ISSN:0975-9646

Richa Agnihotri et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 7 (4) , 2016, 2052-2058

Handling Multi Objectives of with Multi Objective Dynamic Particle Swarm Optimization

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***Abstract*— The transportation network is used widely in various areas such as communication, topological configuration, transportation and many more. The basic functionality of the network is to provide low cost and less time to make source to access the desired location which is remotely located. The important factors which have to be determined by network topology are Reliability and Cost. Network topology contains the nodes and the links between the nodes. The selection of the optimal path in the network topology is NP hard problem. But the selection grows complex with the classical enumeration and the methods for the selection of optimality. Thus for the solution, an evolutionary method is required so that both objectives of the network designing topology are fulfilled and satisfied. Due to above presented characteristics; it is found that transportation requires an algorithm which can select the optimal network topology which takes less time and low cost but should be highly reliable. In this paper, MODPSO algorithm is suggested. It is meta-heuristic algorithm which is inspired by the natural environment and uses evolutionary method. The Particle Swarm Optimization algorithm is implemented dynamic nature i.e. values can be changed during the experimentation is running which forms it Dynamic Particle Swarm Optimization. It is considered as enhancement from the all traditional methods and basic PSO framework implementation. The paper describes the dynamic selection of leaders and uses variant for optimization of multi-objectives. It also provides an efficient solution mechanism to calculate reliability and cost. It is termed as efficient and effective way to optimize network topology. Under the simulation environment results obtains are satisfactory and on comparison it is shown that the optimized results are better than the basic PSO framework.**

***Keywords*— Multi objective particle swarm optimization (MOPSO); Multi objective optimization problems (MOOPs); Particle swarm optimization (PSO); Multi objective dynamic particle swarm optimization (MODPSO);**

I. INTRODUCTION

Every problem is today's scenario contains various objectives and these objectives has to be satisfied all together. Thus, Optimization plays a vital role for handling such situation. Optimization includes either maximization or minimization of the objective functions define in the problem. To understand both PSO and MOOP, it is explained below:

A. *Particle Swarm Optimization*

PSO is meta-heuristic algorithm inspired by the social behaviour of bird flocking or fish schooling. It is population based stochastic optimization technique developed by Eberhart and Kennedy [1]. PSO is characterized as simple as well as fast effective and can be used in various types of optimization. PSO algorithms consists four steps which are iterated until the solution is obtained.

1. Initialization of population with random position and velocities values.
2. Evaluation of fitness functions for each particle.
3. Individual and global best fitness value and position updated.
4. Updation of velocity and position of each particle.

The first three steps of PSO are fairly trivial. Evaluation of fitness function is done by supplying the candidate solution. While individual and global best are updated using past history of the particle stored in archive. Thus, velocity and position is updated using following equation:

$$X_i(t+1) = X_i(t) + V_i(t+1) \quad (1)$$

$$V_i(t+1) = V_i(t) + c_1 r_{i,1}(t) \times (pbest_i(t) - X_i(t)) + c_2 r_{i,2}(t) \times (gbest(t) - Xi(t)) \quad (2)$$

where i = 1, 2,3,…..,n. the position of the ith particle and the velocity at the i^{th} iteration is denoted with X_i (t) and V_i (t) respectively. The best position achieved by entire swarm and particle itself at ith iteration is given by gbest (t) and pbest (t) respectively. There are two acceleration coefficient c_1 and c_2 which define cognitive and social parameter respectively, while $r_{i,1}$ and $r_{i,2}$ are random values within range of [0,1].

B. **Multi Objective Optimization Problems**

Multi objective optimization problems can be defined as the problem with multiple competitive objectives that has to be simultaneously optimized. Optimizations of multiple objectives include finding a set of optimal solution rather than a single solution. Selection of the solution from the optimal set is user dependent. Mathematically, a general MO problem can be formulated as follows [2]:

$$\text{Minimize or Maximize } f_n(x) \quad (3)$$

where n = 1,2,3,…..,N being subjected to :

$$\left.\begin{array}{l} g_i(x) \geq 0 \text{ where } i = 1,2,3,\ldots,m \\ h_k(x) = 0 \text{ where } k = 1,2,3,\ldots..p \end{array}\right\} \quad (4)$$

$$x_i^{(L)} \leq x_i \leq x_i^{(U)} \text{ where } i = 1,2,3,\ldots..,q$$

Here, x is being defined as the vector of n decision variables which can be represented as:

$$x = [x_1, x_2, x_3 \ldots x_n]^T \quad (5)$$

The solving of MOOP is depended on an important concept of dominance. Dominance can be defined as [2]:

