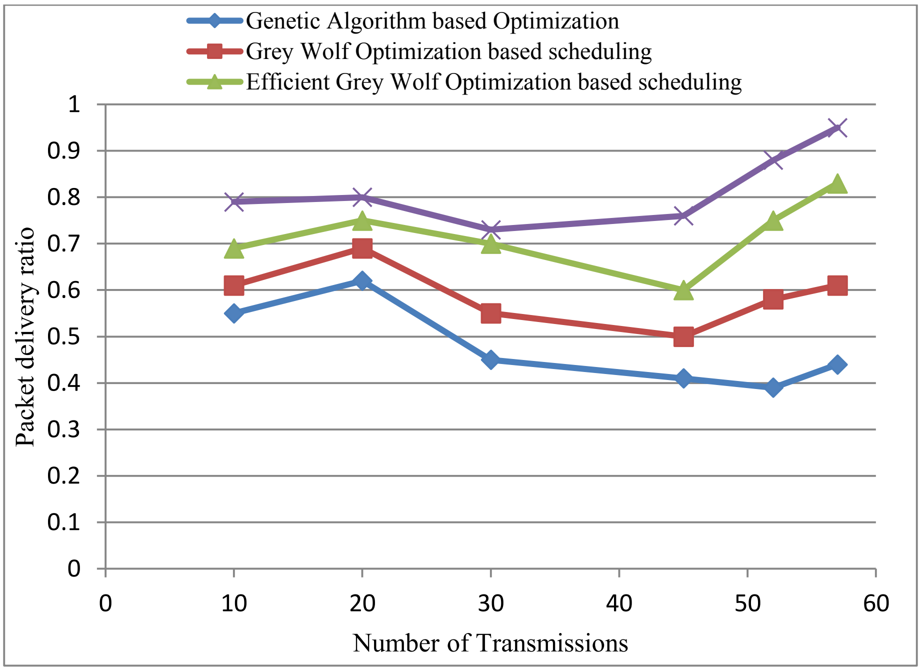

Figure. 8: Packet Delivery Ratios with Respect to Number of Transmissions

Figure 8 shows the packet delivery ratio (PDR): It is the ratio of the data delivered to the destination node to the packets transmitted by the source. The proposed approach HGAABO algorithm has a better result in PDR than other algorithms. It establishes a stable path based on less delay and highest energy between source and destination nodes. This minimizes the probability of link failure as well as packets loss.

