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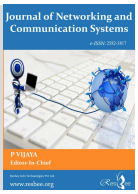

Self Adaptive Harmony Search Algorithm for QoS Routing in MANET

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Abstract: Mobile Ad hoc NETwork (MANET) faces a somber problem of recurrent transform of network topology that guides to the reliability and stability issues of routing. Numerous routing strategies like backup path routing and multi-path routing are introduced to augment the link dependability in the state-of-the-art. For that reason, to model, a backup route concern for the Quality of Service (QoS) routing protocol is proposed. In this protocol, the possible malfunctions of node and network are recognized and a backup routing is started. In order to recognize the malfunction, a path estimate function is decided on the basis of the metrics energy drain rate and interference, congestion status is calculated. The primary path fulfilling the QoS parameters node's dynamic resource availability, static resource capacity, link quality, neighborhood quality is recognized. Once failure is recognized, back up routes are identified and transmission is forwarded on these backup routes. Finally, the experimentation outcomes exhibit that the proposed protocol has minimized recovery delay and enhanced throughput as evaluated with the conventional protocols.

Keywords: MANET; Backup Path; Delay; Throughput; QoS; Harmony Search

Nomenclature

Abbreviations	Descriptions
PAR	Pitch Adjusting Rate
AODV	Ad Hoc On-Demand Distance Vector
CHS	Cluster-Heads
NB	Namely Neighbors
MPR	Multipoint Relay
BW	Bandwidth
MEQSA-OLSRv2	Multipath Energy and Qos-Aware Optimized Link State Routing Protocol Version 2
RF	Response Friends
QoS	Quality of Service
BMO	Bird Mating Optimization
FIB	Forwarding Information Base
MANET	Mobile Ad hoc NETwork
MCNR	Multicriteria Node Rank Metric
ICN	Information-Centric Network
SIR	Signal to Interference Ratio
BCMRP	Bandwidth-Satisfied and Coding-Aware Multicast Routing Protocol
HMCR	Harmony Memory Considering Rate
PAO	Physarum Autonomic Optimization
ABC	Artificial Bee Colony
IF	Interest Friends
CBR	Constant Bit Rate
PFN	Path Failure Notification
PSO	Particle Swarm Optimization
ACO	Ant Colony Optimization
SG	Smart Grid
RFN	Route Failure Notification
GWO	Grey Wolf Optimization

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PIT	Pending Interest Table
NDN	Named Data Networking
B-iHTRP	Bio-Inspired Hybrid Trusted Routing Protocol
PE	Path Evaluation
SN	Sensor Nodes

1. Introduction

A MANET is considered as a wireless multi-hop network of mobile nodes without any centralized infrastructure that configures dynamically [8] [15]. In wireless networking, development creates packets routing a multifaceted and concerning task as networks are linked to the internet [16]. Because of the internet connectivity of minimum wireless networks via gateways, there is a requirement of forwarding methods that surmounts the problems of energy consumption and connectivity because of the mobility [17] [18]. Effectively transmission of data to the equivalent receiver engages the mobility of the nodes as well, that guides to route malfunction and consequently additional energy is utilized in the delivery of the data [19]. Other confronts comprise inadequate heterogeneous communication and available bandwidth associations [1] [15]. Hence, an effectual routing approach is needed to be adaptive to a variety of alters and optimal in resource utilization in processing and communication procedures. The multipath constrained routing is an NP-Complete issue on the basis of the theorem representing that the issue of discovering an optimized path, stated N additive/multiplicative metrics with N constraints, will be NP-Complete issue [4].

MANET is an infrastructure-less wireless network, self-organized, without any central administration [3]. The objective of QoS aware routing is to recognize the optimal path which fulfills the severe needs of QoS parameters such as bandwidth, delay, jitter and so on. Multimedia applications like video and audio have a great deal more severe requirements of QoS [12]. To agreement QoS deliveries for a network, it has to reserve and control resources such as minimum delay guarantees and bandwidth requirements. The main problems and confronts of MANET routing protocols are to pact with association failures and route recovery in these circumstances [13] [14]. The effectiveness of route recovery involves the general performance of MANETs. AODV encompasses two route repair circumstances to pact with connection failure. By either reestablishing a new route starting from source node routes are repaired or by the node that detects it can be locally repaired the link break beside the end-to-end path [1].

AODV routing protocol is the enhanced account of DSDV routing protocol. In MANET, it is an on-demand routing protocol [20] [21]. MANET is stated as the collection of model nodes that considerately engage in communication operation. It does not need any central authority to scrutinize that is no infrastructure. The main technologies of MANET are an earthquake, battlefield, earthquake, and so forth. AODV in MANET routing is on the basis of the two stages such as route Maintenance and route Discovery [4].

In MANET each node is free to move independently in the network. It can abscond or link network topology anytime and consequently, MANET has dynamic behavior. Nodes in MANET dynamically modify their topology because the mobility devices might not capable to receive a packet from other devices. Chances of path breakage and path failure are superior in MANET. However, because the wireless mobility of devices is superior that affects the QoS of the network. Network QoS is nothing but jitter, buffer space, delay, and bandwidth. Hence, preserving stability and QoS in MANET is a complicated task. In MANET, there are diverse routing protocols. These protocols spotlight on this QoS and mobility associated features. The major objective of routing protocol is to raise energy efficiency, throughput, route lifetime and minimized delay. As long as QoS requirements with respect to the end-to-end delay are considered as the main significant targets in such networks, as the actions are done on the surveillance instantly subsequent to the event happens. Optimizing end-to-end delay and energy consumption should be attained to assure QoS needs in WSANs, as routing decisions can crash the complete network. Moreover, numerous open researches are explained in the literature section of the paper.

