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Implementing Energy Optimization by a Novel Hybrid Technique for Performance Improvement in Mobile Ad Hoc Network

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Abstract

Mobile Ad-Hoc Network (MANET) comprises of self communicating devices that do not require infrastructure for sharing information. Network performance enhancement is a vital focus for researchers to improve the efficiency of the central administration lacking network. In this paper, a hybrid technique that integrates Ant Colony Optimization (ACO) and Fitness Distance Ratio based Particle Swarm Optimization (FDR PSO) is proposed. ACO discovers higher enduring energy efficient path based on the ants information to optimize the energy utilization of the nodes in the network. FDRPSO is employed to extend the life span of the nodes by minimizing the expenditure of energy over transmissions. A duty cycle process coupled with the hybrid technique can prevent nodes being active all the time. The proposed hybrid technique (ACO-FDR PSO) is implemented on 100 node network and the metrics such as throughput, delay, overhead, energy utilization and packet delivery ratio are analyzed using NS-2 simulator. The results are compared with other methods.

Keywords: ACO, Duty cycle, FDR PSO, Manet, Residual energy.

INTRODUCTION

Mobile Ad Hoc Network (MANET) comprises of radio interface based communicating devices that operate in an infrastructure less manner. The nodes in the network rely on their neighbors for transmission as position of the nodes changes due to mobility. Each node spends some quantity of energy for transmitting data to the destination through multiple neighbors. Therefore, a few factors like enduring transmission, reliable routing and link stability needs to be ensured by the nodes participating in communication. The route discovering protocols ensure energy efficient routing and intend to minimize delay by selecting shortest path to the destination based on hop count. A few emerging methods prefer route selection depending on the enduring energy so as to achieve prolonged communication in a resource constraint network. The routing protocols and the techniques adopted guarantee network performance optimization [1-3].

Mobility models influence routing metrics like delay, throughput, connectivity, etc that decides the protocols' performance. The connectivity of a node is decided upon the movement pattern and speed adopted by the node [4, 5].

Pursue Mobility Model [6, 7] is a variant of reference point group mobility model in which the movement of other nodes depend upon a single target node. A group of nodes follow the target node with uniform speed. The target node moves in a random manner at varying speed, followed by the group nodes.

A transmission control dependent routing protocol is proposed by the authors in [8] that minimize energy consumption based on distance. The communicating nodes regulate their transmission energy based on the distance to the destination. Though the methods have multi path transmission, it requires lesser broadcast to establish communication between source and other network nodes.

Efficient Power Aware Routing Protocol (EPAR) [9] is min-max problem, to reduce energy utilized by the neighbors within a specific communication range. EPAR prolongs network lifetime but does not hold recovery path to manage link erasures.

Efficient Dynamic Source Routing (EDSR) [10] is a modification of traditional DSR protocol that is introduced to minimize per-packet energy consumption. EDSR prevents energy drop outs that occur due to selfish nodes by detecting and eliminating them. Besides, the authors proposed another variant of DSR with efficient power routing mechanism [11] to ensure sustained node and network endurance.

Qing and Lang [12] proposed a battery cost routing protocol that prefers higher energy nodes for transmission. This protocol is based on min-max function and it also eliminates lesser energy nodes to prevent communication interrupts.

Conditional Max-Min Battery Capacity Routing (CMMBCR) [13] selects nodes with energy greater than threshold for communication. It prevents nodes with energy lesser than the threshold to perform routing.

Yang et al [14] formulated a Power Aware Multipath (PAM) in which the source and sink node are informed about the enduring energy of the path nodes through a route request message. Therefore, PAM can able to switch to a energy efficient path for pursuing transmission.

Lifetime Aware Multipath Optimized Routing (LAMOR) [15] ensures multipath transmission using multiple backup paths. LAMOR employs duty cycle process to improve network endurance amid multi path communication. Unlike the other methods, LAMOR discards low energy nodes.

Young Kim Min [16] proposed ant colony optimization based Energy Saving Routing (A-ESR) to evenly distribute network load so as to conserve energy utilization. A-ESR selects nodes based on the forehand information of their traffic and transmission. A-ESR does not intend to save the enduring energy of a node for sustained communication.

Ant Hoc Max-Min-Path (MMP) is an adaptive routing technique projected by the authors in [17] to improve the liveliness of the routes between communicating nodes. The pheromone update of the ants is based on the level of energy cost function computed for the path. This technique improved packet delivery ratio and minimizes retransmissions due to the awareness of link failures.

