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AN EXPOSURE OF A NEW MECHANISM CAPABLE OF ACHIEVING A HIGH QoS FOR EFFICIENTLY TRANSMITTING MULTIMEDIA DATA IN MANETs

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Abstract- Transmitting various types of data is one of the regular operations performed in MANET; a multimedia file is one of those types which can be an ordinary image, photo, video, or an audio file. Transmitting this type of information requires different robust MANET's routing features such as multicast techniques for fast and efficient route discovery processes and multimedia data transmission applications which help us in achieving a successful transfer of any types of packets either an ordinary or multimedia data. Due to the complexity of this scheme, there is always a very high demand of Quality of Services (QoS), thus, various algorithms have been designed, introduced, discussed, and proposed by various researchers in field aiming at maximizing QoS by taking into acc multiple QoS constraints but none of them provides efficient mechanism for this achievement especially multimedia applications. Two techniques have b proved by various scientists to be very successfu providing a high QoS for this type of applications namely the Genetic Algorithms and Dynamic Priority Packet Scheduling techniques. Despite those efforts, some challenges are still being faced by different protocol designers as various QoS related problems are often arising due to the infrastructureless nature of MANETs. To overcome all those negative issues, we propose a new protocol; **GDAQM** (**G**enetic with **D**PD for **A**ttaining high **Q**oS in **M**ANETs), a very efficient and robust algorithm which is a combination of both Genetic and MDPD-k scheduling algorithms. The Genetic Algorithm which is an energy-efficient mechanism mainly aims at finding out an optimal path which is then selected by considering multiple QoS constraints, it is efficient in solving QoS-multicast related routing problems, and the MDPD-k is used for packet scheduling purposes. We conduct our experiments on the proposed GDAQM, evaluating its performance against the already existing routing algorithms' namely AODV with GA, GA, Energy-GA, and EDGA. The experiments are conducted by varying the number of nodes and nodes' moving speeds using four popular MANET's routing metrics namely Packet Delivery Ratio (PDR), throughput, end-to-end delay, and Energy. The simulation results carried out using the NS-2 simulator for all cases studied confirm that our proposed scheme highly outperforms the existing ones.

Index terms- MANET, Genetic Algorithm, QoS, MDPD-K scheduling, Multicast, and Multimedia applications.

1 INTRODUCTION

An Ad Hoc network is an easily deployed wireless network as it is a self-organized network structure whereas a mobile ad-hoc network [2] is one type of ad-hoc networking which is the most popular wireless network thanks to its ability to increase flexibility and whose deployments is very easy as nodes freely join and leave the network, thus making a dynamic topology. It is an infrastructureless wireless network meaning that it is deployed without any central authority such as a router, access point, and base stations for successful communication.

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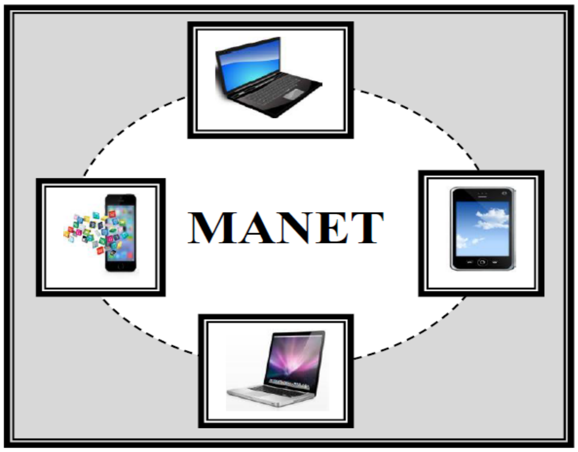

Figure 1: The basic architecture of MANETs

Figure 1 presents the basic architecture of a Mobile Ad Hoc network. Light-weight terminal, multi-hop routing, dynamic topology, and distributed operations are the unique characteristics of this type of wireless network. These prominent features make MANET an excellent wireless network for the emergency situations such namely flood, earthquake, fire, military battlefields, etc. It is also very useful in commercial environments such as collaborative works in business, private networks, for example, Personal Area Networks, and local level access provisions while connecting classrooms or conference halls are the other examples of the usefulness of MANETs. Whatever the purpose of the MANET's deployment, the targeted achievement is unique; the transmission of data from one end to another. Information to be transmitted may be classified into two broader categories; ordinal and multimedia data; the former transmission type does not pose rigorous constraints compared to the later one because multimedia data contain various type of files such as video, audio, photo, image, thus, it requires efficient techniques and protocol for achieving a successful transmission, this is one of the reasons why multimedia applications require a very high QoS achievement. Various researches previously done aiming at dealing with this frequent issue available in MANETs, have faced various challenges, so different techniques and protocols were designed aiming at providing a high QoS for hybrid networks. Multicast mechanisms with the main goal for achieving a fast and efficient route discovery processes are one of the techniques which were introduced for this end. Some protocols were also implemented which aimed to maximize the QoS for this type of applications, for example, QOD (QoS-Oriented Distributed routing protocol) was introduced in [1].

Additionally, a number of parameter metrics were also used to evaluate those protocols for the purpose of gaining a high QoS in MANETs. The most important ones are the power, delay, throughput, and packet loss ratio. To increase the network's life time, for example, the power or energy consumption rate at each node had to be regularly reduced. This proves how the power is one of the major issues to be considered while designing an efficient routing protocol for MANETs. A Genetic Algorithm was introduced in [2] to solve the problem related to the Quality of Service (QoS) for multicast routing related issues with the help of minimum-delay and minimum-cost; parameters required for achieving the successful transmission processes. Genetic is a problem solver tool to resolve the NP-complete problem which was generally used to solve the complex issues in various fields by the researchers; four different steps are followed during the resolving process, these are the input selection, fitness function calculation, mutation, and the crossover technique, the output is then generated based on the iterations provided. This technique identifies the optimum path between the source and destination nodes even in the presence of multiple constraints. Upon the successful completion of the path selection process, the packet scheduling algorithm was used to reduce the unwanted packet dropping ratio and minimize the network's traffic related problems. Those two mechanisms were very efficient in increasing the QoS's ratio in highly dynamic networks with speedy nodes [3]. The Genetic Algorithm was also used in [4], [5], [6], [7], [8], and [11] aiming at providing a high QoS in MANETs by considering the power constraints as the main issue.

In papers [9] and [10], authors implemented various QoS routing protocols for MANET, each routing mechanisms only concentrated on an optimum path selection either after its identification or during the packet transfer process where packet overflow can unpredictably occur. All those researches confirmed that multimedia data transmission processes usually consume a huge amount of energy causing, in turn, some nodes to be unexpectedly shut down, which further produces a higher transmission delay and a lower throughput. Despite all those efforts, none of these schemes fully solved problems related to providing a high QoS in MANETs especially for multimedia data transmission. To fill this gap, in this paper, we propose a new routing protocol GDAQM (Genetic with DPD for Attaining QoS in MANETs), a robust routing protocol which efficiently contains all those routing issues as it combines various techniques and algorithms which have been proved to be proficient in dealing with those transmission problems. The main objectives of our proposed algorithm are discussed in the following section:

- Implement a Genetic Algorithm efficient in solving multiple constraints during the path selection processes;

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- Use MDPD-k scheduling algorithm for efficiently achieving packet scheduling operations;
- Increase both the throughput and PDR ratios at the same time reducing both the end-to-end delay and the energy consumed by nodes during an end-to-end data transmission process;
- Finally provide a high QoS in order to achieve highly successful multimedia data transmission processes using multicast techniques.

