Journal of Current Research in Engineering and Science
JCRES
Bi-Annual Online Journal (ISSN : 2581 - 611X)

Volume 5- Issue 1, Paper 12 January 2022

MEGAPSO: MOBILITY AWARE ENERGY EFFICIENT HYBRID GA & PSO BASED CLUSTERING FOR MANET

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Abstract

In this work, hybrid GA & PSO is used to group the mobile nodes based on the similar behaviour in MANET. The devices in this network have the freedom to go anywhere in any direction at different speeds. The unpredictable movement of a node makes a non-stable network, loss of energy, and repeated changes in topology. This migration behaviour of the devices leads the network to become dynamic. Non-stability may cause link failure, packet loss, repeated root-finding overhead, energy loss, topology change, routing table update, etc. To make the network turn out to be standard, cluster formation is proposed to assemble a number of individuals into groups. Balanced clusters are required to give a long life for the cluster members & clustering can achieve scalability. Clustering is organizing things into meaningful groups based on the similarities among the devices. In this grouping system, there is a cluster head selected for each & every group based on the parameters like mobility, distance, energy, degree of connectivity, and transmission range. The cluster members are associated with the CH based on the mobility of the individuals. The Mobility Aware Energy Efficient Hybrid GA & PSO is proposed here to form the cluster.

Keywords: Genetic algorithm, Cluster Head, Particle Swarm Optimization, Gateway nodes, clustering.

1. Introduction

MANET won't have the permanent infrastructure. There is no central authority to instruct or maintain the sources. It can rottenly change its position anywhere in any direction with different speeds. This non-decidable mobility behaviour causes route failure, packet loss, repeated root-finding overhead, energy loss, topology change, routing table updating, etc. MANET is an uncertainly migrated source. No one is authoritative for this network. All the sources are in flying mode. All the devices have their own transmission range. If the recipient is one of the nodes within the transmission range of the sender, it can directly transfer the packets. However, the receiver is not going to be in the range of the sender, the packet transmission is happening through the intermediate nodes. These are more suitable for applications like disaster recovery, military applications, communication between movement sources, weather forecasting, crisis management, etc. Breaking the uncertainty of the sources of the network is a big issue. So making the sources of MANET become stable is the objective for many researchers.

Hybrid algorithm-based cluster formation is one of the techniques to make the network more stable. An optimization algorithm inspires the natural behaviour of the sources and it gives the optimized solutions based on the gathered inspiration. There are two types of optimization algorithms, called deterministic & stochastic optimization [1]. PSO is a stochastic optimization technique. GA is the method for solving constrained & unconstrained problems based on the natural selection process. Integrating GA & PSO can give the best optimal solution.

Here, the nodes are assembled to form groups if they have similar mobility. In the initial phase, every node becomes a normal node. All the devices have their own transmission range [2]. Figure-1 shows the transmission range of nodes.

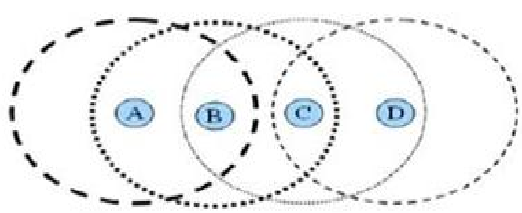

Figure-1 Transmission Range of nodes

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Some devices may migrate their position very fast and some may be slow. Within the network coverage area, devices may have similar mobility. The nodes having the same speed are grouped together to form the cluster. Mobility of the nodes is a big problem for MANET to have a stable path for data transmission. This may degrade the network lifetime & it partitions the network and the energy level of the nodes gets low. To increase the network lifetime & reliable data transmission the clustering technique is proposed.

Natural behaviour like rottenly changing the position of mobile nodes inspires to develop the clustering algorithms. In this clustering method, cluster head (CH) is selected for all clusters based on the parameters like node mobility, energy, distance to reach all nodes & degree of connectivity. CH is the coordinator of its own cluster and maintains the details of its members. A few mobile nodes may be in the range of two or more CH and these are gateway nodes. The remaining nodes are normal nodes. Cluster heads to another cluster head communication are going through the gateway nodes. Generally, the nodes in the network maintain an unnecessary routing table. However, for the cluster-based network, the cluster head is only responsible for routing.