The authors in [18] assimilated ACO and Genetic Algorithm to lesser energy utilization and to improve bandwidth usage. ACO is responsible for discovering all possible paths and GA discards the frail paths based on fitness value. The fitness value is evaluated using residual energy and bandwidth penalty function. Meta-heuristic GA improves network QoS amid resource constraints of the network.

Kim and Jang [19] proposed a variant of AODV with a modified RREQ packet. RREQ is modified to save the energy status of the path nodes. On receiving this RREQ, the path nodes update their energy status to the allocated field of the packet. The destination node initiates RREP with the mean energy of the path nodes. Source nodes select the best path based on the received RREP; that intends in selecting energy efficient node providing network endurance.

Robinson and Rajaram [20] proposed a multipath supporting PSO based energy aware routing to improve energy conservation, traffic handling capacity of the path nodes. PSO selects a node with higher weight that is computed through transmission cost, energy and traffic of the path nodes.

Rashmi and Soumya [21] proposed duty cycle process with network coding by switching nodes between transmission eligible state and idle state. This is a random process to improve the active time of the node that optimizes network life span and packet delivery ratio.

Vallikannu et al. [22] proposed a location based Ant Colony Optimization Technique, ALEEP to improve network throughput by minimizing packet loss. ALEEP cooperates with ACO and identifies node position using received signal strength indicator. It selects shortest transmission neighbors with high enduring energy for packet forwarding.

From the above survey, we intend to provide the following contributions in this paper:

To improve network performance through energy efficient path, ACO and FDR PSO is integrated as a hybrid optimization technique, in this work. Moreover, to preserve nodes' Time-to-Live period and to prevent a node being active all time, duty cycle process is also employed in achieving optimization of the network. This improves both energy efficiency and network performance.

Problem Formulation

MANET optimization and energy efficiency leads to trade-off by concession due to factors like node distance, transmission time, etc that influence the network. A hybrid ACO-FDRPSO method is proposed to achieve energy optimization in networks with minimum trade-offs. Ant Colony Optimization is responsible for retaining the endurance of the nodes with respect to energy. It cooperates with duty cycle process to retain node energy. FDRPSO conserves energy utilization of the nodes.

Network Model

A network consisting of 'n' mobile nodes represented by {N} is considered. A node is linked with its neighbor through link *l*, through a distance'd'. d (i, j) represents the distance between node 'i' and 'j' provided either of the nodes are in the Transmission Range (TR) of each other i.e., $d(i, j) \leq TR(i)$. The mobility of the nodes is defined under Pursue Mobility Model (PMM).

Energy Model

The Energy Consumption (E_c) of the node [23-25] is given by Eq. (1)

$$E_c = E_t + E_r \tag{1}$$

Where, E_t and E_r are the energy used by the nodes for transmission and reception.

Transmission energy and reception energy are computed using Eq. (2) and (3)

$$E_t = d_t \times e_{ut} \times t_t \qquad (2)$$

$$E_r = d_r \times e_{ur} \times t_r \qquad (3)$$

Where, d_t and d_r is the data transmission rate and receiving rate.

e_{ut} and e_{ur} is the energy utilized for the transmission and reception.

t_t and t_r is the transmission and receiving time.

Energy Concentrated ACO-FDR PSO Approach

The proposed hybrid ACO-FDR PSO is a two-fold process.

ACO

The process of ACO is aimed to select nodes with higher Residual Energy (RE) for transmission and the node with lesser RE is moved to sleep state using duty cycle algorithm.

The initial forwarding ants finds energy effective path from the source to commence data forwarding. Once all ants have completed visiting all possible hops to the destination, the pheromone value is computed. Pheromone value (i.e. residual energy of the nodes) is updated on the completion of each ant cycle. New ants that initiate traversal follow the existing ants that have generated higher pheromone values. ACO updates the enduring energy of the visited nodes after a finite set of transmissions (k). In this case, the followers (new ants) move towards the node with higher enduring energy as stated after 'k' transmissions. The active nodes participated in the current transmission are moved to sleep state {S} and the nodes that are present in sleep state will be moved to active state {A} to pursue transmission.