Solution x_i is said to be dominating to solution x_j if and only if:

x_i is better than x_j, (f_k (x_i) > $f_k(x_j)$; for all k = 1,2,3… N

x_i is strictly better than x_j, ($f_k(x_i) \geq f_k(x_j)$; for all k = 1,2,3… N , this concept leads to the pareto optimality. The solution is said to be Pareto optimal is and only if there exist no other solution to dominate it. These solutions are known as non-dominated solution and the set of all non-dominated solution forms Pareto front of optimal solution.

C. **Multi Objective Particle Swarm Optimization**

The relative simplicity and success as single objective optimizer has made researcher to implement PSO to multi objective problems. However, there are certain issues to be addressed when applying PSO to MOOP. The first issue in multi objective Particle Swarm Optimization is the updation of individual and global best because there does not exists any absolute solution rather than a set of non-dominated solution. The solution can be selected from a set using various techniques and its results changes accordingly in MOPSO [10].

The next issue is fast convergence, known as important feature of PSO at the early stage. This feature usually is at the cost of rapid loss of diversity which leads to local optima in MOPSO. Thus, it became clear that the objectives in MOPSO are maintenance of convergence and diversity to obtain it accurate and well distributed Pareto optimal front [10]. These objectives have variant names according to the field of application. There are many MOPSOs published in the last decade. Some special issues in recent years were empirically investigated and discussed in the below section.

II. **PROBLEM DEFINITION**

Designing of network topology considering the reliability of system is been one of the major subject of optimization in the field of research and being applied to the application of transportation network. Network reliability is one of the calculation has to be performed keeping that in mind as all nodes must sink to each other and produce high reliability in low cost. Cost of implementation and maintenance for the network must be kept low and also consume less time to transport from source to destination.

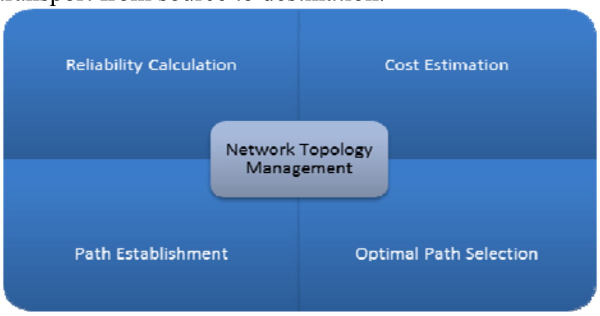

Fig.1 Network Topology Management

Traditional optimization techniques are very difficult to implement as well as the result obtained as well as the result obtained are also not true Pareto as they lack to deal with multiple objectives simultaneously. Many of the cases of multiple objective problems, the problem are being scaled into single objective function thus the results produced single Pareto optimum. Each run of this process of optimization is very sensitive with the weight vector used in the process of scaling. Moreover, multi objectives prefers group of Pareto optimal solution for decision making.

Just because the multi objectives problems work with group of solutions simultaneously so the evolutionary algorithms are not only approach but several more approaches are extended an applied to the transportation network. Several algorithms are developed for analysis of reliability in the network topology. Most of the problems uses these two objectives but in variant manner. The approaches used by the algorithms and models, it is obtained that all these methods works on the pre-defined characteristics. Once the values are set and results is obtained provide no chance to correct if any changes is needed. However, numerous characteristics are used and if any one fails to obtain accurate results whole algorithm fails which increases the complexity of an algorithm.

Since lack of proper optimization can cause great harm to the network topology, thus a large number of solutions have been proposed to optimize the objective of network topology and obtain the best and effective results. Among from all these methods of solution, there is well known mechanism as PSO. PSO is considered one of the most appropriate algorithm and simple to implement over the traits of transportation network. The results obtained are also better than the previous method but there is problem threat is that all values are pre-defined and also there is no selection of nodes dynamically from the neighborhood. PSO does not select the nodes and size and all the characteristics dynamically and value calculated from the static conform. However, it provides the mechanism which simple but due the static path selection procedure it cannot judge it reliable neighbor and selects the path accordingly. Thus dynamic neighborhood selection and dynamic variation in parameter in basic framework of PSO is essentially required.

