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Energy Efficient Sustainable City Monitoring Using IoT Enabled Wireless Sensor Networks and Data Analytics

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As the population in the city is increasing rapidly over the years, due to the scarcity resources and unhealthy ecosystem the demand for sustainable city increases. Sustainable city enables all its citizens to meet their own needs with minimal natural resources and to live a good quality of life, without degrading the existing natural resources or the lives of other people now or in the future. Once after building sustainable city with green building, energy efficient and eco-friendly ecosystem it is important to monitor the same to keep the city sustainable. An Energy efficient Wireless sensor network with internet connectivity improves the regular monitoring, the frequent data received from various monitoring sensors are considered as informative database for future prediction, these huge information can be used for alerting critical situations through data analytics. The integration of various technology yield performance degradation due the energy usage and computational overhead, which can be improved through application of an optimization technique like genetic algorithm.

Keywords: IoT, WSN, energy efficient, green city, data analytics, genetic algorithm, PSO, hybrid optimization

1. INTRODUCTION

Sustainable city is going to be a great demand in the upcoming century as whole world focus on sustainable solutions for all real-world problems. Monitoring and maintaining the sustainable city with energy efficient system is great challenge than building the city. So, monitoring a sustainable city using energy efficient and IOT enabled wireless sensor network will improve overall performance of the eco system.

Fig. 1 shows the concept of green city where various ecosystems are connected with variety of sensors, which collect the required data in regular intervals. The heterogeneous nature of the sensors makes the system accurate but the aggregation become complex.

The city contains various types of places or stations and geographical eco system with different expectation about its energy efficient operations and eco friendliness. The various places are categorized based on its sensitivity towards parameters like environmental pollution, sound pollution, air pollution, water pollution, temperature and humidity *etc.* Similarly, each place is assigned with fitness functions and ideal fitness values. The Genetic

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Algorithm based optimization is used to schedule the sensors to operate on energy efficient and coverage optimized scenario. Hence the geographic aware scheduling of sensors is essential for optimum solution.

The overall setup of the smart green city with deployment of sensors in critical areas are shown in Fig. 1. A fruitful design of energy efficient and IoT enabled Wireless Sensor Network is built as the basic hardware infrastructure to monitoring sustainable city. The system also performs the data analytic on the large amount of data collected from various sensors, the same is used for accurate prediction of upcoming environmental conditions of the city.

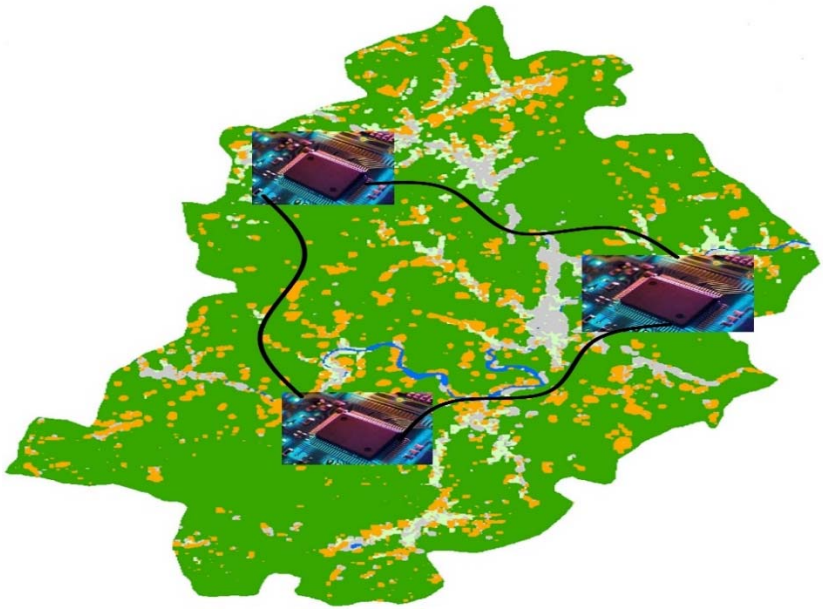

Fig. 1. Green city with wireless sensor networks.

The whole city is covered with IoT enabled sensors based on the parameters to be monitored. The sensors could be temperature sensor, humidity sensors, PH level measuring sensors, fire detection, Camera for video/images, microphone for audio *etc.* As the sensors connectivity is done through IoT, the multimedia communication gives good Quality of Service (QoS) parameters. Due to the IoT based connectivity, access to sensors and devices are easy and also gives good performance in case of scalability.