The remainder of this paper is organized as follows: Related work is discussed in section 2, Section 3 provides the problem description while our proposed routing mechanism; GDAQM (Genetic with DPD for Attaining QoS in MANET) is presented in section 4. We discuss the experiments' results in section 5, Section 6 concludes our work, and we finally dedicate Section 7 to References.

2 Related Works

Ze Li et al. [1] in their paper proposed a new algorithm, QOD (QoS-Oriented Distributed routing protocol) which mainly aimed at enhancing the operational performance of hybrid networks. They stated that the main reason of their study is the advantages provides by this type of networks such as the limited number of transmission hops and anycast scheme related features. Their proposed algorithm was very advantageous as it was able to convert data transmission related problems into resource scheduling problem, it is a robust protocol as it incorporates the following five different algorithms: A QoS-guaranteed neighbor selection used to deal with various delay related issues, to reduce the transmission delay, a distributed packet scheduling algorithm was used, while a mobility-based segment resizing scheme was used to efficiently adjust some segments' size according to nodes' mobility aiming at reducing the time taken for transmitting data, a traffic redundant elimination algorithm was used to regularly augment the transmission throughput, and finally, they incorporated a data redundancy elimination-based transmission mechanism to avoid the duplication of data in order to increase the transmission QoS's ratio. The simulation results of their experiments conducted applying the evaluating parameter metrics namely the overhead, transmission delay, mobility-resilience, and scalability revealed that QOD outperforms for all the studied cases, they are planning to extend their research with a real testbed.

In [2], [4], and [5], an energy efficient QoS multicast routing scheme with the Genetic Algorithm was introduced, the authors focused their studies on the cost and delay metrics in order to find out an energy-efficient routing path aiming at increasing the network's lifetime.

In [2], a power-aware multicasting mechanism was proposed aiming at reducing both the power consumed during the packets' transmissions and the end-to-end delay ratio while maintaining the minimum energy consumption; those network parameters were used for the multicast tree. The NP-complete, which is a QoS multicast routing problem was solved by the energy-efficient genetic algorithm presented in this paper. This study was limited to the source-based routing tree, the outcomes of the simulation proved that the proposed protocol was effective and efficient. In [4], the researchers implemented a genetic algorithm tested in a dynamic scenario, this scheme took into account the energy consumed during the transmission processes, and the simulation results proved the effectiveness of this protocols as it enhanced the overall performance of MANETs. Researchers in [5] implemented an energy-efficient genetic algorithm to solve the problems related to multicast routing with multiple QoS constraints. To achieve this, they designed a source-tree-based routing scheme using a small population size (small number of nodes) in order to minimize the delay time. They thirdly increased the lifetime of mobile nodes thanks to the controlling of the remaining battery's power. The outcome of their simulation revealed that this algorithm was very efficient and worked as expected.

Some other authors implemented the genetic algorithm considering multiple constraints and were able to provide a high QoS, this algorithm has been proved to be very useful for a variety of applications available in MANET. For example in [6] it was implemented considering multiple constraints related to the traffic engineering in MANETs under the name of MQMGA. It was able to provide various advantageous features such as to efficiently maximize the network's link utilization, dealing with the cost of the multicast tree, long-life link selection, calculating the average end-to-end delay and maximum delays. This algorithm was very promising in providing a high performance especially for multicast in traffic engineering technologies and assuring route stability in highly dynamic MANETs. In [8], an algorithm based on the same scheme was introduced which is a novel QoS-based multicast routing protocol based on the genetic algorithms (GA). Here, the genotype presentation used the Prüfer number, some more algorithms were also proposed such as crossover, mutation, and the creation of random individuals. The evaluation conducted while comparing this algorithm with its predecessor; GA-based algorithm revealed that this newly proposed scheme outperformed the existing one, for further enhancement, the authors suggested that this scheme should be applied to the hierarchical routing mechanism.

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Authors in [7] proposed an efficient new strategy of discovering a link between any source and destination nodes in dynamically changing MANETs. As this dynamicity adversely affects the QoS provision, their proposed protocol uses the tradition genetic algorithm which is very efficient in dealing with this kind of problem. They finally stated that they are planning to enhance this algorithm in order to provide very high QoS achievements in MANETs.

In the paper [9], to provide high QoS in real-time applications in MANETs, the researchers designed an extension to the Ad Hoc on-Demand Multicast Routing Protocol (ODMRP), the new enhancement of this protocol was called "an On-demand Quality of Service (QoS) and stability based Multicast Routing (OQSMR) scheme". This new algorithm was implemented as follows: first of all, each participating node in the network periodically calculates various network parameters i.e. link and node stability, bandwidth ratio, and delay at each node. It also performs the link and routes' maintenance in the events of route failures this reduced very much both the overhead and end-to-end delays incurred in the network, thus increasing the Packet Delivery Ratio. The authors stated that in the future, they are going to extend their research by comparing their On-demand QoS and Stability based Multicast Routing (OQSMR) protocol with some more QoS based routing protocols in MANETs.

Different QoS multicast algorithms have been extensively studied and reviewed in order to identify their performance in term of various network performance evaluation parameters namely packet loss fraction, end-to-end delay, and jitter in [10].
These authors stated that implementing a very robust protocol able to satisfy a collection of various constraints faced while transmitting multimedia data is still challenging in MANETs, so they proposed an efficient solution to this problem by surveying
multiple QoS multicast routing with various attributes to provide a current status of the research work in MANETs.

Authors in [11] introduced a Multi-Objective Evolutionary Algorithm; MOEAQ aiming at solving the multicast routing protocol-related problems. The multicast model's limitation and strengths of the "well-known multicast model" with the ''Greedy" and ''family competition"; approaches integrated into this algorithm were successful both in speeding up the convergence and t maintaining the diversity of the population. They then proposed a CBT-based protocol to simplify the MRP; the network scaled from 20 to 200 nodes with different types of service was evaluated using the OPNET simulator, the simulation outcomes revealed that the proposed scheme was able to achieve faster convergence for multicast routing in MANET compared to other GA-based protocols already existing in this field.

In [12], an extension of MAODV protocol; MAODV-BB was proposed. This enhanced protocol combines the advantages of both tree and mesh structures. The main feature of this algorithm was the full use of GRPH messages that the group
l e a d e r b r o a d c a s t s periodically to update shorter tree branches and construct a multicast tree with backup branches, resulting i n o p t i m i z e d t r e e structure and reduced frequency of tree reconstruction.. It is efficient in optimizing the tree structure and reducing the frequency of the tree reconstruction processes. Both mathematical and simulation models proved that MAODV-BB highly increased the network's performance when compared to MAODV in heavy load Ad Hoc networks. In the future, the authors will focus on the reliability of the tree-based multicast routing protocol varying the mobility frequency and group's size. They also intend to solve the problem of fast data rate at the sender by slowing it down when the network is highly loaded thanks to the congestion control mechanism.

In this paper [13], the researchers fully explained how genetic algorithms are very efficient in enhancing the overall performance of the clustering algorithms in MANETs. They said that the mapping process to be successful requires very much the encoding of individual chromosomes. As obtained from the original WCA, each individual may represent one chromosome or many different ones and each chromosome may contain information about a clusterhead and its members. With the help of fitness function, the best solution (chromosome) is found thanks to this information. The proposed algorithm was designed in such a way that each cluster-head is given the maximum possible number of participating nodes in its cluster; this facilitates the MAC protocols' optimal operations. The main goal of this paper was to provide the minimum delay and maximize the utilization of the link; enhancements provided by near optimal path from source to destination based on time.

