INTERNATIONAL JOURNAL
OF SOFT COMPUTING

MEDWELL PUBLICATIONS
SINCE 2000

GA Induced QoS Routing Approach in OFDM Wireless Network

Swati Rawat, Ingrid Beyer, Christine Günther, Anna Kramer and Erika Siebert-Cole
Department of Computer Science, Kanya Gurukul Maha Vidyalaya, Gurukula Kangri Vishwavidyalaya, Haridwar, India, 69121 Heidelberg, Germany

Key words: OFDM, routing, QoS, GA, EA, end-to-end throughput, latency, delay against network load, transmission rate, data traffic

Corresponding Author:
Swati Rawat
Department of Computer Science, Kanya Gurukul Maha Vidyalaya, Gurukula Kangri Vishwavidyalaya, Haridwar, India, 69121 Heidelberg, Germany

Page No.: 70-77
Volume: 15, Issue 3, 2020
ISSN: 1816-9503
International Journal of Soft Computing

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is the new facet of wireless modulation technique. The core strength of this technology lies in effectively good spectral efficiency and tolerance to fading. It appears to be the best-suited modulation technique to harness the ever growing data needs in a wireless network. The QoS (Quality of Service) enabled routing process is a complex set of optimizing features on which quality of data transmission in a wireless network depends while there are certain dynamic changes taking place in channel conditions invariably. The traffic matrix exhibits the frequently changing data traffic requirements in a heterogeneous network. The objective of this paper is to come up with a routing strategy that puts QoS constraints and metrics in focus while evaluating the performance of a routing technique in OFDM wireless network. The traffic matrix is displaying the data connections which are provided to users on their respective QoS demands. This study introduces GA based approach to enhance the QoS routing performance which seems to be an open question as strong data network requirements are growing exponentially. The proposed approach works in two steps starting with improved traffic population and routes by applying Genetic algorithm techniques and later considering QoS constraints to evaluate the performance of routing strategy. GA induced QoS routing approach yields improved results for data routing in OFDM wireless networks.

INTRODUCTION

An OFDM wireless network is a dynamic heterogeneous data supporting wireless network to facilitate high data transfer rate demands of exponentially increasing users and their data needs. The network is generally bounded with limited resources as network resources fall in the category of being overtly expensive[1]. Throughput-maximizing (or latency-minimizing), i.e., end-to-end throughput and latency, delay against network load, transmission rate service are the critical issues with OFDM wireless network. Routing in such ever growing dynamic environment proposes a very bright challenge for researchers. A huge amount of research work has been done for routing in MANET, VANET and other kind of networks but QoS (Quality of Service) requirements are yet to be supported in a way that induces contention for users while using a wireless channel. The scope of this study discusses a scenario of users with heterogeneous data in QoS supported network that finds a routing scheme which enhances QoS. To optimize QoS, four QoS parameters namely[2, 3] bandwidth constraints, delay, reliability and jitter are needed to put into consideration. Hence, Genetic Algorithm (GA) seems to be the answer of this problem as Genetic algorithms has their ability to manipulate several parameters simultaneously, in order to produce multiple good solution in variation for the same problem. GAs are most suited for multi objective optimization problems in which there is no single value to be minimized or maximized but having multiple objectives, usually with trade-offs, i.e., one gets better at the expense of another. GA's are the best to support such problems which are to be optimized while improving multiple metrics like QoS routing in wireless OFDM network. The results have been simulated using java and MATLAB18R a, results indicated that GA induced approach is better than traditional method.

MATERIALS AND METHODS

Genetic algorithm; Overview: GA is one of the variants of Evolutionary Algorithms (EA). The Implicit parallelism of genetic algorithm makes it more appropriate to solve and reduce the time with reducing the complexity of solutions for problems having answers in extensively huge solution search space. The problems which gets covered in this category are referred as "Nonlinear". The GA comprises of four major operations viz. selection, crossover, mutation, evaluation see in Fig. 1. The GA deploys a fitness function to measure the potential fitness of the sampling data, comes up with a collection of solutions which are best suited. There is a development of new populations improving with each iteration of operations over them. GA starts with selecting current individuals for generating the new updated population by making them crossover over a chosen crossover trait. Followed by mutation GA gets the modified individuals. While most of the problems in real world are nonlinear the linear problem can generate solutions in a definite solution search space with no two metrics are having a trade-off. The fitness of each candidate solution depends uniformly on single attribute. Nonlinearity results in a combinatorial explosion and so it results into NP class problems. So, it's not feasible practically to solve these problems with brute-force method on the current generation of computers. Throughput-maximizing (or latency-minimizing), end to end throughput and latency, delay against network load in homogeneous wireless[4] network causes frequent changes in course of routes. Wireless networks are characterized by Transmission rate service guarantee,

