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ECARDM: Energy Consumption Aware Route Discovery for Multicasting in Mobile Ad hoc Networks

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Abstract- Consideration of energy consumption in the case of wireless ad hoc networks leads to effective reduction of energy consumption by the nodes and increases the lifetime of the batteries for nodes. It is imperative from the existing models that there is significant scope for improvement in the energy-consumption based route discovery models. A model of Fuzzy based marginal energy disbursed multicast route discovery model for MANETs can support in reducing the power consumption has been proposed in our earlier research paper. In the present paper, a contemporary solution termed “Energy Consumption Aware Route Discovery for Multicasting for MANETs” has been proposed, which is profoundly a fuzzy reasoning and genetic algorithm based model that focus on both the energy consumption and also the element of end-to-end delay whilst discovering the route. The experimental study of the model in comparison to BWDCMR and GAEEQMR models depicted that the proposed algorithm is very effective and can certainly be result oriented.

Keywords: *fuzzy reasoning, crossover tree, fitness function, end-to-end delay, signal to noise ratio.*

1. INTRODUCTION

MANETs (Mobile ad hoc networks) are predominantly a self-configured network of mobile nodes that can easily develop its dynamic topology. Predominantly, all the nodes are part of maintaining the network connectivity irrespective of any kind of fixed infrastructure requirements like the base stations or the access points for communication. Every node in the network takes part in the routing process, and using the routing function forwards the packets to the other nodes using the intermediate nodes. When two nodes are in the range of transmission for each other, communication takes place directly; else using the support of other nodes the packets are forwarded.

Non-restricted mobility and also the ease of deployment are some of the profound features of MANETs that are vividly used in the services. Also, the challenge of power awareness is also another crucial segment in the mobile wireless networks which has been a crux factor in the implementation of MANETs.

It is very important that the power consumption by the nodes has to be limited for ensuring that the

battery lifetime of the nodes endures. To ensure that battery energies are not wasted, it is very important that the transmission power have to carefully handled, and it has become a significant area of research. From the review of numerous models of source based energy efficient multicast trees oriented algorithms that are depicted, it is evident that significant volume of research is carried out in the domain. [1].

Majority of the multi-media applications are delay-sensitive and it is very important that whilst planning to offer better QoS, issues like end-to-end delay has to be considered. But in the majority of the energy-efficient multicast routing models the scope and issue of “delay” has not been considered as a metric. Even in the case of QoS multicast routing that are developed, some of the multi-constrained metrics (degree-constrained least-cost multicast routing [2] or multi-constrained cost multicast problem [3]) has hardly ever considered the issues of energy consumption. It is imperative that QoS multicast routing schemes shall not be directly adapted in the case of MANETs.

In [4] it is imperative that the issue of QoS multicast routing with multiple QoS constraints can be NP-Complete. NP-Completion problem is predominantly addressed in the artificial intelligence domain, using an effective solution of genetic algorithm model. Despite the fact that the genetic algorithms may not be so effective in handling the delay sensitive applications due to the huge volume of iterations [5], still the scope of computation is much faster. Considering such scope and limitations, in this paper, the proposed model of genetic algorithm is designed to be quite promising in terms of multicast routing in MANETs.

In [6] the authors have presented a model of genetic algorithm for solving the multi-constrained routing problem related to the transmission delay and success ratio. Younes in [7] [8] has also proposed a genetic algorithm for determining the shortest paths envisaging the bandwidth constraints. Liu et.al [9] has also presented an oriented, spanning tree (OST) that is based on genetic algorithm (GA) for addressing the MSPP (multi-criteria shortest path problem). Ting Lu et.al [10] has proposed a different set of energy efficient genetic algorithm for finding the delay-constrained multicast tree and reduces the scope of total energy consumption of tree.

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The proposed source based algorithm shall take in to account energy consumption and also the end-to-end delay in route selection. Algorithm applies the crossover and also the mutation operations on the trees directly, and it simplifies the coding/decoding process. Heuristic mutation technique shall improve the levels of total consumption of multicast tree.

