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Role of Genetic Algorithm in Network Optimization

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Abstract—*In the field of engineering, solving a problem is not enough. The solution found must be the best possible solution. In other words, one must find the optimal solution to the problem. Optimization seeks to improve the performance towards some optimal point or points. Normally single objective optimization is carried out but many optimization problems have conflicting objectives. Use of GAs is considered as most appropriate method for multi objective optimization problems. Genetic Algorithms are search algorithms based on the mechanism of natural selection. Genetic Algorithm (GA) has the ability to manipulate multiple parameters concurrently; their use of parallelism allow them to produce multiple equally good solutions to the same problem. Optimization in network routing by considering multiple QoS parameters such as end-to-end delay, energy consumption, bandwidth, video conferencing, voice-over-IP, end-to-end delay, jitter, packet loss ratio, hop count etc. is a complex research issue. The paper presents a study on the work carried out for optimization in network routing using Genetic Algorithm in various types of Computer Networks.*

1. INTRODUCTION

The paper presents an overview of various genetic algorithms (both single objective and multi objective) which are used for routing optimization in computer networks. This paper has been divided into multiple sections. Section II introduces Optimization and why it is required in Network Routing. In Section III different MO based computer network routing optimization approaches are discussed. Section IV includes issues and challenges in this field.

2. MULTI-OBJECTIVE OPTIMIZATION

Optimization seeks to improve the performance towards some optimal point or points. Normally single objective optimization is carried out but many optimization problems have conflicting objectives. Use of GAs is considered as most appropriate method for multi objective optimization problems.

It is possible that while solving a problem, one may need to optimize more than one objective function usually with tradeoffs involved.

Routing of packets in networks requires that a path will be selected either dynamically while the packets are being forwarded, or statically (in advance) as in source routing from a source node to a destination.

A multi-objective optimization model can be stated as:

Optimize [Minimize/Maximize]

$F(X) = \{f_1(X), f_2(X) \ldots\ldots, f_n(X)\}$

Subject to:

$H(X) = 0$

$G(X) >= 0$

In the above case,

F(X) is the set of functions to be optimized where the vector X is the set of independent variables.

H(X) and G(X) are the constraints of the model.

Optimization in network routing by considering multiple QoS parameters such as end-to-end delay, energy consumption, bandwidth, video conferencing, voice-over-IP, end-to-end delay, jitter, packet loss ratio, hop count etc. is a complex research issue

Representing the optimization of these resources mathematically, let us consider a network represented as a graph G= (N, E), where N is the nodes and E edges. Among nodes we have source node $S \epsilon N$ and let D be some destination, $D \epsilon N$. Let $(i, j) \epsilon E$ be a link from node i to node j. d_{ij}, w_{ij} and b_{ij} be the delay, cost and available bandwidth for the link (i, j). Say P represents the path from source to destination. And a link (i, j) in the path P is denoted as L_{ij} i.e. $L_{ij} = 1$, if the link is selected for transmission of data else $L_{ij} = 0$.

Optimization of few resource functions can be formulated as shown:

Number of Hops:

$$\sum_{a \in C} \sum_{i,j \in P} L_{ij}$$

End-to-end Delay:

$$\sum_{a \in C} \sum_{i,j \in P} d_{ij} . L_{ij}$$

Cost:

$$\sum_{a \in C} \sum_{i,j \in P} w_{ij} . L_{ij}$$

Bandwidth Consumption:

$$\sum_{a \in C} \sum_{i,j \in P} b_{ij} . L_{ij}$$

3. OPTIMIZATION IN NETWORK ROUTING USING GENETIC ALGORITHM

3.1. QoS Based

QoS routing has been receiving increasingly concentrated attention but finding the shortest path with many metrics is a NP complete problem. To overcome these limitations, development of approximated solutions and heuristic algorithms is required for multipath constraints QoS routing.

Bandwidth constraint, traffic from adjacent nodes, delay and number of hop counts to provide adaptive route in MANET are the QoS parameters which require optimization to achieve QoS routing in MANET. A multi-objective GA is proposed in [1] to optimize the above parameters.

A hybrid solution is proposed in [2] in which a hybrid algorithm that combines Genetic Algorithm and Particle Swarm Optimization algorithm is presented to solve anycast routing problem with multiple QoS constraints.

