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Energy-aware and Bandwidth Allocation for Air Pollution Monitoring System using Data Analytics

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Abstract

The most debated phenomena of the 21st century which might change the global landscape for living organisms. The same phenomena could even threaten climate pattern. Because of this, the earth may experience a highly unstable natural disaster like flooding, cyclone, earthquake, tsunami, severe drought and inhabitant environment like the highly polluted atmosphere, intolerable rise in temperature, acid rain, etc, This issue is solved in this research work by the introduction of the technique referred to as the Air pollution monitoring system with Swarm Intelligence (CASI-CSA-IAFSA) that will do the clustering of sensor nodes and the assortment of sensor nodes. Then the aggregated data would transmit the optimal route to the base station designated employing the artificial fish swarm technique. The proposed research technique by the introduction of the strategy referred to as the bandwidth allocation aware Air pollution monitoring system with cuckoo and fish swarm approach (BA-APMS-CSFSO).

Keywords: Air pollution, Bandwidth allocation, optimal path, Energy, Cluster head selection, Cuckoo Search Algorithm (CSA), Distributed Wireless Sensor Cluster Algorithm (DWCA), Improved Artificial Swarm Optimization Algorithm (IASA)

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1. Introduction

Air pollution refers to the induction of particulates, biological molecules, or other dangerous materials into the atmosphere of Earth, leading to diseases, allergies, death in humans, harm to other living organisms like animals and food crops, or the natural or the environment that is built. Air pollution may emerge from sources that are either anthropogenic or natural. Air pollution is an outline of biological molecules, particulates or added harmful particles into allergies, death of humans, diseases, Earth's environment, and harmful living organisms like animals, natural or built-in surroundings, food crops. Air contamination appears from natural sources or anthropogenic.

•Air pollution monitoring can assist in understanding the behaviour of pollutants and their relation with the weather.

•Monitoring the data can be employed for validating the pollution modelling, which is deployed for testing the 'what if' scenarios.

•National and European law necessitates the monitoring of levels of pollution. The results could be utilized for making informed policy decisions.

•The general public can take advantage from the information that is easily available, accurate, and current over the air quality that they breathe.

After their emission, the air pollution behaviour is decided by the weather. Since the weather in this country is varying drastically, the behaviour of the pollution is also highly changing. This situation is further complicated by the atmospheric chemistry; pollutants have reaction with other gases present in the atmosphere and get deposited onto the surfaces like roads and buildings. Currently, the scientific comprehension of air effluence is not passable to be capable of exactly predicting the air eminence all through the country at all times. This is where the monitoring comes into use for filling the gap in having an understanding. Monitoring yields crude measurements of the concentrations of air pollutant that can afterwards be evaluated and understood. This data can thereafter find application in several means.

Evaluation of the monitoring data permits us in assessing how worst the air contamination is on a daily basis, which ranges are poorer compared to the rest and the rise and fall of levels. It can be observed the interaction of pollutants with one another and their relation with the levels of traffic or industrial activity. Through the analysis of the relation between meteorology and the quality of air, it can be predicted if the weather conditions will lead to pollution episodes. Another significant usage lies in the computer models validation. Models are deployed for testing the 'what if' scenarios. For instance, 'how much amount will the air quality improve in case traffic numbers are limited by 20%?' or 'what is the effect of constructing a power station close to a particular town?'. The accuracy with respect to these models can be tested by only through comparing with the real monitoring data. All this data can further be utilized by the Government for making informed policy decisions. The environmental policy is being updated constantly with the scientific research advancement.

The rise in awareness in the air quality problems has resulted in the demand increased for more precise and easily accessible information. The public who have concerns regarding pollution or having health issues that gets worsened by pollution can take advantage from such data. The current information obtained from monitoring sites all through the country can be relayed to the general public through television, tele text, exclusive help lines, or the Internet. Several laws at present need the government and local authorities to guarantee that air pollution does not go beyond particular legal limits. EC law determines the standards (referred to as Directives) for few pollutants and the national governments are required to monitor the air quality to indicate that the standards does not get exceeded. The National Air Quality Strategy of the Government makes the local authorities responsible for using the monitoring information for assessing the air quality for the purpose of showing that the Air Quality Standards will not exceed in their area by specific deadlines.

