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Novel Approach to Multi Constraints Reactive Multicast Routing Protocol for MANET

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Abstract— Mobile Ad Hoc Network (MANET) is a widespread research area, where the protocols face challenges due to its dynamic network topology. The adaptive network is an emerging technology that draws attraction as it is cheaper, concise and powerful. In applications where sharing of information is essential, MANET uses multicast routing protocols, as it is easily deployable. The paper describes various system models (like energy model, LLT model, mobility model etc.) related to MANET. The objective of this paper is to introduce multicast routing in MANET with the aid of tree-based clustering and optimization by proposing Cuckoo Search (CS) and M-Tree based Multicast Ad hoc On-demand Distance Vector (CS-MAODV).

***Keywords* --** Multicast Routing, MANET, Cuckoo Search

I. Introduction

Multicasting is a vital technology to expeditiously support one-to-many or many-to-many applications. The multicast routing protocols designed for wireless mobile ad hoc networks are essentially completely different from those for typical infrastructure primarily based networks in this are self-configuring and shaped directly by a collection of mobile nodes with out relaying on any established infrastructure. In such networks, the heterogeneousness of the hosts makes it troublesome to achieve bandwidth efficiency and service flexibility.

In MANET, the multicast routing protocols aim to achieve on time data delivery, reduced routing control overheads and stable connectivity with reduced packet losses [9, 15]. The multicast routing protocols in MANET are of two types: tree-based and mesh based routing protocols [16]. In tree-based routing, the protocol constructs a tree structure by connecting all multicast members, thereby, providing a path between a pair of source and destination nodes one path between a pair of source and destination nodes; It has low control overhead and bandwidth efficient characteristics [19]. Mesh-based protocols establish multi-paths between the source and the destination nodes, which persist even after the failure of links in the network, i.e. re-computation of the mesh is not required. This ensures the robustness of the mesh based protocols against the link breakage between the mobile nodes [8, 12].

Tree-based multicasting routing topology is a common routing in the wired network, where it is possible to gain the efficiency in data forwarding due to the existence of a single route between a pair of source and destination [4]. In spite of the simplicity of tree-based routing protocols, the packet loss in MANET can be reduced only after the reconstruction of the tree. Bandwidth Efficient Multicast Routing Protocol (BEMRP), Multicast Routing Protocol Based on Zone Routing (MZRP), Location Prediction Based Routing Protocol (LPBR) and Ad-hoc On-Demand Distance Vector Routing Protocol (AODV) are a few tree-based multicast routing protocols [9] in the literature. The two advantages that differ tree-based multicast routing protocols from other protocols are high efficiency in forwarding packets and low utilization of bandwidth [6]. Recent research on cluster based tree structure helps to collect the data from the nodes with an objective of minimizing the energy consumption of the node. The beacon reception of the sensor node from its neighbour develops a cluster tree based on the connection request and connection response. The cluster tree developed transmits the data that are collected by a special cluster head from its neighbour cluster heads in a way to increase the energy efficiency and the network lifetime [1]. For the proper selection of routes in a tree, optimization algorithms may also be preferred [23, 25].

This paper proposes a multicast routing protocol, CS-MAODV for MANET. This tree-based clustering and optimization algorithm for routing is concerned with objectives namely, energy, LLT, distance, and delay. The proposed multicast routing approach consists of two stages:

i. *Construction of M-Tree using DIVC*
ii. *Finding optimal multicast routes using CS algorithm.*

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The paper is organized as:

Section-II	:	Survey of the existing multicast Routing protocols and algorithms in MANET.
Section-III	:	System model along with the energy, LLT and mobility model
Section-IV	:	Working Model of Proposed CS-MAODV.
Section-V	:	Conclusion of the paper

II. RELATED WORK

This section presents a brief description of various multicast routing protocols (MRP) in the literature for MANET.
Yun-Sheng Yen et al. [2], an energy-efficient genetic algorithm approach was developed to solve this NP-Complete problem that dealt with several constraints. Moreover, a source-tree-based routing algorithm was designed, and then, the shortest-path multicast tree was built using the genetic algorithm with a small sized population to minimize the time delay. The algorithm had only a few nodes in the route discovery process. The genetic sequence and the topology encoding were enhanced here, improving the lifetime of the nodes using residual energy computation of all the nodes in a tree. However, the mobile nodes consume considerable energy based on its degree.