If 'a' represents the set of nodes that are transmitting data at a time t, active state of 'a' is represented as

$$\{a_1, a_2, ..., a_i\} :\rightarrow A$$

If's' represents sleep node set that are idle when {A} is active, it is represented as

$$\{s_1, s_2, ..., s_i\} :\rightarrow S \text{ Where } i \neq j$$

At the end of each transmission, the residual energy of the each node {A} is computed using Eq. (5). If the residual energy of nodes in {A} is lesser than that of nodes in set {S}, then the nodes are switched over between the states. The nodes that have higher residual energy among the set of all paths, is identified for further transmissions.

The probability of an ant 'k' choosing node 'j' from 'i' at time't' is given by equation (4)

$$\rho_{ij}^k(t) = \frac{[\tau_{ij}(t)]^\alpha . [\eta_{ij}]^\beta}{\sum_{j \in N} [\tau_{ij}(t)]^\alpha . [\eta_{ij}]^\beta} \text{`` if } j \in N_i^k \qquad (4)$$

Where P_{ij}^k is the probability of node j to be selected by ant coming from node i, τ_{ij} is the pheromone intensity, N_i^k is the set of nodes and η_{ij} is the prior available heuristic value (RE).

Visited nodes RE is computed by Eq.(5)

$$RE = E_0 - E_C. \qquad (5)$$

Where, E_0 is initial energy.

Ants that have finalized traversal, update their pheromone that is given by equation (6)

$$\tau_{ij} \leftarrow (1-\rho).\tau_{ij} + \sum_{n=1}^{m} \Delta\tau_{ij}^{\ n} \qquad (6)$$

Where ρ is the evaporation rate, m is the number of ants and $\Delta\tau_{ij}^n$ is pheromone quantity laid on link (i, j) by the n^th^ ant.

$$\Delta\tau_{ij^n} = \frac{1}{H_n} \text{ if ant n travels on link i, j.}$$

Where H_n is the hop count of the n^{th} ant.

Once the ants return to the source after traversal, they update the factors of their traversed path. Source gathers information about all possible paths to the destination as multiple ants deliver their path information to the source. This enables multipath routing perspective to the source. Among the available paths, ACO selects the higher pheromone path as optimal and passes the solution set to FDRPSO as initial population.

FDRPSO

FDRPSO optimizes the energy consumed by the nodes in the multipath selected by ACO. In FDRPSO, n_{best} particle is considered in the velocity update equation, in addition to p_{best} and g_{pest} particle which maximizes the fitness distance ratio given by equation eq.(7). In contrast to PSO, it is proved in FDRPSO the average and best fitness differs for many more iterations which avoids premature convergence [26].

Energy fitness distance ratio is computed using Eq. (7)

$$\frac{E_C(P_i) - E_C(X_i)}{|P_{id} - X_{id}|} \quad (7)$$

Where, $E_c(P_i)$ is the energy consumed by the particle in the prior best position, $E_c(X_i)$ the energy consumed by the particle in the current position, P_{id} is the p_{best} position of the particle and X_{id} is the current position of the particle.

The velocity update of the i^{th} particle is given by Eq. (8)

$$V_{id}^{K+1} = (w * V_{id}^{k}) + a_1 r_1 (P_{id} - X_{id}) + a_2 r_2 (P_{gid} - X_{id}) + a_3 r_3 (P_{nd} - X_{id}) \quad (8)$$

The position update of the particle is given by Eq. (9)

$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1} \quad (9)$$

Where, P_{id} is the best previous position (pbest) of the particle, P_{gid} is the global best position (gbest) of the particle, X_{id} and V_{id} are the current values of position and velocity of the i^{th} particle, a_1, a_2, a_3 are the acceleration coefficients, r_1, r_2, r_3 be the random numbers between 0 and 1, w is inertia weight [26].

The Steps of ACO-FDR PSO is described below:

Step1: ACO parameters are first initialized.

Step2: Using ant agents the pheromone is initialized based on residual energy using Eq. (4).

Step3: Update pheromone till the last iteration.

Step4: Ant agents recognize the possible paths.

Step5: The population is initiated by FDRPSO based on the ACO solution.

Step7: Energy fitness function is computed.

Step8: Select p_{best}, g_{best} and n_{best} particle for current iteration.

Step9: For each particle, update the position and velocity using Eq.(8) and (9).

Step10: If the last iteration achieved, declare the energy efficient path and terminate. Else go to step 7.

Simulation Setup

Extensive simulation is done to verify the performance of ACO-FDR PSO algorithm and the simulation setup is shown in table 1.

