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Multi Objective Optimization in Wireless Sensor Network

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Abstract:
Abstract—The wireless sensor network is one of the most interesting research topics in the information technology domain. Among various challenges in WSN one of the important challenges is optimization in the presence of different conflicting objective. In this work different conflicting objective has discussed and it was Observed that network coverage, network connectivity and network lifetime are important issue in WSN. With these objective Non-dominated Sorting Genetic Algorithm (NSGA-III) is used for optimization. simulation result is shown and discussed in the result and discussion. we summaries range of different studies of optimization and discuss the open problem to be targeted in future research.

Keywords:*NSGA-III, MOO, WSN*

I. Introduction

The wireless sensor network (WSN) is a type of network which consists of the distributed deployment of autonomous devices used to observe the information about the physical or environmental condition. The sensor nodes are low cost, low power consuming, multifunctioning, self-adapting and self-configure in nature. Since the WSN node has low battery life, maintaining Quality of Service(QOS) is a tough task. The QoS consist of latency, coverage and the impartiality among the sensing node which conflict with each other. Optimizing these QOS parameter is very difficult to achieve. This work consists of multi objective optimization of three object using Non-dominated Sorting Genetic Algorithm (NSGA-III).In single-objective optimization [1]the model mainlytargets for accurate in the context of a single objective, which is gone through many mathematical boundaries as a constrained, that is known as object and terms as Objective function evaluation. In recent years researcher focused on multi-objective optimization (MOO)problems. analysis of the model extends to multiple objectives that are basically non-dominant set. the most common purpose of an analysis is to choose the best trade-off among conflicting objectives.WSN system is faced with trade-offs among various application metrics including deployment cost, reliability of the system, system security, and performance. Designer of this embedded system must consider tradeoffs and make multiple decision. The main characteristics of a WSN include resilience, infrastructure-less system, mobility of hubs, low Power utilization. Ability to continue in cruel ecological conditions, Ease of utilization, Cross-layer plan, Heterogeneity and Homogeneity of nodes, Scalable for medium to large size organization etc. The following are some performance metrics which are conflicting to each other.:

- Coverage and energy efficiency: on the time of reducing the consumed energy in the WSN it automatically reduces the coverage area of the node.
- Energy Consumption and network lifetime: this is another conflicting objective.for maximize the lifetime of network the proposed system must consume low battery

power in all the nodes as well as evenly battery consumption in all the nodes. If the energy consumed at each sensor node is reduced this will cause an increase in latency (the delay time between information transfer and receive)a

- favorable reciprocation between coverage, node connectivity, totalconsumed energy, and lifetime: For deployment of sensor node the system must satisfy some key objective e.g. lifetime of the network, consumed energy and the total number of nodes deployed in the network. The model or system must converge into maximum lifetime, the minimum number of nodes at the same instance of time maintaining node and sink connectivity.
- other metrics in WSN which are challenging to handle are Localization, tracing, selection of route and event Scheduling, the process of integrating data, Security etc.

Optimization process consists of a three-stage process. In the first stage design the model for the desired system. the model consists of mathematical or numerical functions.in the second stage, the algorithm or optimizer function developed. and after these two processes, the performance is measured by evaluator or simulator. many studies have been done in MOO and a various algorithm is developed for solving MOO problem. Many pieces of research have done in the field of the evolutionary algorithm. Earlier where evolutionary algorithm limited to single-objective algorithm now, it expends to MOO.in the next section mathematical formulation and used algorithm for system is discussed.

IIMATHEMATICAL FORMULATION

Three main objectives taken is network coverage, network connectivity and network lifetime. Following are the mathematical equation.

NETWORK COVERAGE:

Network coverage is one of the crucial objectives for a sensor network. Radio coverage is considered as network coverage that is corelated with the sensing range. The network coverage $C_v(x)$ [2]is defined as,

$$C_v(x) = \frac{\sum_{x'=0}^{x} \sum_{y'=0}^{y} g(x',y')}{xy} \quad (1)$$

Here

(x′, y′):cell center

g (x′, y′): monitoring status of the cell

For better coverage the probability of monitored event detection should be higher.

NETWORK CONNECTIVITY:

Network connectivity play important role in WSN. The requirement of the connectivity is that the active node location should be in the communication range of one or more than one active nodes. communication range network connectivity[3] can be expressed as

$$f_{con} = \sum_{i=1}^{x\times y} 1 - e^{-\left(R_{c_i} - R_{s_i}\right)} \quad (2)$$

Here

R_{c_i} : communication range i[th]sensor node

R_{s_i} :sensing range i[th]sensor node

$x \times y$: Grid size

Constraint: for achieving network connectivity $\left(R_{c_i} - R_{c_i}\right) > 0$ must be satisfied.