Wireless sensor network is the emerging area that is used in this research work for monitoring the air pollution in a better manner. In the research work proposed, a new framework is introduced that can effectively have the air pollutant values monitored employing the sensors which are equipped in various locations. The novel algorithm referred to as the bandwidth allocation aware Air pollution monitoring system with cuckoo and fish swarm approach can be helpful in identifying and transferring the air pollutant varying information to the base station, such that an immediate required action can be made to prevent the causes leading to air pollution.

The entire work proposed is systematized as charted: Segment 2 offers different earlier pertinent works. Section 3 discusses the proposed research technique with respect to accomplishing a secured and robust transmission of data which is collected as of from sensor nodes to base station. In section 4, the research work on an overall is assessed with respect of different performance measure values. Section 5 concludes the proposed research strategy.

2. Related Works

Wireless Sensor Network (WSN) is a dynamic area of investigation because of its rising significance in several solicitations that includes the monitoring of environment and habitation, health care purposes, traffic regulator and military linkage systems [1]. With the ground-breaking advancements of Micro-Electro-Mechanical Systems (MEMS) expertise's [2] in which sensors are getting compact and added diversified, WSN has abilities to different novel application regions in the awaiting imminent. A characteristic application of WSNs consists of observing, tracing, and adjusting. Few of the particular applications comprise of habitat monitoring, object tracing, nuclear reactor directing, fire finding, traffic observing, etc.

The earlier progress in WSN was chiefly influenced by military solicitations. But now, WSNs are employed in several civilian request areas for commercial and industrial usage, inclusive of environs and habitat observing, healthcare purposes, home mechanization, nuclear reactor regulatory, fire finding and traffic regulator [3]. This change from the utilization of WSN only in military purposes has received its motivation owing to the characteristics of WSNs that can be implemented in the forest regions, where they may stay for several eons, for monitoring few of the environmental variables, with no necessity of recharging/replacing their power supplies. Characteristics such as this assist in getting over the challenges and excessive expenses which are intricate in the observing of data by means of wired sensors. Following are few areas in which WSN have found successful deployment in the monitoring of the environment.

The Forest-Fires Surveillance System (FFSS) [4] was designed for preventing the forest fires in South Korean Highlands and also for having a prior fire-alarm in factual time. Then the scheme perceives the environment state like the temperature, humidity, smoke and decides the forest-fires risk-level through formula. There are always chances for earlier detection of heat and this permit for the provisioning of an early alarm in real time during the occurrence of the forest-fire, notifying the individuals to have forest-fires extinguished previously it spreads. This way, it saves on the economic damage and environmental harm. In a similar manner, a general purpose of WSN for the aid of flood recognition and avoidance is the alert scheme [5] implemented in the US. Rainfalls, water level and weather sensors are utilized in this method for the detection, prediction and therefore prevention of floods. These sensors provide data to a central database scheme in a pre-determined manner.

Wireless sensor networks could be utilized for controlling the environment involving the monitoring of air, soil, and water. Sensors are fitted all through the arena and these sensors create a system which interconnect with one another to range certain processing center finally that analyses the records which is directed and thereafter adjusts the environmental circumstances accordingly (e.g., in case the soil is very gasping, then the dispensation Centre sends indications which is recognized by the actuators and they can begin the smidgen scheme in accordance. Bio complexity mapping scheme aids in controlling the exterior situation. The sensors are useful in observing the spatial complexity of the plant species that are dominant [6]. An instance is the investigation done over the marine ground floor in which considerate the erosion procedures holds importance for the building of offshore wind ranches [7].