Table 1: Simulation parameters and their values

Simulation parameters	**Assigned value**
Number of nodes	100
Network area	1000m * 1000m
Transmission range	550 m
Data rate	512 Kb
Simulation time	100 s
Number of packets	1500
Mobility model	Pursue

RESULT AND DISCUSSION

The performance of proposed ACO-FDRPSO is analyzed in terms of throughput, delay, energy, overhead and Packet Delivery Ratio (PDR) the results are compared with the conventional AODV and AODV with ACO and PSO algorithms.

THROUGHPUT GRAPH

Figure 1 illustrates the throughput comparison of AODV, ACO, ACO-PSO and ACO-FDRPSO. The proposed ACO-FDR PSO algorithm improves the life span of the path nodes such that the nodes are intended to transmit little higher packets than the earlier energy drain case. As nodes sustaining level is improved, network transmission rates are also improved which enhance the throughput in the proposed approach.

Packet Delivery Ratio Graph

Figure 2 shows the performance of the proposed technique with AODV routing protocol with other techniques for their performance towards Packet Delivery Ratio. Due to improved endurance of nodes and frequent node switching improves energy efficieny of the nodes and pertains network life span. In the proposed ACO-FDRPSO, the energy drop outs are minimized as lesser energy nodes are categorized and are prevented from being drained completely. The duty cycle process is responsible for relaying packets through effective nodes by which the loss rate is minimized. This helps to deliver maximum packets at the destiantion, improving PDR.

Delay Graph

End-to-End delay refers to the time difference between packet transmission at the source and packet reception at the destination. Figure 3 represents the delay graphs. The proposed ACO-FDRPSO integrated with energy effiecient routing process minimizes energy drop outs and earlier energy drain of the nodes. This avoids additional time spent for retransmissions and node repalcements. Thus the delay time in the proposed ACO-FDRPSO is less when compared to the traditional AODV.

Energy Graph

Figure 4 shows the performance of all the algorithms in terms of energy utilization. In our proposed ACO-FDR PSO, the nodes with higher residual energy are selected for transmission. The duty cycle process moves the discarded nodes to sleep state to prevent unnecessary dissipation of nodes' energy. Therefore, the energy spent by the nodes without participating in transmission is controlled, that adds up for lesser energy utilization.

Overhead Graph

Figure 5 illustrates the overhead comparison of proposed method with conventional AODV and ACO algorithms. ACO-FDR PSO produces an optimal solution after being aware of all possible paths to the destination. This requires initial neighbor update and therefore the number of control messages generated in a small scale network is high for the proposed method. As the network size increases, the number Comparison of ACO-FDRPSO with existing method for variable nodes of visiting nodes will be high and it requires appreciable control messages for the nodes that are in range. Besides the ant agents ditinguish between the visited and non-visited nodes that avoids additional control message being generated. The optimal solution is defined over the available set of neighbours and the neighbour update is not frequent in the proposed approach, minimizing overhead.

AODV ACO (AODV) ACO-PSO(AODV) ACO-FDRPSO(AODV)

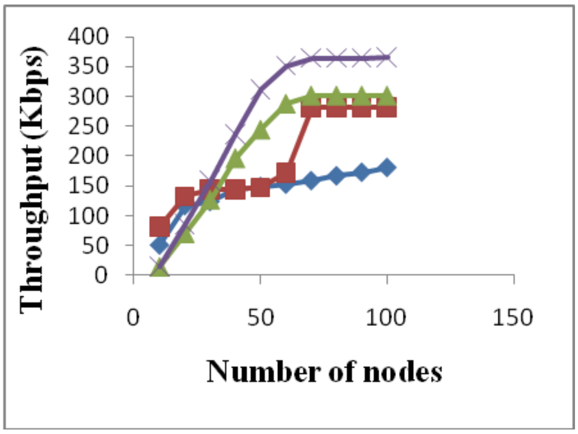

Figure 1: No. of Nodes vs Throughput

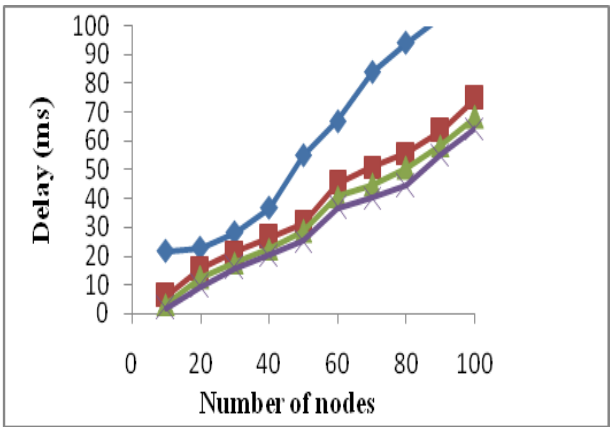

Figure 3: No. of Nodes vs Delay.

