IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol.-6, Issue-6, Jun 2018 E-ISSN: 2347-2693

Differential Evolution for Mobile Ad-hoc Networks: A Review

S. Prabha[1*], R. Yadav [2]

[1*] Dept. of CS and IT, Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, UP, India
[2] Dept. of CS and IT, Sam Higginbottom University of Agriculture, Technology and Sciences, Naini, UP, India

[*]Corresponding Author: shashi17feb@gmail.com, Tel.: +91-8173869853

Available online at: www.ijcseonline.org

Accepted: 13/Jun/2018, Published: 30/Jun/2018

Abstract — Differential evolution is potentially one of the most promising real parameter optimization algorithms. In last few years, time has witnessed the growth and applications of Differential Evolution in the field of science and engineering. This paper focuses on the application of Differential Evolution (DE) in mobile ad-hoc network to solve optimization problems. According to the conducted studies the applications are classified on the basis of four categories of optimization problems: clustering, routing, security and topology control mechanism. In this article, we review the main work and discuss the future scope of differential evolution with mobile ad-hoc networks. The results of conducted literature survey shows that maximum amount of articles were published in the years 2012 and 2015. About 62.5% of articles were related to topology control mechanism whereas rest of categories shared the similar contribution of about 12.5% each. From the review, it was found that research has been conducted on the application of DE in solving issues such as handling networks (up to 500 nodes) with minimum overhead and strengthening of cryptographic algorithms (up to 9 key size). In future these works can be extended to solve similar problems in large networks. Moreover, it was found that no work has been carried out to find secure route for dissemination using DE.

Keywords— Differential Evolution, Mutation, Crossover, Fitness Function, Topology control mechanism, Routing, Clustering

I. INTRODUCTION

In today's era of Internet of things, the concept of wireless network being able to be deployed anywhere motivates the development of intelligent system like cyber-physical system (CPS), where the wireless systems are utilized for commercial and development purposes. According to the report of——United Nations Environment Program (UNEP) and International Fund for Agricultural Development (IFAD) [1], about 2.5 billion people survive from agricultural production systems. Research and development program by the governmental initiatives [1] are trying to increase the productivity by applying CPS to guide production systems such as watering [2] and spraying pesticides [3]. These types of applications make mobile ad-hoc network (MANET) more attractive for researchers.

MANETs are collection of self-organized mobile nodes that are deployed without any centralized unit and it is also dynamic in nature. The analysis and study of MANETs has been carried out by event-based simulators due to very expensive actual test-bed implementation in terms of high hardware cost and difficulty to create simulation's replica in controlled environment (like laboratory). Therefore, event-based simulators such as NS-2, NS-3, OPNET, QualNet are utilized to evaluate the performance of MANET. Studies revealed that in MANETs, many parameters are intercorrelated [4], [5], due to which optimizing analytical model through theoretical point of view become very difficult. This fact is motivating many researchers, to explore new approach of evolutionary algorithm for optimization such as differential evolution.

Differential evolution (DE) is inspired from the process of evolution. It is a mathematical model introduced by Kenneth Price and Rainer Storn [6]. Literature survey conducted has shown very less applications of differential evolution in MANETs, whereas a review article by D. G. Reina [7] focuses the latest application of evolutionary algorithms for mobile multihop ad-hoc networks. Our article extends the idea of solving optimization problems by adding the aspects of security in it. Here, the motive is to explore the research gap and new ideas to develop different strategies with respect to optimal solutions for the MANET issues. According to the conducted research the optimization problems are classified into different categories like clustering, topology control mechanism, routing and security.

The main aim of this article is to collect existing work about the application of DE in the field of MANETs. The rest of paper is organized into five sections as follows: section II brings out basics of classical DE in lime light, section III covers the application of Differential Evolution in MANETs, section IV covers discussion on future scope, and section V concludes the article.

II. DIFFERENTIAL EVOLUTION

DE is a class of evolutionary algorithm, a stochastic population based technique, considered to be the most recent technique to solve real-valued optimization problems [8]. DE exhibits many advantages first; it is much simpler than any other evolutionary algorithm. Its simplicity became attraction for researchers of other fields to solve their domain-specific problems. Second, it has few parameters to work with F, NP and Cr, which directly influence the performance of DE. Third, overall performance is still better than other evolutionary algorithm in terms of convergence speed, accuracy and robustness. Fourth, it requires less storage space complexity to handle large scale higher dimension problems. All these together enforce DE algorithm to be an effective global optimization algorithm [9].