Exactitude agriculture is a rapidly evolving WSN application region for the monitoring and controlling of the quantity of pesticides which is extant in swallowing water, then do the monitoring of the degree of soil destruction and the degree of air contamination [8]. Exactitude agriculture considers various features like the observing of soil, crop and weather in a arena. Large quantities of sensor information from the large-scale agricultural arenas get produced often in a solicitation such as this. Issues related to the effects of human existence in the observation of plants and animals in the arena situations have been overcome by WSNs to a huge extent [9]. Now the sensors can be equipped before the breeding season starts and when the plants are in dormancy or the ground is icy and also on insignificant islets in which it is quite hazardous or not smart to have repeated attempts of meadow studies. Such kind of arrangement indicates a more substantial economical technique for carrying out studies than the conventional personnel-rich techniques in which where considerable portion of logistics and organization has to be dedicated to maintaining the arena studies, frequently with some uneasiness and sometimes at certain actual hazard. In [10], discussion over a smart sensor system for the use of air superiority monitoring purposes has been presented. The writers have proved that by making use of single-output artificial neural networks (ANNs) inherent issues of the cast-off sensors, multi-input, such as the enslavement over both the environment temperature and relative moisture can be resolved. Replicas for the concentrations of air contamination in the form of a purpose of the emission dissemination have also been examined in [11]. In [12], an auto-calibration technique for a vibrant gas sensor system for air pollution observing is introduced. It is shown from the imitation outcomes that by means of this technique a greater accurateness can be accomplished. Additional work on this can be seen in [13-17].

3. Proposed System Architecture

Air pollution monitoring system is the most necessary field in the real time world in which the atmospheric air is impacted by various pollutants which are emitted by various industries. There are different researches which have been carried out in the works already done by multiple authors with respect to the identification and resolution of the air pollution. One among the popular methodologies which can monitor the air pollutant varying behaviors well is the wireless sensor networks. In a wireless sensor networking environment, sensors will be equipped in several regions of the monitoring environment for the purpose of tracking the pollutant behaviour change.

The chief aim of WSN in air pollution monitoring system is the collection of the data from the sensors which are positioned in different areas, and then transmit it to the base station where immediate action will be taken for the respective air pollutant change in order to save the living organisms. The data collection and transfer in the wireless sensor network environment would result in different problems like limitation in resource, packet dropping, packet loss, intruder violation and so on and so forth. These challenges are overcome in this research work by the introduction of the new technique known as the bandwidth allocation aware Air pollution monitoring system with cuckoo and fish swarm approach. The entire flow of the newly introduced research technique is illustrated in the fig. 1.

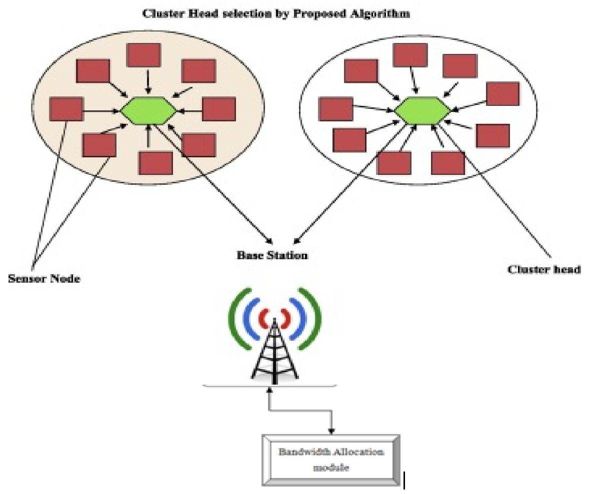

Figure 1. Proposed system Architecture

From the figure 1, it is evident that the research methodology proposed results in providing a better facts collection and transfer of information from the sensor nodes to the (BS) base station. The steps are followed in accomplishing a better air pollution monitoring system are as below:

- •Cluster formation and cluster head selection making use of cuckoo search algorithm
- •Data gathering and duplication aware aggregation
- •Computing the priority of the data that are forwarded to base station
- •Assign the necessary bandwidth to the data transmission path selected

By carrying out the steps which are listed above, a better and effective data transfer can be attained. The elaborate explanation of the novel research strategy is provided in the sub sections.