To elect the cluster head it must have some capabilities like:

- CH must have more energy compared to another member of its cluster.
- Mobility must be the same in its own group to save the topology stability.
- It must have the shortest distance to reach all the members of the cluster.
- The degree of connectivity must be high.

After electing the Cluster Head can start the process of assembling the nodes into its own cluster based on the device velocity. The fitness function is calculated for all nodes to assign the fittest node into its cluster. Combining GA & PSO will give the optimized cluster.

2. Related work

We have seen some approaches for clustering and it developed for ad hoc networks. Many approaches have been proposed depending on the mobility and energy of nodes. Naghma Khatoon and Amritanjali have presented mobility and energy-based clustering with PSO for their work [1]. In this paper, they form the cluster based on the awareness of nodes' mobility & they proposed how to maintain the energy efficiency of the network. B.Bharanidharan and B.Shanthi have proposed energy-efficient clustering for wireless sensor networks with a Genetic Algorithm[3]. They proposed this work for energy efficiency and load balancing to get better clusters. Waseem Shahzad, Farrukh Aslam Khan, and Abdul Basit Siddiqui have been presented with Comprehensive Learning PSO-based clustering for MANET[4]. All nodes are having different weights and the weight is calculated based on the parameters. Based on the weight of the nodes the cluster is formed. Hamid Ali, Waseem Shahzad, and Farrukh Aslam Khan have proposed multi-objective PSO for clustering[5]. In this work, they focused on traffic reduction and the energy efficiency of the network. They are presented like MOPSO provides a set of solutions for their work. It provides an energy-efficient solution and reduces network traffic. Feng WEN, Shingo MABU, and Kotaro HIRASAWA have developed a clustering method with the help of a genetic algorithm for multi-level networks[6]. Based on the clustering algorithm, they will find the optimal route. Padmalaya Nayak and Bhavani Vathasavai have proposed genetic algorithm-based clustering for wireless sensor networks to find optimal routes[7]. In this work, they used two parameters like distance and energy for clustering and routing. Kale NavnathDattatraya, K. Raghava Rao have been proposed Hybrid based cluster head selection for maximizing network lifetime and energy efficiency in WSN [8]. The algorithms are combined here to form the clusters.

3. Modelling the Network

$U = \{n_1 \ldots\ldots\ldots\ldots n_p\}$ set of nodes

$\Psi = \{ch_1 \ldots\ldots\ldots\ldots\ldots\ldots ch_q\}$ set of cluster heads (p>q)

$Tran^{(n)}$ = Transmission range of a node

Dist (n_i,n_j) = Euclidean distance between the nodes n_i and n_j

X – axis = 1000 meter

Y – axis = 1000 meter

3.1 Energy Model

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The initial energy for all nodes is 90000 NJ. Energy consumption is calculated for all activities such as movement, packet sending, packet receiving, packet transmitting & idle state.

$Econ\ (n_i,\Delta t) = Eres\ (n_i,t_o) - Eres\ (n_i,t_1)$ ....(1)

$Econ\ (n_i,\Delta t)$ – Energy consumption

$Eres\ (n_i,t_o)$ – Initial energy

$Eres\ (n_i,t_1)$ – Present energy

3.2 Transmission Range of the node

The devices form a circle with a radius to have their own transmission range. The neighbouring nodes may be in this circle or maybe out ofrange. Figure-2 shows the neighbour's direction scenario.

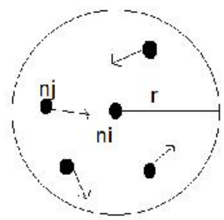

Figure-2 Transmission Range of a node n_i and direction of neighboursn_j

3.3 Mobility of the nodes

The ability to move from one position or situation to another usual position is called mobility. All the nodes are initialized with a random velocity vector. Some may move fast, and some may move slowly. Based on the velocity vector, the nodes are grouped together to form the cluster. Within the cluster, the nodes have the same velocity to maintain the topology stability. All the node's behaviour is watched by the CH after the cluster formation. Here the velocity of the node is calculated like, the distance traveled by the source in a unit of time.

$V = \Delta s / \Delta t$.. (2)

V =velocity, Δs = displacement, Δt = change in time

3.4 Distance Calculation

Distance is calculated to know the distance between the nodes.

