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Genetic Algorithm based Optimised QoS Routing in MANET

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Abstract—Ad hoc wireless network may be a dynamic multi-hop network, which is established by a assembly of mobile nodes on a shared wireless channel. Mobile ad hoc network (MANET) is a collection of independent nodes that communicate with each other by forming a multi hop radio network. The design and analysis of routing protocols is a crucial issue in dynamic networks such as packet radio and ad- hoc wireless networks. While the previously proposed routing algorithms are shown to perform well in providing fair sharing of bandwidths among the single-hop wireless flow, they might not considered the multi-hop flow with an end-to-end perspective. Hierarchical, cluster-based routing greatly reduces the routing table sizes (compared to host- based routing) and therefore the amount of routing related signaling traffic, at the expense of reducing path efficiency and generating some management traffic.

This paper focuses on Genetic Algorithm based Optimized Quality of Service Routing in MANET. A node generates or forwards a RERR for a destination when the last path to the destination breaks. In GA based multipath routing also includes an optimization to salvage packets forwarded over failed links by re- forwarding them over alternative paths through crossover and mutation. Maintenance of discovered/established route is necessary for two main advantages, first to achieve stability in the network and secondly to reduce the excessive overhead required in discovering network..

Keywords—Mobile ad hoc network, MANET, Quality of Service, QoS aware Routing, Genetic Algorithm, QoS Metrics. AODV

Introduction

In Mobile ad hoc Networks, nodes are self-organized and can communicate directly with each other independently. Nodes of Ad hoc mobile network communicate with each other through broadcast radio transmissions in the limited transmission range. Due to radio transmission range limitations, we may require a multi-hop scenario, where packets are routed through intermediate nodes. There are many applications of mobile ad hoc networks ranging from battle field communications, which needs immediate network setup without the support of wired and fixed network infrastructures, to inter-vehicle communications, designed for both traffic safeties and enhanced entertainment purposes. Due to dynamically changing topology and to provide a continuous exchange of broadcast information in support of traffic control, the inter-vehicle communications applications poses the firm requirements.

MANET consists of mobile nodes which poses a character of rapidly changing topology because of nodes mobility. The wireless ad hoc networks throw complicated challenges to the design of an effective Quality of Services allocation algorithm to maximize the effectiveness of flow of data and to maintenance the basic fairness between multiple flows, because of its shared medium and the multi-hop nature. Ad hoc wireless network is a collection of wireless mobile nodes forming a temporary network without any centralized administration. Here, each node operates not only as a host but also as a router, which broadcasts the route request packet and the neighbouring nodes exchange the QoS parameters using the broadcast packets. These broadcast packets increase the network traffic. Cluster formation can reduce this unnecessary network traffic. The main network design problem is to find a least cost or a maximum revenue network, reducing the redundant broadcast packets.

The main objective of the research is to improve the Quality of Service in Mobile Ad hoc Network and improve the performance of routing protocol. For performance enhancement of QoS in MANETs, the network is expected to guarantee a set of measurable metrics, such as delay, delay variance (jitter), bandwidth, packet delivery rate, etc.

However, the hidden node problem, the need to share channel resources, the distributed organization of the network and the dynamic topology of MANETs bring challenges to offering QoS Routing.

In order to facilitate QoS support in MANETs, it is important to understand the metrics that are used to specify QoS.

- ***Bandwidth:*** Bandwidth is concave, which means that the end-to-end bandwidth is determined by the bottleneck bandwidth along the path.
- ***Delay and jitter:*** Delay and jitter are additive. End-to-end delay and jitter are the accumulation of each single hop delay/jitter.

Supporting more than one QoS constraint is an NP-complete problem. However, delay is associated with network load and degree of congestion. When bandwidth is sufficient, delay is relatively short, but when congestion occurs, delay increases dramatically. The relationship between bandwidth and delay.Therefore, while in this only study the bandwidth constraint, solving the bandwidth problem inherently helps in solving the delay problem. Data transmission is the collaboration of each network layer

I. QoS Routing

Routing in MANETs is a complex process, satisfying intrinsic resource constraint attributes while achieving the desired QoS. It is hereby introduced Genetic Algorithm (GA) for rectifying routing deficiencies in MANETs and to achieve better QoS. The conventional decision making in the route discovery process is preceded by genetic operations for spawning better solutions. The properties of the network like autonomous-nature, infrastructure-less support, wireless communication medium, etc inflate the gap between performance and optimization techniques.