Chia-Cheng Hu [3], had designed a bandwidth-satisfied multicast protocol for dividing the large-scale MANET into two-tier infrastructures. In this two-tier multicast protocol, hosts with fewer hops and that had a longer connection time to the other hosts would be selected as backbone hosts (BHs). In addition to the establishment of short and stable multicast routes, the protocol developed a stable two-tier infrastructure with less packet loss. This multicast protocol had built multicast trees with the bandwidth-satisfied concept for the applications concerning QoS in MANETs. It could improve the network performance, as the number of forwarders was reduced in a multicast tree. Although the number of packet drops is minimized, the network suffers overhead issues as the messages in the beacons are too short.

Shiow-Fen Hwang et al. [4], developed a cluster-based multicast routing protocol with multi-source so that the network could attain efficiency in multicasting. A weight-based clustering algorithm was used to maintain the nodes and the topology. The shared data delivery structure of a source with other sources in the group had maintained the efficiency in forwarding the data packets. The multicasting protocol had reduced the control overhead and flooding of control messages with robustness provided against node mobility. The network could adjust the changing topology with the maintenance of route and the group membership. The drawback of this protocol is in the back-off time period that delays the construction of multicast trees.

Moonseong Kim et al. [5], designed a scheme, Weighted Parameter for Multicast Trees (WPMT), to obtain Steiner trees aptly for effective multicast routing by relating link cost and link delay with a weighted multicast parameter. The technique developed multicast tree across a source-destination pair such that the tree could satisfy certain QoS requirements like minimum tree cost, minimum tree delay, minimum tree delay with constrained tree cost, minimum tree cost with bounded tree delay, and so on. The algorithm used a weight ω, indicating the delay that ranges from 0 to 1 so as to adjust the cost and delay measures. However, the delay of the tree increases as the parameter is close to unity.

Xu Li et al. [6], proposed an optimization protocol MAODV-BB, by analyzing the effect of load on MAODV protocol. MAODV-BB algorithm updates the shorter tree branches and thereby, built a multicast tree with backup branches by using the GRPH messages of the group leaders. The robustness was improved as the shorter branches had minimized the utilization of resources, while the backup branches reduced the reconstruction of trees to a great extent. Even though the protocol enhances the robustness, the heavily loaded network can worsen the robustness.

Vincenzo Maniscalco et al. [7], presented a tree-based Genetic Algorithm (GA) in MANET for QoS routing to support Ubiquitous and Pervasive Computing (UPC). GA was a soft computing paradigm that could solve the NP-complete problems with multiple constraints. The tree-based GA indicated the set of paths that exist from source to destination as a tree and it had encoded the tree along the crossed junctions. When most of the applications had used m-ary encoding in the chromosomes to represent a single path, this algorithm utilized binary encoding with an objective of enhancing the speed of convergence. The binary encoding had defined the classes of paths in the chromosomes providing a local search on the classes, which were collectively exhaustive and mutually exclusive. The limitation of the algorithm is the larger population that makes the computation complex reducing the convergence speed.

N.C. Wang [8], designed a Power-aware Dual-Tree-Based Routing Protocol (PDTMRP), which used a power-aware metric to control the power consumption of the forwarded data packets. All the mobile nodes in the MANET were categorized into two groups, group-0 and group-1, in a random approach. The protocol had created two multicast trees, tree-0 and tree-1 for group-0 and group-1, to balance the network load. The power in the battery could discard the unstable nodes to improve the reliability, which could prolong the lifetime of the network. Even though the protocol can improve the network lifetime, high-speed mobility nodes incur link breakages.

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Ajay Kumar Yadav and Sachin Tripathi [9], developed a QoS based Multicast Routing Protocol using Reliable Neighbour nodes Selection scheme (QMRPRNS), by integrating the scheme in MAODV protocol to overcome the constraints in MANET. The RQ and RP packets had found multicast routes in the route discovery process. QMRPRNS could solve the problems regarding the failure of nodes with the route maintenance approach. The energy available in the transmission nodes calculates a reliability pair factor by which it eliminates the low energetic nodes, but if the energy of all the nodes becomes lower than the threshold, the communication is impossible.