3.1 Cluster Head Selection and Formation using Cuckoo search algorithm

In the air pollution monitoring system proposed, wireless sensors are seen to be distributed in the environment scatter for monitoring and gathering of the information concerned about the air pollutant values. Those sensors distributed are clustered with one another for the purpose of reducing the overhead of data transfer between the sensor nodes which are located far from one another. The sensor nodes which are closes to one another, i.e. sensor nodes which are within the same region will be clustered together to make the data transmission process easy.

Once the clustering is done, the cluster head for each cluster would be selected with the right concern. This is carried out because, the cluster head holds the responsibility for collecting and transferring the information from the sensor nodes to the (BS) base station. At first, the clustering is carried out on the basis of the values of the transmission range. The sensor nodes would compute the transmission range of every one in its neighbourhood. The nodes falling within the transmission range of its neighbourhood sensor nodes would then be clustered together. The distance between the 'n' sensors from the base station, i.e., with the point is given in (1).

$$d_{ij}(n) = (x_i - x_n)^2 + (y_i - y_n)^2 \quad (1)$$

Thus, the transmission range is calculated by using the formula

$$T_r = \sqrt{\left({}^{(dn_d/dn_c)}/_{\text{coverage area}} \right)} \quad (2)$$

Where dn_d indicates the required node degree and dn_c refers to the current node degree and the coverage area equals to the area which is covered by the cluster.

$$dn_d = S + 1$$
$$S = \text{nodedensity} * d(C, N) \quad (3)$$

$$d\,(C, N) = \sqrt{\sum_{i=1}^{n} (N_i - C_i)^2} \quad (4)$$

C=cluster head, N-node.

At first, the node performs a check over the broadcast series of the neighbourhood nodes, if the neighbourhood is inside the broadcast range, then it broadcasts the ID beside with rest of the data to the neighbourhood nodes. After the clustering is done, the cluster head (CH) assortment is conducted grounded on the energy consumption. The node having a higher energy consumption would be designated as the (CH) cluster head. Cuckoo search algorithm is deployed for a better and optimal assortment of the cluster heads from the sensor nodes that are present in the cluster. The objective function that is to be the energy consumption is computed as follows: The total consumed energy E_t

$$E_t(s_i\,, d) = \begin{cases} s_i E + s_i \varepsilon_{fs} d^2, d \le d_0 \\ s_i E + s_i \varepsilon_{mp} d^2, d > d_0 \end{cases} \quad (5)$$

$$d_o = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (6)$$

The cuckoo search algorithm for the cluster heads selection for certain number of clusters is formulated in the algorithm 1.

Algorithm 1: Cuckoo search algorithm for the data cluster head selection

Produce the primary population of nb_nest host shells in random
Compute the fitness of these results and get the finest solution
While (t < MaxGeneration) or (stop criterion)
Produce nb_nest novel results with the cuckoo search
Compute the fitness of the novel solutions
Associate the novel solutions with the old results, if the novel result is enhanced than the old one, substitute the old result by the novel one
Produce a fraction (p_a) of the novel results to substitute the poorer shells
Relate these results with the old results. If the novel result is enhanced than the old result, substitute the old result with the novel one
Discovery the best result
End while
Print the finest shell and fitness (cluster head)

3.2 Data Gathering and Duplication aware Aggregation

Just after the cluster formation, information about air pollutant would be collected from each sensor nodes which exist within the cluster. Those collected information would then be forwarded to the cluster head with the aim of transmitting it into the base station. In order to minimize the communication expense that may occur because of repetitive transmission of data, data duplication would be carried out. The data duplication is conducted through the elimination of the data which is received from the sender id that is the same.

Once after duplication, the data aggregation will be done for the purpose of reducing the bandwidth consumption that happens owing to the transmission of each individual data. The data aggregation is carried out having the security into consideration, in which the data collection from any of the sensor node having more variations would not be included in the data transmission. After the aggregation of data, it would be evaluated in order to determine if the information has to be forwarded to the (BS) base station or not so as to render the security for the data of air pollution.