Optimization of reliability and cost in network topology is very challenging issue because lack of dynamic selection of neighbor nodes as well as dynamic variation in parameter. Thus, the transportation network in terms of defined objectives does not guaranteed the optimal solution path for service of reliable data delivery to the receivers in less time and low cost.

Figure 2 shows the mechanism for obtaining results of multi objective problems using the traditional methods which uses the process called scaling.

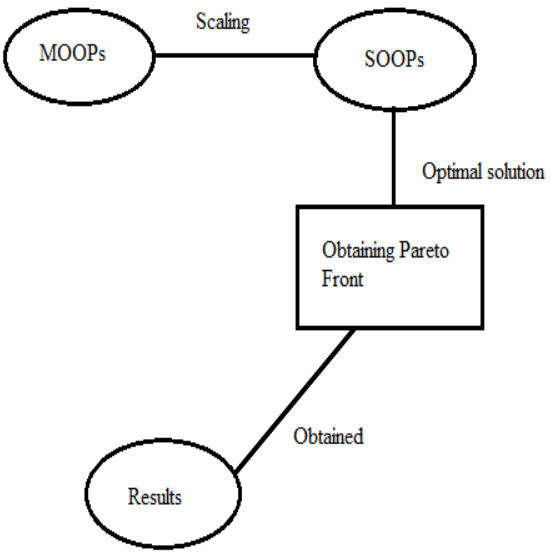

Fig.2 Traditional Mechanism for MOOPs

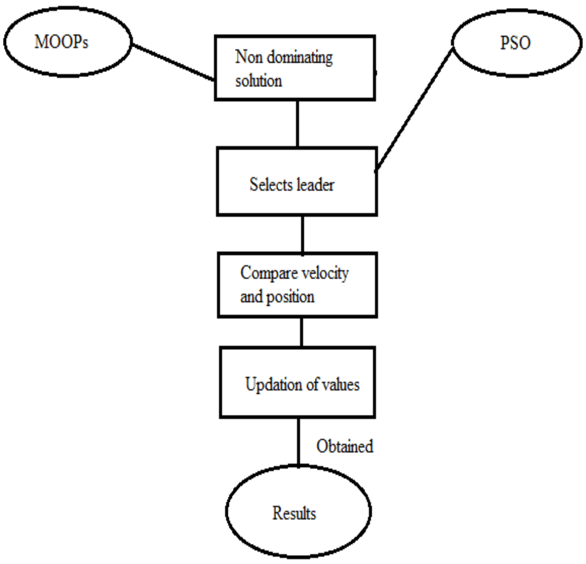

Fig. 3 MOPSO mechanism for MOOPs

Figure 3 also implicates the mechanism for solving multi objecting problem using basic PSO framework. But these methods fail to produce satisfactory results for maintaining reliability constraints when it is applied to network topological area. Thus, it requires the promising method which can simultaneously handle cost and reliability constraints of transportation network.

III. Proposed Work

The transportation network provides the optimal path for communication from source to destination. The basic objectives of the network topology are to obtain the path with higher reliability and low cost. Solving this problem with the evolutionary algorithm named PSO provides simple and effective results. But the problem lies in the dynamic adaptation of the parameters and the dynamic node selection.

Hence here we proposed the new algorithm which is meta-heuristic in nature and evolutionary algorithm which overcome the dynamic variation of characteristics and selection of neighbour node. The proposed algorithm is called as Multi Objective Dynamic Particle Swarm Optimization (MODPSO). The algorithm mainly focuses on the following things:

a) A. Optimization of objectives of Multi Objective Problem of network topology.
b) B. Dynamic variation in characteristics of PSO framework.
c) C. Dynamic selection of neighbour node.