2.1 Challenges in Multicast Routing

The following aspects discuss few challenges that MANET faces during multicast routing.

Since MANET shares all the nodes in the region of communication, there is restrictions in the transmission range, memory, storage capabilities, power and so on, which form the major constraints [18] in the MANETs?

The reservation of resources in the transmission path affects the QoS behaviour of the network even if a link cannot adjust with the available resources [5].

Constructing cluster tree-based multicast routing is one of the challenges, as the protocols designed for multicast routing is for single source multicasting. The data shared with the other sources within a multicast group may increase the overhead making it inefficient.

Another challenge in MANET is the robustness, which is hard to sustain due to the mobility of nodes and regular node failure. Frequent route failure adds up the channel and processing overhead [17].

2.2 Problem Statement

A multicast routing protocol designed with multiple QoS constraints updates the solution without considering its quality, distance, and the fitness values. Similarly, in the protocol QMRPRNS, it selected the neighbours considering only the energy. Multi-objective consideration is one of the challenges that most of the algorithms of multicast routing fail to follow.

Some of the problems identified in the existing algorithms are:

- Back-off time period that delays the construction of multicast trees.
- Delay of the tree increases as the parameter is close to unity.
- Even though some of the protocols enhance the robustness, the heavily loaded network can worsen the robustness.
- Larger population that makes the computation complex reducing the convergence speed.
- Even though some protocols can improve the network lifetime, high-speed mobility nodes incur link breakages.
- For some proposals the energy of all the nodes becomes lower than the threshold, the communication is impossible.

The proposed algorithm overcomes the above issues providing appropriate transmission along the selected suitable routes from the source to a set of destination “D”.

III. SYSTEM MODEL

Let a graph G represents a MANET having N number of nodes, $N = \{n_1, n_2, \ldots, n_i\}$ within the coverage area A. L Denotes a set of links that connects two nodes in the MANET. The figure 1 shows a MANET, in which the data packets are forwarded from the source S to a set of destinations D, such that $D = \{D_1, D_2, \ldots, D_j\}$. There are N mobile nodes in MANET that covers the region of dimension $A \times B$. The nodes are distributed uniformly in random manner and are positioned at location (A_n, B_n). Each node moves in the coverage area in a direction θ_n. All the nodes in the MANET are not involved in data transmission. The selection of nodes depends on certain constraints, which develop routes for the transmission with a suitable routing mechanism.

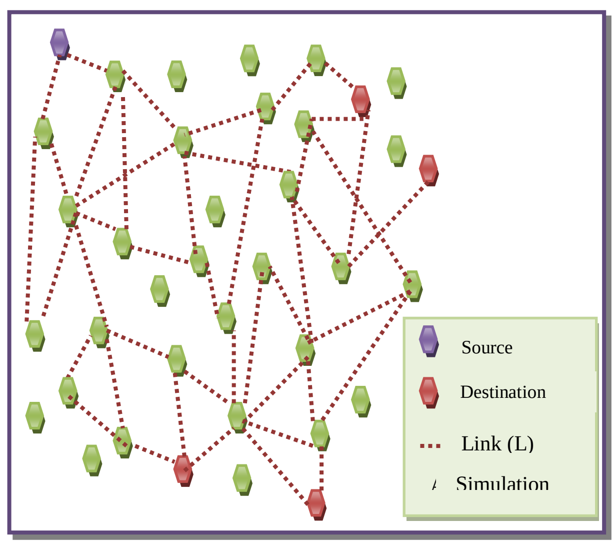

Figure 1. MANET Model

3.1 Energy Model

When a node transmits or receives a bit, it consumes energy E from the battery, both at the transmitter and the receiver end. Let B denotes the battery energy, which is full initially, i.e. $B = 1$. As the transmission continues, the energy of the

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node begins to reduce. The battery energy of a node determines a constraint, multi-factor, to select a node for the transmission. The total energy loss in the network at a time l is,

$$E_{Loss}(l) = E_{Loss}(l-1) - (E_T * t_{l-1}) - (E_R * t_{l-1}) \quad \text{-------------- (1)}$$

where, E_T is the energy acquired in a node during the transmission of an information bit at a time $l-1$, t is the transmitted number of bits, and E_R is the energy acquired in a node to receive a bit.