Swati Atri et al. in [14] introduced an ABC (AntColony Based Clusterhead) selection algorithm, using the MATLAB tool; they tested this algorithm which is based on the fuzzy logic technique. Ant Colony Optimization (ACO) scheme helped them so much in determining a node within a cluster to be chosen as a clusterhead or not with the help of the probability function. They finally conclude their work suggesting that the ABC technique should be enhanced in future for overlapping cluster formation in highly dynamic MANETs.

In [15], authors have conducted their research on a fleet-based cooperative streaming, a new and specific

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infotainment server over the hybrid vehicular networks. They said that based on a fleet, a requested video file can be downloaded in the k-hop range by the requester in cooperation with the helper. With this proposed algorithm the video data is divided into one BL and eight ELs using the H.264/SVC codec. Here, ELs to transmit through helpers' 3G/3 are scheduled on a 5G links and then forwarded to the requester using helpers' 802.11p links. BL on their turn, are transmitted through the 3G/3.5G link of the requester. A PF or DF assignment algorithms can be used by the requester to assign parts of the video file to each helper which are determined with the help of *k*-hop 3G/3.5G bandwidth aggregation scheme. When packets are lost, BARTS technique is used to retransmit them. The simulation scenarios exhibited some advantages of PF assignment scheme with PFRS retransmission mechanism because it has the best PSNR values and the smoothest video playback than other schemes. They finally suggested that possible future work would focus on the following: 1) The delay-tolerant networking issue to relay video data back to the requester and 2) Having multiple 802.11p interfaces to forward video data back to the
Requester.

Researchers in [18] presented two very important techniques in MANETs; an enhanced protocol for routing in Ad hoc networks using Dynamic Source Routing (DSR) and Swarm Intelligence technique which uses the Ant Colony Optimization (ACO) used to optimize each node's pause time. The outcomes of their research revealed that this technique improved very much routing's performance in MANETs as routes are built based upon the pause time of each node which results in both high packet delivery ratio and end-to-end delay.

A paper which discusses a new probabilistic approach dynamically adjusting the broadcast probability as per the node distribution and movement was present in [19]. This technique uses the information available locally without any help of distance measurement or exact location determining devices. This proposed algorithm was evaluated comparing its performance with a fixed probabilistic approach and simple flooding techniques. The test results confirmed that the proposed scheme exhibits a superior performance in term of both saved rebroadcasts and reachability parameters. The authors stated that their future planning consists of enhancing this successful approach.

Researchers in [20], [21] focused their research on previously discussed protocols in the literature, for example in [20], the authors conducted a performance evaluation of various multicast routing protocols available in MANETs namely IMAODV, MAODV, ODMRP, and ADMR. This study revealed that IMAODV outperformed other protocols in term of PDR and end-to-end delay making it a better protocol for broadcasting and multicasting applications such as reliable and time-sensitive multicasting in MANETs' environments but surprisingly for multimedia applications such as audio and video conferencing the throughput was too low for this protocol, to solve this problem, they plan to modify IMAODV in such a way that it can be compatible to MAODV in term of throughput.

In [21], various prominent multicast routing protocols available in MANETs are discussed in this paper categorized into three types: mesh-based protocols, tree-based protocols, and hybrid- based routing protocols. The researchers distinguished those protocols according to their performance and stated that tree-based protocols are the best in performing efficient data transmission while the mesh-based ones are robust in dynamic topology change handling and are more stable than the former ones. Both types have their own advantages and disadvantages while the hybrid protocols combine the best features of both.

In [22], authors proposed a genetic algorithm aiming at solving the problem related to delay-bounded multicast application, a frequent issue always arising in multimedia conferencing. They used source-based routing where each source node determines the Steiner tree for multicast purposes. This algorithm proved to be very robust in providing solutions to the delay-bounded multicast problems.

3. Problem Description

3.1 Energy Consumption with packet forwarding

Packet transmission processes between various nodes in MANET consume some amount of energy. Papers [2] and [3] discuss some useful algorithms which are efficient in managing the power consumed during the network traffic in order to provide a high QoS in MANETs. To achieve this, a lower energy consumption is required for a link between two different nodes v_i, v_j during unit transmission of message, which is defined as follows,

$$P_{i,j} = y_1(r_{i,j})^{\beta} + y_2 \qquad (1)$$

Where $r_{i,j}$ is the Euclidean distance between v_i and v_j, y_1 a constant dependent on the properties of the antenna, β is a path loss exponent whose value

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depends on the propagation losses in the medium and y_2 is a constant used to represent the overheads incurred during electronics and digital processing operations. Here, we only assume that during the multicasting processes only a unit message is transferred. To reduce the packet's overflow, MDPD-k scheduling algorithm which is efficient in handling the packet scheduling operations in an effective manner is used.

3.2. The proposed Network Representation and Problem Description

In our proposed work, we presume that every node in the network calculates the distance between itself and its neighbor nodes by using the distance calculation method [2]. The network connectivity is shaped in bus topology with a backbone connecting all nodes, each one having its own transmission power which can be dynamically changed. For example, for each multicast tree, the transmission power level of each participating node v_i is changed based upon each node's participation. In this paper, we use an Omni-directional antenna for each node (v_i) where two coverage areas are available for each node present in the network namely Control Coverage area (CR_i) and Data Coverage area (DR_i) where $DR_i \subseteq CR_i$.

Depending upon both the transmission power required for transmitting data and the quantity of control packets for each node (v_i), the coverage area for various nodes will differ. This network model can be represented in the form of a graph G(V,E) which will depend on the control coverage area of each participating node, where V is a finite set of vertices (the number of nodes or mobile devices), so, $V = \{v_1, v_2, \ldots, v_n\}$ is a set of nodes, and $E = \{(i,j)|v_i, v_j \in V\}$ is set of links, $(i,j) \in E$ denotes that both v_i and v_j are within the coverage area of each other. Each link status is dependent on the values of the delay ($d_{i,j}$), distance ($l_{i,j}$), and bandwidth ($b_{i,j}$) parameters.

Data transmission delay between nodes v_i and v_j is denoted by ($l_{i,j}$. $d_{i,j}$), this includes both the queuing and the propagation delay. Euclidean distance between nodes v_i and v_j is denoted by ($l_{i,j}$) and the bandwidth of the link between v_i and v_j is denoted as ($b_{i,j}$). The ($d_{i,j}$), ($l_{i,j}$) and ($b_{i,j}$) are all positive real numbers. Let us consider the multicast source ($s \in V$) and multiple destinations ($D \subseteq V - \{s\}$). Let $d = |D|$ be the number of multicast destination nodes in a multicast tree. M is a destination group and {s} U D is the multicast group. A multicast tree denoted as $T(s,D) \subseteq G$, this is a tree having a root from a single source to all the destinations in D. A delay occurred during a data transmitted along a path from source (s) to destination nodes participating in a tree (T) ($v_t \in D$) is denoted as delay($p_T(s,v_t)$) where ($p_T(s,v_t)$) is a unique path from s to ($v_t \in D$).

$$\text{delay}\ (p_T(s,v_t)) = \Sigma_{(i,j)\in\ pT(s,vt)}\ {}^{di,j} \qquad (2)$$

The minimum bandwidth of a path from source s to destination ($v_t \in D$) is denoted as bandwidth ($p_T(s,v_t)$).

$$\text{bandwidth}\ (p_T(s,v_t)) = \min\{b_{i,j}\ ,\ (i,j) \in p_T(s,v_t)\ \} \qquad (3)$$

Let Δ_d be the delay-constraint and B_d the bandwidth constraint of the destination node ($v_t \in D$). Then, the delay-bandwidth-constrained minimum Steiner tree problem is to find minimum cost multicast tree T^* (s,D) is,

$$\text{delay}\ (p_T{}^*(s,v_t)) \le \Delta_d,\ \ \forall v_t \in D \qquad (4)$$

$$\text{bandwidth}\ (p_T{}^*(s,v_t)) \ge B_d,\ \ \forall v_t \in D \qquad (5)$$

Once T^* (s,D) is identified, during data packets transmission in tree $T^{*,}$ each node will itself adjust its transmission power level.