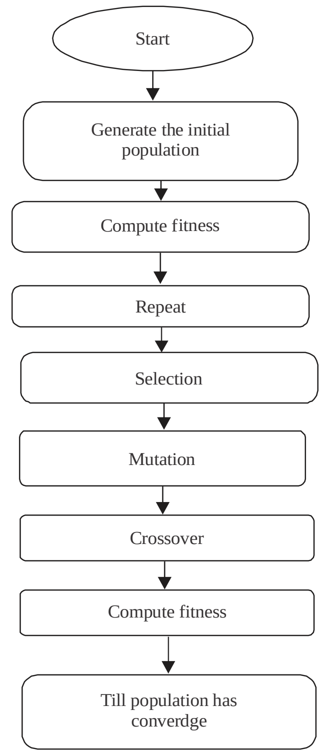

Fig. 1: Basic working of GA

Routing and Spectrum Assignment (RSA) requirements high and packet loss ratio with transmission error probability. Multitudes of research has been carried out in improving QoS routing in wireless networks such as Manet, vanet[5, 6], mobile ad-hoc networks[7] LTE (long term evolution)[8] but QoS constraint satisfaction and more data strong network connections demands with QoS seems to be in loop. The essential task for QoS routing is to find a feasible path through the network between the source and destination that will have the necessary resources available to meet the QoS. So, it is acceptable and necessary to develop multi-objective heuristic function to deal with the QoS Routing problem[9]. We have provided algorithm based upon Genetic approach for two main reasons:

- To optimize route satisfying QoS parameters
- To provide QoS adaptive route with optimized throughput and end to end delivery in OFDM
- To optimize network route resources
- To provide a routing approach which have adaptability to dynamic changes in the channel while providing end to end QoS

GA induced QoS packet routing in OFDM wireless network: To optimize the routing problem in OFDM allocation and mapping of candidate routes possible for a data transmission request over a wireless network wavelength of suitable capacity is required. The large no. of data transmission request demanding QoS aware routes involves complexity and conflicts. While devising a solution for such routing problems QoS suffers[10, 11] a lot in OFDM network. The contiguous allocation of network resources to multiple users is a tough task to break down. The no. of network resources and routes required by different data transmission request will require the same no. of network wavelength allocation[12, 13]. Hence, the optimized solution for this problem has to be independent of the no. of network resources. Figure 2 depicts an Internode QoS based routing model network and Fig. 3 shows a network topology example of 35 nodes for wireless QoS routing in OFDM wireless networks.

The physical arrangement within this orthogonal frequency supported network can be represented with the help of a Graph G = (v, e) having a set v = (v_1, v_2, ..., v_n) of nodes and a set e = (k_1, k_2, ..., k_n) of edges, each link in e connects a pair of nodes in v. The graph G has a list of edges, E⊂L which represents the shortest path between a Source node (Sr) and a Destination node (Dt). In the given network, E is possible if the Routes in the given network are bound with the Qos aware constraints, as in the following:

Assume L links are there in a given Graph G which have N Network Routing resources (NR). The current position of ith link at a given time (t) is presented by the vector:

$$NR_t^{(i)} = \begin{bmatrix} NR_t^{(1)}(1) \\ NR_t^{(1)}(2) \\ NR_t^{(1)}(3) \\ NR_t^{(1)}(4) \\ \vdots \\ NR_t^{(1)}(N) \end{bmatrix}$$