The methods used for removing illegal routes during initialization, crossover and mutation increase the algorithm complexity and time. To solve this issue a Genetic Algorithm is proposed in [3] wherein the algorithm is brought out with a new encoding and decoding method. It describes that how possible routes can be produced from prior knowledge and then selected based on fitness with respect to QoS.

Multiple QoS anycast routing is categorized as a nonlinear combination optimization problem. To solve this problem an adaptive Genetic Algorithm in [4] is proposed in which adaptive probability of crossover and mutation over and over again is used in simple GA to achieve QoS routing.

Intelligent Agent Antnet based Routing Algorithm (IANRA) algorithm is proposed in [5] wherein enhancement of load balancing strategy is done in Wireless Network to find optimum and near optimum route by means of Genetic Algorithm using breeding capability of ants is the main goal of IANRA.

As in multimedia applications strict quality of service is required during the communication between a source and multiple destinations here raises the requirement for an efficient QoS multicast routing strategy. A multi-objective Genetic Algorithm is proposed in [6] that provide a model for resolving the routing problem and propose a new multicast tree selection algorithm based on GA to simultaneously optimize QoS parameters.

A hybrid genetic algorithm is proposed in [7] that enhance the advantages of GA and Ant Colony optimization Algorithm to optimize QoS routing of wireless mesh network. Simulation results prove that this algorithm has the fast calculation speed and high accuracy and it also can improve the efficiency in wireless mesh network QoS routing.

In [8] a genetic algorithm is proposed for QoS routing in ad hoc networks wherein a Search Space Reduction Algorithm is implemented to reduce the search space of genetic algorithm.

After the reduction of search space the GAMAN search time improves.

A genetic algorithm based unicast routing is proposed in [9] to provide energy efficient unicast, multipath route by considering multiple QoS parameters such as end to end delay, energy consumption, bandwidth and hop count in MANET.

Maintaining appropriate Quality of Service (QoS) for MANETs is a complex task due to the dynamic behavior of the network topology. A genetic based routing approach is defined in [10] to optimize the routing in MANET. The genetic approach will generate an optimized route on the basis of congestion over the network.

A multi-objective GA is proposed in [11] based on the idea of SPEA-II, to solve the QoS routing and wavelength allocation problem. The algorithm is experimented on a set of different scale test problems and the experiment results show very encouraging results in terms of the solution quality and diversity.

Increase on demand of applications such as streaming video, multiplayer interactive games and financial services imposes a

strict guarantee on quality of service basically on end to end delay, and cost bandwidth consumption. Further challenges occur with routing in dynamic environment where nodes are mobile. A multicast routing technique is proposed in [12] that is based on multi objective Genetic Algorithm. This algorithm optimizes multiple QoS parameters in MANET to find optimal multicast tree.

Current routing strategies such as distance vector (DV) and Link State (LS)are not optimal in terms of Quality of Service (QoS) for applications such as Voice over IP(VoIP),video on Demand. A QoS aware routing strategy based on Ant Colony Optimization concept is proposed in [13] to overcome this limitation.

To achieve QoS routing in Wireless Mesh Network a mathematical model is proposed in [14] which include QoS parameters such as power consumption, packet loss rates and delay and bandwidth. In the proposed model, multi objective evolutionary algorithm is used, specifically NSGA-II, where all required objectives are considered providing an optimal solution.

A QoS aware routing protocol is proposed in [15] to support heterogeneous layered unicast transmission and to improve energy usage through Cooperative Network Coding (CNC).

QoS multicast routing problem is categorized as a non-linear combination optimization problem and proved to be a NP complete problem. The solution to this problem is a hybrid algorithm proposed in [16] with ant colony optimization algorithm and particle swarm optimization algorithm.

Routing optimization with the goal to improve the quality of service provides a means to balance the traffic load in the network. The proposed solution in [17] deals with routing optimization in IPv6 network. The experimental results prove that the hybrid algorithm can meet QoS constraints of multicast routing problem excellently.

In [18] a priority based evolutionary multi objective optimization algorithms is described to find the optimal routes for the data flows of various QoS classes via optimizing multiple QoS parameters namely response time, bandwidth requirements and reliability according to the applications' priorities.

Quality of Service support becomes an essential aspect in wireless ad hoc networks such as VANET. An efficient routing technology is proposed in [19] in which routing protocol is optimized by applying a metaheuristic algorithm ACO. Meta heuristic algorithm can improve the QoS parameters such as end to end delay in routing which is comparable to well-known existing multipath routing protocols.