4 Proposed System

In this paper, we propose a new protocol, GDAQM (Genetic with DPD for Attaining QoS in MANET). It's a combination of both the Genetic and Modified DPD-k (Dynamic Priority with Deadline Considerations) scheme resulting in DPD-k scheduling algorithms.

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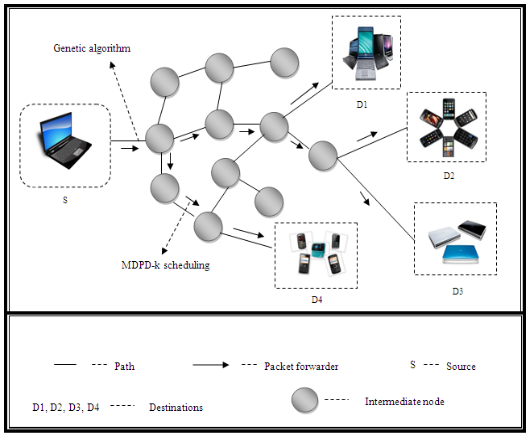

Figure 2: Overview of GDAQM architecture

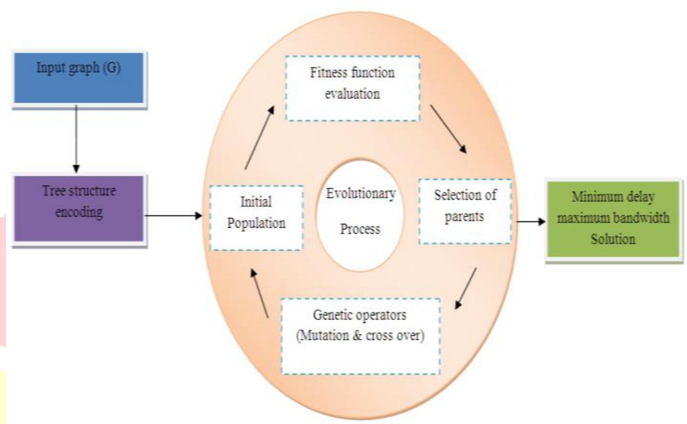

Figure 3: Architecture of a genetic algorithm

By using the genetic algorithm, we find out a routing path with energy-efficient, least-delay, and maximum-bandwidth features. Three different parameters namely delay, bandwidth, and cost are used during the overall route selection process. The MDPD-k scheduling algorithm is then used to avoid packet and traffic overflow events which further increases the QoS (Quality of Service) of the network.

Encoding, initial population, fitness function evaluation, selection of parents, mutation, crossover, and analysis of convergence are the operations available in the genetics' research field. Algorithm 1 presents a detailed explanation of the proposed Genetic Algorithm aiming at selecting an energy-efficient, least-cost, maximum-bandwidth, and multi-constraint QoS path. Here, the function RandomDFS () represents the random depth-first search algorithm, N_g is the number of generations and $N_{optimal}$ denotes the number of the best individuals. Figure 2 exhibits an overview of the proposed GDAQM routing mechanism which is a multicast routing protocol where multiple destination nodes are involved.

4.1 Genetic Algorithm

4.1.1 Coding

To design a well-represented genetic algorithm, a suitable solution for candidate individuals' representation is very much required as it plays a major role in genetics. Various representations of a tree such as one-dimensional binary code, sequence, and topology encoding (ST encoding) found in [2], and Prüfer number [8] have been introduced by different previous researchers. One main problem with this representation was that they generated illegal trees, may have poor locality or a low efficiency which always further results in the remarkable augmentation for the required search space as the network's size increases.

To contain all those negative issues, some researchers studying the network optimization techniques related issues, have introduced a new scheme with which they directly manipulated trees i.e., using a data structure of a tree to describe the chromosome [2]. With this method, a tree directly represents a chromosome. Therefore, the coding/decoding operations are omitted. In this study, we use the tree structure coding method, in which a chromosome represents a multicast tree directly. Figure 3 shows the overall working process of the genetic algorithm.

4.1.2 Initial population

The initial population process is the foundation of the genetic algorithm; here a new generation is created by using the reproduction mechanism. The population size (N_p) and the method of population formation are two important issues taken into consideration during this prominent stage. In this proposed algorithm, the initial population is generated based on the random depth-first search algorithm [22] where the searching process begins at s and randomly select the unvisited node to be next visited. This iteration loops until the end of the process i.e. when all the individuals have been visited.

4.1.3 Fitness Function

Upon completing the initial population formation process, the next step is to select individuals according to their performance. A node's performance is estimated by

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calculating the efficiency of each individual using the evaluation parameters, for example, delay, bandwidth, and cost in our case. Here "good individual" has a bigger fitness than the "bad one's"; this is the job of the fitness function which is defined in the following mathematical expression:

$$f(T) = \left\{ \frac{a}{cost(T)} \prod_{v_t \in D} \varphi\left(delay\left(p_t(s, v_t)\right) - \Delta_d\right) \prod_{v_t \in D} \varphi\left(bandwidth\left(p_t(s, v_t)\right) - B_d\right) \right\}$$

(6)

Where,

$$cost(T) = \sum_{v_i \in T} c_i^T = \sum_{v_i \in T} b[y_1 (r_i')^{\beta} + y_2] \quad (7)$$

And,

$$\varphi(Z) = \begin{cases} 1, if\ Z \le 0, \\ \gamma, \ if\ Z > 0. \end{cases} \quad (8)$$

In the Equation (6), a is the positive real weighting coefficient, δ the maximum allowable delay from s to vt, where $vt \in D$. cost(T) is the energy cost of tree T . $\Phi(.)$ is a penalty function. The value $\gamma(0 < \gamma < 1)$ determines the degree of penalty: the smaller the value of γ, the higher the degree of penalty. In our experiments, we set $\gamma = 0.5$. We reduce the energy consumption of a multicast tree to maximize the network service time. In Eq. (7), c^T_i is the energy cost of vi, b is a positive real coefficient, and $r\_ i$ is the maximum distance between vi and vj, where $vj \in B(vi)$. $B(vi)$ is the set of immediate succeeding nodes of vi on T . Note that the energy cost of leaf nodes is zero. Particularly, we set $k1 = 1$, $k2 = 0$, $b = 1$ and $\beta = 2$ in our experiments.

4.1.4 Selection of Parents

For selecting parent individuals, a suitable elitist model is used; the process is performed as follows: we first select the best individuals, and we then copy them into the next generation, we further select the rest of individuals by the roulette wheel selection model. Here, the probability of selecting a given parent, for example T_i, denoted as $p(R_i)$, is given by:

$$p(R_i) = \frac{f(T_i)}{\sum_{j=1}^{N_p} f(T_i)} \quad (9)$$

Where $f(T_i)$ represents the fitness of individual, Np is the population size.

4.1.5 Crossover Scheme

Also called recombination, the crossover is a genetic operator used to vary the programming of a chromosome or different chromosomes from one generation to the next one. In networking, this technique is specially used to find out an optimal route to transmit packets through. A single offstring is produced thanks to a pair of chromosomes selected as the parents based on the roulette wheel. Let us consider Ta and T_b as the selected two respective parents. The crossover operator generates a new child Tc while identifying the same links between Ta and Tb, but retaining these common links in Tc. Here the common links between the two parents will represent the "good traits" as according to the fitness function which states that the "better individuals have a very high probability to be selected as parents", but these common links in Tc may generate sub-trees as they are retained, various links are required to connect these sub-trees into a multicast tree.

