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Multi objective optimization for performance analysis of Cooperative Wireless Communication

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ABSTRACT

Decision making is a critical issue in all most all the fields. Making an optimal decision is not only economically beneficiated but also improves the overall efficiency of operations. A variety of multi objective optimization (MOO) algorithms has been made and successfully deployed to produce remarkable results for performance analysis. In this paper, we review the optimization technique and we also demonstrate its application in wireless communication. Especially we focused on multi-objective optimization techniques in cooperative wireless communication to find the optimal relay node and also we compare the results with the game theory approach for the same.

Key words: Multi-objective optimizations, cooperative communication, relay.

1. INTRODUCTION

The optimization is a process to find the best solution of given problem. These solutions could be finding the minimum or maximum value with one or more objective functions. Multi-objective optimization (MOO) handles more than one objective function to find the optimal solution. Almost in every field, such social sciences, engineering, finance and more we found the application of these powerful optimization technique for fast and accurate results.

In finance time series analysis can be by NGPA ie niched-Pareto genetic algorithm [1]. The after analyzing the data through NPGA it provide the better execute a better understanding of up and down stream trends in in short interval. The capital investment and annual energy expenditure in relation to minimization of resources in mechanics can be done by the genetic algorithms (GA) [2]. For the optimal values of design variables the MOO algorithms are being used. To find aspiration level in goal programming for the decision making such optimization techniques are being used [3 - 4].

The optimization is stochastic process, and unlike the other optimization techniques multi objective evolutionary algorithms also follow the same analogy [5] but to find solution for a specific problem these algorithms use the concept of domination, instead of population-based approaches.

For cooperative communication, Ahn et al. [6] have presented a transmission scheme and the adaptive relay selection scheme. The presented scheme shows for selecting the relay it does not need any early information from the source. The optimal relay can be chosen by the source without channel state information by utilizing the presented relay selection scheme. The properties of Reed-Solomon codes have been utilized by the presented approach so that the optimal relay can be chosen by the source. Moreover, the conferred adaptive scheme can change the maximum throughput based on the optimal selection result. The developed system has been considered as more reliable and adaptable on utilizing the proposed adaptive transmission scheme and relay selection.

Saghezchi et al. [7] have used game theory concepts and have formulated the issue as an assignment game. The optimal relay selection has been formulated as a linear programming issue, whose solution allocates appropriate relays to their corresponding resources in the initial stage. The core solution has been obtained which ensures a fair distribution of the payoff between players for maintaining them satisfied and preventing them from quitting the coalition in the final stage. A credit-based system has been presented by the solution to reward cooperative players and to prevent selfish players from the cooperative coalition. The results have shown that the presented approach has significantly saved energy utilizing cooperative relaying with an increase in battery life.

The main motive behind this paper is to introduce the MOO in the field of cooperative wireless communication without being used the rigorous mathematics. The flow paper is starting from the introduction including discussion with the fundamental aspects for optimization then second part is devoted to MOO and before conclusion the application of MOO in cooperative wireless communication is being demonstrated.

2. INTRODUCTION TO MOO

Optimization can be classified in many ways nut in this paper we will discuss only the multi-objective optimization techniques and its related theory. By MOO we used to find the of those problems which more than one objective functions. With the MOO rigorous mathematical equations could be avoided that why researcher motivated towards the use of these MOO algorithms to summaries their findings. Vilfredo Pareto introduces the MOO and nowadays many more refined algorithms have been evolved. In MOO objective function is a vector space has a direct relation to the solution vector. MOO computation provides a series of the best solution rather than a single solution.

Mathematically MOO can be written in the following manner:

$$\textbf{MIN/MAX} \quad \mathbf{f_1(x), f_2(x), \ldots, f_n(x)} \quad \textbf{(1)}$$
$$\textbf{Subject to} \quad \mathbf{x \in U}$$

Here x is a solution vector space, n represents the total numbers of objective functions,$f_n(x)$ represents n^{th} objective function and U is a total possible set and min/max is the combined operator.

In the analysis solution vector of MOO exhibits the multi-dimension relationship between the objective function and decision variables. The relation between them is depicted in Figure 1[8]. The condition for the optimal solution is that there should be the convexity in the mapping. If we found the convexity then there exists variety of optimization techniques to find the optimal solution. The convexity can judged in initially in the problem statement. For the condition of convexity following equation must be satisfied.

$$\mathbf{f(\theta x + (1-\theta)y) \leq \theta f(x) + (1-\theta)\, f(y)} \quad \textbf{(2)}$$

here x, y lie in (01). Equation (2) inferred that there exist a linear relationship between x & f(x) and y f(y) as shown in Figure 2.