In all the aforesaid works, the authors have focused upon finding efficient and feasible path depending on energy consumption for the multicast routing in MANETs. But the performance of these models fall downwards, if number of nodes in network and number of initial routes are increased. Also limited to one or two QoS metrics. Hence, the proposed work shall focus on optimal energy-efficient multi-metric QoS multicast routing using GA

By reviewing the existing models of source-based multicast routing problems that are adapted using a genetic algorithm, in this paper, the proposal is a genetic algorithm about an energy efficient and delay-constrained multicast tree discovery. Testing under simulated conditions evinced the efficacy of the proposed model.

a) *Energy Consumption Model*

In [11] the energy consumption required for an effective link amid of two nodes has been studied. In the instance of transmission of a unit message, the quantum of minimum energy that is essential amid of minimum energy that is essential amid of nodes v_i and v_j is $P_{i,j} = k_1(r_{i,j})^\beta + k_2$, in which $r_{i,j}$ is Euclidean distance amid of v_i and v_j , k_1 shall be constant dependent on the properties constituted by the antenna, β shall be the path loss exponent which is dependent on the level of propagation losses taking place in the medium, and k_2 shall be a constant that accounts for the overheads taking place from the digital processing and electronics. In the above instance, one of the presumption is that each of the multicast session shall be multicasting only a unit length message.

b) *Network Model and Problem Description*

It is presumed that every node of the MANET shall evaluate the distance between them and the other neighbour nodes using some kind of distance estimation methods [12]. Transmission power of a node has direct impact on the connectivity of the network, and every node can alter its transmission power levels in a dynamic way. Every node can use the different set of power level for each of the multicast tree in which the node functions and predominantly the nodes use Omni-directional antennas. Every node in a network shall have two coverage areas like the control coverage area (CR_i); and data coverage area $\{DR_i \exists DR_i \subseteq CR_i\}$.

Such coverage areas mostly rely upon the transmission power chosen by the selected node v_i for transmitting its control and data packets categorically.

As per the control coverage area for every node, a MANET can be depicted as a graph $G(V, E)$, in which $V = \{v_1, v_2, \dots, v_n\}$ shall be a set of nodes (mobile hosts) and $E = \{(i, j) | v_i, v_j \in V\}$ is a set of links. $(i, j) \in E$ Denotes that v_i and v_j shall be in the limits of control coverage area of each other. Every link (i, j) is constituted with a delay $d_{i,j}$ and distance $l_{i,j}$. $d_{i,j}$ Indicates the delay of data transmission between v_i and v_j , also comprising inputs on queuing delay and propagation delay. $l_{i,j}$ denotes the Euclidean distance amid of v_i and v_j . Both $d_{i,j}$ and $l_{i,j}$ shall be real numbers that are positive.

If $s \in V$ be a multicast source and $D \subseteq V - \{s\}$ shall be set of destinations. A multicast tree $T(s, D) \subseteq G$ will be a tree rooted at s and reaching all of the destinations in D . The delay of a path on T from s to a destination $v_t \in D$, indicated as $\text{delay}(pT(s, v_t))$, is $\text{delay}(pT(s, v_t)) = \sum_{(i,j) \in pT(s, v_t)} d_{i,j}$. In such conditions, the delay-constrained minimum Steiner tree problem is all about finding minimum cost multicast tree $T^*(s, D)$ such that $\text{delay}(pT^*(s, v_t)) \leq \delta, \forall v_t \in D$, in which δ is the overall permissible delay from s to a destination $v_t \in D$. Once $T^*(s, D)$ is identified, every node on T^* works on adjustments of its transmission power effectively for transmitting data packets along the tree.

II. ENERGY CONSUMPTION AWARE MULTICAST ROUTE DISCOVERY BY GA

a) *Coding*

In the process of developing an effective and well-performing genetic algorithm, representation of candidate solutions play a vital role. In the case of number of representations for a tree which is like one-dimensional binary code [13] or the Prefer numbers [14], alongside the sequence and topology encoding

(ST encoding) [15], has been developed in a significant manner.

But many of these representations could lead to generation of more illegal trees, or the ones that has very poor neighbourhood or even the ones that have very low efficiency leading to surge in the required search space whenever there is rise in the network size. Some of the recent studies that have focused on network optimization [16] have overcome the problem by adapting the tree manipulation. For instance, processes like using a data structure of a tree for defining the chromosome as an option. Such processes are resulting in the omission of tree structure coding methods where the chromosomes denote the multicast tree directly.

b) *Initial Population*

In the population initialization, two of the significant issues that are considered are about population size NP and the population formulation method. NP is effectively set by a system. In the algorithm proposed, random multicast trees which are formed as initial population is completely on the basis of MAODV [17].

c) *Fitness Function*

Individual performance has to be depicted in the fitness function: For the proposed model, the inference is that the good individual has better fitness than the bad ones. Also, the definition of the fitness function is profoundly based on set of heuristics that are devised in [18]. Following are the set of heuristics considered for defining the fitness.