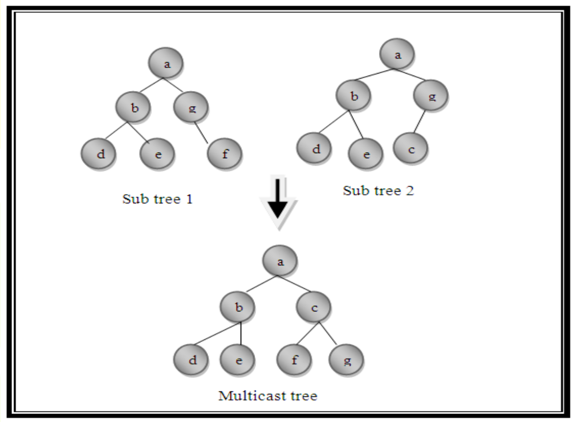

Figure 4: Crossover operation

In order to connect those sub-trees the following processes are followed: first of all, we randomly select two separate sub-trees among the others. Then a new sub-tree is formed by those selected ones linked by a least-delay path. This connection loop continues until a multicast tree is fully constructed. Two nodes are added in order to find this least-delay path between these two sub-trees. One node is connected to all of the nodes of one sub-tree with links which have zero-delay associated with them. Similarly, the other node is connected to all the nodes of the other sub-tree with zero-delay links. Hence, the least-delay path between two sub-trees is the least-delay path between the two added nodes. This connection scheme is very efficient as it avoids routing loops in the multicast tree as shown in figure 4.

4.1.6 Mutation

Upon completing the offspring production operations, the mutation stage begins according to the mutation probability p_m. Here, the mutation procedure randomly selects a subset of nodes and some separate sub-trees are broken from the multicast tree by removing all the links that connect these selected nodes and their farthest child node on T. Those separate sub-trees are reconnected into a new multicast tree with least-delay paths. Now a new multicast tree is generated by connecting two sub- trees by using a powerful

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mutation operator.

4.1.7 Analysis of Convergence

Our proposed genetic algorithm focuses on to the global optimal solution based on the theorem discussed in [23]. It's a time-consuming task to find out an optimal solution for the NP-complete problems when considering large scale networks. By setting the suitable iteration time for the genetic algorithm, we overcome those negative issues. Hence, in implementing our proposed genetic algorithm we use the methodology described in [2], in this way, we can obtain a near-optimal solution within a reasonable time limit.

The following figure shows the pseudo code of the proposed genetic algorithm. *RandomDFS*() function denotes random depth-first search algorithm, N_g is the number of generations, $N_{optimal}$ is the number of the best individuals:

Algorithm 1: GA

```
Genetic Algorithm(G, s, D)
{
  For(i=1; i<=N_p; i++) {
    Chromosome(i) = RandomDFS(G, s, D);
    }
  For(j=1;j<=N_g; j++){
     Choose the best individuals and copy them into the next generation;
   For(k=1;k<=N_p-N_optimal; k++) {
      R_a=MSTSelect(Chromosome);
      R_b=MSTSelect(Chromosome);
      R_c=Crossover(R_a, R_b);
      If(rand()<p_m)
           Mutation(R_c);
     }
 }
 Choose the best individual and output it;
}
```

Figure 5: The pseudocode of the proposed Genetic Algorithm

4.2 PACKET SCHEDULING

Upon completing the path selection process, for forwarding data during the multicast transmission we use MDPD-k packet scheduling algorithm. Generally, for achieving successful packet scheduling processes, any one of the parameters such as the deadline or priority was used but without success as they do not provide good results, for this reason, authors in [3] combined both of them. In this study, we follow a different approach by achieving the same operation using the slack time. Packets are scheduled at each node using Least Slack First (LSF) scheduling algorithm [1] in order to achieve fairness in the packet scheduling for soft-deadline driven application for achieving the successful forwarding operations. A packet's slack time is calculated by using the following formulation:

$$S_t = D_p - t - c' \quad (10)$$

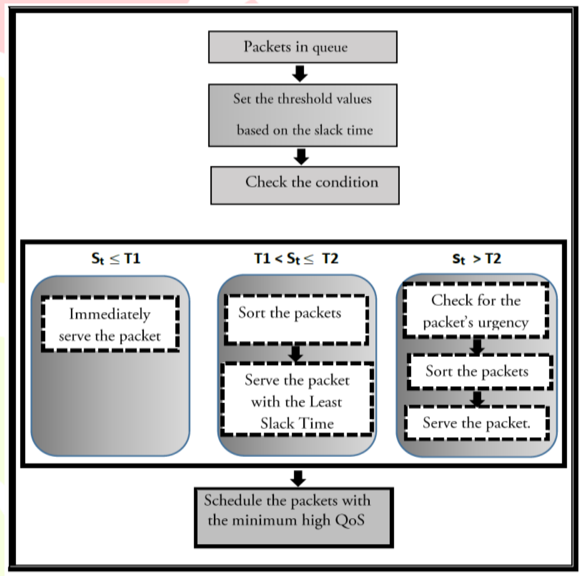

Figure5: Working process of the MDPD-k scheduling algorithm

From Eqn (10), D_p represents the deadline of a packet, t is the current time and c' is the residual packet's transmission time. An intermediate node in the path periodically calculates the slack time of packets, it'll then forward the ones with the least slack time. When slack times of all the packets are equal, we have to randomly pick out any one of them and send it out. We will use this efficient scheme with the DPD-k scheduling algorithm; we then extend this algorithm with the Modified Dynamic Priority with Deadline Consideration (MDPD-k) scheduling algorithm. DPD packet scheduler sorts the packets based on their priorities but the priority level can be dynamically changed. For this reason two different threshold values are set based on the remaining slack time, this algorithm can change the priority level of any waiting packet stored in the buffer, it has also the ability to perform partial sorting operations.

For the MDPD-k notation, 'k' denotes the degree, this algorithm sorts the first packets present in the buffer, k packets with the highest priority are scheduled or put into a waiting state to be lat\ter transmitted. It is decided for packet stored in the header to be or not to be served depending upon its remaining slack time. For example, when the header has the t-units of remaining slack time (s_t)

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Algorithm 2: MDPD – K scheduling

1. Q← Φ; Q← Entering new packets
2. For each packet calculate s_t from Eqn (10)
3. Calculate T_1 and T_2

   $T_1 = Min\_ s_t$

   $T_2 = (\sum_{i=1}^{n} s_t) / n$

4. s_t of a pckt_header is tested against T1 and T2

4.1.1 if ($s_t \le T_1$)
   then pckt_header→ served
   end if

4.1.2 if ($T_1 < s_t \le T_2$)
   then first k_pckts→ sorted and
   pckt_header→ served
   end if

4.1.3 if ($s_t > T_2$)
   if (pckt_header = urgent_pckt)
   then pckt_header → served
   else first k_pckts → sorted
   then pckt_header → served
   end if
   end if

for a packet, this means the t-units packets are compared with the two threshold values (T1 and T2 where T1<T2). The process of the packet scheduling algorithm is performed based on the condition satisfied by the slack time (s_t). The conditions are stated as follows:

- $s_t \le T_1$
- $T_1 < s_t \le T_2$
- $s_t > T_2$

The working process of this MDPD-k algorithm is detailed below:

- If $s_t \le$ T1: Without considering the priority of a packet, it is immediately served as it is in a critical condition, otherwise, it will have no remaining slack time and will be considered as lost.