The basic nomenclature, to represent different DE variants is: DE/a/b/c, a stands for vectors to be perturbed which is randomly selected according (to DE variants), b denotes number of difference vectors and c represent types of crossover (bin or exponential). The classical DE consists of four main steps: initialization, mutation, crossover or recombination, and selection which are described below as follows:

Initialization: To search global optima in multi-dimension space, DE algorithm perform initialization only once, rest of three steps reoccur repeatedly, till the fulfilment of termination criteria. The Figure 1 depicts the basic working of differential evolution. It starts with the initialization of population NP_g in d-dimensional real-value vectors space and the subsequent generation is denoted by g={0,1,2,3,………………..,g_{max}}. To represent i-th vector of current generation we adopt following notations:

$$X_{i,g} = [x_{(1),i,g}, x_{(2),i,g}, x_{(3),i,g}, \dots\dots\dots\dots\dots\dots, x_{(d),i,g}] \quad (1)$$

Mutation strategy: Biologically, sudden change in genetic material is known as Mutation. After initialization, next step is to create donor vector (mutant vector) $\vec{M}_{i,g}$ for each target vector $\vec{x}_{ra,g}$ from current population. Most frequently used mutation strategies [9] are referred below:

- DE/rand/1 :

$$\vec{M}_{i,g} = \vec{x}_{ra,g} + F * (\vec{x}_{rb,g} - \vec{x}_{rc,g}) \quad (2)$$

- DE/best/1 :

$$\vec{M}_{i,g} = \vec{x}_{best,g} + F * (\vec{x}_{ra,g} - \vec{x}_{rb,g}) \quad (3)$$

- DE/best/2:

$$\vec{M}_{i,g} = \vec{x}_{best,g} + F * (\vec{x}_{ra,g} - \vec{x}_{rb,g}) + F * (\vec{x}_{rc,g} - \vec{x}_{rd,g}) \quad (4)$$

- DE/rand/2:

$$\vec{M}_{i,g} = \vec{x}_{best,g} + F * (\vec{x}_{ra,g} - \vec{x}_{rb,g}) + F * (\vec{x}_{rc,g} - \vec{x}_{rd,g}) \quad (5)$$

In "(2)-(5)", ra, rb ,rc ,rd, and re are randomly selected values from the population [1... NP_g]. Actually, the different investigated mutation strategies occupy distinct characteristics, and so are used for solving various optimization problems [10].

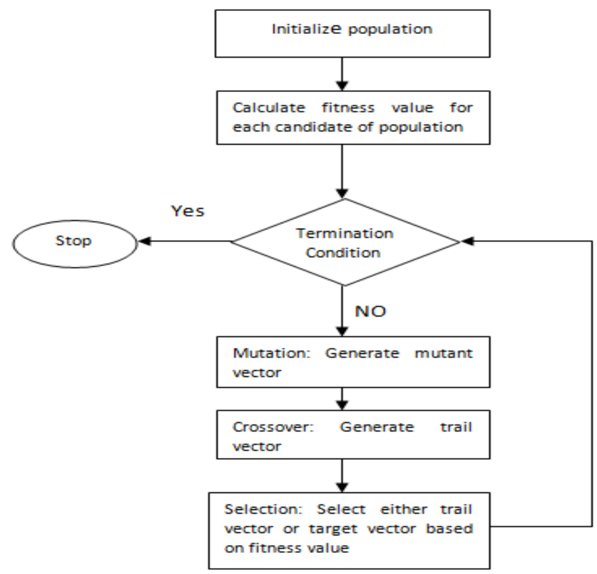

Figure1. Basic working of Differential Evolution

Crossover operators: After Mutation, next step is to interchange the information in between donor vector $m_{i,j,g}$ and target vectors $x_{i,j,g}$ to form new offspring vector. There are two most popular crossover techniques, binomial (uniform) and exponential (two-point modulo). We elaborate only binomial in this section:

$$u_{i,j,g} = \begin{cases} M_{i,j,g} & if\ rand(0,1) \le CR\ \ or\ j = j_{rand} \\ x_{i,j,g} & otherwise \end{cases} \quad (6)$$

Here, "(6)" rand (0, 1) is uniformly distributed random values in between 0 and 1,CR is crossover rate, j is a random number selected from 1 to (d).

Selection: Now, next step is selecting the fittest candidate in selection phase. The fittest candidate can be target vector or corresponding generated trail vector. Selection strategy as follows in "(7)":

$$\vec{x}_{i,g+1} = \begin{cases} \vec{u}_{i,g} & if \quad f(\vec{u}_{i,g}) \leq \; f(\vec{x}_{i,g}) \\ \vec{x}_{i,g}\,, & otherwise \end{cases} \quad (7)$$

Here, $f(*)$ is the value of objective function. If objective function value of trail vector is less than or equal to target vector value, trail vector is selected for next generation otherwise target vector will survive in next generation.

III. APPLICATION OF DIFFERENTIAL EVOLUTION IN MANETs

This section describes the issues of optimization problems and their proposed solutions. These issues are classified on the basis of conducted survey as follows: routing, topology control mechanism, security and clustering. The outlook of existing work is depicted in Table 1.