Despite all these design issues and challenges, optimization and performance enhancement of the network is essential due to its varied real-time applications. Optimization is the most prominent way to improve network performance; the concept is usually inspired by nature or machine learning process. Genetic Algorithm based solution provisioning for MANETs have been designed from the past, many of which serve the purpose to a certain limit. A few other optimization solutions address limited issues, improving specific network metrics. Some conventional genetic solutions are trapped in convergence and the NP-hardness problem (Zheng et al. 2012; Liu et al. 2012; Beena 2012) as the evaluation constraint is less.

The hybrid optimization is powered by genetic integrated Particle Swarm Optimization (PSO). Confined to the network dynamics, the proposed GAPSO improves packet delivery ratio under controlled delay.

II. Problem Statement.

MANET performance relies on the attributes of the nodes and the application support that gains much attention for real-time scenarios. Due to the trade-off between performance and application supportive algorithms or optimization (Asraf et al. 2010; Striegel & Manimaran 2002; Delavar et al. 2012; Gavhale & Saraf 2016), the desired performance level is not attained. Conventional non-adaptive optimization solutions are stuck into local optima problem without apposite iterative evaluation.

Considering the absence of an iterative evaluation, this paper's contribution introduces a GA based QoS Routing (GA-QR) for addressing NP-hardness and local optima issues. The convergence time is extended using a fitness directed function for prevailing over node-level alterations.

III. Network Model.

Consider a MANET with {n1, n2,…nn} ∈ N nodes connected using a set of edges E. The network can be represented as a graph G(N,E) where two nodes ni and nj are said to be connected if each other is present within their range. The network is segregated into clusters; each cluster is administered by a Cluster Head (CH). The nodes that are present in 1-hop to the CH are its Cluster Members (CM). At the time of CH election, the CMs nominate themselves as Candidate Nodes (CN). Let S and D denote the source and destination correspondingly that are present in different clusters separated by a Euclidean distance. A path P exists between S and D, then P(S,D) ∈ G. Figure 1 exemplifies the network model for this proposed system.

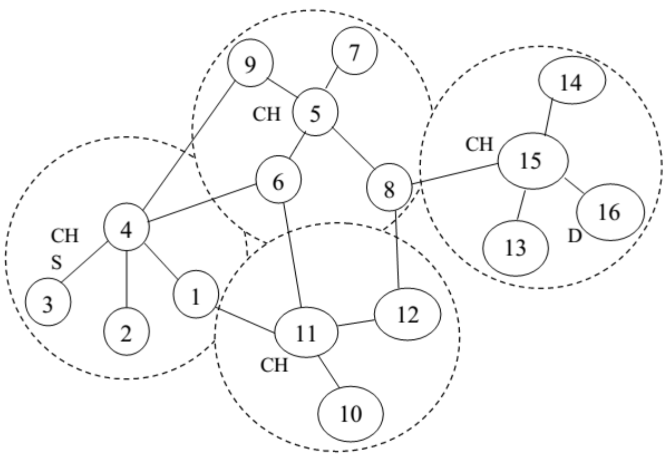

Figure 1

A. Methodology

The proposed GA-QR for improving MANET performance is designed as a two-fold process: Recommendation Preference Clustering and GA based QoS Routing. The cluster head selection process is facilitated using recommendation preference assessed for the candidate nodes. The selected CH then aids optimal path construction using the GA process. In QoS routing, the fitness of the nodes is evaluated to form a more optimal routing path that achieves better performance. The process of the proposed GA-QR is illustrated in Figure 2.

IV. RECOMMENDATION PREFERENCE CLUSTERING:

Recommendation Preference Clustering is designed to select stabilized cluster that cooperatively works with genetically fused routing. The support of the clustering process is required to achieve better network performance over local optimal problem. Conventional clustering process eases data gathering and transmission process in a delay-less manner and also controls overhead. In the process of clustering, selection of CH is a fundamental operation. The process of clustering varies with both implicit and explicit factors of the nodes and its region. Selection metrics considered exhibiting different measures due to which the selection process is biased. Different from the so far existing cluster head selection methods, the proposed RPC accounts the concave and additive metrics of the nodes for electing them as a CH.

The first CH is selected in a random manner to instigate communication, Depending on the first CH, the network is partitioned into clusters with their own members. The further CH is selected by evaluating the recommendation function by assessing the following factors: bandwidth, delay and node connectivity. Figure 3, portrays the procedure of RPC.