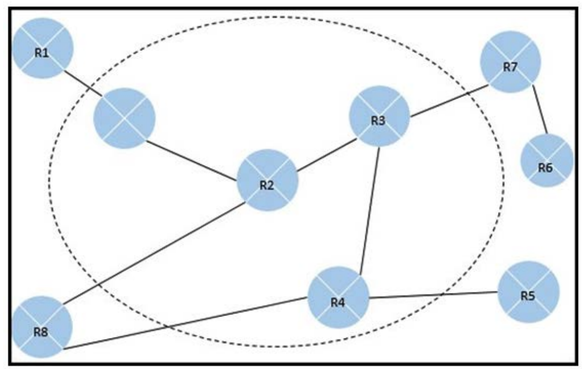

Fig. 2: An internode QoS based routing model network

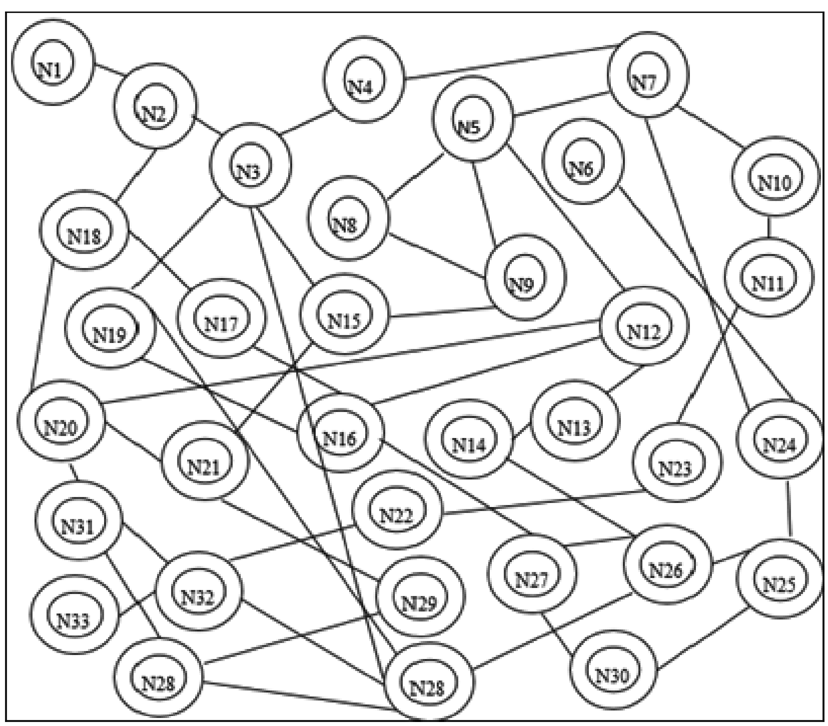

Fig. 3: Network topology example of 35 nodes for wireless QoS routing in OFDM wireless networks

Table 1: Notation used

Abbreviations	Description
T_{max}	Through maximizing coefficient
L_{min}	Latency minimizing
D_N	Delay against workload
TR_{sg}	Transmission rate service guarantee
T_M	Traffic matrix
n	N is the No. of links

Table 2: Simulation parameters

Channel types	OFDM wireless channel
Network interface type	Phy/Wireless Phy
Channel data rate	2 (Mbps)
Maximum speed	20 (m sec^{-1})
No. of nodes	3, 5, 10, 20, 30, 35
Simulation time	15 (sec)
Radio range	250 (m)
Iterations	100
Transmission rate	5 packets (sec)
Packet size	1000 bytes

And the network status can be depicted with the help of following matrix:

$$NR_t^{(i)} = \begin{bmatrix} NR_t^{(i1)}(1) & NR_t^{(i2)}(1) & NR_t^{(i3)}(1) & \cdots & NR_t^{(L)}(1) \\ NR_t^{(i1)}2) & NR_t^{(i2)}(2) & NR_t^{(i3)}(2) & \cdots & NR_t^{(L)}(2) \\ NR_t^{(i1)}(3) & \cdots & \cdots & \cdots & NR_t^{(L)}(3) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ NR_t^{(i1)}(n) & NR_t^{i2}(N) & NR_t^{i3}(N) & \cdots & NR_t^{(L)}(N) \end{bmatrix}$$

$$\text{Traffic population matrix} = \begin{bmatrix} T_1 \\ T_2 \\ :: \\ :: \\ T_N \end{bmatrix}$$