Table 1. Outlook on Existing work

S.No.	Optimization Problem	System model & Methodology	Results
1.	Routing [13]	***System model*** Area: 100x100 Assumptions: 1. All nodes are stationary and randomly distributed. 2. All nodes have global knowledge of networks. 3. Energy cost between two nodes a and b: $E_{a,b} = (d_{a,b})^{\beta}$ β is path- loss exponential, $d_{a,b}$ is Euclidean distance between nodes. Transition delay ($T_{a,b}$): $T_{a,b} = q_a + 1$ q is the queue length of node a and it has been assumed to have one unit time delay ***Methodology:*** 1. Multi-objective 2. Fitness function: Delay and energy consumption. 3. Proximity of pareto optimal solutions are compared with solution achieved by two algorithms (NSGA-II and MODE). 4. Path loss β=3, p_m=0.5 and p_c= 0.9.	1. Evolutionary algorithm can deal with many objectives. 2. Both the evolutionary algorithms can achieve true pareto optimal solution. 3. MODE converges faster than NSGA-II.
2.	Clustering [31]	***System model*** Assumption 1: network is considered as graph. Assumption 2: Link matrix for all connection information. Mobility has been considered. ***Methodology:*** 1. Novel technique of clustering. 2.DE variant: DE/best/bin 3. Fitness functions: Remaining battery power, power consumed by cluster heads and aggregation of degree differences of all cluster heads. 4. GA parameters - p_m=0.02, p_c=0.8. DE parameters- F=0.8 and Cr=0.7	1. Algorithm is tested on different sizes of networks sizes. Sizes – 200, 250, 300, 350, 400, 450 and 500. 2. Results shows that DE based approach generate better quality of solution than Genetic algorithm based approach.
3	Topology [18]	***System model*** Area: 100x100,Number of nodes: 40 ComR=16, MovR=4,6 and 8. ***Methodology:*** 1. Single node is considered as chromosome with two dimensions speed and direction of movement. 2. The fitness function was inspired from the diffusive properties of liquid and gases. 3. DE variant: DE/rand/1	Results in terms of metrics NAC: TCM-DE converges faster with larger communication area. ADT: Network life time increases due to uniform distribution and total area coverage.
4.	Topology [22]	***System model*** Deployment Area: 100x100,Number of nodes: 40,ComR=10,MovR=3 Minimum number of nodes desired to connect: n=2,3,4. P=2n, P is the number of Yao partitions ***Methodology:*** Fitness function: inspired from Yao graph DE variant: DE/rand/1	Results Analysis shows that TCM-Y leads CC-MSN, with respect to all three metrics
5.	Topology [23]	***System model*** Deployment Area: 100x100,Number of nodes: 40,ComR=10,MovR=2 Minimum number of nodes desired to connect: K=2 and 3 P=6, P is the number of Yao partitions ***Methodology:*** TCM-DE [17] and TCM-Y [21] are compared	Results Analysis shows that TCM-Y leads TCM-DE, with respect to all three metrics

Routing: In MANET, routing protocols are heavily used for data dissemination and it also plays significant role in appropriate performance. In a recent article by Lubdha M. Bendale et al. [11] various routing strategies has been compared and discussed, to show its pros and cons over each other. As far as we know, it has no any centralized unit and it faces many issues due to having dynamic nature. Initially, the objective of routing was to find most suitable path, but with evolution in wireless networks, it has to accomplish multiple objectives in optimal manner. In other words, it has to satisfy various metrics like end to end delay, jitter, packet loss, energy and bandwidth. For more, accomplishing multiple objectives for the network is categorized as a NP-complete problem [12]. In conventional strategy, only one objective is satisfied whereas other desired objectives are considered as constraints. This motivates to have a routing different from the conventional strategy in terms of satisfying various objectives for better performance of networks. Therefore, it requires an efficient heuristic based search algorithm which reduces complexity and improves the performance.

Under above premise, in article [13], author investigated two evolutionary algorithms. The first one was based on Non-dominated Sorting based Genetic algorithm-II (NSGA), while another one was Multi-objective Differential evolution (MODE). Both algorithms are technically employed for optimizing two objectives, energy consumption and delay. All objectives were considered simultaneously and their proximity is compared with Pareto optimal solution of multi-objective algorithm. The Pareto optimal solutions are those solutions, which lies on Pareto optimal front and are non-dominated by other sets (solutions). The goal of multi-objective optimal technique is to produce set of diverse solutions to strive out trade-off between different objectives. NSGA-II was proposed by Deb et al. [14] and it is based on sorting of population by considering Pareto optimal solutions. Earlier to the article [13], Camelo et al. [15] proposed this concept to solve the routing problems for maintaining the quality of services (QoS) in terms of Voice over internet protocol and file transfer. Further NSGA-II was modified [13], to fit into optimization requirements. The classical GA operator's (crossover and mutation) assistance evolves the individual candidate of specific population by generating new solution; i.e. new routes other than the existing one in order to improve the solution. In context to NSGA-II algorithm, initially encoding was performed as-parents (routes) are sequence of nodes, where first and last locus is reserved for source and destination respectively. These routes can be of variable length (due to number of relay nodes) and loops were avoided (as if it increases the energy consumption cost and delay). The binary tournament techniques were involved to select parents for optimization process. Single point, common node crossover strategy was used with p_c probability. The reason behind this approach was that, the routes costs were directly dependent on intermediate node, therefore it's quite logical to have common node based crossover operation as illustrated in Figure 2.