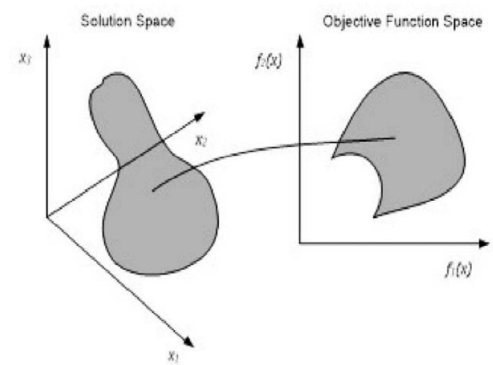

Figure 1: Relation between solution space and objective function [8]

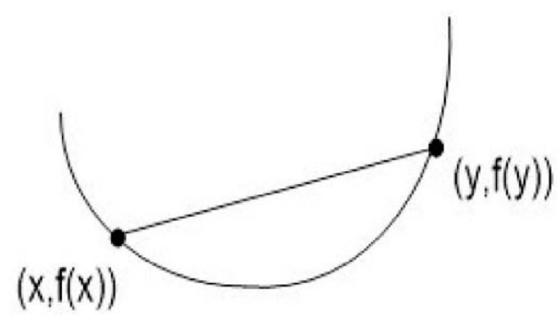

Figure 2: Convexity mapping [8]

The fundamental solution of MOO problem can be categorized as either Pareto method or Scalarization method [10]. The concept of Pareto optimal front used in first one for display the desired solution and performance indicators. While in case of second one the scalar function is integrated with the fitness function to find the performance indicator [11]. A brief introduction is mention in the next section.

2.1 Pareto method

The problems related to MOO can be formulated and represented as below:

$$\mathbf{f_{1,opt}} = \mathbf{minf_1(x)}$$
$$\mathbf{f_{2,opt}} = \mathbf{minf_2(x)}$$
$$\mathbf{f_{n,opt}} = \mathbf{minf_n(x)} \qquad \mathbf{(3)}$$

The solution vector uses the concept of dominance. When there is inverse effect of one objective function over other objective function then there exist dominance solution and we can find the optimal solution. This is known as Pareto optimality, which exhibits the number of possible optimal solutions in MOO. In non-dominant objective function further results can be upgrade independently in absence of shrinking the other objective function. This solution is also known as an inferior solution [12].

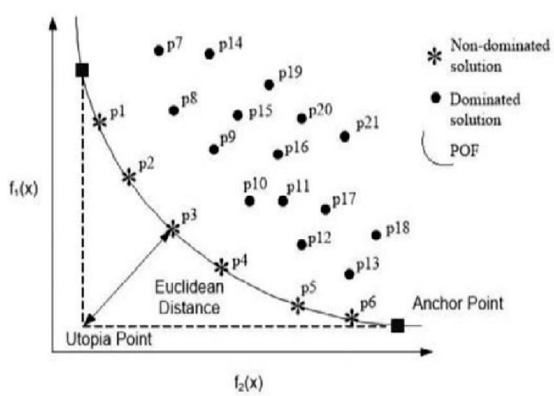

Figure 3: POF for objective functions

There are following terminologies used in solving the Pareto optimal solution.

i. Anchor Point: It presents the location for the optimality of an objective function.
ii. Utopia Point: It is represent intersection of max/ min value of different objective functions [13]

The optimization problem including two or more objective functions then there non-dominant solution can be explained over the POF in two-dimensional surface. Figure3 shows an example of minimization problem i.e. minimizing both the objective function [14-15].The dominated solution $(p_7, p_8 \dots \dots . p_{21})$and non dominated solution p_1, p_2, p_3, p_4, p_5 & p_6 are located in the graph.

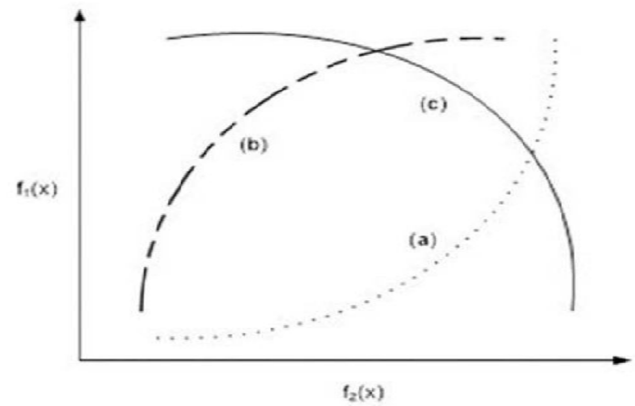

Figure 4: POF among objective functions

There are a total of four different combinations of the optimization problem can be modeled with objective functions f_1(x) and f_2(x). One we have discussed above and the remaining three reflected through a different curve on the following graph. Curve (a) shows the POF to minimize the one objective function and maximize the other, curve (b) shows the POF to maximize the objective function one and minimize the second objective function, and curve (c) shows the POF to maximize both the objective function f_1(x) and f_2(x).