$Dist\ (n_i,n_j) = \sqrt{\sum_{i=1}^{N}(n_j - n_i)^2}$..................(3)

3.5 Degree calculation

The degree of connectivity is calculated for all nodes to know how many nodes are there in their own transmission range.

3.6 Cluster to Cluster Communication

Here are some devices that may be positioned within the range of two or more cluster heads that will be the gateway nodes. The node that has only one cluster head in its range is called a normal cluster member. All cluster heads can communicate through the gateway nodes. Gateway nodes involve minimizing the energy consumption of the cluster heads. Figure-3 depicts the position of gateway nodes.

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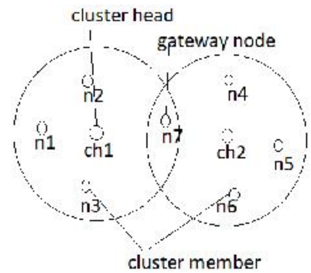

Figure-3 Gateway nodes in the cluster

3.7 PSO Algorithm

PSO is being applied to individuals' social behaviour-based problems by considering multi-agent stochastic parallel search techniques. The number of individuals or particles constructs the swarm & it moves towards the search space to find the best optimal position. With the help of the fitness function, the goodness of the particle is evaluated. The particles called agents can adjust their position based on the flying experience. With the flying experience of its own, it will find the personal best position & the flying experience of the others will find the global best position. The best global position for a node must be the minimum possible distance to reach the cluster head. All the individuals are trying to modify their position. The position and velocity will be updated based on the following terms,

$v_{id} = \omega \times v_{id} + c_1 \times r_1 (p_{id} - x_{id})_+ c_2 \times r_2 (p_{gd} - x_{id})$(4)

$x_{id} = x_{id} + v_{id}$..(5)

ω = inertia weight

c_1,c_2 = constants for acceleration factor, r_1,r_2 = random numbers between 0 & 1

The iteration goes until the termination criteria met.

3.8 Genetic Algorithm

Genetic Algorithms are metaheuristic optimization procedures that are encouraged by the natural behaviour of the strings or chromosomes. In a large space with randomly generated chromosomes, the selection operator can control the direction of search & the other operator offers newly generated chromosomes. In very large and multi-model search spaces, GA can provide near-optimal solutions.

- Chromosomes: The initial possible population for the problem, to give the best optimal solution, is called chromosomes.
- Fitness function: To evaluate the chromosomes fitness function is used. The fitness function has a deep connection with all chromosomes to check the goodness of the string. The best valued or the fittest chromosomes are selected to generate new offspring.
- Selection: Different types of selections are there in the genetic algorithm to select the parents. Depending upon the problem obligation, you can use any selection technique.
- Crossover: Two parents are selected & then swap the part of their gene information with each other [3].

Parent 1 .... aaa | aaa
Parent 2 ....bbb | bbb
Offspring 1 .... aaa | bbb
Offspring 2 .... bbb | aaa

- Mutation: Instead of searching for the solution from the whole space it searches for the current better place for mutation.

Parent .... aaaa
Offspring .... abaa

These three operations, called Selection, Crossover & Mutation can iteratively go until the termination criteria are met.

4. **Proposed Methodology**

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The important focus of the proposed work is to increase the network lifetime by considering the mobility & energy of the nodes. So for that, the clustering approach is the best one to group the nodes with the help of a hybrid GA & PSO algorithm. The scenario behaves like CH election & cluster formation to maintain the network stability.

4.1 CH election

All nodes are tested in this scenario to check whether it is best or not to elect as a CH. CH is selected based on parameters like mobility, energy, degree of connectivity & distance to reach the members. The node has a particular velocity & high energy and depletion of low energy compared to another node within its transmission range & a minimum distance to reach neighbours with a high degree of connectivity is selected as CH.

$W(n_i)$ = energy(n_i) + degree weight (n_i) + distance weight(n_i) ....(6)

- Distance weight calculation: Adding the distance value of all one-hop neighbours is considered as the distance weight of the node and Figure-4 shows the distance consideration scenario. Distance weight of n_i = 72.