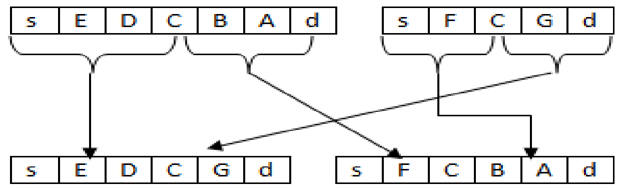

Figure 2. Explaining Crossover Operation

In NSGA-II algorithm both the procedure, selection and crossover are applied twice in order to generate new solutions, equal to the size of population. Further mutation was carried out by following three techniques – insertion, removal and exchange of the nodes with p_m probability. Another algorithm (MODE) followed the same encoding strategy as mentioned in Figure 2, but path variation depends upon the heuristic of power attenuation model, as described in [16]. The author had followed the similar strategy as described in [16] and [17] for generating the new solution space. At, implementation part MODE operates in similar manner as NSGA-II, only the difference lies with crossover operation. In crossover operation two candidates were selected to undergo single point, common node crossover operation: the first candidate is chosen from dominated front where every individual candidate participate and another candidate is chosen randomly from Non-dominated front. In case, non-dominating sets were found empty that means all the individuals were moved into pareto-optimal set. Both the algorithms were tested for optimizing routing, in the network with varying number of nodes n ($n \in \{6,8,10,12\}$). As number of nodes increases, the number of pareto-optimal solution also increases and initiates to have reduced energy consumption cost due to increased number of route availability. Furthermore, MODE achieved higher convergence rate than NSGA-II, while the number of fitness function to achieve true Pareto front was ultimately same and both were also capable of finding true Pareto optimal solutions.

Topology control Mechanism: Mobile ad-hoc networks are an impressive outlook for recognizing numerous complex multi-agent frameworks. It would be a great deal, to develop autonomous system with capability to distribute node uniformly in un-known terrain. These systems must facilitate maximum network coverage in minimum energy consumption, plus it must be simple, efficient and also adaptable to various environments. Therefore, to achieve all these facilities there must be a topology control system (mechanism) for self-deployment and organization of mobile nodes. Differential evolution has been very helpful to predict a new location and node's movement, that's why it had been utilized as topology controlling mechanism and described in this section.

In their article, Stephen Gundry et al. [18] introduced Topology control mechanism called TCM-DE to control MANET's topology and configuration of nodes in unknown terrain. This mechanism was inspired from diffusive properties of liquids and gases, and it works as a software agent for any network node to predict next location. Initially, each node was considered as a chromosome with two attributes speed and direction. The range of direction and speed were [0,2π] and [0, Mov_R] respectively. Here, Mov_R is the distance which a node can travel and apart from this, each node has its own communication range Com_R, therefore the largest distance travelled by the node will be $Mov_R < Com_R$. The virtual force applied to any node N_X is inversely proportional to the distance between the local neighbours which are within its communication range (Com_R). If nodes are uniformly distributed in deployment area, the sum of virtual forces applied on a node N_X by its neighbour nodes is equal to zero. To, predict the next placements of the nodes, the fitness function based on virtual forces are used to adjust the node's movement by minimizing the virtual forces of neighbouring nodes on it. In other words, smaller the fitness function's value lesser the distance between neighbouring nodes. Therefore, the virtual force on node N_X has been described mathematically as follows in "(8)":

$$VF_{XY} = \begin{cases} \frac{Com_R}{d_{XY}} - 1, & if\ 0 < d_{XY} < d_{th} \\ 0, & if\ \ d_{th} \leq\ d_{XY} \leq \text{ComR} \end{cases} \quad (8)$$

Here, d_{XY} is the Euclidean distance between node N_X and N_Y, threshold d_{th} is defined within the range of (0, ComR]. The sum of virtual force is described on N_X by n number of neighbouring nodes is given in "(9)", as follows:

$$f_X^t = \sum_{Y=1}^{n} VF_{XY} \quad (9)$$

Here, f_X^t is the fitness function of TCM-DE. It performs mutation and crossover to generate the new candidate population and select the fittest candidate, as a member of next generation. The mutation factor and crossover rate were selected from the range of [0, 2] and [0, 1] respectively. Consequently, the performance of TCM-DE was tested on MASON software libraries [19] with respect to three metrics to satisfy desired objectives, the first one is uniformity test according to the terrain deployment in the Voronoi tessellation [20]. The second metrics was ADT (average distance travelled) and third was network coverage area (NAC). The node with larger Mov_R had efficiently travelled more distance to acquire suitable locations within a single unit time. ADT metrics effectively estimate the power consumption with the assistance of node movement during its distribution. The NAC was described as the ratio of area covered by all candidate nodes in the given geographical territory. The node with larger movement converges faster acquire better network coverage.

Afterwards, Setphen Gundry et al. [21], investigated convergence rate of TCM-DE [18] with the help of markov chain model. Markov model is stochastic process composed of various states $s_n \in S$, with $Pt(S) = Pt(s_1) + Pt(s_2) + \cdots \ldots + Pt(s_n)$. The distributions of various states are interconnected by a transition matrix. The markov model had been utilized to analyze the convergence of TCM-DE. The distributions of various states are interconnected by a transition matrix. The movement of nodes were mapped on the basis of directions : east as$\left(\frac{15\pi}{8}, \frac{\pi}{8}\right]$, north-east as $\left(\frac{\pi}{8}, \frac{3\pi}{8}\right]$, north as $\left(\frac{3\pi}{8}, \frac{5\pi}{8}\right]$, north-west as $\left(\frac{5\pi}{8}, \frac{7\pi}{8}\right]$, west as $\left(\frac{7\pi}{8}, \frac{9\pi}{8}\right]$, south-west as $\left(\frac{9\pi}{8}, \frac{11\pi}{8}\right]$, south as $\left(\frac{11\pi}{8}, \frac{13\pi}{8}\right]$ and south-east as $\left(\frac{13\pi}{8}, \frac{15\pi}{8}\right]$. According to the node's movement the fitness has been effectively inferred and compared to the desired threshold. For any node two states were possible: either in (stop, 1) state or (stop,0) state. State (stop, 1) means a node has acquired better location whereas state (stop,0) means a node is tightly bounded by surrounding due to which it have no other location to improve the fitness value. The simulation results shows that, the ratio of Mov_R/Com_R had reduced from 50% to 25% which means that node had taken longer time to stabilize with decreased Mov_R in deployment territory. The results show that TCM-DE has higher convergence rate. In both the articles TCM-DE is evaluated, to prove different prospective in [18] distribution uniformity and in [21] convergence rate.