The shortest Euclidean distance gives the optimal solution over the POF, if the Utopia point is found [16]. The continuous search and update method is used for non-dominated solutions [8]. This search algorithm can summarize as:

a) Start with non dominated path $P' = 1$ and counter set to$i = 1$.
b) Take another variable $j = 1$.
c) Analyze both solution i.e.ith and jth to search for additional dominant solution in P' .
d) Delete the number of –j from P’ add j with one if the ith solution rule over the jth one, and jump to step c otherwise jump on step e. Add i with 1 and go back to step b if P’ dominates number –j.
e) Replace P’=P’$_i$ If i < N, where N represents the total number of the solution. Further

increment i and jump to step b. In absence of this condition process will be halted and P' will be selected as a non-dominated set of solution. This will create the POF.

The Utopia point is determined after continuously updating of the algorithm. The Utopia point is responsible for optimal solution value. The shortest Euclidean distance [17] is the optimal represent the optimal solution which can be found using equation 4.

$$\mathbf{d_E = min\sqrt{\left(\frac{Q_1-Q_1^*}{Q_{1norm}}\right)^2 + \left(\frac{Q_1-Q_2^*}{Q_{2norm}}\right)^2}} \quad \textbf{(4)}$$

Here point (Q_1^*, Q_2^*) in figure 3 represents the Utopia point of the $f_1(x)$ i.e. first objective function whose minimum value has been searched, and the minimum value is looked for the second objective function$f_2(x)$, which should be minimum value to determine the point (Q_1, Q_2) on POF, and point (Q_{1norm}, Q_{2norm})represent normalized coordinates in the problem area. (Q_{1norm}) found by selecting the minimum value of Q_1, while (Q_{2norm}) is evaluated over the minimum value of Q_2.

2.2 Method of Scalarization

In method of scalarization used to find the single solution of a given problem. In this approach weight has to be determined before to begin the process of optimization. The mapping has to be done between multi-objective function and scalar fitness function as mention in equation (5)[18]:

$$\mathbf{F(x) = w_1 f_1(x) + w_2 f_2(x) + \cdots + w_n f_n(x)} \quad \textbf{(5)}$$

The solution space of the fitness function will be determined by the weights and these weights show the priority findings in performance. [19]

The priority will be given to that objective function which has larger weights compare to others. There are three different ways to find the weights of scalarization. These are mentioned below [20]:

1. **Equal weights:**

The following equation can be used to find the equal weights:

$$\mathbf{w_i = \frac{1}{n}} \quad \textbf{(6)}$$

Here ndenotes the number of objective function for i=1, 2, 3… up to n.

2. **Rank Order Centroid (ROC) weights:**

By the ROC weights one can give the criteria. The weights with ROC can be evaluated using the following equation: [21]

$$\mathbf{w_i = \frac{1}{n}\sum_{n}^{k=i}\frac{1}{k}} \quad \textbf{(7)}$$

3. **Rank-sum (RS) weights:**

Every criterion can be put in a relative position by RS weights. For RS weights calculations one can use the following equation:

$$\mathbf{w_i = \frac{2(n+1+i)}{n(n+1)}} \quad \textbf{(8)}$$

The minimization function is labeled as negative and maximizing function labeled as positive in the scalarization method. Interpretation of each objective function require normalized root mean square value [22]

$$\mathbf{F(x) = -\frac{w_1 f_1(x)}{\sqrt{E(f_1^2(x))}} + \frac{w_2 f_2(x)}{\sqrt{E(f_2^2(x))}} - \frac{w_3 f_3(x)}{\sqrt{E(f_3^2(x))}}} \quad \textbf{(9)}$$

Here $F(x)$ is the fitness function, $f_1(x), f_2(x), f_3(x)$ are the three objective functions and w_1, w_2, w_3 are three weights.

To determine the optimal value using MOO exhaustive search methods deploy to check the complete solution. For this algorithm like GA, particle swarm optimization, spider monkey optimization, ant colony optimization, etc can be utilized.