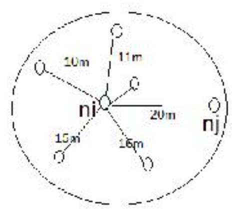

Figure-4 Distance of neighbours in one hop

- Degree weight calculation: The number of received hello packets from the one-hop neighbours is considered as the degree weight of the node and Figure-5 shows the degree consideration scenario. Degree weight of n_i = 4

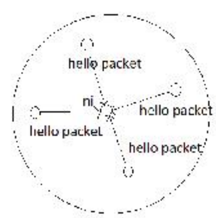

Figure-5 Received hello packets

4.2 MEGAPSO

The first step is the initialization of particles in random positions. If the node has the same velocity as the CH, the node will be assigned as a cluster member for that particular cluster.

- Initialization of swarm

Non-cluster head members are taken as particles to initialize.

K = U – Ψ

K = non cluster members, U = number of nodes, Ψ = number of cluster heads.

K = k1..........km

- Fitness function

Fitness function is calculated for all non-cluster head nodes to find the best optimal solution. The velocity and position are updated for all iterations and the solution moves towards the best optimal solution. The particle's current fitness value is compared with its personal best value. If the solution is best then Pbest value is updated. Gbest also updated when we get the global best solution.

Fitness f(K)

- Optimized Cluster formation

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Based on the fitness value, the members are attached to their own cluster. The position & velocity is updated for each & every movement. The iteration can go until to reach the most optimal position. For every cluster, there are two types of nodes, like normal nodes & gateway nodes. The gateway nodes' position is optimized to be in the range of two are more CHs. The normal nodes position is optimized as if it will become a member-only for that particular cluster. The repetition can routinely go until you reach the most optimal clusters

The fitness function checks the goodness of the particles to assemble the particular node to its cluster. Members having the same mobility according to CHs can join their own clusters, but some may not have any opportunities to join the clusters. In that situation, the Genetic algorithm is applied to create a new generation to make the optimized clusters. The non-cluster members are Parents here to generate new offspring. The crossover & mutation operations are performed. New generations are achieved. After that CH is selected based on the parameters of those non-cluster members. Now the fitness function is calculated for a new generation and the nodes are assigned to their own optimized cluster.

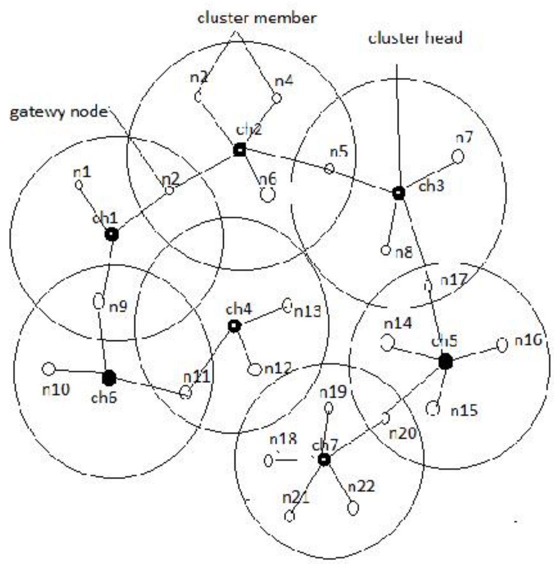

Figure-6MEGAPSO based clustering

- Optimizing the strength of CH

Optimizing the energy consumption of the CH is most important to increase the cluster lifetime. When the distance of the node from the CH increases, they have to spend more energy on data transmission. CH is solely responsible for data transmission. All cluster members can send the data packets through their own CH. The path from the source to the destination is constructed through the CH. Hence, the CH may face a higher workload than the normal nodes in the cluster. The loads for the cluster must be equal because the unequal distribution may cause the early death of CH. This may cause a link failure &reclustering overhead. So the workload for all clusters is optimally equalized to maintain the cluster standards. The effective cluster must be depending upon how the nodes are affiliated with CH. The node positions are optimally affiliated, having a minimum possible distance to reach the CH. When the node position becomes the global best, it will be considered the best fitness of the node. To achieve the best fitness & to minimize the energy depletion of CH the Gbest solution of a node is optimized.
The fitness function is directly proportional to the strength of CH. Fitness $\propto$ S