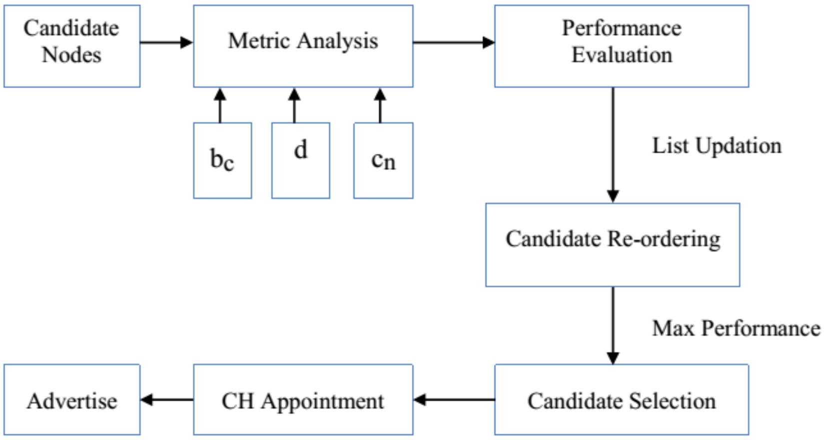

Figure 2: Process of RPC

The process of further CH selection is based on the degree of the candidate node in the network. As different metrics are considered, CH selection remains biased. To stabilize the selection factors for achieving a precise cluster head selection based on a derivative function. The derivative function operates over single (initial CH selection) and multi-metric (consecutive CH selection) as per the demands. The decision-making process harmonizes the diverse metrics as a single entity to provide the reference value of the candidate node. The preference value of the CN is its recommendation priority. Let fun(CNp) denote the derived preference function of a candidate node CN. This function uses bandwidth, delay and connectivity of the CN to conclude its preference value.

Consider a node n whose bandwidth requirement over an edge $e \in E(b_e)$ (Thenmozhi & Rajaram 2011) is estimated as

$$b_e = g_p \times t_t \times e_c \quad \text{..... (1.1)}$$

Where, g_p, t_t and e_c are the packets generated, transmitting time of the packet and bandwidth capacity of the edge 'e'. The bandwidth requirement of an edge must be minimized to achieve fair optimality at the time of packet transmission. Routing optimization along with multiple issues like path errors, nonresponsive nodes, etc. requires immediate alternate selection other than awaited path reconstruction. Therefore, the required bandwidth over an edge 'e' is not sufficient at the time of admitting multiple transmissions. In this scenario, the nodes need to share the available bandwidth to retain packet delivery at the destination. Hence, the bandwidth requirement of the edge is considered as a concave metric. To achieve a fair routing solution over a path P, it must satisfy equation (3.2) (Krishna et al. 2012; Nivetha & Asokan 2014).

$$b(P) = \min\{b_e, e \in E(P)\}, \quad b(P) \geq B \quad \text{..... (1.2)}$$

Where, B is the minimum bandwidth required.

The second factor, the delay is considered as a stabilizing metric between connectivity and bandwidth. Both bandwidth requirement and node connectivity are subjected to change with respect to link availability and node mobility. This results in biased recommendation value at the time of CH selection; delay factor rationalizes the difference in CH selection. Considering the fact that all optimized routes deliver the packet successfully, the delay is estimated as the sum of control (tctrl), MAC (tmac) and transmitting time (tt) for a node. As per the consideration, delay d is estimated using Equation (1.3)

$$d = tctrl + tmac + tt \quad \ldots..(1.3)$$

Let us consider D as the maximum delay that can be achieved. The minimum delay required by a node is therefore modelled as

$$d(P) = \sum e\ d(e) + \sum n\ d(n)\ ,\ d(P) \leq D \quad \ldots.(1.4)$$

Finally, node connectivity factor is estimated for the preference function. Let R be the range of a node, two nodes ni and nj are said to be direct neighbors if dist (ni, nj) < R(i)||R(j). If the above is true then eij=1, there exists an edge between node ni and nj else eij=0. This connectivity between the nodes is mobility dependent. The survival of the edge availability is directly influenced by the mobility of the nodes; higher the mobility, lesser is the endurance of the edges. The random mobility is considered for the nodes that influence the connectivity factor. The number of active neighbors with eij=1 is subjected to vary depending on the position and velocity of the nodes. If rn and σn are the relative velocity and degree of a node, then Equation (1.5) defines the connectivity of the nodes (Kulkarni & Yuvaraju 2015).