Another, contribution of Stephen Gundry et al. [22] is a fault- tolerant differential evolution based topology control mechanism (TCM-Y), to guide the activity of independent vehicles that dynamically regulate their locations (speed and direction). Fitness function of TCM-Y is inspired from Yao graph concept [23] to maintain the minimum n connecting node for fully functional network. The TCM-Y is compared with CC-MSN [24] and performance evaluation is done on the basis of three metrics- Normalized area coverage (NAC), Average distance travelled (ADT) and Average connectivity (µ). Results observation shows that average distance travelled (ADT) by TCM-Y running node satisfies the network coverage in approximately 50 steps whereas, CC-MSN nodes are adjusting themselves to achieve better network coverage. When n=2, 3, 4, the average connectivity of node equipped with TCM-Y is higher than the CC-MSN equipped node. In other words it is also capable of maintaining minimum connectivity (than CC-MSN) as well. The node acquires higher NAC with smaller n and it decreases with increased user-defined n, which concludes that TCM-Y maintains higher NAC than CC-MSN. In another article [25] Stephen Gundry et al. have investigated the strength of TCM-Y in hostile environment where nodes become deliberated due to random node destruction and failures.

In next of their article Stephen Gundry et al. [26] have compared the effectiveness of TCM-Y over TCM-DE. The simulation result shows that TCM-DE running nodes distribute uniformly and provide better network coverage area than TCM-Y. This is because to achieve uniform distribution TCM-DE running node have generated topology with disconnected nodes which provides no utility to MANET, therefore TCM-Y outperforms in this case due to capability of generating fully functional network. When n=3 TCM-Y running node generate smaller NAC than n=2, but configuration with n=3 provide better handling of fault tolerant situations. TCM-Y running node provides higher average connectivity than TCM-DE equipped node. Later, the performance of TCM-Y [27] was evaluated on real-time test bed. Actually, the experiment was conducted by implementing TCM-Y mechanism on human operated laptops to guide their next movement for uniform distribution by voice instructions. Its effectiveness was compared with Artificial Bee Colony (ABC) algorithm which shares the same objectives as TCM-Y. Significantly, it outperformed ABC algorithm in terms of NAC, ADT, average connectivity and disruption tolerance acquired by node. It was found that TCM-Y is also capable to maintain predefined minimum number of connecting neighbour nodes.

Clustering: The idea of clustering in mobile ad-hoc networks is to reduce the size of routing table and control overheads. The problem of clustering is classified as NP-hard problem [28]. Typically, the objective of clustering algorithm is to construct cluster on the basis of some similarity among nodes (mainly topological information) that are different to some other cluster in some other manner. The ability of clustering algorithm, to handle large problem size, however remain difficult to achieve so far: the problem size of about 200 nodes has been solve by Genetic algorithm based technique [29], [30]. The DE based clustering method, discussed in this section has solved problem size up to 500 nodes.

The DE- based clustering proposed by U. K. Chakraborty and S.K. Das [31] evolves the selection of cluster-head and cluster members, with novel encoding methodology to handle discrete variables in the form of continuous variables. The encoding scheme persuades with selection of optimal cluster head and cluster members where two nodes are grouped together, only if they are relatively stable [29]. Here, complete cluster is encoded as chromosome whereas single node is considered as gene. All clusters are of fixed length and variable length left unaddressed. The components of fitness function are based on three metrics- battery power, ideal degree and energy consumption, to evaluate the fitness of clusters. A given set $S=\{C_i\}$ represents all clustering C_i solutions. The clustering problem is framed as minimization of problems, described in "(10)" as follows:

$$f = k^1 * \Delta S + k^2 * Dis_S + 1/RB_S \qquad (10)$$

Here, k_1 = 1.0 and k_2 = 0.001, ΔS = the sum of degree differences of cluster heads, Dis_S = Overall power consumed by the cluster-heads in the terms of distance acquired by all the clusters. The proposed approach was compared with GA; each run was executed up to 2000,000 fitness evaluations and it was found that proposed algorithm have lower standard deviation and mean than GA. The comparison of DE algorithm processed on two fronts: (1) quality of solution and (2) time to produce, a required quality of solution. In both the fronts DE- based algorithm outperformed GA-based algorithm.