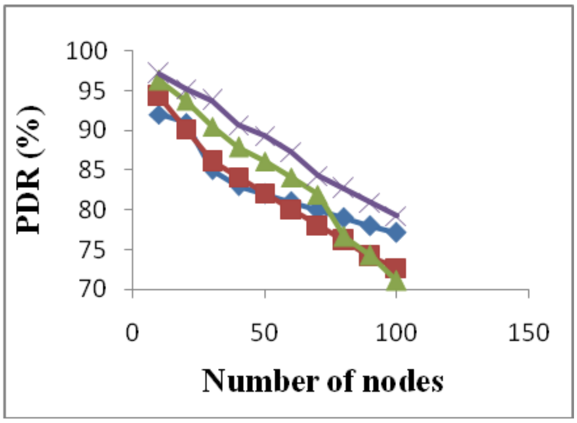

Figure 2: No. of Nodes vs PDR.

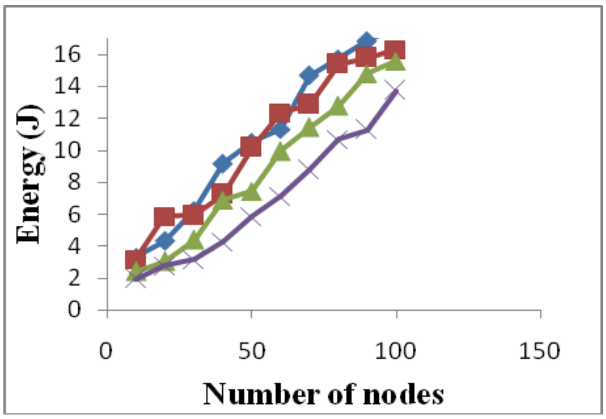

Figure 4: No. of Nodes vs Residual Energy.

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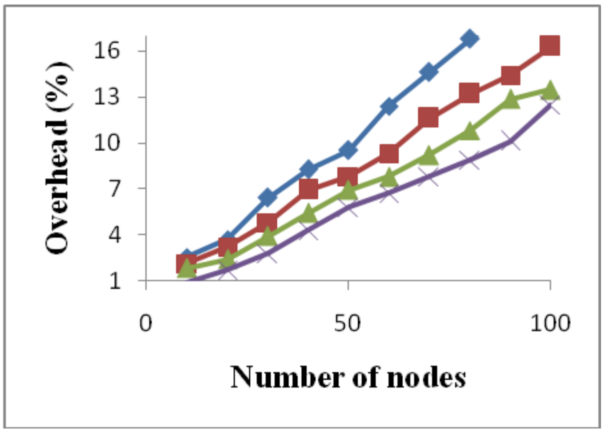

Figure 5: No. of Nodes vs overhead

Graph shows the comparison of ACO-FDR PSO with existing methods for variable nodes.

Table 2 shows the comparison of results obtained by AODV, ACO, ACO-PSO and ACO-FDR PSO techniques with respect to number of nodes.

Table 2: Comparison of various parameters of different techniques with respect to number of nodes

Parameters	AODV	ACO	ACO-PSO	ACO-FDRPSO
Throughput (Kbps)	181	282	301.72	366.51
PDR (%)	77.09	72.64	71.97	79.2
Delay (ms)	108.475	74.704	68.263	64.302
Energy (J)	17.68	16.31	15.61	13.75
Overhead (%)	21.34	16.28	13.46	12.47

CONCLUSION

This paper proposes a hybrid ACO-FDR PSO with duty cycle process concentrates in energy optimization to improve network performance. A hybrid optimization technique is proposed in which, ACO and FDRPSO are integrated together to optimize the network performance. This hybrid approach selects neighbors based on its enduring energy and lesser energy consuming nature. Besides, the duty cycle process conserves node energy by periodically switching them between active and idle states based on the fitness function. The proposed approach is compared with traditional AODV, ACO, and ACO-PSO for throughput, delay, overhead, energy utilization and packet delivery ratio metrics. Due to the manifold integrated working nature, the proposed approach improves network throughput and PDR, minimizes delay energy consumption and overhead.

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