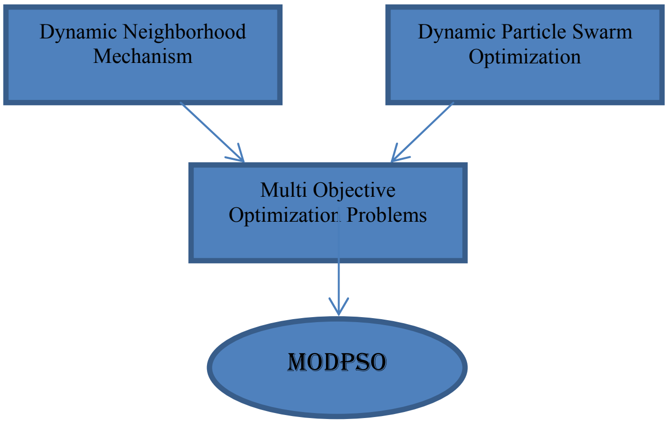

Fig.4 Development of proposed algorithm

These factors make the proposed algorithm variant from basic MOPSO framework. In this proposed we present a heuristic approach to design transportation network considering concern of system reliability with respect to their reliability constraints. There are following assumption been made as considering that all nodes are perfect and reliable and are fixed. Each pair of node is properly connected by a single link which is bi-directional and has their stated reliability and cost. Thus here the optimization is carried out by two ways: firstly, reliability is optimized to maximum and the cost is minimized which is being done by DPSO mechanism.

The DPSO describes the variation with the swarm size and the variation in network topology. The concept of DPSO contains that at each time step, the changing of values of parameters which can be velocity, inertia and many more. It also provides the authority to node to selects its corresponding neighbour during the execution. Therefore the node himself decides for the neighbour from which it wants to share the path. Thus, following the continuous process to the maximum iteration until the solution is attained. The solution obtained must have maximum reliability and minimum cost as compared to the basic PSO framework.

Proposed approach provides the reliable path from sender to receiver with all aspect of optimal path requirements. That increases the network reliability and decreases the cost of transportation in network.

Proposed work differs and is enhanced from previously used mechanism in term of following points-

a. Types of evolutionary algorithm (DPSO)

b. In our work PSO works as variant because there is feature of dynamic adaption of characteristics and also dynamic selection of node to form neighbour through which all possible solutions are attained and from them optimal path is selected.

c. In our model, reliability is calculated as reliability function and considering the link cost with neighbour's node recommendation.

The exact evaluation of network reliability in network topology is very expensive as it is NP-hard problem. Thus our proposed work evaluates the cost and reliability by MOOM and performed estimation by DPSO mechanism. The proposed algorithm results in calculation of efficient reliability of the network in the best economic manner and also requires less time for obtaining the solution. Considering the cases of large node topology, our proposed algorithm still obtains the higher reliable path in low cost. The performance of the network is improvises in terms of time consumption, throughput, delays, cost and reliability. MODPSO makes the optimization of multiple objectives simultaneously which results in better performance with feature of dynamic variation in PSO framework neighbourhood selection. Hence, the proposed algorithm provides advantages to the applied area better than current technology, methods and mechanism.

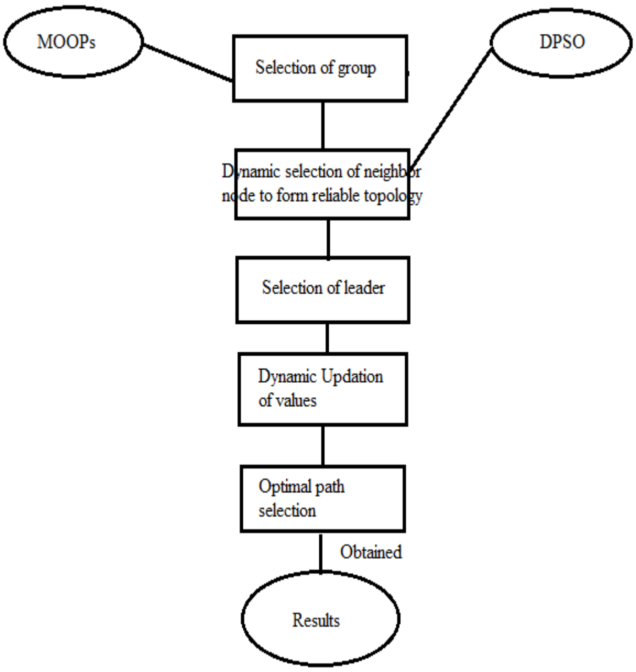

Fig.5 MODPSO mechanism for MOOPs

A. **Proposed Algorithm**

1. Objective: Optimization of Multi Objectives such that

Optimize C(r),R(r)
Such that $R(r) \geq R^c$

2. Initialize the parameter as Number of iteration, swarm size, inertia, coefficients c1 and c2, pbest, gbest, particle position, particle velocity and objective function.
3. Initialize the parameters with their initial values.
4. Determine dominant solutions.
5. Plot the Pareto curve.
6. Calculate the fitness function
7. Leader selection with satisfaction of the fitness function and remark it as gbest
8. Calculate new pbest and if:

New pbest > pbest
Then update pbest with new pbest
Else
No change

9. Calculate new gbest and if:

New gbest > gbest
Then update gbest with new gbest
Else
No change

10. For each particle calculates velocity and position and if needed update those in equation stated:

$$X_i(t+1) = X_i(t) + V_i(t+1)$$

$$V_i(t+1) = V_i(t) + c_1 r_{i,1}(t) \times (pbest_i(t) - X_i(t)) + c_2 r_{i,2}(t) \times (gbest(t) - X_i(t))$$

11. New particle is selected dynamically to form the swarm particle chain.
12. Check the values from dominant set and if:

Values obtained < dominance value
Then discard the solution
Else
Add solution to dominated solution set

13. Iterate the values to maximum until solution is attained.

IV. Experimental Work And Results

To obtain the status of experiment, some standard benchmark functions of Multi Objective Optimization are considered.

Problem ZDT 1 [68] was adopted for study of experiment been performed. We perform the simulation to obtain the optimal path in the transportation network which satisfies both of the constraints of cost and reliability. Values of parameters involved in equation are taken as 0.5 for inertia and the values c_1 and c_2 are 1 and 2 respectively and particle swarm size is 200 for iteration. Simulation has been carried out for 200 iterations. In which firstly, dominated points are found and then cost of the function values for each dominated values which gives us the set of optimized dominated point.

Thus then we obtained non dominated points and then finally compare this points by non- dominated mechanism which provides optimized non dominated points. The set of these points gives us the true Pareto front.

I. TABLE 1 BENCHMARK FUNCTION

Function	**Objective Functions**	**Solution space**	**Variable Bound**
ZDT 1	$f1(x) = x1$	6	[0,1]
	$f2(x) = g(x)\left(1 - \frac{\sqrt{x1}}{g(x)}\right)$		
	$g(x) = 1 + 9\left(\sum_{i=2}^{D} xi\right) / (D-1)$		

A. **Obtaining the dominated solution:**
Thus result is shown in figure 6.

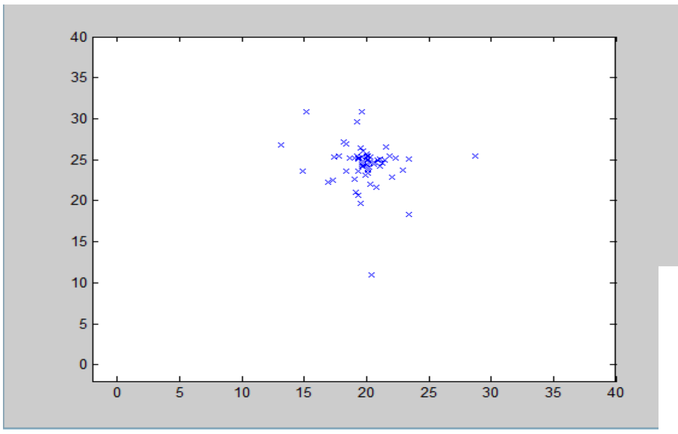

Fig. 6 Set of dominated solutions

B. **Obtaining the Pareto Curve:**

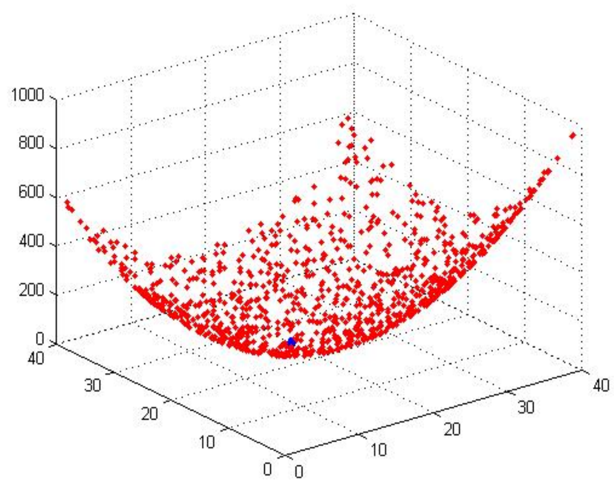

Fig. 7 Pareto curve for dominance solutions

C. **Obtaining the Reliability:**

Reliability: Reliability R(r) is the probability that the system will operate successfully under the stated condition for stated duration of time.