Initially, at time $l = 0$, the energy that remains in a node is the full battery energy that exists in the corresponding node, i.e. $E_{Loss}(l) = B$. The energy required to transmit and receive a bit during the communication is,

$$E_T = E_R = 0.01 \quad \text{-------------------- (2)}$$

Assume an energy ratio in terms of battery energy remaining in a node as,

$$R = \frac{E_{Loss}(l)}{B} \forall 0 < E_{Loss}(l) \le 1 \quad \text{------------------- (3)}$$

Where, $E_{Loss}(l)$ is the energy loss in a node and B is the full battery energy. The energy loss will be in either low range or high range, as in equation (4),

$$E_{Loss} = \begin{cases} LR, if\ 0 < R \le T_h \\ HR, if T_h < R \le 1 \end{cases} \quad \text{-------------- (4)}$$

Where, LR is the low range value, HR is the high range value, and T_h is the threshold.

This range of energy loss of a node depends on a threshold T_h, which determines whether the available energy in the node of a network is sufficient to transmit the data. The value of T_h is fixed as per the user requirement.

3.2 LLT Model

LLT defines the lifespan of a link that connects two nodes at a time until the transmission of data packets exists in the network. The dynamic network topology in MANET is one of the main reasons for link breakage and thereby, the route failure. To reduce the effect of the link failure in the network, the protocols compute the lifetime of the links beforehand. The lifetime of the link depends on the mobility of nodes, the direction of mobility, and the coordinate of nodes. Let n_1 and n_2 denote two mobile nodes located at (A_{n1}, B_{n1}) and (A_{n2}, B_{n2}), for which the LLT is,

$$LLT = \frac{-(pq + rs) + \sqrt{(p^2 + s^2)a^2 - (ps - rq)^2}}{(p^2 + s^2)} \quad \text{-------------- (5)}$$

Such that, $p = M_{n1} \cos\theta_{n1} - M_{n2} \cos\theta_{n2}$,

$q = A_{n1} - A_{n2}$,

$r = M_{n1} \sin\theta_{n1} - M_{n2} \sin\theta_{n2}$, and

$s = B_{n1} - B_{n2}$

where, a is the transmission range, M_{n1} represents the speed of mobility of the node n_1, M_{n2} is the speed of mobility of the node n_2 , (A_{n1}, B_{n1}) is the coordinate of the node n_1, (A_{n2}, B_{n2}) is the coordinate of the node n_2 , θ_{n1} is the direction of motion of node n_1, and θ_{n2} is the direction of motion of node n_2 .

3.3 Mobility Model

As the nodes are mobile, it requires a mobility model that demonstrates the movement of nodes specifying its location, velocity and acceleration that varies at each time [9]. MANET requires a perfectly designed mobility model so as to determine the performance of the routing protocol. The mobility model of MANET with the position of the nodes at varying time instants is as follows: Assume n_1 and n_2 as two nodes located at (a, b) and (a', b') at a time $l = 0$. The nodes n_1 and n_2 move in its desired directions with two angles θ_{n1} and θ_{n2} in varying velocities. At the time $l = 1$, the node n_1 takes a new position (a_1, b_1) and node n_2 takes a position (a_1', b_1') within the coverage region. Similarly, at the time $l = 2$, the nodes n_1 and n_2 move to positions (a_2, b_2) and (a_2', b_2') and so on, such that the distances D_{T1} and D_{T2} between the nodes at each time instant are minimum. The distance between the nodes represents the Euclidean distance, which is as follows,

$$D_T(n_1 n_2, 0) = \sqrt{|a - a'|^2 + |b - b'|^2} \quad \text{-------------- (6)}$$

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where, $D_T(n_1 n_2, 0)$ is the distance between the nodes n_1 and n_2 at the time $l = 0$, (a,b) is the location of the node n_1 at $l = 0$ and (a',b') is the location of the node n_2 at $l = 0$.

Let u_{n1} and u_{n2} denote the velocity of node n_1 and that of node n_2 when the nodes move with angles θ_{n1} and θ_{n2} in a distance at time l expressed as,

$$D_{T1} = u_{n1} \times l \qquad (7)$$

$$D_{T2} = u_{n2} \times l \qquad (8)$$

The node $n_1(a,b)$ moves to a new location (a_1, b_1), at a distance D_{T1} with an angle θ_{n1} at a time l ,as in the equations (9) and (10),

$$a_1 = a + u_{n1} \times l \times \cos(\theta_{n1}) \qquad (9)$$

$$b_1 = b + u_{n1} \times l \times \sin(\theta_{n1}) \qquad (10)$$

Where, u_{n1} is the velocity of the node n_1.