3. APPLICATION OF MOO IN COOPERATIVE COMMUNICATION

The cooperative communication will play a critical role in the 5G and upcoming generation of wireless communication. In dense network deployment for the high date relay assisted network able to provide the not only the highly reliable network but also increase the throughput and demand the low power transmitters as base stations. In cooperative communication end to end delivery supported by the intermediate nodes [23].Through the cooperative communication the broadcast nature for transmitting the signal could be perceived as more directive without any new hardware requirement. By carefully deploying the relay node using the optimization techniques one achieved improved results in terms of reliability and power efficiency.

In the relay assisted network the fundamental problem is how to select the optimal relay nodes for end to end communication. In other words we can say that the relay selection is the key factor by which the cooperative communication influences the performance parameter to a great extent [24]. Under the ages of absence of non-line of sight scenario between the transmitter and receiver by selecting the few or more intermediate relay nodes in support increase the reliability of the transmission link. A variety of network resource mechanism technique have been proposed by the researchers in past and a continuous effort is going on the field of cooperative communication [25]. The wireless cooperative communication the network performance relies on optimal relay node selections between the transmitter and receiver [26]. Depending the upon the nature of the transmission scenario relay node cooperative communication can exploited be any of the three renewed relaying strategies. These are Amplify and Forward (AF), Decode and Forward (DF) and Compress and Forward (CF). In AF whatever signal received at the relay node will be directed to the designation without changes while in case of DF signal received at the relay node is getting regenerated by the intermediate node before to direct further towards the destination node. In such a case if signal get attenuated will be boosted for next hop [27]. Finally in CF relay cannot able to decode the message but provide the support for the forwarding the compressed version of message encoded by the source [28].

Depending upon the channel conditions AF and DF the strategies compliments each other [29]. The relay node selected for the cooperative communication under the consideration of random channel characteristics is a complex job. In presence of direct link relay and feedback received from the destination relay node act a silent node and remain idle. When relay node destination send back the acknowledgement to the sender about the not availability of direct link or unsuccessful transmission then relay activated and transmit the signal via the relay nodes using either AF or DF protocol with extra overhead [30]. For relay selection in cooperative communication lot of approached tested and demonstrated by the researcher in past. These approached uses either signal to noise ratio or channel gain as single objective for the relay node selection. With this approach researchers had made assumption of either partial or full channel state information is available to the source [31]. As discussed the underlying issues related to cooperative communication and especially in relay node selection as the fundamental problem we have demonstrated the novel approach for the relay node selection using the multi objective based algorithms (MOO) [32].

3.1 Remedy for the Identified Problem in Cooperative Communication

The cooperative communications have the potential to enhance the performance of wireless communication in context to the link quality and throughput but at the same it has significant issues also. These issues are related to the how to decide the cooperation strategies or more specifically how to select the intermediate relay node for the cooperation to deliver the messages end to end. Major part of the cooperation is concern with optimal resource allocation. These resources are transmitted power and available channel capacity. The problem of identifying the optimal relay node was handled by the earlier researcher based on the signal parameter like signal to noise ratio (SNR) or power consumption. The author in [32] has introduces the novel approach for selecting the optimal relay node by exploiting the multi-objective optimization technique. In this approach he framed multi objective function based on the SNR, channel gain and power consumption and optimized these parameters for the relay node selection. The lion optimization algorithm was presented in [32] by the author which is based on hunting behavior of lion for the optimal relay node selection. The results were compared with the game theory approach for the performance comparison which we will discuss in the next section.

3.2 Objective functions selected for the relay node selection

Author frame three objective function which was executed for the optimal relay node selection using the Lion optimization algorithm. These objective functions are mention below.

Signal to Noise Ratio (SNR): First objective function is based on the SNR value. The relay node selection is using this objective function select the relay node based on the minimum SNR value exhibited among the hops.

Channel gain: The second objective function selected for the optimal relay node is done by minimizing the channel gain of two hops.

Power consumption: The third objective function for relay node selection with maximum residual power is selected as an optimal relay node. Residual power is calculated based on the initial power and consumed power by the relay node.

Objective functions related to SNR, Channel gain and Power consumption relay node selected by passing the parameter in the Lion Optimization Algorithm. In the next section we will discuss the parameter selected for the execution algorithms and discuss the LOA.

3.3 Implementation and Result Discussions

The MATLAB programming used by the author for the implementation of multi objective Lion Optimization Algorithms for the optimal relay node selection [32]. The common system configuration was used to run the code. Table 1 shows the simulation parameter and its limits. Simulation is run with 200 nodes out of which 198 nodes treated as the relay node while remaining two nodes selected as the source and destination. Among these 198 nodes relay node selected for the end to end delivery using lion optimization.