As the large number of sensors are periodically collects the information, the amount of data received at the central database is going to be huge. The major challenge is to segregate the fruitful information in order to predict the critical issues expected to be happen. Suitable classification technique is applied on the received data to separate the useful information from the periodic data received.

The collected and stored information base is considered as big data and this is considered for detailed data analytics in order to identify the overall the scenario in the eco system, help us to predict the future performance, which helps the authority plan the necessary precautions and theirs by ensure the best performance of the sustainable city.

2. LITERATURE SURVEY

According to the United Nation's report the global population will rise to 70% in urban [1] area by 2050. The energy usage of wireless sensor networks deployed in the green city for monitoring can be improved by cooperative approach among sensors. As the cooperative [1, 8] approach enables the nodes to share the information collected, the coverage and average life time of the network [8, 12] also improved

Energy harvesting [2] of sensor networks in green cities include data collection [11] from smart building, street lights, parking yard *etc.* As it is a long term process a threshold-based scheduling [2] policy for energy harvesting will improve the long-term average usage. As a result of optimal threshold, the memory usage and complexity of the algorithm also improved.

Energy usage of mobile devices [3] in the green city need to optimized as it will adversely affect the energy consumption [11], radiation, overall temperature *etc.* of the eco system. An energy efficient Wireless sensor [12] networks which sense information from smart transportation, and smart buildings *etc.* where environments are continuously changing are affected by dynamic change of transmitting power [4], which may adversely impact on the throughput of the network. The overall throughput of the network is improved by two operation harvest and transmission is harmonized well. WiFi coverage and energy management [5] is essential in green city as large number of devices and access points (AP) are connected and continuously operating in the networks.

Bigdata approach with cooperate sensing is incorporated into sensors in a cloud environment [6] for sensing huge real time data. Another approach is ASC where an agent is included into sensor-cloud for transmission of sensed data and that can be considered as big data. The third approach SSC [6] where social network is integrated into sensor- cloud for sharing big data. The application of IoT or IOT enabled sensor network always makes the network scalable and it also yield good interoperability [7] among different devices.

It is expected that more than 50 billion devices with internet usage capability is going to be connected to internet by the year 2020. As this large no of internet driven devices are generating huge volume of data [8], their by energy usage, it is important apply green approach [9] to bigdata especially in energy aware applications like green city. The Internet of Things (IoT) applications [10] like smart parking, waste management, and traffic congestion management [13] *etc.* used in smart cities enable the sensor network to collect huge amount of data. A proper energy aware data aggregation technique is essential to collect fruitful data effectively else it may induce huge overhead.

Over the last two decades WSN become one of the most popular implementation due to its inherent nature of Energy Efficiency (EE) [14] even in a relatively long transmission through muti-hop mechanism. The routing and data aggregation techniques are well conservative in terms of energy at the same time it yield relatively good reliability due to its fault tolerant nature. Hence the approach of energy efficiency along with fault tolerance in a multi hop based cluster environment [15] will be able to provide improved service.

3. THE ENERGY EFFICIENT MONITORING OF GREEN CITY

The concept of green city is mainly affected by energy usage hence the new sys- tem implemented for monitoring the environment should not be expensive in terms of energy.

Since the large and variety of sensors are deployed to collect heterogeneous data from various parts of the city, the improper schedule of these sensors may adversely affect the energy efficiency of the system. Since coverage and sensor network life time is inversely proportional, a proper optimum scheduling is essential. The parameters that is considered for optimizing the scheduling is energy of individual nodes, average network life time, coverage of the network, load balancing factor *etc.* Fig. 2 shows the system operation where optimum scheduling of sensors provides energy efficient operation and all collected data is used for prediction after classifying fruitful information.