$$cn = (\alpha * rn) + (\beta * \sigma n) \quad \ldots..(1.5)$$

Where α and β are constants. The connectivity factor requirement must be high for a better routing. Therefore, requirement to satisfy Equation (3.5) for a maximum connectivity C is defined as in Equation (1.6)

$$cn(P) = \max\{ cn\},\ cn \geq C \quad \ldots.(1.6)$$

Now, fun(CNp) is computed (Lee &Jeong 2011; Li & Yang 2015) for each of the candidate nodes using {b(P), d(P), cn(P)} as in Equation (1.7)

$$fun(CN\ p\ )(n;\ b(P),\ d(P),\ cn\ (P)) = \{ \max\ (\ e\ b(P) \cap e\ d(P) \cap$$

$$cn(P)\ \Delta t\ )\ 0,\ \text{otherwise} \quad \ldots..\ (1.7)$$

Equation (1.7) is independently assessed as in Equation (1.8) that each node needs to achieve for increasing their preference as CNs.

$$fun(CN\ p\ )(n;\ b(P),\ d(P),\ c\ n\ (P)) = \{\ b(P) \geq B\ d(P) \leq D\ c\ n \geq C,\ n \in N \in P \quad \ldots..\ (1.8)$$

Now, the preference of each CN is derived and the node with maximum preference is elected as the CH. It is mathematically represented as max {fun(CNp1),fun (CNp2), ..,fun(CNpn)} , n ∈ {CN}. For evading complexity in cluster formation, the other CNs is prevented from being evaluated until the next iterate. The next iterate is achieved when the current CH does not satisfy either of (1.8) or the wholesome (1.7). The complexity of frequent cluster head changes is confined by avoiding other CN persuading CH position.

Let [CN1,CN2, ... , CNm], {CN} ∈ N and {m} ∈ CM denote the list of candidate nodes and selected CH. Until the cluster is deformed, the candidate nodes list is maintained to track the mobility changes. The nodes in the list are subjected to vary depending on the GA induced routing process. If GA selects nodes of its type, then the list of CN will be updated for the most recent node that is optimal. Hence, the derivative function is evaluated for the second iterate. If the updated list contains nodes that are better than the current CH and then based on local preference, the CH is replaced. The complete set of CN list contains new nodes or even retains the older ones or might be less than the previous state. This is because, due to mobility, some nodes would have newly joined or even left the cluster. The next set of list is represented as

[CN1*,CN2*,…, CNm*],{CN*} ∈ N and {m} ∈ CH.

This representation is prominent in initializing the population of GA. The new cluster head instigates communication through a broadcast from its ID to the available neighbors that route to the destination. The destination acknowledges the CH with a route reply message confirming the new path. The new path is advised by the genetic-based routing process, and further transmission is pursued by the new CH until the next preference function evaluation necessity. Algorithm 3.1 describes the procedure of the proposed RPC.

A. *Genetic Algorithm based QoS Routing*

The external node selection process is governed by QoS routing aided by genetic algorithm. The genetic implication in routing requires node-level attribute monitoring for discovering optimal routes. The internal operations of the cluster are administered, scheduled and streamlined by the cluster head. The external nodes are autonomous for which routing optimization is essential to retain the quality of transmission as destined by the CH. The conventional genetic process consists of five stages: Illustration of the genetic form, Population Initialization, Evaluation of Fitness Function, Chromosome Selection and Genetic Operation implication. In this route optimization, the fitness of the nodes is evaluated using the same metrics as considered for the CH selection. This reduces the time for acquiring and resolving new attributes for the path nodes. Figure 3.4 portrays the routing function using a genetic algorithm.