The proposed algorithm considers the four major factors which qualifies to enhance QoS with no doubts viz. Throughput maximizing (T_{max}), Latency minimizing (L_{min}) and Delay against workload (D_N) with Transmission Rate service guarantee (TR_{sg}) to assess improved QoS in the given network. The T_{dt}(Total delay time) corresponds for total time taken by a test packet to reach from one node to another one. The TRsg depicts the accurate rate at which data packets are being transmitted without any loss. For each packet moving from source A to destination B (S_a, D_b), we predetermine the k paths which improves a set QoS parameters. Let P_{ab} be a set of candidate paths for Source to Destination and $P\cup a,b$ the complete set of candidate paths. Note that we can formulate the problem without using any set of predefined paths but allow routing over any feasible path. Such an algorithm will give at least as good solutions as the algorithm that uses pre-calculated paths but will use a much higher number of variables and constraints and thus would be less scalable. To alleviate given problem an optimal solution has to be found with an algorithm that uses pre calculate paths, given a large enough set of paths.

Table 3: Varying number of nodes, routes and branches

Nodes	3	5	10	20	30	35
Total No. of routes	36	54	72	828	12492	20439
Total No. of branches	9	15	18	36	83	243

The objectives of the proposed algorithm are listed below in tables namely Table 1-3 where Table 1 is for minimization of Delay against workload (D_N) for given pair of source to destination with R No. of routes.

To find: R = (L_{Sr} to L_{Dt})
To minimize: Delay against workload (D_N)
Over: G, NR_t
Subject to: NR (I) t (j) = 0, $\forall Li\in R$, $D_N = \Sigma^N_{i=1} D(L)_f$
(Where $\forall$ j such that $1\leq j\leq N$, $NR^{(f)}_{(t)} = 0$ (It would be available) Network routing resources must be free in all link of route R for data transmission request at any time. QoS constraint in this problem is two routes must be assigned the same j at a given time in a given link) and
Where D_N is the sum of delay occured during data transmission from source to destination over the given link

To find: R = (L_{Sr} to L_{Dt})
To maximize: Throughput maximizing (T_{max}) with transmission rate services guarantee (TR_{sg})
Over: G, NR_t
Subject to: NR (I) t (j) = 0, $\forall Li\in R$
(Where $\forall$ j such that $1\leq j\leq N$, $NR^{(f)}_{(t)} = 0$ (It would be available) Network routing resources must be free in all link of route R for data transmission request at any time. QoS constraint in this problem is two routes must be assigned the same j at a given time in a given link)

To find: R = (L_{Sr} to L_{Dt})
To minimize: Latency minimizing (L_{min})
Over: G, NR_t
Subject to: NR (I) t (j) = 0, $\forall Li\in R$
(Where $\forall$ j such that $1\leq j\leq N$, $NR^{(f)}_{(t)} = 0$ (It would be available) Network routing resources must be free in all link of route R for data transmission request at any time. QoS constraint in this problem is two routes must be assigned the same j at a given time in a given link)

The working of the algorithm is divided in two parts namely generation of Data rich population which is prone to all the QoS of affecting features and fitness function to evaluate the QoS Routing performance in OFDM wireless networks.

Generation of data rich population with different QoS requirements: The GA process starts with an initial population of Traffic data matrix and a pair of initial source and destination pair. The fitness function is deployed in the algorithm for choosing the best and highest scorer for the Qos constraints. The more the no. of individuals in the population more is the probability of finding a largely optimized solution for the problem. In this step of algorithm traffic matrix data set is generated according to certain QoS requirements in OFDM wireless requirements. The selection of population which needs to get optimized is done over a fitness function which in turns ranks the given input variables over its fitness. The input traffic data has to be transmitted over a link from source (S_r) to destination (D_t). For each traffic data packet to be in the queue to get optimized paths has to have a certain level of fitness score. QoS constraints for data to get in to the sampling population of routing strategy optimizing is less delay tolerant ($\leq$150 msec latency), service type (guaranteed or non-guaranteed), packets per second in a data segment, jitter sensitive ($\leq$150 msec), packet loss (1 out of 100 packets is permissible).