NETWORK LIFETIME:

Lifetime of network is also important object in WSN. sensor have limited energy and most of the time replacement of the battery is almost impossible. the lifetime of the network is defined as[4]

$$T_{sys}(q) = \min_{i \in N} T_i(q) \quad (3)$$

$$T_i(q) = \frac{E_i}{\sum_{j\in S_i} e_{ij}^{t} \sum_{c\in C} q_{ij}^{(c)} + \sum_{j:i\in S_j} e_{ji}^{r} \sum_{c\in C} q_{ji}^{(c)}} \quad (4)$$

Here

e_{ij}^{t} : Transmission energy to absorb at node *i* to transmit a data to its adjacent node *j*

e_{ij}^{r} : Energy consumed by the receiver *i* from node *j*

$q_{ij}^{(c)}$: Transmission rate of c from i node to j node to be allocate by the routing algorithm

Failure may cause partition of the network and resulted in uncovered area.For fitness function the global objective is to have maximum coverage connectivity and network lifetime. If all sensor can be able to communicate with sink node and transmit report on monitored information in periodically manner. For chromosome definition random function is used to generate individual initial population. the selection phase is identification of individual participation to reproduce in one generation. The individual having better fitness value are mostly selected as comparison to other individual and named as parents. The crossover phase is basically applying a process with certain probability on individual which are going to select. After cross over mutation operator is applied. The applied operator with low probability is called mutation rate and for evaluation pareto based genetic algorithm is applied. In the next section the algorithm used for solving the above three-objective optimization is discussed.

The two aims of solving MOO problem are achieving theconvergence and the diversity. These goals are shown in figure 1. The first goal, convergence, is the closeness of converged Pareto set to the truePareto optimal solution set. The true Pareto set represents the best possible non-dominated combinations of the fitness values of both the objectives. The second goal, diversity, is the spread and the distribution of the converged Pareto set.

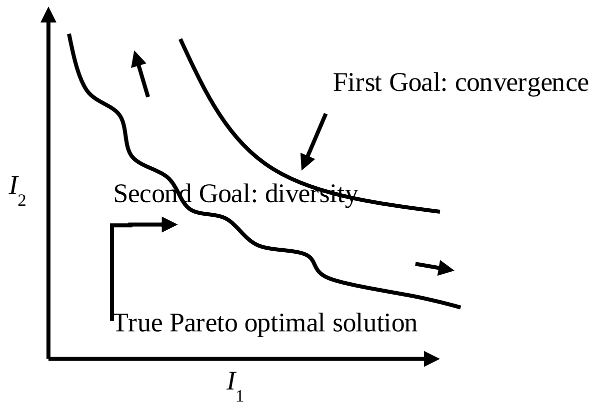

Fig.1Goals of a multi-objectiveoptimizationalgorithm

The spread represents the extent to which the maximum fitness of the two objectives are achieved, individually. While, the distribution represents how much equally spaced are the non-dominated solutions of the converged Pareto set. Thereare numerous multi-objective optimization algorithms which are inspired by the evolution theory and can attain both the above-mentioned goals simultaneously. One of the most successful family of evolutionary MOO algorithms is NSGA (NSGA-I, NSGA-II and NSGA-III). All the three algorithms are based on non-dominated sorting of the solutions. The improvement in NSGA-II over NSGA-I was focused on the first goal, i.e. improving the convergence. This is done by introducing the concept of elitism. The elitism in NSGA-II follows a very simple procedure to preserve the converged solution from getting lost in next generations of the algorithm.

The improvement in NSGA-III over NSGA-II was focused on the first goal, i.e. improving the diversity. The concept of thereference pointsis used in NSGA-IIIfor maintaining the diversity. While the concept of crowding distance was used in NSGA-II. The reference point-based approach used in NSGA-III is reported to be better than the crowding distance approach for a MOO problem with more than two objectives. In NSGA-III,[5] first a well distributed reference pointsare created on a normalized plane.