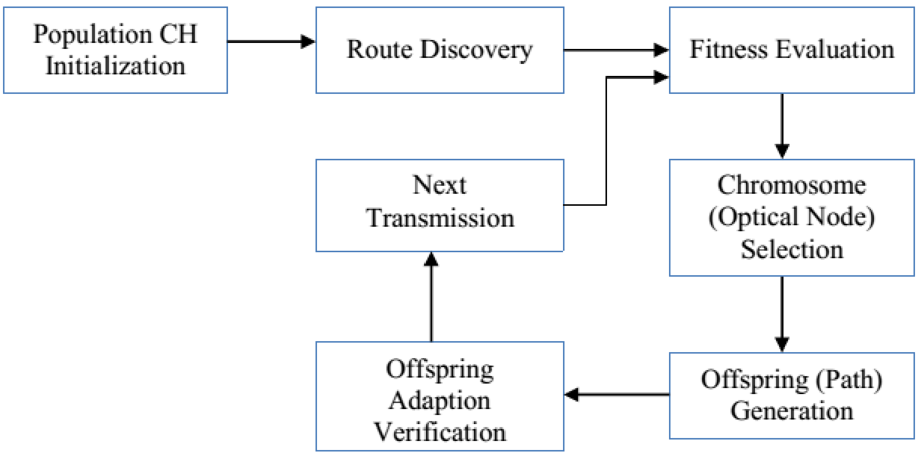

Figure 3: Routing Function using Genetic Algorithm

To prevent unnecessary CH evaluation and minimize controversies in path selection, there are two conditions to be adopted:

✓ The chromosomes must not be redundant i.e. the nodes in the routing path must not be redundant over any hop to the destination.

✓ Availability of the nodes is predominant in determining the CH preference other than satisfying Equation (1.7) or (1.8). The genetic set is represented [C1,C2, … ,Cn] ←: {CH1,CH2,…, CHn}∈ {CH}.

V. Initial Population

CH discovers the available paths from source to destination based on distance (before preference function evaluation). Distance-based paths form the initial population of the genetic representation. Let Q denote the initial population of the genetic solution for k chromosomes, then k+1< q ∈ Q feasible chromosomes are segregated as optimal (Cheng et al. 2013). For a set of chromosomes,{CHR1,CHR2,..,CHRn}, the feasible chromosomes are represented as{CHR1,CHR2,..,CHRj}, j < n (or) j =k+1. Therefore, the initial population is represented as in Equation (1.9)

$Q = \{CHR1, CHR2, .., CHRj\}$ (1.9)

The behavior of the chromosomes is not the same to retain optimality in routing. This result in fluctuating results of the chromosomes selected. In this case, the individual chromosome analysis is required to filter optimal chromosomes from j =k+1.The individual chromosome assessment is carried out using a cost-based fitness function.

The metrics that are assessed for selecting the CH are used for assessing the chromosome fitness. For all $e \in E$, a cost metric (f [cost(CHRi)]) of the i th chromosome is evaluated using Equation (1.10)

$$f[(CHRi)] = (bi(P) \cup ci(P)) \cap bi(P) \quad (1.10)$$

This cost function serves as the fitness evaluation in the genetic routing process. Equation (1.11) shows the mathematical representation of Equation (1.10)

$$f[(CHRi)] = (bi(P) + ci(P)) - bi(P) \quad (1.11)$$

Equation (1.11) concludes that both bandwidth and connectivity factors are positive factors wherein a delay is considered as a diminishing variable. The derived cost values swing between 0 and 1 for all the available chromosomes. The chromosome with a higher cost value is portrayed as the best solution. The next generation offspring is generated using the higher fitness chromosome, the process is repeated until the chromosome or the CN is updated. For ease of neighbor selection, the chromosomes are descended based on their cost. From the descended list, the first position chromosome is selected for pursuing transmission. The chromosome with higher fitness is recursively used until a new best-fit chromosome is discovered.

VI. Genetic Algorithm Implication

To improve the persistence of the solution so as to avoid local optimal problem, crossover and mutation operations are performed. For a crossover operation, a minimum of two parents is required to generate a new set of offspring. The offspring are evaluated or their fitness to ensure the best fit offspring takes part in routing. As the chromosomes are organized in descendent order, the first two are selected as parents for generating the new set of offspring.