The function F (T_M) used to select as data packets for QoS constraint specific routing algorithm from the regular flow of traffic is given below.

$$F(T_M) = \text{QoS constraints} \cup \text{delay} \cup \text{latency} \cup, \text{jitter} \cup \text{reliability} \cup \text{packetloss}$$

$$T_M = \begin{bmatrix} & 1 & 2 & \cdots & n \\ 1 & p_{11} & p_{12} & \cdots & p_{1n} \\ 2 & p_{21} & p_{22} & \cdots & p_{2n} \\ 3 & p_{31} & p_{32} & \cdots & p_{3n} \\ \vdots & \vdots & \cdots & \ddots & \vdots \\ m & p_{m1} & p_{m_2} & \cdots & p_{mn} \end{bmatrix}$$

1. **Initialization**
2. Set time (t) = 0
3. Initialization traffic population (P) {$P_1(t)$, ..., $P_n(t)$}
4. Randomly select one individuals as per fitness function ($F(T_M)$) $P_i(t)$, i = 1, ..., n
5. Randomly select one individuals and perform $F(T_M)$
6. **Repeat**
7. Set t = t++
8. Select a new population {$P_1(t)$, ..., $P_N(t)$}
9. Replace a random packet with the best packets of the previous generation, eg., $P_{best(t-1)}$
10. Perform crossover to each pair of selected individuals
11. Perform mutation to each of element T_M
12. Evaluate each individual $p_i(t)$, i = 1, ..., n
13. Randomly select one individual and perform $F(T_M)$ on it
14. Till terminating condition met

Fitness function to evaluate population generated for QoS aware routing: The fitness function used to evaluate the QoS aware routing algorithm is given by:

$$F(T_{max}, L_{min}, D_N, TR_{sg}) = \frac{\sum_{i=0}^{n} T_{max\,i} + L_{mini} + D_N}{\prod_{i=1}^{n} TR_{sg}}$$

where, Throughput maximizing (T_{max}), Latency minimizing (L_{min}) and Delay against workload (D_N) and Transmission rate service guarantee (TR_{sg}) are chosen metrics to assess the QoS performance. The function (f) is the fitness function to evaluate the fitness of routes for desired QoS specification. The function computes the total sum of all network QoS routing metrics over number of links for a given routes. The output of the computation is used in evaluation of routes, considering current state of the network. The function output is the key performance measurement of the proposed algorithms. The objective of the algorithm is to optimize the throughput while maintaining a tradeoff to reduce latency and minimize delay. The Transmission rate service guarantee ensures the network is not overloaded resulting in more delay and jitter degrading QoS. The fitness function is very particular to the problem discussed above. If the scenario and parameters of network changes the whole fitness function and simulating parameters have to be redevised (Fig. 4).

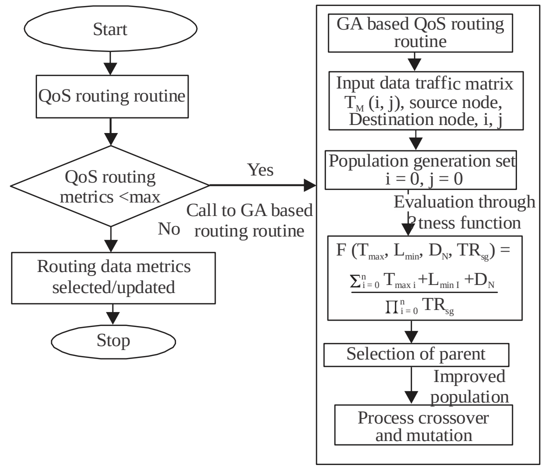

Fig. 4: Proposed routing approach data flow diagram

A. Path discovery phase:

Step 1: Data packet to be sent over source S to destination D with QoS requirements such as higher transmission rate, less delay and more bandwidth. A Route R is the existing best path consisting nodes taken by earlier parents generation

Step 2: Selection of parents -> source (S). The Route R will be initialized with S

Step 3: S initiates a Path_Request_parent 1 to destination D through all its neighbors which are in 1-hop distance from S. The Path_Request_parent 1 contain source address, destination address, hop count and bandwidth

Step 4: After that the crossover and mutation of all I hop distance node will be calculated. Each node (i) maintains a table called “route _qos_tab” a table of parents specifying the no. of generations went through on eack link (Vi, Vj). This quantity is initialized to constant C

Step 5: Then we calculate the path the ranking by evaluation function of all the 2-hop distance nodes.