3.3 Allocate the required Bandwidth to the selected Data Transmission

In this stage, an algorithm is formulated for the allocation of bandwidth for reducing the delay- subtle traffic in multi-hop wireless sensor networks. The new result takes both the intermittent and the real-time traffic into consideration together. In this section, the bandwidth allocation to wireless nodes is taken into consideration for the purpose of meeting real-time traffic mandate, i.e., to meet the traffic sum and deferral needs. The packets that are produced by a node are referred to as confined packets. Local packets may also have combined messages sent from the cluster head nodes. As it follows, the end-to-end latency stands for the delay that is incurred over a multi-hop route from a wireless node to the (BS) base station.

The bandwidth allotted is used up for transmitting local packets and for routing packets. It is assumed that a single slot is sufficient enough for the transmission of one information packet and the organized messages which are related with the broadcast. Consider a node $n(h,i)$ sending n^p delay subtle real-time periodic packets for each P_n units of time. In order to prevent the representations becoming as well bulky, it shall be often dropped in the arguments whenever any ambiguity comes up ($e.g., n(h,i)$ is shortened as n). Suppose D_n refer to the comparative deadline of these packets. No restraint is imposed on the limit. The system proposed uses T to represent the dimensions of one single TDMA (Time-division multiple access) cycle.

Periodic traffic: The management below is performed for the bandwidth provision for the case of episodic real-time traffic on a node to node foundation. Let l_n represent the bandwidth per T units of time assigned to node $n[h,i]$ for local periodic traffic. The packets that are scheduled at the start of a cycle, suppose at time t, should range the base station by time $t + D_n$. As nodes should pass on at-least one time for each D_n units of time, T cannot go beyond the least D_n for all n:

$$T \leq D_{min} \quad (7)$$

The figure of cycles which is limited in time D_n is$\left\lceil\frac{Dn}{T}\right\rceil$. Using the equilibrium circumstance over the rate of packet group in addition to the amount of packet ingestion at the base station, the following expression is got

$$L_n\left\lceil\frac{Dn}{T}\right\rceil \geq \left\lceil\frac{Dn}{P_n}\right\rceil n^p \quad (8)$$

Hence the least l_n is expressed by

$$l_n = \frac{\left\lceil\frac{Dn}{P_n}\right\rceil}{\left\lceil\frac{Dn}{T}\right\rceil} n^p \quad (9)$$

Let M represent the number of nodes whose packets are directed (making use of Algorithm 2) to n.

Algorithm 2 Routing Procedure
Input: $[h,i]$ →Node address, $q \leftarrow \lceil i/h \rceil$
Output: $[h,i] \Rightarrow [h-1, i-q]$ →Route

Let f_n refer to the bandwidth which is allotted to node n for packets forwarding. Hence,

$$f_n = \sum_{m \in M} l_m + f_m$$

Let $S(h,k)$ (or, S if no ambiguity rises) represent a side, in addition to, the wireless nodes which are positioned on the side, where h refer to the range of the concentric wireless where the side is situated and k refers to its wireless medium. Let $S^p (\equiv S^p(h,k))$ represent the total periodic bandwidth which is allocated to the side S. Thus,

$$S^p = \sum_{n \in S} l_n + f_n$$

It is noticed that S^p is non-increasing monotonically in h, i.e., $S^p(h,k) \geq S^p(h+l,k)\ \forall\, l \leq H-h$. As a single packet from each side in any partition given might be arranged in a concurrent manner without any conflict, the adequate bandwidth allocation for partitioning j for the episodic traffic, B_j^p , is provided by:

$$B_j^p = \mathrm{Max}\left(S^p \middle| S \in \mathrm{partiiton}(j)\right)$$

Aperiodic delay-sensitive traffic: The system proposed budgets the aperiodic real-time traffic mandate. The per T a periodic bandwidth modestS^a, that is communal by every node of a side S is given by $n_S / \left\lceil\frac{Ds}{T}\right\rceil$, where n_S refers to the amount of packets which is arranged for transmission in one single limited period. Thus, a periodic bandwidth distribution necessary for splitting j, $\widehat{B}_j^a$, is expressed by

$$\widehat{B}_j^a \triangleq \mathrm{Max}(S^a | S \in \mathrm{partiton}(j)) \quad (11)$$