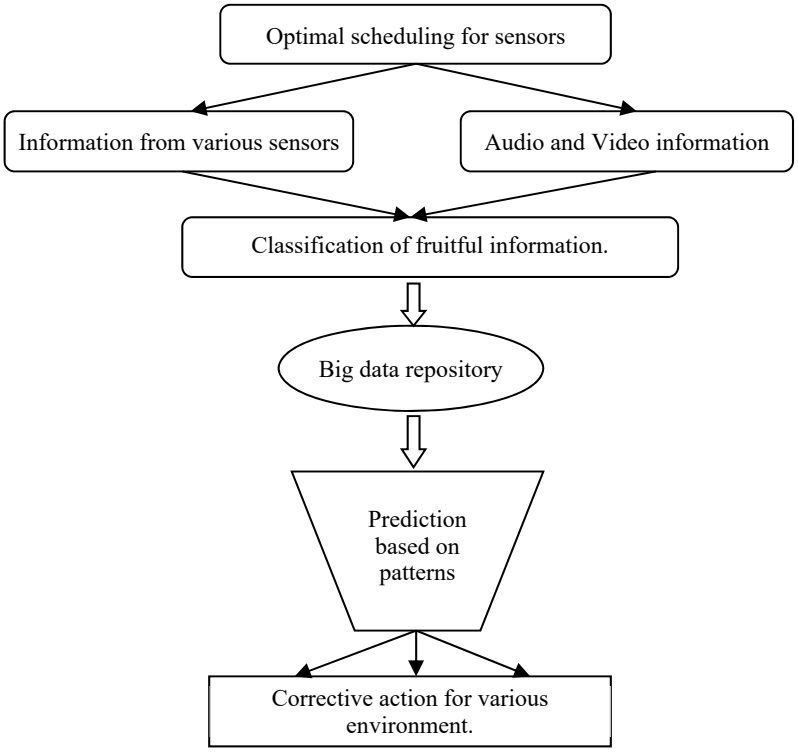

Fig. 2. Energy efficient wireless sensor networks based sustainable city monitoring.

Since optimization is essential for the effective scheduling a Genetic algorithm (GA) based optimal scheduling (GAOP), Neuro-Genetic based optimal scheduling (NGOP) and Particle Swam based Optimization (PSOP) is implemented and compared against the performances.

3.1 Genetic Algorithm (GA) Based Optimal Scheduling (GAOP)

The genetic approach always proved to be an effective load balancing technique in the heterogeneous environment with energy and coverage are the parameters considered for the optimization. The chromosome with interference free node in the network is selec-

ted for genetic operation like mutation and crossover with reference to the parameters to be optimized. Fig 3 shows genetic operation in stepwise towards optimization and the optimization result always depends on the ratio of local and global parameters in the chromosome, crossover probability P_c, and Mutation probability P_m.

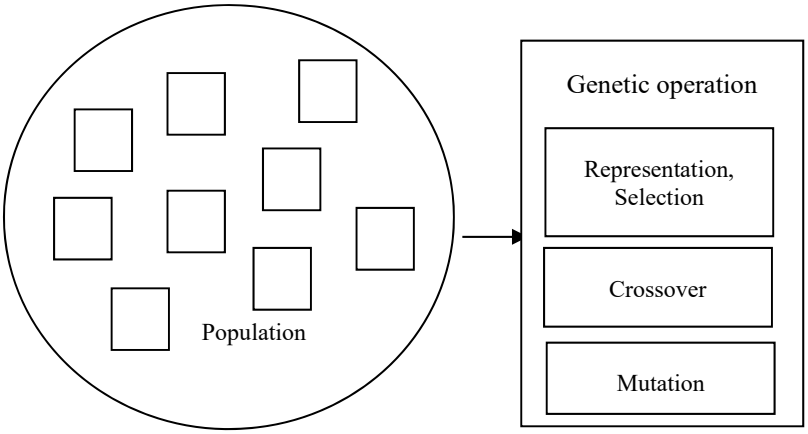

Fig. 3. Genetic optimization approach.

The approach of applying genetic based optimization in GAOP method improved the overall load balancing factor of the network, this approach is very effective in geographically distributed sensor network. The efficiency of the network is further improved by removing interference nodes from the overall network using a binary search approach, which will also reduce the search complexity to algorithmic scale.

The steps involved in Genetic Optimization applied to GAOP method.
//Genetic based Optimization procedure.
Input: Initialize the Chromosome with suitable technique.
Step 1: Initialize the generation count and fitness function.
Step 2: Use suitable selection procedure.
//Crossover
Step 3: Suitable pair of chromosome is selected and applied the crossover.
Step 4: Fitness is calculated from all offspring.
//Mutation
Step 5: Suitable mutation technique is applied based on the mutation probability P_m.
Step 6: Remove the chromosome with less fitness and node with interference.
Output: Energy & Coverage optimized collision free sensor network with balanced node.