- If T1 < $s_t \le$ T2: with this situation the packet is served based on the corresponding SPD-k scheduling. Thus, the first k packets are sorted and the ones with the highest priority will be served. The packet which was at the head of the buffer is then placed in its appropriate position by increasing its priority one level as a way of compensation for removing it from the head of the buffer, this procedure is the same for the DPD-k scheduling algorithm.

- If s_t > T2: Again the same SPD-k scheduling technique is used to serve the packet. But, here, the remaining slack time of the packet located at the head of the buffer is still high; its priority will remain unchanged.

Algorithm 2 presents a detailed explanation of the MDPD-k scheduling algorithm. Each node maintains the queue to randomly store the received packets. For each packet, we have to calculate the slack time by using the Equation (10). We then calculate the threshold values based on slack time; those values help us in taking rational decision while serving packets to each node under various checking conditions where each packet's slack time is compared to those threshold values. The following is a simple example of MDP-k scheduling algorithm:

The packets' initial input stage is presented as follows:

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2	5	9	6	7	4	8	3

➢ If $s_t \leq T1$:

These input packets are scheduled to nodes comparing their slack time with the threshold values set as T1=2 ms, T2= 5.5 ms, the degree of the nodes is set to 4, and packet in the header has a slack time set to 2. The scheduling process is then performed as follows:

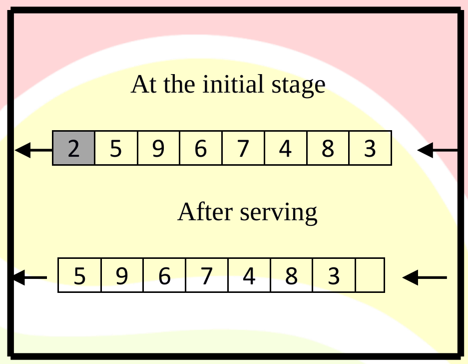

Figure 6: MDPD-4 Algorithm with st ≤ T_1

The given input has satisfied the first condition, this packet is then immediately scheduled.

➢ If $T1 < s_t \leq T2$:

Figure 7 illustrates the example of MDPD-k scheduling algorithms at the second stage where the packet at the head of the queue with the priority value of 7 has a remaining slack time range of $T1 < s_t \leq T2$. Here, the first 4 packets are sorted according to the slack time. We then reset the header of the buffer with a packet having least slack time set to 2 which then is then immediately served.

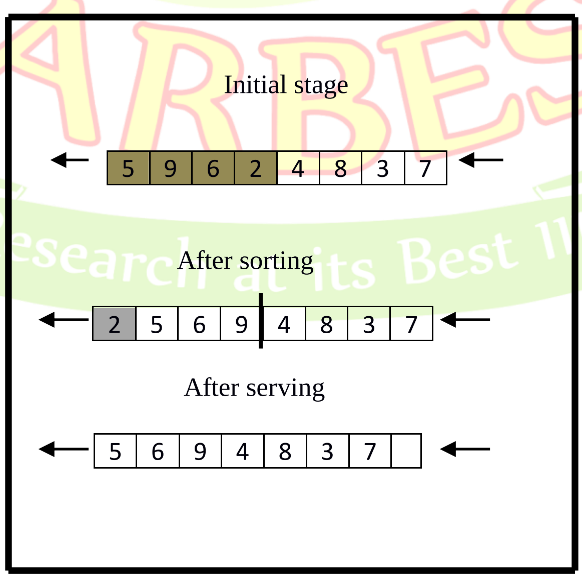

Figure 7: MDPD-4 algorithm when $T1 < s_t \leq T_2$

➢ If $s_t > T2$:

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At this last stage, the first input has the same value as the threshold it'll be then moved on the third condition, here we firstly have to check whether the first packet 9 is to be sent immediately or not.

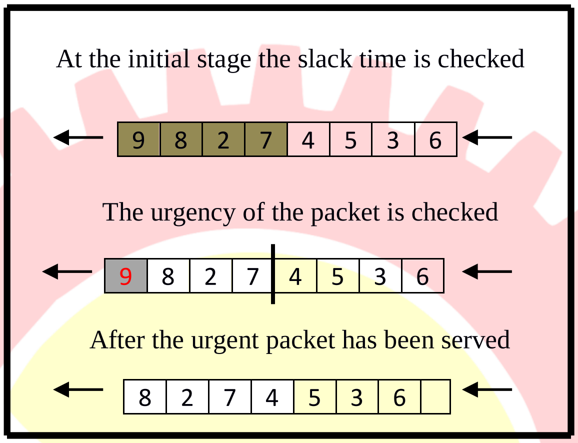

Figure 8: MDPD-4 algorithm with st > T_2

The 9 is urgent so it will be served otherwise we sort the packets based on slack time and allocate them according to the least slack time. The previous example clearly explains the working procedure of MDPD-k packet scheduling algorithm. First of all the given input is checked with three different conditions. If the first condition is satisfied the packet is then immediately served otherwise it is checked with the second condition, where we sort the packets in ascending order of the least slack time and the first packet is immediately served. If the second condition is not satisfied, we automatically move to the third one. At this stage, first of all, the packet is checked for its urgency if so, we allocate the packet otherwise the processes are moved back to the second stage and executed. The threshold values' calculation is explained in [3].

5 Experimental EVALUATIONS

This section demonstrates the sole property of our proposed protocol; GDAQM which make it more advantageous compared to the existing approaches namely EDGA [2], GA [4], QOD [1], and AODV with GA [23]. A short overview about those protocols is given below:

Genetic Algorithm for Energy-efficient Delay-constrained multicast routing (EDGA) [2]:

This routing mechanism uses a genetic algorithm, which with the help of an efficient delay-constrained multicast routing features is able to find out an optimal path. This algorithm is a source-based protocol which takes into account the energy consumed at each node as well as the end-to-end delay for route selection criterion. It applies crossover and mutation operations directly on trees, which simplifies the coding operation and omits the coding/decoding process. The heuristic mutation technique can improve the total energy consumed at the multicast tree. This unique property is taken into account in our study for performing an efficient coding/decoding process.

Genetic Algorithm [4], [24]:

Authors in [4] proposed a protocol which is both energy-efficient genetic mechanism and a source-based algorithm which takes into account the energy consumption as well as end-to-end delay during the route selection processes. This algorithm applies crossover and mutation operations directly on trees, which simplifies the coding operation and omits the coding/decoding processes. Compared to LDT approach, the simulation results revealed that this algorithm is efficient in discovering Multicast QoS path in a dynamic environment. In [24] a Genetic Algorithm based on a route selection protocol was proposed to solve the multi - constrained QoS, the algorithm was compared with AOMDV and the results showed that this scheme was providing efficient results for different metrics such as delay, throughput, and Delivery ratio, etc.

AODV with GA [23] and QOD [1]:

In [23], a new technique by using the concept of Genetic Algorithm (GA) with AODV protocol to make a routing decision in computer networks was introduced. The main purpose of the study was to find out an optimal path between source and destination nodes at the same time increasing both QoS and throughput's ratios. This algorithm was compared in performance with the AODV protocol; the results revealed the proposed algorithm was better than the traditional AODV. But in [1], authors

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proposed a QoS-Oriented Distributed routing protocol (QOD) to enhance the QoS support capability of hybrid networks. QOD incorporates five different algorithms. Experimental results showed that this new algorithm can achieve high mobility-resilience, scalability, overhead, and a low transmission delay. For this study, we propose a very efficient routing protocol which takes into the account multiple constraints related to multicast routing to find out an optimal path, we also use the packet scheduling algorithms in order to provide a very high QoS in MANET. QOD protocol incorporates LSF scheduling algorithm used in the DPD-k scheduling algorithm.