Security: Information sharing and distributed collaboration are viewed as crucial functionality to achieve the deployment goals of MANETs in harsh environment. Collaboration will be fruitful only when, all participating nodes are trustworthy. Still, due to inherit traits (e.g., various vulnerability, limited resources, wireless medium) of such networks, they are more likely to have malicious node attack such as black hole attack [32], wormhole attack [33]. Besides, as the behaviour of node changes with environment and time, member nodes must be attentive enough during collaboration (due to MANETs characteristics), to communicate with other new member nodes. Therefore, it is visible to have security as an urgent issue, which needs to be addressed. Much solution has been proposed by various methodologies such as Cryptography, trust management, Intrusion detection system, Game-theory. This section focuses security of MANET by application of DE strategy.

Trust*:* Ramya Dorai and Rajaram [34] proposed an improved variant of ad-hoc on-demand multi-path distance vector (AOMDV) with DE optimization technique. The improved AOMDV extends the concept of link quality and channel utilization with optimization of trust and reputation to filter the malicious activity (wormhole attack). Trust optimization carried on the route request and route reply initiated by source and destination respectively. The results showed the effectiveness of AOMDV variant (with trust) over conventional AOMDV.

Cryptography*:* In early ages to secure messages, data were used to send in encrypted form and receivers have prerequisite to decrypt it. But, now days in this new era the way of transmission has been changed along with various introduced cryptographic techniques such as symmetric and asymmetric cryptographic algorithm with the aim of providing data transmission security. In general, there are two ways to examine the strength of cryptographic algorithm one is brute force and other is cryptanalysis. Cryptanalysis is a method of finding appropriate candidate key to attack the encrypted cipher and this scheme assists to check the strength of key generated by cryptographic algorithm. This section covers the application of DE with respect to cryptography which can be applicable to MANETs in terms to secure data transmission.

Gia et al. [35] applied differential evolution to attack transposition cipher to fulfil cryptanalysis. Mostly, DE works for the real numbers but to break encrypted cipher text through cryptanalysis only integers are required. To overcome this requirement author proposed some modification in mutation operator which was inspired from utilizing integers order criteria (IOR) [35]. The designed fitness function was based on trigram and bigram statistical equations. This algorithm worked only to decrypt short length cipher up to 9 permutation length; it was inefficient to break longer length cipher text. Saptrishi N. Sinha et al. [37] proposed Cryptanalytic attack using differential evolution for Merkle-Hellman knapsack cipher. In this population produces offspring until appropriate solution is not found. In these two [35] and [37] DE algorithm were used to consider two different type of cryptographic method for cryptanalysis.

IV. DISCUSSION AND FUTURE SCOPE

Conventional routing can fulfil single objective, whereas multi-objective algorithm like MODE can fulfil many objectives together, by calculating pareto-optimal solutions. This concept can lead to investigate various Multi-objectives DE algorithms for MANET applications. In simple words, DE mechanism can be utilized to counterbalance many objectives together such as packet delivery ratio, normalized network load, end-to-end delay. DE heuristics has given efficient way to optimize the routing algorithms. Either, it can be clubbed with conventional routing or works as routing protocol to search optimal path. The appropriate fitness function can be the best assistant to achieve the optimal goal with respect to any optimization problem. In DE-based clustering scheme [31] all clusters formation, were of same sizes. The variable size, clustering optimization problem is open to work with. The appropriate fitness function can be helpful in achieving better clustering goal.

Trust can be described as, reliability between two entities to exchange information. For MANET trust works as parameter to find the trustworthy path for data delivery. Trust can be easily integrated with differential evolution through appropriate mapping in form of fitness function which is useful to find appropriate reliable path for data delivery. Optimization of direct trust and indirect trust both can be integrated with conventional algorithm to improve the performance of MANET.

The DE can be used to strengthen the cryptanalysis algorithm, by making few changes and recognizing appropriate fitness function components. The cryptanalysis in both of the articles [35], [37], can be applied to set security primitives for MANETs. Differential evolution can be useful for cryptanalysis to cross check the strength of cryptographic algorithm. Its integration with other cryptographic algorithms can develop better methodology to secure the network. Although it add on extra overhead cost but when it comes to security it can be tolerable. Since DE generate better offspring in every generation it is possible implement DE for key generation by making few changes in classical DE.

V. CONCLUSION

In this paper we reviewed the main existing work found in scientific journals and highlighted the gap which needs to be considered for further research. This review paper has explored all the promising solution given by DE to solve MANET optimization problems. We believe that use of DE optimization technique; can open new gates of evolution in the field of MANET application. The existing work shows that DE is an appropriate metaheuristics to guide solution for optimization problems such as clustering, routing, security and topology mechanism. According to the conducted research most of the research has been conducted in topology control mechanism (approximately 62.5%) and about 37.5% work has been carried out to solve optimization problems with respect to routing, clustering and security. In case of routing, multiple objectives can be achieved through DE, which can resolve the problem of conventional strategy to fulfil multiple objectives. Topology control mechanism with DE metaheuristics can be useful as a guidance tool to predict next location in hostile environment or controlled environment. This methodology can also be helpful for commercial purpose to provide full connectivity for communication. Regarding clustering DE methodology can manage large mobile nodes (more than 500 [31]) with comparatively less overheads. Moreover, a key issue is still open to work with, that is to design encoding scheme which can handle variable length cluster. Appropriate fitness function in terms of clustering attributes can add intelligence to form and predict the best cluster in the network. Apart from all these optimization problems, checking security of mobile ad-hoc network is most challenging job but DE methodology can assist to map a cryptanalysis algorithm to check the strength of cryptographic algorithm which can check key size more than 9. The conducted studies shows that no work has been carried out to find secure path which can be achieved by framing trust into fitness function to find the optimal path for data dissemination.