Simple series: **R(r)** = $\prod_{i=1}^{n} ri$
Simple parallel: **R(r)** = $1 - \prod_{j=1}^{n}(1 - rj)$
Parallel series: **R(r)** = $\prod_{i=1}^{n}[1 - \prod_{i=1}^{n} 1 - rij]$
Series parallel: **R(r)** = $1 - \prod_{j=1}^{n}(1 - \prod_{i=1}^{n} rij)$

The reliability for PSO and MODPSO are as follows:

Reliability	**MODPSO**	**PSO**
r_{12}	0.67	0.67
r_{13}	0.71	0.74
r_{14}	0.68	0.67
r_{15}	0.79	0.75
r_{23}	0.98	0.98
r_{24}	0.78	0.78
r_{25}	0.88	0.85
r_{34}	0.67	0.69
r_{35}	0.79	0.78
r_{45}	0.96	0.96

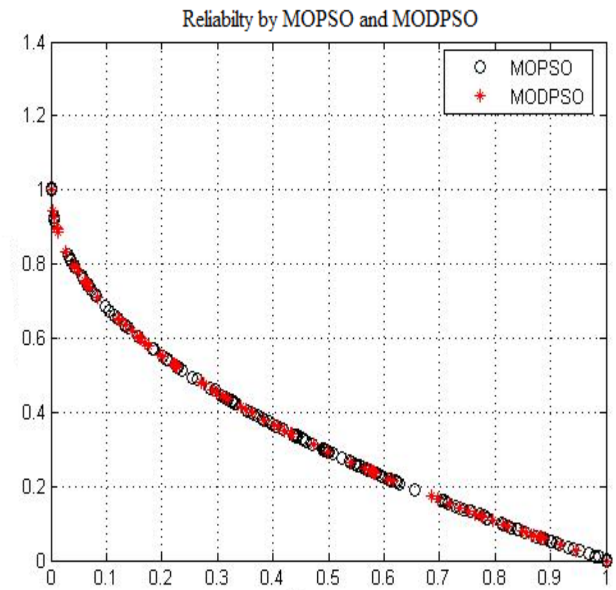

Fig. 8 Reliability comparison by MOPSO and MODPSO

D. **Obtaining the Results in terms of reliability and cost:**

II. TABLE 2 COMPARISONS OF SOLUTIONS

	PSO	**MODPSO**
Reliability Of Network	0.55	0.57
Cost Of Network	57	48

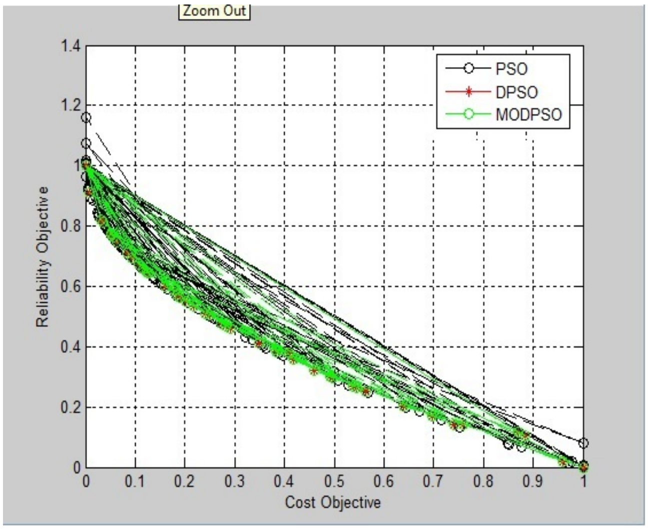

Fig. 9 Results for 50 iterations

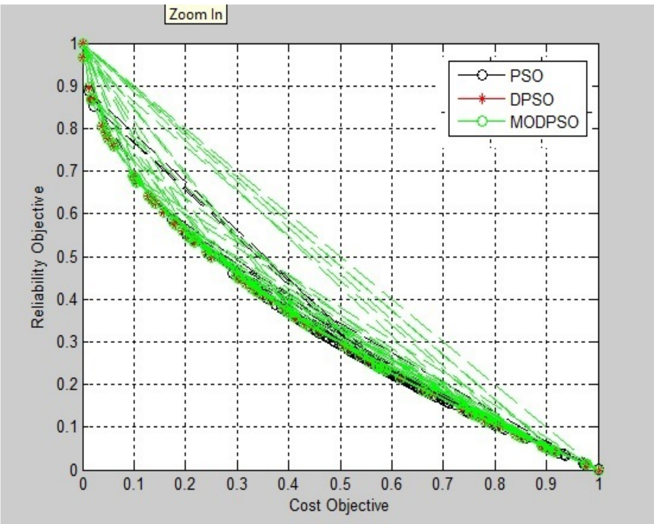

Fig. 10 Results for 100 iterations

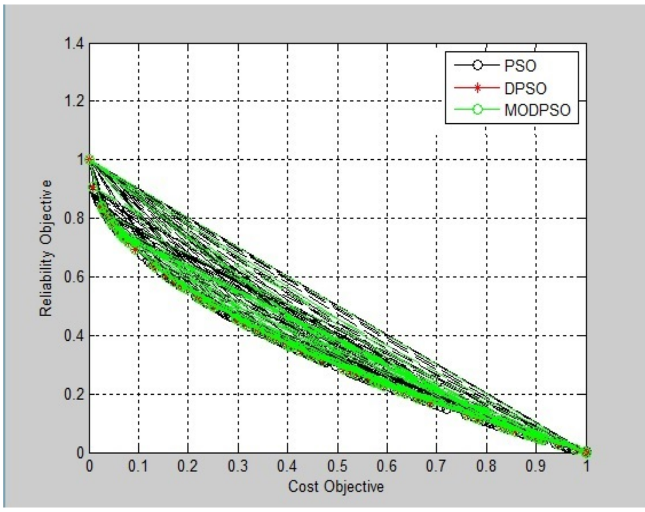

Fig. 11 Results for 150 iterations

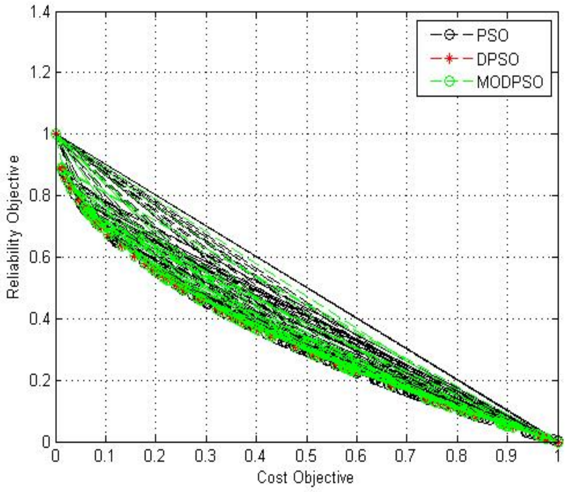

Fig. 12 Results for 200 iterations

V. FUTURE WORK

(1) The proposed MODPSO uses dynamic neighbourhood with the variation of PSO and it further can be extended with other variation of PSO and can provide better results.
(2) MODPSO (Multi Objective Dynamic Particle Swarm Optimization) is implemented on network topology for transportation network and in future it can be implementing for clustering of Big Data and finding the shortest path being required by all types of network routing.
(3) The proposed work now has reliability and cost as their objectives constraints but in future it can also add time as constraints so that no delay can affect the network topology.

VI. CONCLUSION

In this proposed work, we compare the MODPSO with PSO. PSO is a framework that uses biological mechanism to optimize the MOOPs. But MODPSO uses the Dynamic framework of PSO and also uses Dynamic Neighbourhood mechanism. The MODPSO describes the variation with the swarm size and the variation in network topology. The concept of MODPSO contains that at each time step, the changing of values of parameters which can be velocity, inertia and many more. It also provides the authority to node to selects its corresponding neighbour during the execution. Therefore the node himself decides for the neighbour from which it wants to share the path. Thus, following the continuous process to the maximum iteration until the solution is attained. The solution obtained must have maximum reliability and minimum cost as compared to the basic PSO framework.

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