The following equations denote the new position (a'_1, b'_1) of the node $n_2(a',b')$ at a distance D_{T2} with an angle θ_{n2},

$$a'_1 = a' + u_{n2} \times l \times \cos(\theta_{n2}) \qquad (11)$$

$$b'_1 = b' + u_{n2} \times l \times \sin(\theta_{n2}) \qquad (12)$$

where, u_{n2} is the velocity of the node n_2.

Hence, the distance between the nodes n_1 and n_2 at a time l in the new positions $n_1(a_1, b_1)$ and $n_2(a'_1, b'_1)$ is

$$D_T(n_1 n_2, l) = \sqrt{|a_1 - a'_1|^2 + |b_1 - b'_1|^2} \qquad (13)$$

IV. Working Model of Proposed CS-MAODV

The working model of the paper is to perform multicast routing in MANET using CS-MAODV protocol. At first, a tree-based clustering technique, DIVC creates M-Tree using three constraints, namely, destination flag, path-inclusion factor and multi-factor. Secondly, the routing process requires an optimization algorithm to choose feasible routes for multicasting, for which it introduces CS algorithm to select the optimum paths. During the process of optimal path selection, it considers the three models such as Energy model, LLT model and Mobility model which helps to select energy efficient nodes, stable links and short distance nodes for optimal path and reliable packet delivery. The selection scheme of CS algorithm for routing utilizes four objectives, such as energy of the nodes, LLT, distance between the nodes, and delay.

CS-MAODV algorithm works under two phases: i) M-Tree construction using DIVC and ii) Multicast routing an optimization algorithm, CS algorithm. In DIVC, the M-Tree is built using RQ and RP mechanism with the utilization of three constraints: multi-factor, path inclusion factor, and destination flag. Once the DIVC technique completes the construction of M-Tree, CS algorithm selects optimal routes from numerous routes available in the M-tree. The purpose of CS algorithm is to choose the best fit solution as the optimum path for transmission. The fitness function uses energy, LLT, distance, and delay, as the objectives to improve the performance of multicasting. Figure 2 shows the block diagram of the proposed multicast routing method that combines DIVC and CS algorithm for routing.

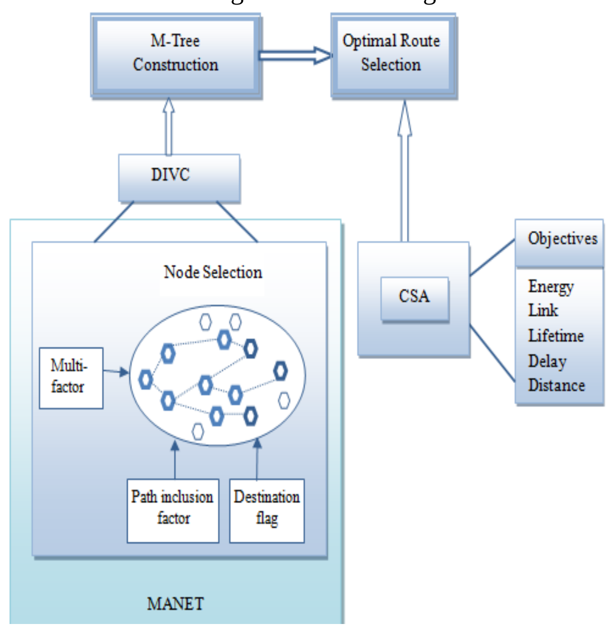

Figure 2. Block diagram of the proposed CS-MAODV protocol

V. Conclusion & Future Work

The proposed method CS-MAODV which uses tree-based clustering and optimization through Cuckoo Search (CS) and Multicast Ad hoc On-demand Distance Vector (MAODV) could be a better solution for multicast routing in MANETs with respects to energy, LLT, distance, and delay, as the objectives to improve the performance of multicasting.

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CS-MAODV simulation and experimental results of the proposed model will be analyzed and presented in the future papers.

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