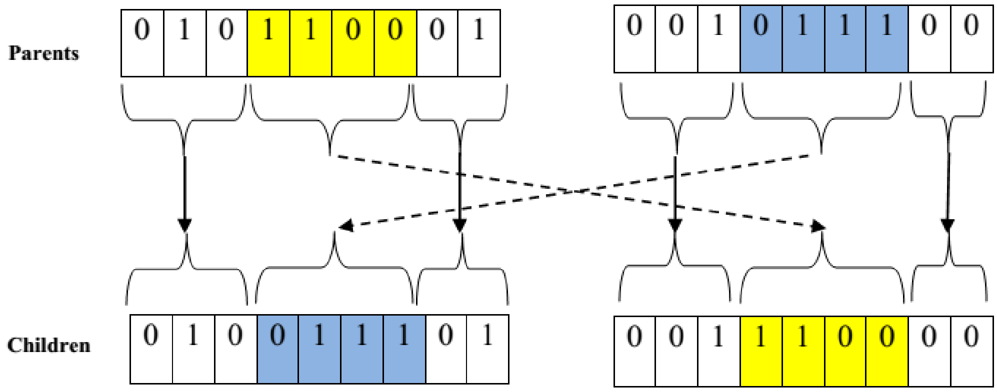

Figure 5: Crossover Operation

The performance of the proposed GA based QoS routing is assessed through simulations using Network Simulator.

Table 3.1 Simulation parameter and values

Parameters	Value
Network Region	1000 m X 1000 m
Number of Nodes	300
Node Speed	10-30 m/s
Mobility Model	Random Way Point
Transmission Range	250m
MAC	802.11
Application	Constant Bit Rate
Application Rate	256bytes
Simulation Time	360s

The proposed routing is compared with the existing Genetic Algorithm induced Ant Colony Optimization GA-ACO) (P. Madhavan et al. 2019) and particle swarm optimization integrated genetic algorithm (GA-PSO) (Rajan & Shanthi 2015). Table 3.1 details the simulation setup parameters and their 6: .

VII. RESULTS AND CONCLUSION

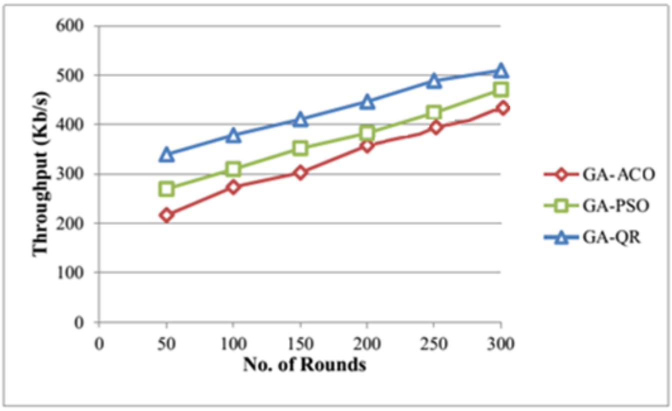

Figure 6: Throughput Analysis

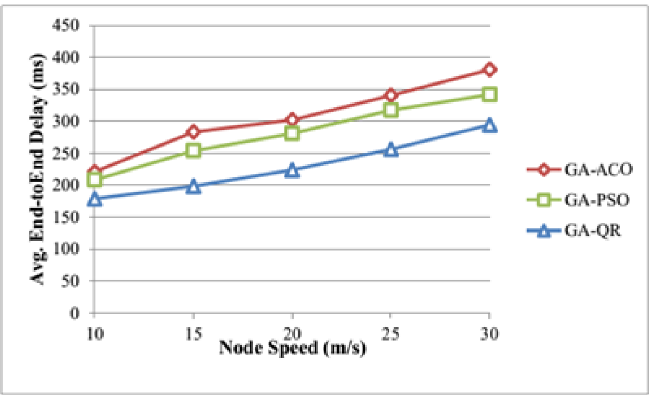

Figure 7: End to End Delay Analysis

VIII. CONCLUSIONS

The proposed GA-QR is compared with the existing GA-ACO and GA-PSO (Figure 6 & 7). In GA-QR, two levels of QoS optimization are achieved through CH selection and GA routing that abides the same QoS metrics for relaying. Therefore, the number of neighbors selected converges towards successful transmission post CH selection. The two-level process avoids a local optimal problem that retards the relaying and minimizes communication pause time. The two-level process is a mutual recommendation based that aims to sustain the transfer rate despite node mobility and cluster changes.

The proposed method is intended to improve network performance by evading the local optima problem. This convergence is resolved using a common fitness evaluation and the process is prolonged using mutation adaption evaluation. The conventional genetic approach is modified to co-operate with the behavior of the nodes so as to improve network performance with a range of non-converging solutions. The proposed GA-QR improves network throughput by 7.64%, PDR by 3.63% and reduces delay, control overhead and cost factor by 11.88%, 10.16% and 13% respectively compared to the existing GA-PSO.

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