Generally, the bandwidth that is allotted for episodic traffic will go beyond the bandwidth needed by a side. As these bandwidth slack can be used for scheduling the aperiodic packets, the excess bandwidth exceeding B_j^p that is allocated for partitioning j for aperiodic traffic, represented by B_j^a, meets $B_j^a \leq \widehat{B}_j^a$. Let B_j^a define the minimum bandwidth allocation more than B_j^p that the aperiodic bandwidth wants of all the sides are met. The entire bandwidth distribution of partition j for the case of real-time circulation, represented by B_j is$B_j = B_j^p + B_j^a$.

4. Results and Discussion

This section evaluated the newly introduced BA-APMS-CSFSO methodology employed MATLAB 12. The clustering with swarm intelligence (Bandwidth Allocation-Air Pollution Monitoring System –Cluster based Swarm Fish Optimization- (BA-APMS-CSFSO) proposed is thereafter compared with the already available Cluster based Air pollution monitoring employing Swarm Intelligence algorithms such as Clustered based Air pollution monitoring system using Swarm

Intelligence(CASI)-CSA-IAFSA, CASI-GSO-HBA, CASI-FA-HGA. The simulation Specific parameters are tabulated in table 1.

Table 1. Simulation Parameters

Area	100*100
Nodes number	100
Initial energy	0.5J
BS location	(50,50)
Packet size	4000bits
E	50nJ/bit
ε_{fs}	10pJ/bit/m2
ε_{mp}	0.0013pJ/bit

The performance measure values which are taken into consideration in this technical work for the assessment of the enhancement of the newly introduced research technique with the available techniques are throughput, Packet delay, energy consumption.

4.1 Throughput

Throughput is defined to be the quantity of data which is moved from one place to another with success in a time period given, shown in table 2.

$$\text{Throughput} = \frac{\text{number of packets moved}}{\text{total number of packets}}$$

Table 2. Throughput Comparison

Number of Iterations	DWCA	WDA	HGA	HBA	IAFSA	BA – APMS
0	0.4	0.5	0.6	0.8	0.86	0.89
20	0.45	0.56	0.64	0.84	0.89	0.91
40	0.52	0.61	0.68	0.87	0.91	0.92
60	0.58	0.65	0.72	0.89	0.93	0.95
80	0.65	0.67	0.78	0.92	0.95	0.95
100	0.68	0.72	0.8	0.95	0.969	0.97

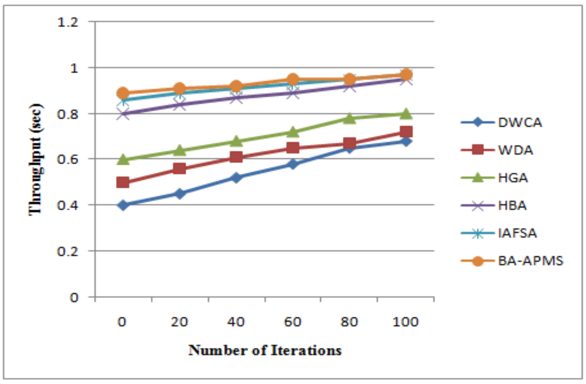

Figure 2. Throughput Comparison

The throughput comparison is graphically represented in the figure 2. The graph shows that the algorithms proposed have better throughput when compared to the other available algorithms such as CASI-GSO-HBA, CASI-FA-HGA and CASI-CSA-IAFSA.

4.2 Packet Delay

The delay is defined as the time which a packet takes in order to get propagated through the communication media from the source towards the destination, shown in table 3.