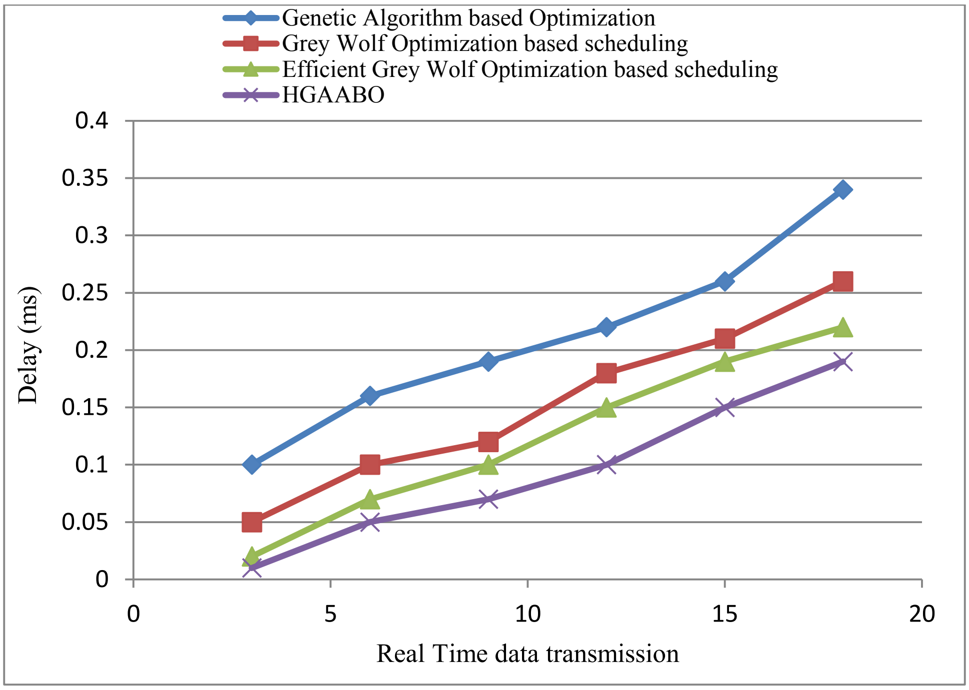

Figure. 9: Delay with Respect to Real Time Data Transmissions

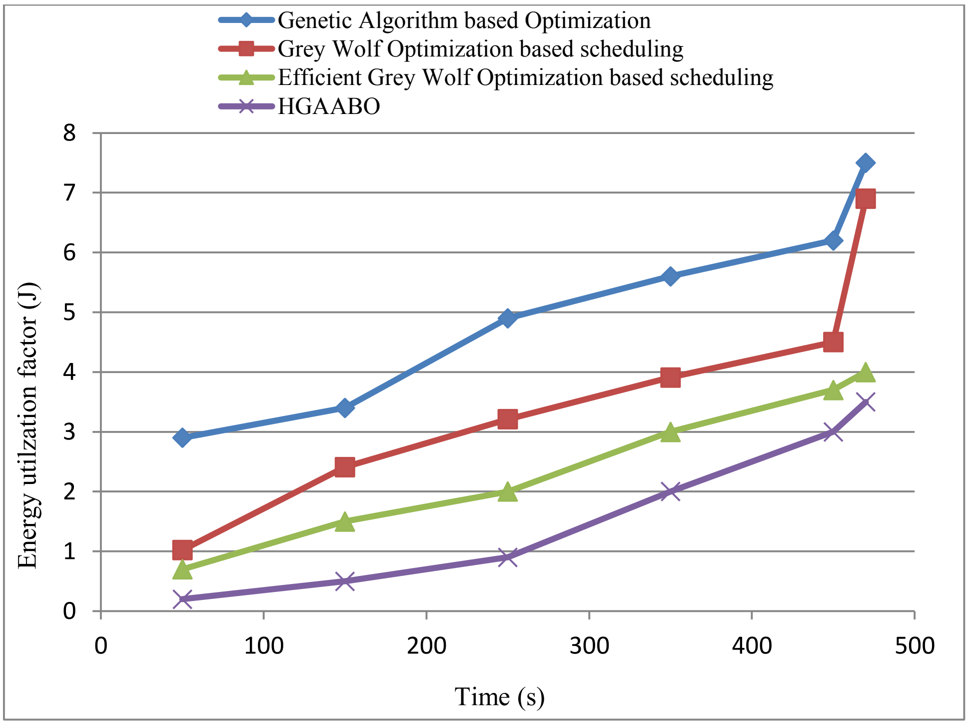

Figure. 10: Energy Utilization Factor with Respect to Time

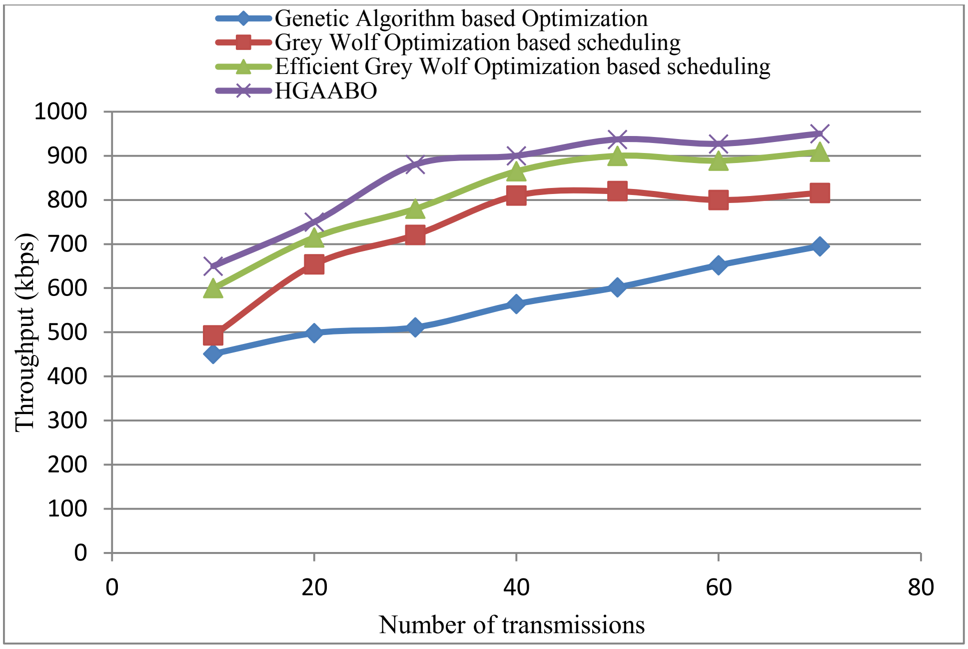

Figure. 11: Throughput with Respect to Number of Transmissions

Figure 9 depicts the End-to-end (E2E) delay: This metric represent the amount of time spent to transmit the data packet from source to destination. The proposed approach HGAABO algorithm is better by searching for the path from source to destination nodes relay on the minimum delay between the nodes.

The variations of energy consumption for different algorithms are presented in figure 7. It is defined as the amount of energy consumed by all nodes in the network in a given simulation time. If the node mobility increases the energy consumption also increases. Results clearly show that proposed approach HGAABO algorithm is better than other approach in term of energy consumption. Because once the protocol selects the best path, then, the same path will be used to transmit all packets. This path is highest energy level. Therefore, as the intermediate nodes will not perform route discovery and it need not have to waste its battery power.

Figure 9 shows the variation of average throughput (TP): The number of bytes that have been successfully received by the destination. While the node mobility increased the throughput decrease in routing protocols. The proposed approach HGAABO algorithm shows better throughput, as it selects the most active route to the destination. This route has less delay and more energy level than other routes; therefore the link is more stable which leads for fewer packets dropped. This, in turn, increases the throughput.

CONCLUSION

In this paper, IEEE802.15.4 ZigBee networks based on different mobility models are in demand of real time applications. The networks has been studied intensively and obtained the results by using various performance metrics like throughput, end to end delay, packet delivery ratio and data loss, then we compared between these networks. Hence, beacon mode is synchronized with the duty cycles and time slots to provide collision free transmissions. The collision problem is avoided by African buffalo algorithm. This paper proposed an HGAABO algorithm which satisfies energy and delay constraints and the simulation study shows that compared to existing methods, Even though with the extensively saving energy of the network. Our holistic optimization can guarantee to enhance the network lifetime as well as the E2E delay.

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