The proposed heuristics for the selection of optimal nodes in each hierarchy of the set shall be quoted as $H = \{h_1, h_2, \dots, h_{|H|}\}$ are

i. *Ratio of Battery Depletion* [18]

This is one among the heuristics which define the quantum of mediocre energy that is essential for transmitting each unit of data for the nodes that comprised in routing path. Also, the average levels of energy that is essential for transmitting the frame by a node in the hierarchy h_i for all optimal nodes that are selected in consecutive hierarchy h_{i+1} .

ii. *Foreseen Residual Battery Life* [18]

This heuristic shall support in forecasting the residual life of a node nd towards the completion of the routing process that is already scheduled. The sum (aec) of Battery Depletion (bd) expected for transmissions amid of the node nd and towards its hop level successor nodes, at node's idle time (ibd) the levels of batter depletion time and obligatory battery depletion (obd) which reflects the energy consumption resulting from factors like retransmissions, jitter and control packets. Also, the resultant sum aec shall be deducted from the present residual battery life ($prbl$). Such resultant values have to be more of positive and should be greater than the threshold values defined.

iii. *Assessing Opportunistic multicast range* [18]

This metric shall be an effective heuristic signifying the hop level multicast link amid of the optimal nodes for a hierarchy h_i to the quantum of optimal nodes in continual hierarchy h_{i+1} .

iv. *Assessment of Signal to Noise Ratio*

In the signal to Noise ratio (snr) of a node n_i shall be the average loss of signal ration pertaining to noise that is observed at the links amid of node of node n_i and all the successive nodes that are connected.

v. *Assessing Fitness of the Given Multicast Route* [19]

In terms of fitness that is considered for an individual node which is assessed by adapting the fuzzy logic which is applied in terms of battery depletion ratio, signal to noise ration and the foreseen residual battery life, and also the levels of opportunistic multicast range.

Fuzzy notations that are used for the heuristics that are proposed, for performing the fuzzy reasoning which are ranged with the ranks that are of scale 1 to 5, with most optimal ranked as high in the scale (5) and for the least optimal it is range as low which is 1. The divergent fuzzy state ranking of the heuristics are depicted in the Table-1

Table 1: Notations adapted for performing fuzzy reasoning using the proposed heuristics

| | Foreseen Residual Battery Life ($frbl$) | Opportunistic Multicast Range (omr) | Battery Depletion Ratio (bdr) | Signal to Noise Ratio (snr) |
|-----------|---|---|-----------------------------------|---------------------------------|
| Very Low | 1 | 1 | 5 | 1 |
| Medium | 3 | 3 | 3 | 3 |
| Very High | 5 | 5 | 1 | 5 |
| High | 4 | 4 | 2 | 4 |
| Low | 2 | 2 | 4 | 2 |

In terms of membership function, which is adapted for fuzzy reasoning in terms of estimating the fitness for a given tree is:

The mean m of the low l and high h values for a heuristic observed for all nodes comprised in the given route shall be estimated initially as follows

$$m = \frac{(l + h)}{2}$$

- But in the lower value l to $\frac{m}{2}$ it shall be considered as the range of very low,
- $\frac{m}{2}$ to $3 \otimes \frac{m}{4}$ will be considered as the range of low,
- $3 \otimes \frac{m}{4}$ to m is observed as the moderate,
- m to $m \oplus \frac{m}{2}$ is observed as range of high
- and $m \oplus \frac{m}{2}$ to h is observed as range of very high.

Also, the average of ranks that are observed towards a heuristic h for all nodes in a given route shall be assessed and is also normalized by divided with max rank (5 is the max rank proposed in the model). The resulting normalized values towards the respective

i. *The Optimal Route Discovery Function*

Repeat {

$tT \leftarrow T$ /clone the initial multicast trees discovered in route request phase

$\bar{T} \leftarrow \phi$

$\forall_{i=1}^{|T|} \{t_i \exists t_i \in T\}$ Begin // for each multicast tree t_i discovered in route request phase

$\forall_{s=1}^{|T|} \{t_j \exists t_j \in T \wedge i \neq j\}$ Begin// for each multicast tree t_j discovered in route request phase, which is not equal to t_i

$\bar{T} \leftarrow GAPE(t_i, t_j)$

//see sec ii

//Invoking the function that performs Genetic Algorithm with progressive evolutions on given multicast trees