Table 3. Packet Delay Comparison

Number of Iterations	DWCA	WDA	HGA	HBA	IAFSA	BA – APMS
0	1.02	0.82	0.7	0.5	0.35	0.3
20	1.9	1.65	1.4	0.8	0.68	0.59
40	2.5	2.2	1.7	1.2	1.04	0.96
60	3.2	2.8	2	1.6	1.32	1.11
80	3.8	3.2	2.3	1.9	1.68	1.35
100	4.3	3.6	2.5	2.2	2.04	1.85

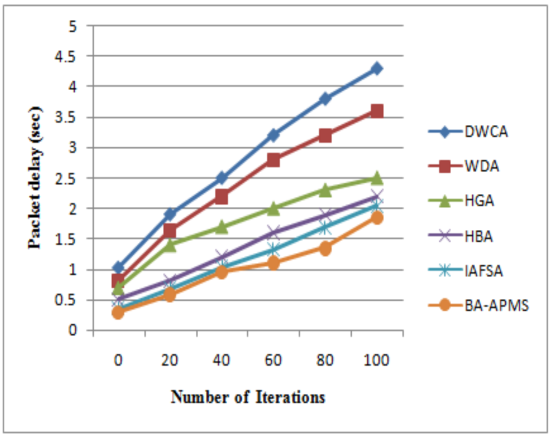

Figure 3. Packet Delay Comparison

The graphical representation of the packet delay comparison is illustrated in the figure 3. The graph shows that it is lesser for the algorithm proposed in comparison with the other available algorithms like CASI-GSO-HBA, CASI-FA-HGA and CASI-CSA-IAFSA.

4.3 Energy Consumption

The comparison of the energy consumption is graphically represented in the figure 4. From the graph it is evident that the algorithm proposed has lesser energy comparison in comparison with the other available algorithms such as CASI-GSO-HBA, CASI-FA-HGA and CASI-CSA-IAFSA, shown in table 4.

Table 4. Energy Consumption Comparison

Number of Iterations	DWCA	WDA	HGA	HBA	IAFSA	BA – APMS
0	31	26	20.4	17.7	15.3	13.4
20	33	27	21	18.2	16.3	14.1
40	36	30	21.4	18.8	17.4	16.8
60	40	35	24.9	21.2	19.6	17.1
80	46	41	30	24	22.12	18.6
100	50	45	31.2	25.2	23.05	20.9

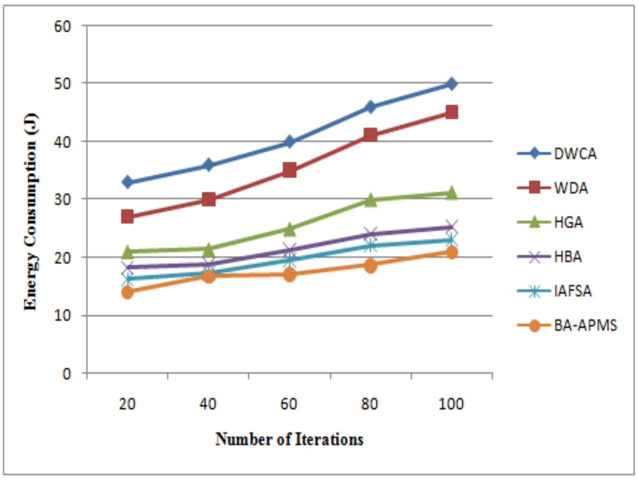

Figure 4. Energy Consumption Comparison

5. Conclusion

Air pollution is huge concern developing in the world that might lead the humans to several diseases. Therefore, air pollution monitoring has become the most necessary task that is required to be carried out with more care. This work proposed focuses on rendering the optimal air pollution system by introducing the technique referred to as the bandwidth allocation aware air pollution monitoring system making use of cuckoo search and fish swarm optimization approach. The CSA algorithm is proposed for an efficient cluster head selection and cluster formation. Thereafter the Air Quality Index (AQI) based fuzzy rule is generated using the Fuzzy logic. The data aggregation methodology is deployed for reducing the communication burden. The IAFSA is thereafter introduced for an effective data aggregation. At last the bandwidth allocation mechanism is utilized for providing the bandwidth evenly for the optimal paths, so that the data transmission can be carried out with easy. The imitation outcomes reveal that the anticipated methodology achieves improved than the other available ones with regard to network energy consumption, and throughput.

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