REFERENCES

[1] International Fund for Agricultural Development (IFAD), The United Nations Environment Programme (UNEP), *"Smallholders, food security, and the environment"*, Report, United Nation, 2013.

[2] Zhaohui Wang, Houbing Song, David W. Watkins, Keat Ghee Ong, Pengfei Xue, Qing Yang, Xianming Shi. 2015, *"Cyber-physical systems for water sustainability: challenges and opportunities"*, IEEE Communications Magazine, Vol. 53, Issue. 5, pp. 216 – 222, 2015.

[3] Bruno S. Faical, Gustavo Pessin, Geraldo P. R. Filho, Andre C. P. L F.Carvalho, Pedro H Gomes and Jo Ueyama, *"Fine-tuning of UAV control rules for spraying pesticides on crop fields dynamic environments"*, International Journal of Artificial Intelligence Tools, Vol. 25, Issue. 01, 2016.

[4] H.Pucha, M. Gunes and Y. C. Hu,*"Performance impact of traffic patterns on routing protocols in mobile ad-hoc network"*, Computer Networks, Vol.51, Issue. 12 pp. 3595-3616, 2007.

[5] J. M. Garcia-Campos, D.G. Reina, S.L. Toral, N. Bessis, F. Barrero, E. Asimakopoulou, R. Hill, *" Performance evaluation of reactive routing protocols for VANETs in urban scenario following good simulation practices"* , In Proceeding of the 9th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS' 15), Brazil, pp. 1-8, July 2015.

[6] R. Storn, K. Price, *"Differential evolution – a simple and efficient adaptive scheme for global optimization over continuous spaces"*, Technical Report TR-95-012, ICSI, 1995.

[7] D. G. Reina, P. Ruiz, R. Ciobanu, S.L. Toral, B. Dorronsoro and C. Dobre, *"Review article: A Survey on the application of evolutionary algorithms for mobile multi-hop ad-hoc network optimization problems"*, International Journal of Distributed sensor networks, Vol. 12, Issues. 02, Article ID 2082496, pp 13, 2016

[8] R. Storm, K. Price," *Differential evolution – a simple and efficient heuristic for global optimization over continuous spaces"*, J Global Optim 1997, Vol. 11, Issue. 4, pp. 341–59, 1997.

[9] K. Price, R. Storn, J. Lampinen, *"Differential evolution – a practical approach to global optimization"*, Springer, Berlin, 2005.

[10] S. Das, P.N. Suganthan, *"Differential Evolution: A Survey of the State-of-Art"* , In Evolutionary Computation, IEEE Transaction on, Vol. 15, Issue. 1, pp. 4-31, 2011.

[11] Lubdha M. Bendale, Roshani. L. Jain, Gayatri D. Patil, *" Study of Various Routing Protocols in Mobile Ad-Hoc Networks",* International Journal of Scientific Research in Network Security and Communication, Vol.6, Issue.1, 2018.

[12] K. Kotecha, S. Popat,*"Multi objective genetic algorithm base adaptive QoS routing in MANET"*, In IEEE Congress on Evolutionary Computation (CEC'07), India, pp. 1423-1428, 2007.

[13] H. Yetgin, K.T. K. Cheung, L. Hanzo, *"Multi-objective routing optimization using evolutionary algorithms",* in Proceeding of the IEEE Wireless Communication and Networking Conference (WCNC' 12), China, pp. 3030-3034, 2012.

[14] K. Deb, A. Pratap, S. Agarwal, T. Meyarivan, *"Fast and Elitist multi-objective genetic algorithm: NSGA-II"*, IEEE Transactions on Evolutionary Computation, Vol. 6, pp. 182-197, 2002.

[15] M. Camelo, C. Omana, and H. Castro,"*QoS routing algorithm based on multi-objective optimization for wireless mesh networks"* , In IEEE Latin American Conference on Communications (LATINCOM' 10), (Bogota)Colombia, pp. 1-6, 2010.

[16] F. Xue, A. Sanderson R. Graves, *"Multi-objective routing in wireless sensor networks with differential evolution algorithm"*, In IEEE International Conference on Networking, Sensing and Control (ICNSC' 06), USA, pp. 880-885, 2006.

[17] F. Xue, *"Multi-objective differential: Theory and Application"*, PhD. thesis, Rensselaer Polytechnic Institute, New York, 2004.

[18] S. Gundry, J. Kusyk, J. Zou, C. S. Sahin, M. U. Uyar, *"Performance Evaluation of differential evolution based topology control method for autonomous MANET nodes"*, 2012 IEEE Symposium Computers and Communications (ISCC) , Turkey, 2012.