End

End

If $(|T| \square |T \cup \bar{T}|)$ Begin

$T = \phi$

$T \leftarrow \bar{T}$

} Until $(tT \square T)$ // repeat the process till tT and T become approximately equal under given threshold Δ

ii. *The Genetic Algorithm with Progressive Evolutions*

GAPE (t_i, t_j) BEGIN

Consider a set RT to preserve the resultant multicast trees from progressive evolutions

Consider the set cn to store the resultant crossovers, which are sub trees exists in both given trees t_i and t_j

heuristic at the route level shall be either > 0 and ≤ 1 . Similar process shall be applied for all of the heuristics that are considered for fuzzy reasoning. Also, the route level values that are observed for every heuristic shall be aggregate and divided by the total volume of heuristics (4 is the notion value in the proposal) with resulting values being in the range of > 0 and ≤ 4 , depicting the fitness value of the given route.

d) *Energy Consumption Aware Multicast Route Discovery*

The initial population in terms of discovering all the possible multicast routes shall be carried out using the bench marking routing strategies like MAODV [17].

Also, the incremental genetic algorithm towards redefining the multicast route discovery for QFSRD [20] shall be adapted for optimal route discovery.

To accomplish the evolutionary strategy, adapting Genetic Algorithm comprising incremental evolution process is focused upon. An incremental evolution strategy which is adapted on set of possible routes P which is found between the source and also the destination nodes and the number of evolutions at the initial level shall be limited to max evolution count provided.

i. $\forall_{p=1}^{|t_i|} \{st_p \exists st_p \in t_i\}$ // for each subtree st_p such that

$st_p \in t_i$ Begin

ii. $\forall_{q=1}^{|t_j|} \{st_q \exists st_q \in t_j\}$ // for each node st_q such that

$st_q \in t_j$ Begin

iii. $if(st_p \equiv st_q \ \& \ p \equiv q \neq 1)$ Begin // if sub trees $\{st_p \exists st_p \in t_i\}$ and $\{st_q \exists st_q \in t_j\}$ are identical and p, q are not equal to 1

a. $cn \leftarrow st_p$ //move subtree st_p to set cn

End // end of iii

End // of ii

End // of i

Split the given multicast tree t_i in to two subtrees lt_i and rt_i , //where lt_i is the subtree, which is predecessor to st_p , rt_i is the sub tree, which is successor of st_p

Split the given multicast tree t_j in to two subtrees lt_j and rt_j , //where lt_j is the subtree, which is predecessor to st_q , rt_j is the sub tree, which is successor of st_q

Then create new multicast tree, such that new multicast tree ct_1 is created by concatenating the left part lt_i of the tree t_i , crossover subtree st_p and right part rt_j of the tree t_j , which is as follows

$ct_1 \leftarrow lt_i$
 $ct_1 \leftarrow st_p$
 $ct_1 \leftarrow rt_j$

Further, create new multicast tree ct_2 , by concatenating the left part lt_j of the tree t_j , crossover sub tree st_p and right part rt_i of the tree t_i , which is as follows

$ct_1 \leftarrow lt_i$
 $ct_1 \leftarrow st_p$
 $ct_1 \leftarrow rt_j$

Find fitness of the routes $t_i, t_j, ct_1, and ct_2$
 //Assessing fitness as explored in section-c(v).

Order the $t_i, t_j, ct_1, and ct_2$ in the descending order of their fitness

Move first two routes in the ordered list to **RT**

Return **RT**
 END

In accordance to [22, theorem 2.7], algorithm shall be resourceful in converging as a global optimal solution. In a large-scale network, it shall be much time consuming for obtaining the optimal solution to an NP-complete problem, still such issues could be overcome if there is proper iteration time set in the genetic

algorithm. By carrying out such process, obtaining near-optimal solution within a reasonable time limit can be expected.

III. EXPERIMENTAL STUDY AND PERFORMANCE ANALYSIS

In the experimental process of the proposed genetic algorithm, the process adapted is to implement in expression language R [21].