Step 6: At last we calculate the path preference probability value of each path from source S with the help of specific evaluation function of every node. A node j from a set of adjacent nodes (j, k, ..., n) of i is selected as qos_eff node such that it covers all the 2-hop distance node and its path preference probability is better than others

Step 7: If (PQE) path_qos_Efficient value is better than the requirements, the path is recognized with a valid unique no. in qos_eff_path table

Step 8: When the path_parent_1 reaches the destination, it will be converted as Path_parent_optimum and forwarded toward the original source. The Path_parent 2 will take the same path of the corresponding Path_parent_1 but in reverse direction

Step 9: The path having highest values for metrics determining path_qos_Efficient will be considered as the optimum path and data transmission will be initialized

B. Path maintenance phase:

Step 1: After the initialization of data transmission the paths will be fed with data inducing self-improvement and hence, come up with new desired path solutions

Step 2: The other candidates were put to test by inputs such as heterogeneous work load with delay intolerant and tolerant data with lesser bandwidth available

Step 3: If (PQE) path_qos_Efficient value decrements other alternatives which were closer to the highest value of PQE can be reconsidered. The candidates path are constantly re-evaluated with new user experience data to induce self-improvement feature

RESULTS AND DISCUSSION

The proposed algorithm is evaluated with simulation parameters and experiments performed on MATLAB R MATLAB provides a good blend of tools to perform simulation. Data traffic matrices were created as the number of data packets required for connection source(S_r) Destination D_t) over a link (L). The result obtained are tested and averaged over 100 randomly created matrices. The objective of the simulation model is to provide the testament of the proposed routing algorithm. The algorithm uses GA techniques to perform the assigned task of QoS improvement. On receiving a new data transmission request the router implements the proposed routing algorithm to determine the QoS aware path from S_r to D_t. Then, the fitness function is used to evaluate the fitness of the initial path. The routing algorithm attempts to assign a QoS aware path to each data transmission request by traversing the whole region covered by source to destination nodes. In experiments 35 nodes were considered and used for producing simulation results while transmitting data from source to destination. Two terminating conditions were used firstly the number of generations and other is checking when we find a new route which utterly satisfies the given specified QoS parameters. The GA search provides different routes in different iterations which are sorted according to their ranking. So the first one can be considered the best route but other routes can be used as backup routes in critical situation. Table 1, lists the simulation parameters used in the experiment.

The simulation has been carried out in different settings of topologies with different numbers of nodes, varying routes and numerous branches. The different results were noted down with varying size of nodes increasing from 3, 5, 10, 20, 30 and 35 see in Table 2. In Table 3 depicts the time taken for producing one improved generation. In Table 4 the performance of proposed algorithm is shown for different parameters. The parameters named as average rank, Gen_{avg}, QoS_Quotient are observed. Such that the average rank symbolizes the rank required to find a new distinct route. Gen_{avg} is the average no. of generations taken by algorithm to find a new route as solution. QoS_Quotient whereas shows the impact on QoS factors whether enhancing or stable. The pattern noticed while simulating the experiment was the nodes increment increases the probability of finding a new route in channel. While the shorter the number of nodes to consider the faster was the time rate. In this study, we proposed the routing algorithm based on GA which supports QoS routing in OFDM wireless channel. The proposed algorithm was compared to its counter peer algorithm and results show QoS is well supported and enhanced by the proposed technique (Fig. 5-7 and Table 5-7).

Table 4: Time taken for generating one improved population

Node	Avg.	High	Low
10	4.20	16	-
20	4.80	20	-
30	6.41	30	-
35	10.70	50	-

Table 5: Time taken by GA to produce QoS supported routes

Node	Average rank	Gen_{Avg}	QoS_quotient
10	2.64	1.00	Enhanced
20	5.62	8.00	Enhanced
30	6.44	42.30	Stable
35	5.38	28.72	Enhanced

Table 6: Results of delay in (milli seconds) with increasing data rate

Data rate	Wireless routing	QoS based wireless routing	GA based improved QoS routing
100	12	30	32
300	18	22	35
600	32	31	40
900	55	40	48
1200	88	42	60

Table 7: Results of delay in (milli seconds) with increasing No. of nodes

No. of nodes	Wireless routing	QoS based wireless routing	GA based improved QoS routing
3	80.443	77.657	70.231
5	86.875	79.243	73.483
10	174.308	155.549	120.902
20	191.406	179.301	153.791
30	191.806	181.203	162.731
35	193.098	182.604	163.900

The results were analyzed and compared over Throughput maximizing (T_{max}), Latency minimizing (L_{min}) and Delay against workload (D_N) with Transmission rate service guarantee (TR_{sg}).