QoS based multimedia routing is an important requirement in Mobile Ad hoc networks. Ant Colony Optimization Algorithm is proposed in [20] as it exhibits number of desirable properties for MANET routing.

An adaptive QoS routing algorithm based on discrete particle swarm optimization is proposed in [21] for wireless sensor network as the already developed QoS routing algorithms can't take count into both network energy consumption and adaptive ability in room environments.

To achieve QoS based routing for real time services in wireless sensor network a solution based on NSGA II is proposed in [22].The proposed solution provides energy efficient QoS routing in cluster based WSNs.

3.2. Sensor Network

Routing is a challenging issue in wireless sensor networks due to their dynamic topological design. To solve this problem a genetic algorithm is proposed in [23].The proposed algorithm is a GA based simple straight forward address based shortest path routing in wireless ad hoc sensor networks.

A probabilistic performance evaluation framework and swarm intelligence approach for routing protocols is analyzed in [24] in which the survey analyzes the ACO and PSO based algorithms with other approaches applied for the optimization of an ad hoc and wireless sensor network routing protocols.

The sensors in Wireless Sensor Networks are characterized by limited battery life and low processing power which results in a limited network lifetime. A spanning tree topology is proposed in [25] in which the topology for wireless sensor network changes dynamically according to the nodes' remaining energy, in order to maximize the usage of the network.

A novel energy efficient clustering mechanism is proposed in [26] based on artificial bee colony algorithm, to prolong the network life-time.

3.3. Ad hoc Network

An optimization algorithm is proposed in [28] that use the load accepted rate, topological variety rate and routing delay time as measurements value to select the routing paths in ad hoc networks. The routing tables are replaced by pheromone tables which realize the network load dynamic distribution.

The dynamic shortest path routing problem occurs with the advancement in wireless network as more and more mobile wireless network appears. A solution to this problem is a genetic algorithm with immigrants and memory schemes is proposed in [29]. In the proposed algorithm MANETs are considered as target system. The experimental result show that

the immigrants and memory based Genetic Algorithms can quickly reorganize according to the environment changes (i.e. the topological changes) and after each change produce high quality solutions.

Multipath routing for MD video in wireless ad hoc networks is an important issue to solve. A metaheuristic approach is proposed in [30] which is eminently effective in addressing complex cross layer optimization problems. A tight lower bound for video distortion as well as a solution procedure for the GA based approach is provided in the proposed approach.

The limitation of high delay occurs in the ad hoc networks of high mobility. To overcome this limitation a swarm optimization strategy is proposed in [31].A hybrid particle swarm optimization algorithm combining genetic algorithm is presented which can be used in a routing protocol and then establish an on demand routing protocol based on the novel algorithm.

Setting up routes in Maritime Tactical Network that meet high reliability is challenging issue as the network topology may change rapidly and unexpectedly in such type of network. Therefore a Genetic Algorithm based technique is proposed in [32] for optimized routing in MTN between shores and ships.

The multicast routing protocol are vulnerable to the component failure in ad hoc network due to the lack of redundancy in multipath and multicast structure that causes route selection tragedy in MANET. A new HGAPSO (Hybrid Genetic Algorithm Particle Swarm Optimization) based optimized MAODV is propose in [33], which improves the performance in the routing messages for multicast applications.

Dynamic route planning problem (DRPP) involving the optimization of a route for a single vehicle traveling between a given source and given destination has a solution proposed in [34] wherein HEADRPP comprises a graph partitioning algorithm (GPA) and a fuzzy logic implementation (FLI) applied into a genetic algorithm (GA) core, and provides both optimized ST and SP paths to the user.

4. CONCLUSION AND FUTURE WORK

Genetic Algorithms provide the best possible solution for the routing problem in a computer network by efficiently using the network resources.

Table 1: Summarize various works done in the field of network routing optimization using Genetic Algorithm

Major Focus	References
QoS Parameters	[1-22]
Anycast Routing	[2]
Multicast Routing	[6]
Sensor Network	[24,25,26]
Shortest Path Routing	[23,29]

The survey shows that GA based approach of optimizing various network parameters achieve better results as compared to the traditional methods of solving complexoptimization problem.

In future GA can be used for optimizing more complex problems of Network Routing to improve QoS of a network.

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