[19] S. Luke, C. Cioffi-Revilla, L. Panait, K. Sullivan, G. Balan, *"MASON: A Multiagent Simulation Environment"*, Vol. 81, Issue 7, pp. 517-527, 2005.

[20] A. Okabe, B. Boots, K. Sugihara, *"Spatial tessellations: concepts and applications of Voronoi diagrams"*, Wiley Series in Probability and Mathematical Statistics, 1992.

[21] S. Gundry, J. Zou, J. Kusyk, C. S. Sahin, M. U. Uyar, *"Markov chain model for differential based topology control in MANETs"*, 2012 35th IEEE Sarnoff Symposium (SARNOFF), USA, 2012.

[22] S. Gundry, J. Kusyk, J. Zou, C. S. Sahin, M. U. Uyar, *"Differential Evolution based fault tolerant topology control in MANETs"*, MILCOM 2013 - 2013 IEEE Military Communications Conference, USA, 2013.

[23] A. Yao, *"On constructing minimum spanning tree in k-dimensional spaces and relates problems",* SIAM Journal on Computing, Vol. 11, Issue 4, pp. 721-736, 1982.

[24] S. Poduri, G. Sukhatme, *"Constrained coverage for mobile sensor networks"*, In Proceeding of the 2004 IEEE International Conference on Robotics and Automation, Vol.1, pp.165-171, 2004.

[25] S. Gundry, J. Zou, C.S. Sahin, J. Kusyk, M.U. Uyar, *"Autonomous and fault tolerant vehicular self deployment mechanisms in MANETs"*, IEEE International Conference on Technology for Homeland Security (HST), USA, 2013.

[26] S. Gundry, J. Zou, J. Kusyk, M. U. Uyar, C. S. Sahin, *"Fault tolerance bio-inspired topology control mechanism for autonomous mobile node distribution in MANETS"*, MILCOM 2012 - 2012 IEEE Military Communications Conference, USA, 2012.

[27] S. Gundry, J. Zou, M. U. Uyar, C. S. Sahin, J. Kusyk, *" Differential evolution-based autonomous and disruption tolerant vehicular self-organized in MANETs"*, Ad Hoc Networks, Vol. 25, Part B, pp. 454-471, 2015.

[28] R. Bollobas, *"Random graph"*, Academic Press, 1985.

[29] H. Cheng, J. Cao, X. Wang, S. K. Das, S.Yang, *"Stability-aware multi-metric clustering in mobile ad-hoc networks with groip mobility",* Wireless Communication and Mobile Computing,Vol. 9, Issues 6, pp.759-771, 2009.

[30] D. Turgut, S. K. Das, R. Elmasri, B. Turgut, *"Optimizing clustering algorithm in mobile ad-hoc network using genetic algorithmic approach"*, Global Telecommunications Conference, 2002. GLOBECOM '02. IEEE, Taiwan, 2002.

[31] U.K. Chakraborty, S. K. Das, T. E. Abbott, *"Clustering in mobile ad hoc networks with differential evolution"*, 2011 IEEE Congress on Evolutionary Computation (CEC), USA, 2011.

[32] Umesh Kumar Singh, Jalaj Patidar, Kailash Chandra Phuleriya,*"On Mechanism to Prevent Cooperative Black Hole Attack in Mobile Ad Hoc Networks"*, International Journal of Scientific Research in Computer Science and Engineering ,Vol.3, Issue.1, pp.11-15, 2015.

[33] A.Vani, *" Detection and Elimination of Wormhole Attacks in a MANET"*, International Journal of Scientific Research in Computer Science and Engineering ,Vol.5, Issue.5, pp.35-40, October (2017).

[34] R. Dorai, M. Rajaram, " *Trust and Reputation Mechanism with Path Optimization in Multipath Routing",* World Academy of Science Engineering and Technology International Journal of Electronics and Communication Engineering, Vol. 9, Issue 3, 2015.

[35] GiaS. Wulandari, W. Rismawan, S. Saadah, *"Differential evolution for the cryptanalysis of Transposition Cipher",* 3rd International conference on Information and Communication Technology (ICoICT), Bali, 2015.

[36] C. Erbao, L. Mingyong, *"The open vehicle routing problem with fuzzy demands",* in Expert Systems with Applications Vol. 37, Issue 3, pp. 2405-2411, 2010.

[37] S. N. Sinha, S. Palit, M. A. Molla, A. Khanra, M. Kule, *"A cryptanalytic attack on knapsack cipher using differential evolution*

algorithm", Recent Advances in Intelligent Computational Systems, Trivandrum, pp. 317-320, 2011.

Authors Profile

Shashi Prabha is presently pursuing her Ph.D. degree from Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad, India. She has obtained her M.Tech degree from Bansathali University, Rajasthan. She has 6 year of teaching experience and her area of research interest field are mobile ad-hoc, artificial intelligence and softcomputing.

Raghav Yadav is an assistant professor in Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Allahabad, India. He obtained Ph.D. and M.Tech degree in computer science and engineering from (MNNIT), Allahabad and B.E. degree in electronics engineering from Nagpur University. He guided various project and research at undergraduate and postgraduate level. He has published more than 20 research papers in national/international conferences and refereed journals. His research interests are in the field of optical network survivability, ad-hoc networks, and fault tolerance systems.