5.1 MATERIALS AND METHODS

We next describe the materials and methodology we used to conduct our experiments:

5.1.1 Simulation environment

A detailed simulation model based on NS-2 is used to model the comparison of our proposed scheme with the existing ones. NS-2 is an object-oriented tool with core concept executed in C++ as back-end and OTCL (Object oriented Tool command Language) as front-end. Table 1 shows the experiments' scenario and settings. We use 10 to 50 nodes for conducting the simulation within an area of 1500X1500, the total time to complete the simulation is 100 seconds. We only use the Omni-directional antenna and IEEE 802.11 MAC layer, 201 packets are maintained in the queue. Nodes move at a speed ranging from 1 to 20 m/s with a random waypoint movement. We use Two-Ray Ground radio propagation model and the following three metrics to compare the performance of our proposed protocol with the existing ones; PDR (Packet Delivery Ratio), Throughput, Delay, and Energy. Those metrics are explained in detail below:

- ***Packet delivery ratio*** is the fraction of the number of delivered data packets to the destination. This fraction illustrates the level of packet delivery. The greater value of the packet delivery ratio means the higher performance of the protocol.

  Packet delivery fraction=∑ Number of received packets / ∑ Number of sent packets

  *Energy= power * time.*

- ***Throughput is*** defined as the total number of packets delivered over the total simulation time. It is represented in bits per second (bps).

  Throughput = received_data/DataTransmission Period

- ***End-to-end delay fraction*** is the average time necessary for a packet reach to the destination. It may be caused by many factors such as route discovery cycle and queuing process used during data packet transmission. Only data packets that have been successfully delivered to the destination are counted. The performance of the protocol is determined by the value of end-to-end delay; the lower ratio means the higher is the performance of the protocol.

  End-to-end delay ratio=∑ (packet-arrive time – packet-send time) / ∑ Number of connections

- ***Energy:*** The energy model represents the energy level of nodes in the network. The energy model defined in a node has an initial value that is the level of energy the node has at the beginning of the simulation. This energy is termed as initialEnergy_. In a simulation, the variable energy represents the energy level in a node at any specified time. The value of initialEnergy_ is passed as an input argument. A node looses a particular amount of energy for every packet transmitted and every packet received. As a result, the value of initialEnergy_ in a node gets decreased. The energy consumption level of a node at any time of the simulation can be determined by finding the difference between the current energy value and initialEnergy_ value. If an energy level of a node reaches zero, it cannot receive or transmit anymore packets. The energy level of a network can be determined by summing the entire nodes' energy level in the network.

Power is the rate of doing work. It is equivalent to an amount of energy consumed per unit time

5.1.2 Parameter values

Table 1: Network parameters

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Simulation metrics	Values
Number of nodes	10, 20, 30, 40, and 50
Interface type	Phy/WirelessPhy
Channel	Wireless Channel
Mac type	Mac/802_11
Queue type	Queue/DropTail/PriQueue
Queue length	201 Packets
Antenna type	Omni Antenna
Propagation type	Two-Ray Ground
Size of packets	256-1280
Simulation time	100 seconds
Simulation Area	1500X1500

5.2 SIMULATION RESULTS DISCUSSION

We conduct a performance comparison of our proposed algorithm with the existing ones by varying routing metrics as shown in both table 2 and table 3.

Table2: Performance comparison considering Number of Nodes

Parameter / value	QOD	EDGA	GA	AODV with GA	Energy-GA	GDAQM
PDR	-	-	61.5	13.16	67.2	83.4
Throughput	60	-	-	-	-	68.6
Delay	-	5.56	13.69	10.4	5.26	3.86
Energy	-	-	11.13	-	-	10.25

Table 3: Performance comparison considering Nodes' Speed

Parameter / value	QOD	Energy-GA	GDAQM
PDR	-	60	70
Throughput	59.63	-	67.16

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5.2.1 Performance evaluation with PDR

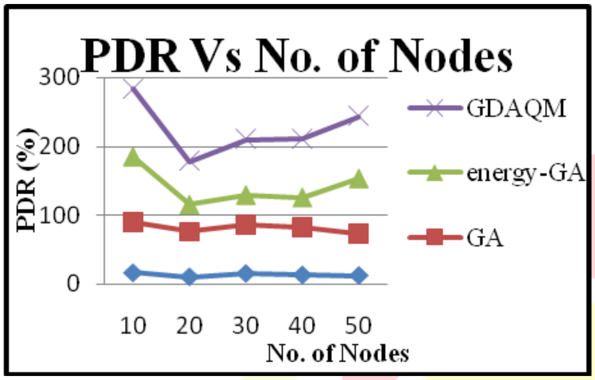

Figure 9: Comparative results of PDR Vs No. of Nodes

Figure 9 and 10 exhibit the outcomes of the performance evaluation conducted considering the PDR as our evaluating parameter metric. We organize the experiments in two different scenarios when considering the packet delivery ratio metric. We first evaluate the performance of the algorithms using PDR against the number of nodes ranging from 10 to 50; we then evaluate our proposed scheme with the Energy GA algorithm considering the nodes' speed ranging from 0 to 20 m/s as shown in figure 10.

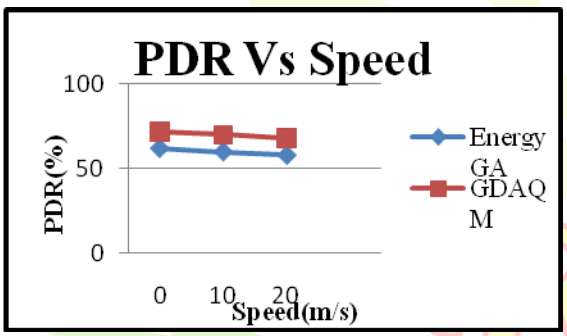

Figure 10: Comparative results of PDR Vs Nodes' Speed

As we can see on figure 9, our proposed protocol GDAQM outperforms for the large number of nodes even if its PDR's ratio drops at nearly to 170% when the number of nodes is 20, starting almost progressively increasing as the number of nodes augments. One interesting observation for all the four algorithms is that their PDR does not decreasing nor increase very much as the number of nodes is increased, this is the opposite situation to the one on figure 10, where PDR is evaluated against the nodes' speed both Energy-GA and GDAQM's PDR decrease as the number of the nodes augments. This is due to the fact that the fraction of dropped packets increases caused by many factors such as congestion in the network with high speedy nodes, frequent route failures and breaks which then results in minimized number of received packets at the receiver but GDAQM performs better in networks with small and large nodes' speed. For both of performance evaluation's scenarios (figure 9 and figure10), the simulation results show that our proposed algorithm performs better for all the cases studied.

5.2.2 Performance evaluation with Throughput

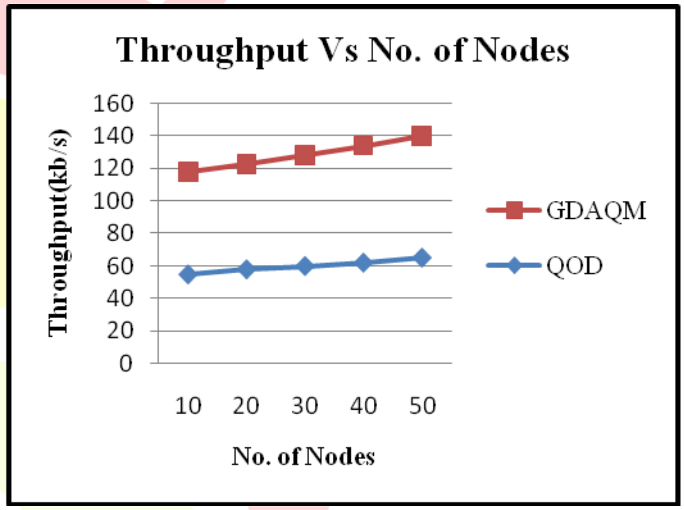

Figure 11: Comparative results of Throughput Vs No. of Nodes

On the figure 11, the comparative study of GDAQM with QOD reveals that our proposed protocol performs better than QOD in term of throughput for the small, medium, and large number of participating nodes. The overall observation about the performance of those two protocols is that their throughput continually increases proportionally to the increasing number of nodes with a big difference in their throughputs' ratios, the main reason of this throughput's increasing ratio is self-explanatory as specifically, with a larger node density, the required hop count is reduced, resulting in exponential growth of the throughput.