Algorithm

1. U = {n_1............n_p} set of nodesinitialized randomly
2. Parameters are initialized for all nodes (Speed, transmission range, energy)
3. Each node broadcast and receive “hello” packets from its one hop neighbours

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4. Calculate degree weight(n_i)
5. Calculate the distance weight between (n_i,n_j) ϳє Tran (n_i) using (3)
6. Calculate W(n_i) using (6)
7. For (all nodes)
   If W(n_i)> W(n_j) ϳє Tran (n_i)
   Is elected as cluster head
8. CH broadcast CH declaration message to all.
9. Non-cluster head nodes are considered here as particles K = {k_1..........k_m}
10. An assignment of k →Ψ with a maximized objective function
11. Non cluster head members From K =k_1 to k_m
    If K hasthe same mobility according to CHsthen it can join its cluster as a member
12. Calculate the fitness of K and initialize pbest&gbest
13. The particle's velocity and position is updated using (4) & (5)
14. Evaluate fitness of K
15. If f(K) > f(pbest)
    Pbest = K
    If f(pbest) > f(gbest)
    Gbest = pbest
16. The non-cluster members are initialized.
17. Mutation and Crossover operations are performed to generate new offspring
18. New generations are achieved.
19. Go to step 3 to make an optimized cluster

5. Results and Discussion

We have used NS2 network simulator to execute our simulation work. Nodes are deployed like 1000m × 1000m in the simulation area. The transmission range of the node is 100m &the initial energy is 1000J. The simulation result shows the efficiency of the proposed MEGAPSO over CLPSO & WCA in terms of cluster lifetime.

Table 1 - Simulation parameters

Parameter	Value	Parameter	Value
Number of nodes	100	Packet rate	35/s
Simulation area	1000m×1000m	Transmission range of node	100m
Simulation time	500 sec	Routing protocol	DSR
Simulation iteration	200	Traffic type	Constant bit rate
Initial energy	1000 J	Movement model	Random way point
Packet size	1024 bytes	Initial speed	10-100 m/s
		Radio propagation model	Two ray ground

5.1 Packet Delivery Ratio (PDR):

Packet delivery ratio is the measurement report to analyzehow many a number of packets are received. To achieve the highest rate of packet delivery is the main objective of this proposed methodology,

$$PDR = \left(\frac{Number of received packets}{Number of sent packets}\right) * 100$$

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Table 2 – PDR

Data Packets	WCA	CLPSO	MEGAPSO
25	74	78	91
50	80	84	85
75	82	79	80
100	80	84	87
125	85	86	88
150	75	80	81
175	86	85	86
200	88	84	85
225	89	79	90
250	81	80	83

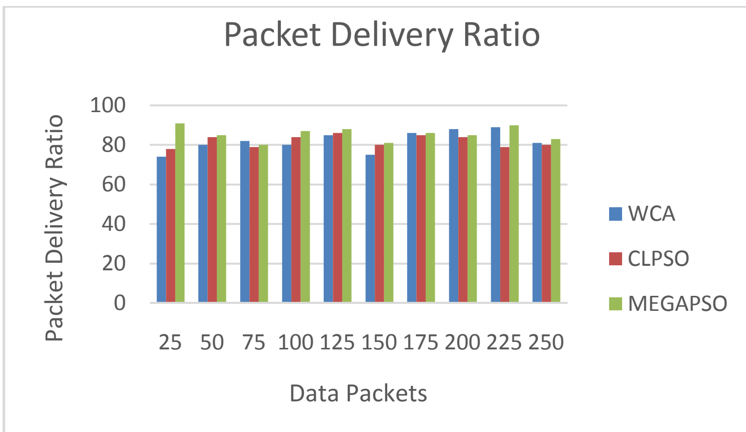

Figure-7 PDR

5.2 Throughput:

How many bits are transferred in each second is the measurement report of throughput. Highest throughput is the reason for fast data delivery. The data packets can reach the destination with very minimal delay when the throughput becomes high.

$$\text{Throughput} = \frac{numberofbitstransferred}{unitoftime\ (s)}$$

Table – 3 Throughput

Size of Packets (kb)	WCA	CLPSO	MEGAPSO
10	150	143	151
20	178	170	175
30	188	189	198
40	198	190	210
50	210	222	214
60	223	254	268
70	245	312	315
80	345	270	378
90	412	432	457
100	450	447	467