3.2 Neuro-Genetic Optimization Procedure (NGOP)

This is a hybrid approach where Artificial Neural Network (ANN) and Genetic Optimization is blended together to yield improved performance. The ANN based classification

or prediction is used to identify network configuration with improved performance and load balancing. The traditional algorithms for weight balancing of ANN is not expected to yield good results as the number of parameters involved are more and heterogeneous in nature. The GA based weight balancing of ANN provides excellent results in terms of classification overhead and accuracy.

To illustrate the above concept, assume that we have to setup an ANN with 4 input nodes, 3 hidden layer nodes and one output node. This implies that there will be 10 weights to be adjusted for effective training. The chromosome is represented as shown Table 1 where local and global parameters are included with suitable participation to ensure global optimum.

Table 1. Chromosome Structure used with hybrid optimization.

W11	W12	W13	W21	…	W21	W31
G 0	G 1	G 2	G3		G10	G 11
84321	46234	78901	32104	…	87640	14261

The Neuro-Genetic approach improves the required parameters like load balancing, average life time and coverage of network as required. The improved load balancing in geographical distributed environment gives overall system performance and their by huge amount of fruitful information could be aggregated. The overhead in packet transmission is significantly reduced due to removal of duplicate packets.

3.3 Particle Swarm Optimization for Scheduling (PSOP)

The GA based approach always start giving improved performance in the early stages of iteration but it does not guarantee these improved performance in a varying node environment hence optimization is replaced with Particle Swarm Optimization (PSO) based approach where improved performance is expected in later iterations with long term improvement. The inherent properties of PSO like Cohesion, alignment and separation *etc.* is extremely suitable for a heterogonous WSN scenario.

Procedures of the Global Version: The algorithm for PSO based approach is as follows.

Step 1: Initialize an array of the population of particles with random positions and velocities in D dimensions in the problem space.

Step 2: Each particle fitness calculation using suitable method.

Step 3: Calculated fitness value may be compared with reference Value ‘pbest’. Update the value of ‘pbest’ based on the current value in ‘D’ dimensional space.

Step 4: Update ‘gbest’ by comparing current value.

Step 5: Update the particle position and velocity using Eqs. (1) and (2).

$$V_{id} = V_{id} + C_1 r_1 (P_{id} - X_{id}) + C_2 r_2 (P_{gd} - X_{id}) \quad (1)$$

$$X_{id} = X_{id} + V_{id} \quad (2)$$

‘V’ represent velocity of particles, ‘X’ represents position of particles, ‘P_i’ represents previous best, ‘P_g’ represents global best, ‘r’ is a random constant and ‘C’ is a constant

known as social parameter. It is evident that due to difference in operational principle GA based approach and PSO based approach yield different results in various contexts.

4. EXPERIMENTAL EVALUATION

Genetic algorithm based optimal scheduling (GAOP), Neuro-Genetic based optimal scheduling (NGOP) and Particle Swam based Optimization (PSOP) in wireless network is implemented and network performance is measured through simulation using NS-2 network simulator. The network layout size is fixed to a value of 1000×1000 for simulation and the available trace file is observed for the collision process during data transmission. The simulation is repeated for varying number of nodes and the corresponding trace file is used for data collection and inference.

Random Waypoint Model (RWM) is developed and used so that all the nodes move randomly, which gives improved similarity with real-time situation. The route discovery is done with an average number of 80 nodes. Dynamic Source Routing (DSR) is the routing protocol used and since nodes are moving randomly it is observed that lot of packet drop is happened due to congestion in the network. All the nodes in the network moved randomly by the speed of the movement is fixed by parameters in the simulation tool or it moved with a predefined speed.

The random movement and corresponding progression seem to be constant over the period of simulation. The speed of movement is varied from 5.0m/s to 40 m/s for each node. The information received from trace file is utilized to evaluate load balancing efficiency, packet delivery ration, routing overhead *etc*.

Table 2. Measure of packet delivery ratio.

Node density	Packet Delivery Ratio (%)		
	GAOP	NGOP	PSOP
10	72.5	66.3	60.3
20	65.3	59.1	53.1
30	61.4	54.2	46.2
40	55.2	49	43
50	60.26	66.33	52.33
60	44.55	38.53	32.53
70	40.25	34.23	29.23
80	40.72	33.7	33.7

Fig. 4 and Table 2 shows the network performance in terms of packet delivery ratio plotted against varying no of nodes. It is evident from the plot that consistency of Genetic algorithm-based approach GAOP gives a better average performance comparing with the other two techniques. The hybrid approach NGOP gives a random high performance at certain optimum values but poor consistency. The third technique PSO yields only poor performance due to its complexity and delay in reaching optimum value.