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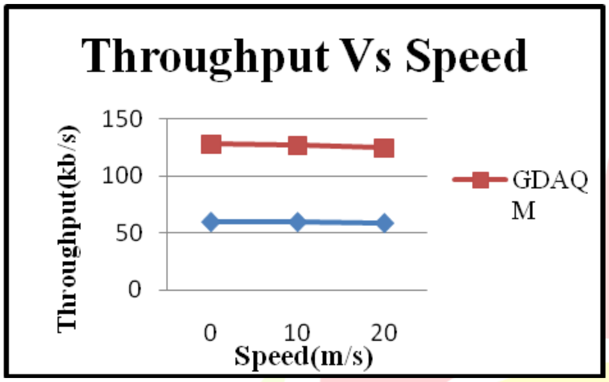

Figure 12: Performance evaluation of Throughput Vs Nodes' Speed

Concerned with the throughput versus nodes' moving speed, figure 12 presents the comparative outcome for both protocols (GDQAM and QOD), the throughput ratio is almost independent to the increasing speed of nodes as it remains unchanged for the overall simulation time, this is almost an exception as normally the higher mobility of nodes leads to frequent link breakages, so the link reestablishment operation then takes place which causes a long transmission delay, which further results in drop of throughput ratio followed by the prolonged total transmission time, but here, despite those issues, our proposed algorithm; GDQAM which always selects the path with both least-delay and maximum bandwidth, is performing better than QOD as it is shown it seems that the node's speed does not affect its performance, QOD always performs worse as its throughput is maintained lower at a static level for small and high nodes' speed.

5.2.3 Performance evaluation with Delay

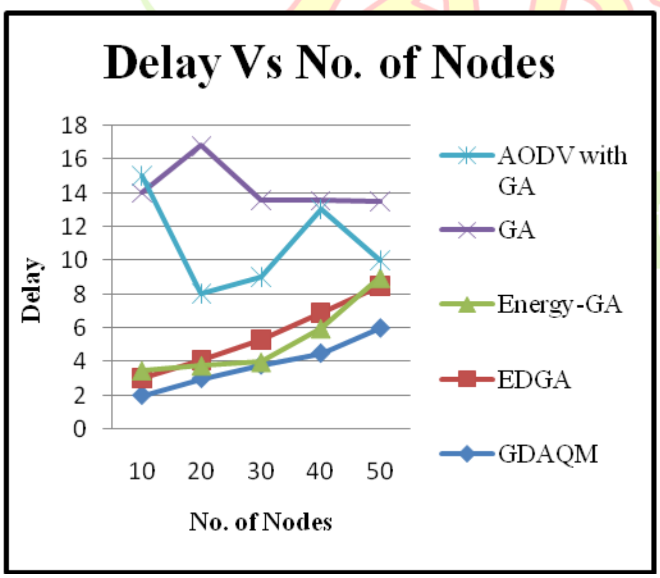

Figure 13: Comparative results of Delay Vs No. of Nodes

As we can see on the figure 13, GDAQM protocol again outperforms other four algorithms as it maintains an average delay lower for the overall simulation time but with a minor differential with the Energy-GA and EDGA. GA performs badly as it maintains a very high average end-to-end delay. One important observation for GDAQM, EDGA, and Energy-GA is that their end-to-end delays almost augment proportionally to the increasing number of nodes, this is possibly due to more hops or queuing available in the network but the same does not apply to the remaining two protocols i.e. AODV with GA and GA whose delays are shaped in crisscross pattern.

5.2.4 Performance evaluation with Energy:

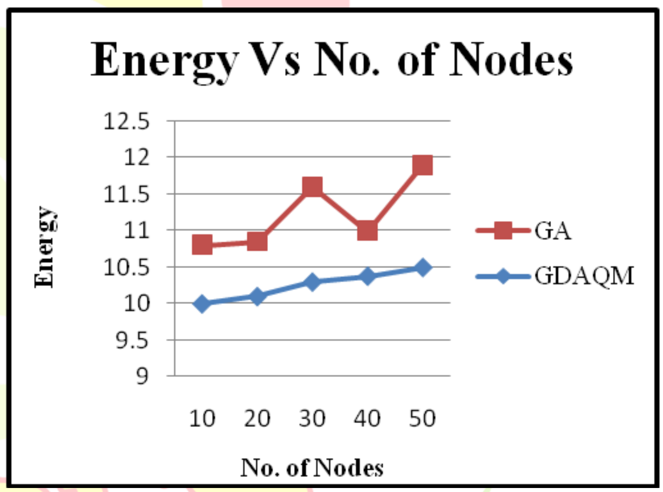

Fig.14 Simulation outcomes of Energy Vs No. of Nodes

As long as the Energy parameter metric is concerned, figure 14 exhibits the performance evaluation's result of our proposed algorithm GDAQM compared with GA. Usually, the genetic algorithm provides an efficient scheme in managing the power consumed by nodes because it is good at selecting an energy-efficient path. Nodes consume lower energy during the multicast process which mainly aims at finding routes to further achieve successfully multimedia data transmissions. Incorporating the genetic algorithm in our proposed protocol efficiently lowers the energy consumed by nodes thanks to the tree structure coding/decoding mechanisms used within this protocol and the addition of the packet scheduling algorithm's enhancement supplied during the packet transmission processes. One more observation is that the energy consumed by nodes is slightly increased as we augment the number of nodes which of course consume more

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power.

6 CONCLUSION

In this paper we conducted a performance evaluation of our proposed algorithm; GDAQM (Genetic with DPD for Attaining high QoS) in MANETs, a combination of different mechanisms namely the Genetic Algorithm and MDPD-k (Modified DPD-k) scheduling algorithm. The Genetic Algorithm which is a source-based technique was used to find out an optimal path between a source and multiple destinations (multicast technique); it achieves a very high QoS as it selects a least-cost, maximum-bandwidth, and energy-efficient path while MDPD-k scheduling algorithm was used for achieving an effective packet scheduling scheme. Combined together, those two techniques resulted in a very efficient algorithm able to achieve successful multimedia data transmission process. During this evaluation, no coding/decoding process was performed; we instead invited the tree-structure-based encoding method, efficient crossover, and mutation techniques. Upon completing the route identification process using the Genetic Algorithm, a MDPD-k packet scheduling scheme was then used with which packets were maintained in a queue and two different thresholds values were calculated which were compared with each packet's slack time to check whether this packet was to be urgently served or not using three different test conditions. This algorithm is very successful in providing fairness in the packet forwarding scheduling processes. A set of experiments were conducted on the GDAQM routing mechanism with NS-2 simulation tool using the PDR (Packet Delivery Ratio), Throughput, Delay, and Energy as the evaluating parameter metrics. For all the cases studied varying the number of nodes and nodes' speeds, our proposed algorithm, GDAQM outperforms very much other protocols, this achievement was possible thanks to its multi-featured techniques combined together in one protocol.

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