Experimental study is carried out on a PC with configuration of Pentium Dual-Core 2.5 GHz CPU and the Ram capacity of 2GB memory. Preliminary tests that are carried out with the 20 initial multicast routes discovered under route request phase. The proposed algorithm model is evaluated and compared with least delay multicast tree algorithm model of Bandwidth and Delay Constrained Multicasting by GA (BWDCMR) [8] and Genetic Algorithm for Energy-Efficient QoS Multicast Routing (GAEEQMR) [10]. As BWDCMR and GAEEQMR are among the most effective models found in recent literature, which is in terms of connecting the source and the destination with the least possible delay in the path, such a model is considered for comparison. The RRSR (route request success ratio) of an algorithm can be defined as the numerous requests that are successfully routed which are divided by the total number of routing requests. In the case of the multicast tree if the delay constraints are addressed, then the routing request is considered to be effectively and successfully routed.

The results from the experiments that are carried out are depicted for random networks. The process of simulation that is conducted depicts the outcome for the random networks to be between 20-100 nodes and the distance for each of the link shall be distributed in uniform manner in the range of 10 to 200 units (pixels in simulation) and the delay for each of the link is between 0 and 50 milliseconds focused upon. Also, the maximum permissible delay in the process is uniformly distributed as in the range of 30 to 160 milliseconds.

Source and destinations are randomly generated for every request. MANETs that are considered can be adapted in vivid sectors under the real-time conditions. Also, the network comprised in the application shall be of various sizes which range from small to medium and even in the levels of tens of nodes. Simulation process considered in the experiment depicts the realistic conditions

Max Lifetime of the Route, Energy Consumption Ratio and the Route Discovery process Completion Time are key elements that are tested in the experiments. Results are the outcome of 10000 randomly generated requests of routing for each network. For every request, the source and destination are generated randomly.

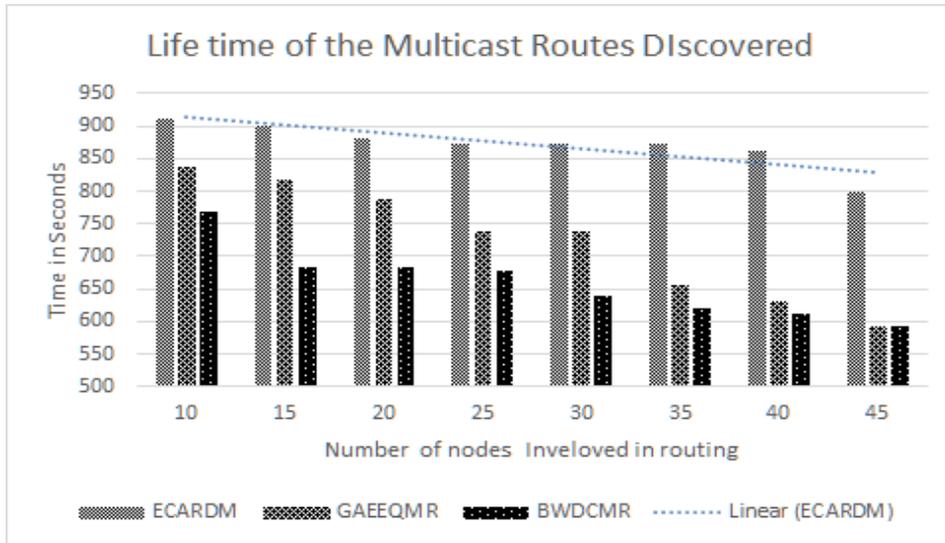


Figure 1: Lifetime of the Routes Discovered

In the Fig 1 depicts the comparative results of delay bound and energy efficient routes discovered by the proposed and other two benchmarking algorithms BWDCMR and GAEEQMR. It is imperative from the

figurative representation that the proposed model is outperformed the other two with an average of 25% and 17% max route life than BWDCMR and GAEEQMR respectively.