Delay against workload: There are two graphs for delay one is plotted against the data rate and delay other is delay versus increasing no. of nodes.

Throughput maximizing: Results of throughput maximizing in Table 8.

Latency minimizing: Table 9 and 10 show the result of latency comparison (Fig. 9 and 10).

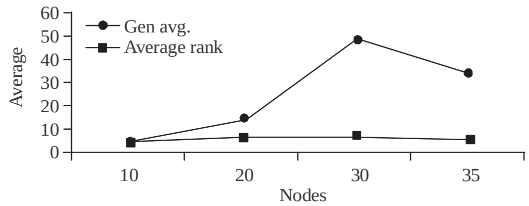

Fig. 5: Time taken by GA to produce QoS supported routes

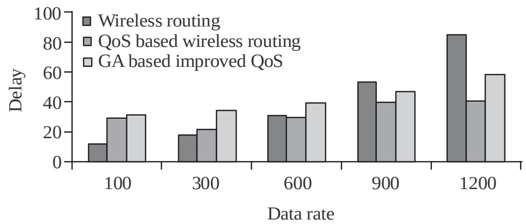

Fig. 6: Delay with increasing data rate

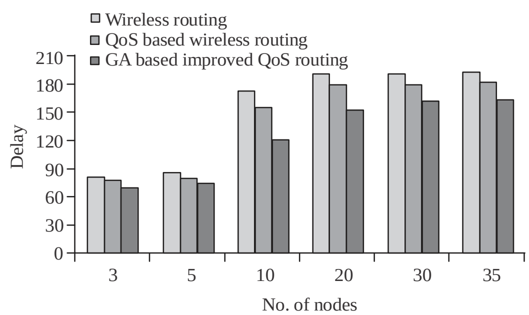

Fig. 7: Delay with increasing no. of nodes

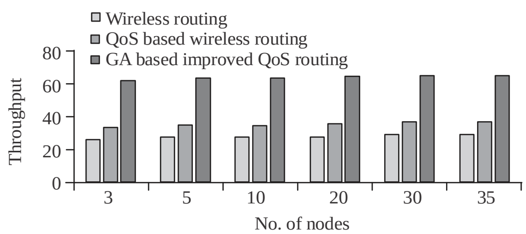

Fig. 8: Throughput with increasing no. of node

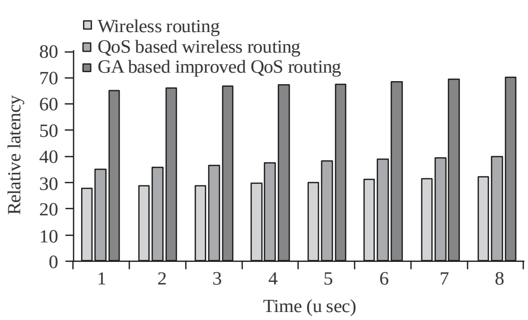

Fig. 9: Relative latency

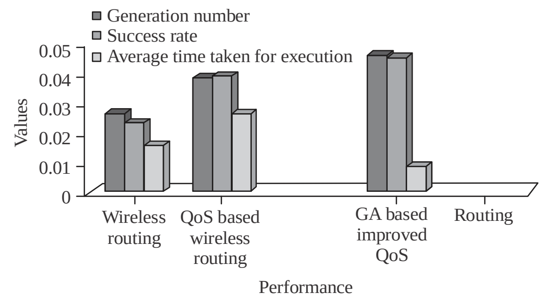

Fig. 10: Performance comparison of proposed algorithm with existing ones

Table 8: Results of throughput maximizing comparison

No. of nodes	Wireless routing	QoS based wireless routing	GA based improved QoS routing
3	26.3	34.5	63.04
5	26.9	34.9	64.1
10	27.3	35.5	65
20	28	36.3	65.8
30	28.9	37	66.2
35	29.2	37.6	67

Table 9: Results of latency minimizing comparison

Time	Wireless routing	QoS based wireless routing	GA based improved QoS routing
1	28	35.2	65
2	28.8	36	65.9
3	29.3	36.5	66.4
4	29.7	37.5	67
5	30.3	38.1	67.7
6	31	38.5	68.3
7	31.6	39.2	69.5
8	32	40	70.3

Table 10: Results performance comparison of proposed algorithm with existing ones