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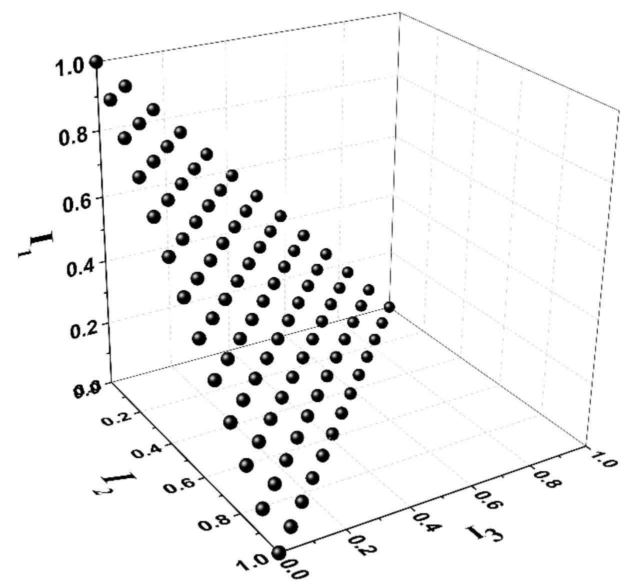

Fig.2 Reference plane used NSGA-III

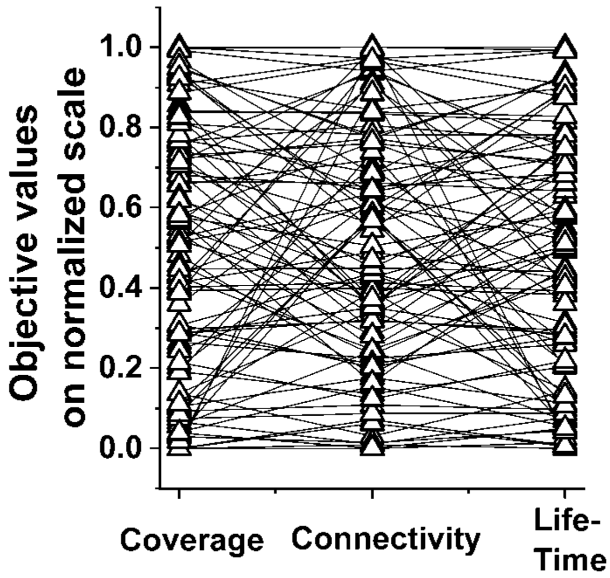

Figure 3. Coordination of three objective

Figure 2 shows the reference points for an optimization problem withthree objectives. Thesolutions of the given front are then projected into thenormalized plane. Each solution that is projected on the normalized plane is then link with the closest reference point. A selection process is done after the association process.The solutions are selected such that maximum count of reference points are represented in the selected solution set.

In this study NSGA-III is used for solving the three objective optimization problem. The value of population number is 92, the total count of generations is 400. The values of crossover probability and mutation probability used are 0.9 and 0.5. A similar reference plane is used as shown in Figure 2. The value of total number of parts a side is divided is 10. The result of the MOO problem is discussed in the next section. MATLAB is used for solving the objective values and solving the MOO problem.

III RESULTS AND DISCUSSION

The result of the MOO problem is shown in figure 3. The objective values shown in Figure 3 are plotted on normalized scale.

The reason of this normalization is to show the distribution of the MOO results.The performance of the planning methodology is evaluated through comparing the fitness and time efficiency of the multi objective optimization approach. The homogeneous node environment is taken for simulation It is clearly observed from the figure that all the three objectives are well distributed (equally spaced). The value of population number is 92, the total count of generations is 400. The values of crossover probability and mutation probability used are 0.9 and 0.5. A similar reference plane is used as shown in Figure 3. The value of total number of parts a side is divided is 10. MATLAB is used for solving the objective values and solving the MOO problem. This result shows the usefulness of the reference point-based NSGA-III.

VI CONCLUSION

The last decade the evaluation algorithm developed, and the new era of MOO come into the importance. The paper discussed and implement MOO with NSGA-III. The parallel simulation result with three objectives i.e. network coverage network connectivity and network lifetime is shown and discussed. Despite development in MOO optimization in WSN. there are open discussion problems for future work. Some of them are the following:

1. Single hop to multi-hop transmission: previous studies most of the time find the fact about transmission by single hop in MOO, whereas improvement in the multi-hop transmission can be done in a WSN system. This can lead to conserving transmission energy to prolong the network lifetime.
2. Network security: Security attacks in WSNs include active and passive attacks and denial-of-service (DoS) which can seriously affect the overall performance of the network. Thus, to ensuring the data integrity of the transmitted data is the foremost security concern in WSNs. Routing attack is one of the most common active attacks that affect information exchangebetween network sensors. Jamming attacks interfere with radio frequencies that the sensor nodes use for communication. An intermittent jamming attack may hurt transmitted data especially if this data is time sensitive. The balance between sensors security and achieving the required QoS is a challenging problem as noted in many studies
3. Spread of sensor from 2D plane to 3D plane: Exiting systems are designed for the two-dimensional plane, the system can extend to (3D) plane in nature
4. Other challenges: other challenges include the harsh environment, varying spectral characteristics, variable link capacity etc.

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