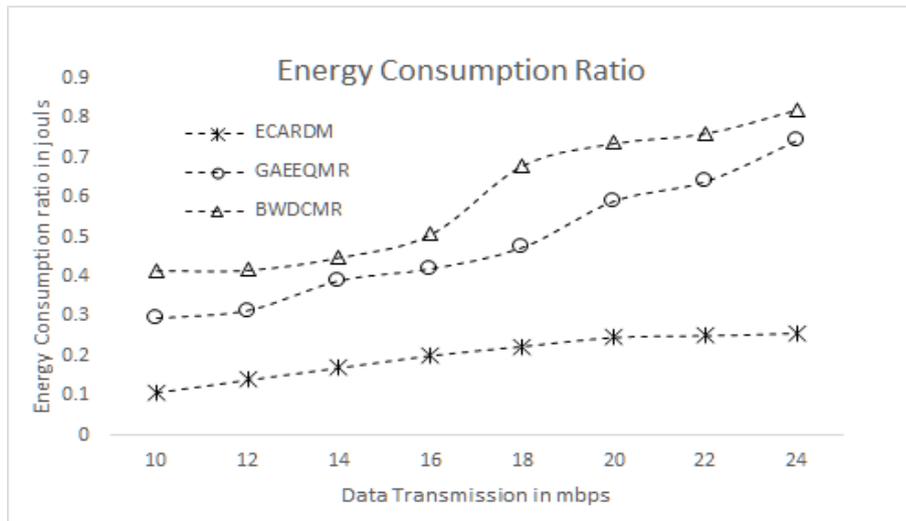


Figure 2: Energy Consumption Ratio Observed

Also, in Fig.2, the comparative results of ratio of energy consumption observed for proposed and other two models is denoted. It is evident from the results that the energy consumption ratio in the proposed model is significantly minimal than the other two models, which emphasizes that the proposed model can support in finding the multicast tree that consumes minimal energy.

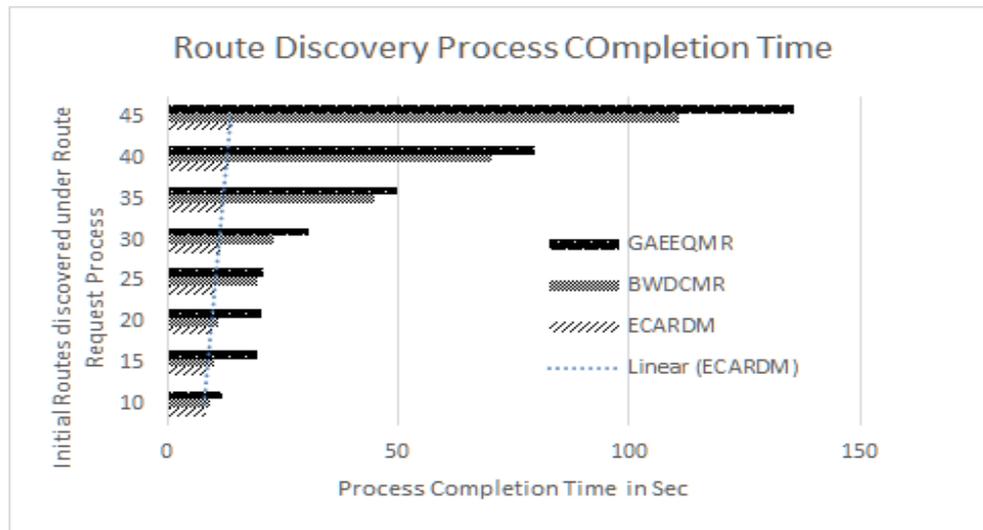


Figure 3: The Process Completion time observed

In the Fig.3, the route discovery process completion time obtained by all three models has been depicted. The results reflect the fact that the Route discovery time of the proposed algorithm and BWDCMR are linear and equal by approximate against to the number of initial routes given as input, whereas in the case of GAEEQMR, the route discovery time is multifold if number of initial routes increased.

IV. CONCLUSION

Power awareness is very important element in mobile wireless networks, categorically in the case of MANETs. It is predominantly important that the nodes have to significantly reduce their power consumption to envisage endured battery lifetime. Considering the existing models of energy consumption aware route discovery models, it is imperative that though some of the models are turning to be very effective, still there is scope for improvement. Even in the case of some of the bench marking models like the BWDCMR and GAEEQMR, the computational complexity levels are high and NP-hard. There is need for improved ways of finding the multicast route discovery with less complexity.

The algorithm that is proposed in this paper is the energy-efficient delay-constrained multicast routing algorithm. The source-based algorithm that is proposed considers the level of energy consumption and also the end-to-end delay in route selection. Crossovers and the mutation operations are directly applied on trees, by the proposed algorithm. Such a process results in simplification of coding operation and results in scope of omitting the coding/decoding process.

Heuristic mutation techniques shall result in improved total energy consumption for a multicast tree. Some of the experiments that are performed for verifying the convergence performance, S R and also the running

time for the proposed algorithm and when compared to the BWDCMR and GAEEQMR models for comparative analysis, the results depict that the proposed model has linear computational complexities and NP-Complete. Also it can be very resourceful in improving the route discovery based on source-based routing trees. In the future works even the shared multicasting trees can be focused upon.

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