Routing algorithm	Generation number	Success rate	Average time taken for execution
Wireless routing	0.0265	0.0234	0.0155
QoS based wireless routing	0.0389	0.0393	0.0264
GA based improved QoS routing	0.0466	0.0457	0.0083

CONCLUSION

The proposed routing strategy can be optimized to support heterogeneous high speed data transmission in OFDM based networks through evolutionary cum GA based QoS routing. The major complexity in wireless network is to maintain the QoS for a variety of users having dynamic requirements for data in spontaneously changing channel conditions. The challenges reside in any wireless networks is to find a path between the communication end points satisfying user's QoS requirement which need to be maintained with consistency. The algorithm consists of two steps and is powered by GA techniques which are best suited for multi objective problem optimization. This proposal is based on evolutionary cum GA based QoS routing to establish multiple stable paths between source and destination nodes. GA based population is used to select multiple nodes and these nodes used to establish connectivity with intermediate nodes.

RECOMMENDATIONS

The future scope the work can be extended for multicasting by using any other Evolutionary or AI based approach with distinct QoS objectives such as Radio resource allocation with spectrum efficiency and energy conservation.

ACKNOWLEDGEMENTS

The researchers are thankful to Department of Computer Science, Gurukul Kangri University for providing the support and lab resources.

REFERENCES

01. Wang, L., L. Lin and L. Du, 2017. Design and simulation of a topology aggregation algorithm in multi-domain optical networks. Commun. Network, Vol. 9, 10.4236/cn.2017.94017
02. Wen, M., B. Ye, E. Basar, Q. Li and F. Ji, 2017. Enhanced orthogonal frequency division multiplexing with index modulation. IEEE. Trans. Wirel. Commun., 16: 4786-4801.
03. Rawat, S. and P. Chaturvedi, 2017. A comparative analysis of different QOS strategies in OFDM wireless network. Proceedings of the 2017 International Conference on Next Generation Computing and Information Systems (ICNGCIS), December 11-12, 2017, IEEE, Jammu, India, pp: 116-121.
04. Rawat, S. and P. Chaturvedi, 2019. An enhanced QOS aware scheduling algorithm for OFDM wireless network. Int. J. Hybrid Inf. Technol., 12: 27-36.
05. Chahal, M. and S. Harit, 2019. Optimal path for data dissemination in vehicular ad hoc networks using meta-heuristic. Comput. Electr. Eng., 76: 40-55.
06. Xue, Y., J. Jiang, B. Zhao and T. Ma, 2018. A self-adaptive artificial bee colony algorithm based on global best for global optimization. Soft Comput., 22: 2935-2952.
07. Lu, T., G. Liu and S. Chang, 2018. Energy-efficient data sensing and routing in unreliable energy-harvesting wireless sensor network. Wirel. Networks, 24: 611-625.
08. Madan, D., M. Jyoti and K. Vats, 2016. Performance evaluation of WLAN network based TORA protocol using OFDM (802.11 a) and extended rate PHY (802.11 g). Int. J. Sci. Res. Manage. (IJSRM.), 4: 3938-3946.
09. Yin, M., S. Zhao, F. Meng, B. Lu, Z. Qi and D. Li, 2017. Energy efficiency optimization in OFDM power telecommunication network. Proceedings of the 2017 International Conference on Computer Technology, Electronics and Communication (ICCTEC), December 19-21, 2017, IEEE, Dalian, China, pp: 36-40.
10. Thanigasalam, M. and P. Dananjayan, 2016. Performance analysis of OFDM receiver with modified PTS technique. Int. J. Commun. Networks Distrib. Syst., 17: 43-60.
11. Hindumathi, V. and K.R.L. Reddy, 2018. Delay aware optimal resource allocation in MU MIMO-OFDM using enhanced spider monkey optimization. Int. J. Commun. Networks Inf. Secur., 10: 410-418.
12. Jain, M. and A. Priya, 2017. Impact analysis of transmission range on AODV, DYMO and ZRP routing protocol on QOS issues in WiMax. Int. J. Online Sci., Vol. 3,
13. Hasan, M.Z., H. Al-Rizzo and F. Al-Turjman, 2017. A survey on multipath routing protocols for QoS assurances in real-time wireless multimedia sensor networks. IEEE. Commun. Surv. Tutorials, 19: 1424-1456.