3.4 Performance comparisons and result discussion

This section devote to the discussion on the results produce by author after executing the code to simulate LOA for optimal relay node selection [32] and also we discuss the comparison of results with the existing game theory approach for the different parameter. To capture the dynamic behavior of channel between source and destination distance parameter also analyzed among nodes. By changing distance between source to relay node and varying data rate, the performance had been evaluated and compared

Table 1: Simulation Parameter to execute the LOA

Parameters	Assumptions
Number of nodes	200
Initial energy of source	0.3J
Initial energy of RNs	[0.1J, 0.5J]
Channel model	Rayleigh fading channel
Bandwidth of channel	1MHz
Relaying protocol	Amplify and Forward (AF)
Receiver noise	Additive White Gaussian Noise
Data rate	100-500kb/s

3.4.1 Optimal relay location by varying distance between Source and Relay Node

The SNR between source and relay node and SNR between relay node and destination have been analyzed by varying the distance between source node and relay nodes as shown in Figure 5. The signal to noise ratio value of the source and relay link and distance between relay and destination decrease when the distance between source and relay increases. Also, there is increases in SNR value between relay and destinationas the distance between source and relay increases. At the intersecting point shown in the Figure 5 the optimal location for the relay node is approximately found at 1450m from the source node.

3.4.2 Energy consumption comparison by varying Data rate

In Figure 6 shows the comparison of two approaches. One suggested by the author based on LOA and another based on game theory approach by varying the data rate for the transmission. The energy consumption increases with the data rate as shown in the figure. There is 18% reduction in energy consumption has been recorded by the novel LOA approach suggested by the author in contrast to existing approach. So by optimal relay node selection

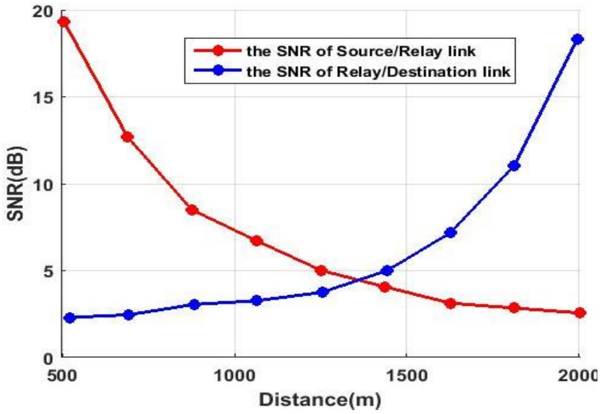

Figure 5: Optimal relay node location

the developed approach using the concept of multi objective optimization exhibit the energy efficiency and improve the network life time. In [33] author also

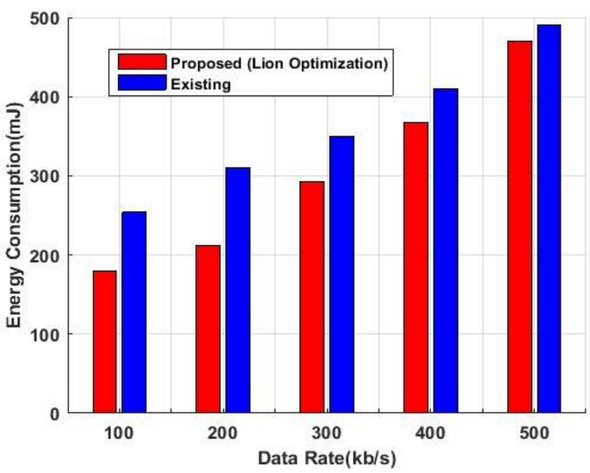

Figure 6: Comparison of Energy consumption to vary the data rate for different approaches

introduced an another multi objective optimization technique for the optimal power allocation in cooperative communication and compare the results with existing approach for the network performance parameter. The utility of these algorithms in network provide easy to implement and analyze network performances.

4. CONCLUSION

To find the solution in different aspect of human life we can use the MOO algorithms. These are flexible and customised according to the given problem. By reviewing the MOO we found two important conclusions. Firstly these MOO algorithms do not require complex mathematic and they are simple to use in finding the optimal solution. Pareto and scalarization methods can select for the multiple or single solution of the problem using the concept of dominance and optimise further. The author also used these multi objective based optimization techniques for the performance evaluation and comparison in his previous research work [32-33] in cooperative wireless communication domain.

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