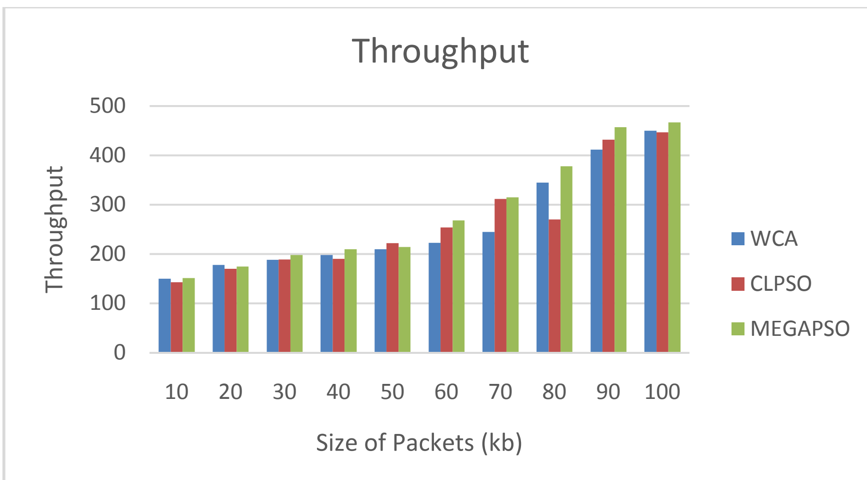

Figure-8 Throughput

5.3 Transmission Delay:

Transmission delay is the time taken to push all the data packets on the transmission link.

$$D_t = \frac{L}{R}$$

Where L is the length of the packet and R is the transmission rate.

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Table – 4 transmission Delay

Data Packets	WCA	CLPSO	MEGAPSO
25	13	15	10
50	17	18	14
75	22	21	13
100	27	26	17
125	34	32	25
150	27	28	27
175	36	37	27
200	35	39	31
225	39	35	29
250	41	40	33

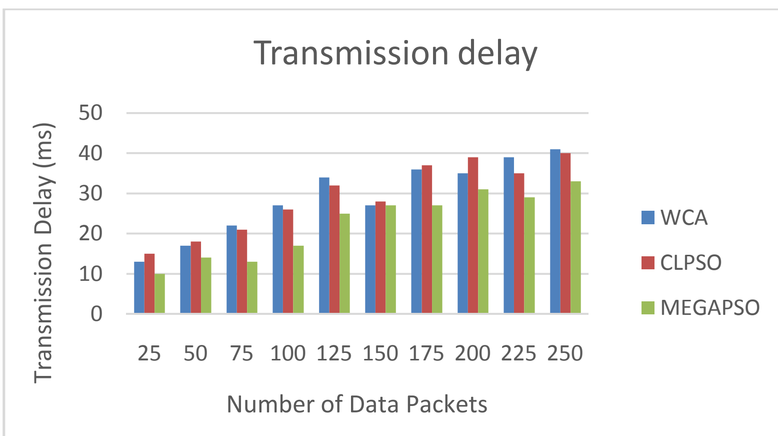

Figure-9 Transmission Delay

6. Conclusion

In this proposed methodology the solution is provided for energy efficiency and cluster formation. By observing the performance through the parameters like packet delivery ratio, throughput, and transmission delay the proposed methodology gives great results. The main challenge of MANET is mobility management. Coordination of the cluster head is wonderful work to achieve the stability of the network. In the future, machine learning and ensemble methods will be considered to minimize energy consumption and the best solution will be found for mobility management.

Acknowledgment

Journal of Current Research in Engineering and Science
Bi-Annual Online Journal (ISSN : 2581 - 611X)

The first author sincerely acknowledges the financial support (University Research Fellowship) provided by the Department of Computer Science, Periyar University under the grant: **PU/AD-3/URF Selection Order/016175/2020.**

The second author sincerely acknowledges the financial support (Rajiv Gandhi National Fellowship) provided by the UGC (University Grand Commission) under the grant:**RGNF-2017-18-SC-TAM-49179.**

And we are very much thankful to UGC-SAP (Special Assistant Program under University Grants Commission) for their help and support.

Conflicts of Interest - Not applicable

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