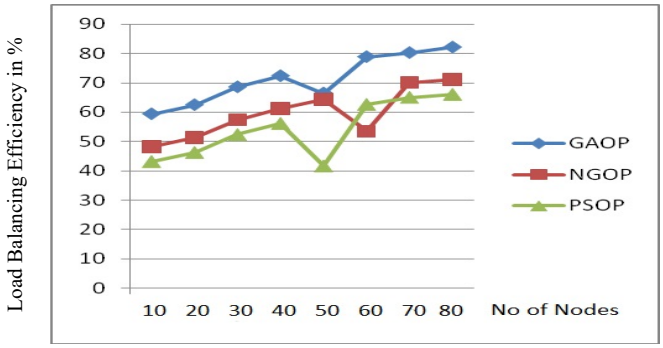

Fig. 4. Packet delivery ratio performance based on the varying no of nodes.

Fig. 5 and Table 3 show the performance of the in terms of overhead or load balancing against varying no of nodes. Genetic algorithm based approach is best in load balancing also because of the improved performance of genetic operators. The Hybrid approach NGOP is performing average due to the operational overhead, it loses the load balancing in certain situation, which may ultimately cause system crash. The PSO based approach is a distributed approach and due to the operational complexity this technique also performing poor in terms of load balancing.

Table 3. Measure of load balancing efficiency.

Node density	Load Balancing efficiency in terms of load balancing factor (%)		
	GAOP	NGOP	PSOP
10	59.35	48.15	43.1
20	62.45	51.25	46.2
30	68.55	57.35	52.3
40	72.35	61.15	56.1
50	66.45	64.24	41.59
60	78.85	53.45	62.6
70	80.25	70.05	65
80	82.13	71.08	66.03

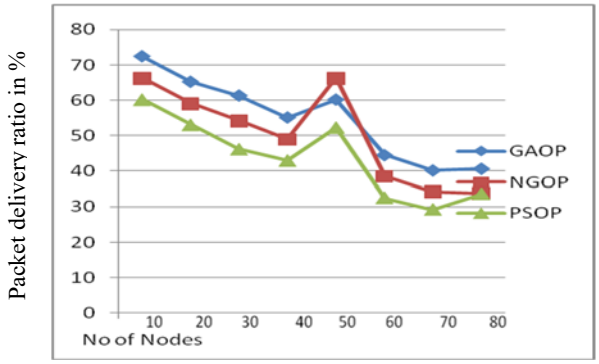

Fig. 5. Load balancing efficiency based on the varying no of nodes.

Classification of data collected from sensors are processed using machine learning approach. The performance of classification is essential as it seriously affect overall system performance. The performance of classification is tested using Weka tool where data set is prepared in Attribute Relation File Format (ARFF) and classification performed using Random Tree method. Table 4 shows the classification summary with accuracy in percentage, various parameters and performance measure indicate that this particular classification provides relatively good accuracy. Table 5 shows the detailed analysis on accuracy in terms of True positive (TP), False Positive (FP) and precision.

Table 4. Classification summary.

Correctly Classified Instances	44	83.0189 %
Incorrectly Classified Instances	9	16.9811 %
Kappa statistic	0.3057	
Mean absolute error	0.1896	
Root mean squared error	0.3912	
Relative absolute error	58.8354 %	
Root relative squared error	102.8465 %	
Total Number of Instances	53	

Table 5. Detailed accuracy of random tree classifier.

	TP Rate	FP Rate	Precision
	0.531	0.098	0.586
	0.902	0.469	0.881
Weighted Avg.	0.826	0.392	0.820

5. CONCLUSION

The bio-inspired computing and hybrid approach to monitor the sustainable city along with data analytics and prediction is compared against various performance measures. The performance of the system optimized through different approaches and performance is measured in terms of the packet delivery ratio and load balancing. The genetic algorithm-based approach performs 10%, 15% better that other approaches in case of packet delivery ratio and load balancing respectively. The GA based approach gives improved performance due to the effectiveness of genetic operators used and the performance is stable for varying no of nodes of sensor networks. PSO based approach shows improvement in certain context but performance is not stable for a varying number of nodes especially for small network. The hybrid approach always gives an average performance but the performance gave a random improvement for certain eco system. The data analytics performance measured in terms of classification accuracy and the Random Tree method provided an accuracy of approximately 83%, which is fairly good in case of large and frequent data collected.

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