The main objective of this work is to propose the backup route connection method for the QoS routing protocol. By exploiting the self-adaptive harmony search algorithm, the primary path is chosen by adapting the fitness model integrating dynamic resource availability, node's static resource capacity, link quality neighborhood quality. Subsequently, the backup path is connected by exploiting the path evaluation function that contemplates three important parameters such as interference, energy, and congestion. Each intermediate node that comes in the primary path is verified by exploiting the path evaluation function and the next path is established if any nodes are depleted on the basis of the path evaluation function.

2. Literature Review

In 2017, Waheb A. Jabbar et al [1], proposed a hybrid MEQSA-OLSRv2 that was presented to manage with the concerns proposed by traffic congestion limited and energy resources, through data transmission. This protocol exploits a node rank consistent with MCNR. These MCNR collectives multiple parameters associated with QoS and energy into a wide-ranging metric to noticeably decrease the complexity of multiple constrained deliberations and shun the control overhead origins by unconnectedly broadcasting multiple parameters. These metrics were the lifetime of node's, remaining battery energy, idle time of nodes, speed of the node's, and queue length. For multiple-route computation, the MCNR metric was used by a new connection quality evaluation function. Additionally, it was used to choose an MPR set of nodes exploiting QoS-aware energy and MPR chosen method for flooding topological information.

In 2017, Yu-Hsun Chen et al [2], presented the coding circumstances to recognize a coding host. The bandwidth utilization of a coding host was subsequently calculated under the disputation-based wireless networks with an arbitrary access method. At last, a BCMRP was proposed. By considering the residual bandwidth of the carrier-sense neighbors of the forwarders, the presented protocol can assure the requirements bandwidth for the requested flow and additional continuing flows. Accordingly taking into consideration coding opportunities in multicast tree construction, the proposed multicast protocol can decrease the total bandwidth utilization.

In 2018, Dapeng Qu et al [3], presented a cache-aware social-based QoS routing model for NDN in ICN. Moreover, 3 types of social relationships, NB, IF and RF were devised to clarify the relationships between nodes. Hence, whilst there was a malfunction in performing the PIT method, a forwarding method on the basis of the social relationships was performed previous to performing the FIB method. In addition, a caching strategy and its equivalent substitute rule on the basis of the cache space, content popularity, and neighbor caching information were proposed.

In 2017, M. Faheem and V.C. Gungor[4], worked on a WSN-based extremely dependable communication infrastructure, which was done for the triumphant operation of the subsequently-generation electricity power grids. Moreover, to address this requirement, a new dynamic clustering based energy efficient and QoS-aware routing-protocol named EQRP that was enthused by the real behavior of the BMO, was developed. The developed distributed model enhances network reliability considerably and minimizes extreme packets retransmissions for WSN-based SG technologies.

In 2017, Souraya Yahiaoui et al [5], developed a novel routing protocol that offers QoS regarding energy utilization and delay. The network was prearranged in clusters overseen using CHs, selected along with significant metrics, that was the energy ability, the resources of connectivity that was exploited to choose the CH with maximum node density, and the ease of use degree in term of all the actuators. The latter metric was the distance in a number of hops of SN in relation to the actuator nodes. This metric improves further the network reliability using minimizing the communication delay whilst attentive to the actuator nodes, and therefore, minimizing the energy utilization. To attain capably the actuator nodes, a delay and energy-sensitive routing protocol on the basis of the demand routing approach were designed. Moreover, the protocol acquires minimum delay and energy competence.

In 2017, Mingchuan Zhang et al [6] proposed a new B-iHTRP on the basis of the dependent evaluation, ACO, and PAO. Initially, the cross-layer perception into ACO to attain perceptive ants was introduced. Subsequently, the network into multiple zones was divided. The route table was maintained proactively within each zone, using the observant ants that can sense apprehensive parameters. Between zones, the perceptive ants were transmitting to reactively discover routes to destinations whilst sensing apprehensive parameters. Next, B-iHTRP exploits PAO to choose the best possible one from the established routes.

3. Proposed Algorithm for QoS routing in MANET

3.1 Path Evaluation Model for Backup Path Selection

Once the prime path is connected, communication of data has the ability to occur on the basis of the chosen routes. Subsequently, the failure of the route is verified using the evaluation of the path model to connect the secondary route that is chosen for the data session as a backup path. PE model is a metric that proposed the performance of the route from a sender node to the receiver node. It is associated with metrics interference, congestion status, and energy drain rate. The scientific function exploited to discover the evaluation of the path model P_{pk} is stated in eq. (1).

$$P_{pk} = w_1.Er_k + w_2.I_k + w_3.C_k \quad (1)$$

In eq. (1), I indicates interference, C indicates congestion status and E indicates energy drain rate are calculated. w_1, w_2 and w_3 are the values of positive weight such as E, I and C, correspondingly. Moreover, they are in the range of 0 to 1. Based on eq. (2), the evaluation of the path model is directly proportional to E, I and C. That is if interference, energy congestion status and drain rate, are maximum, PE is maximum which shows the probability for the failure of the path.

Rate of energy drain: Assume that every node i observes its energy utilization creates by the transmission, reception, and activities of overhearing and calculates the energy drain rate, indicated by $Er_i(t)$. This is done for each Δt second sampling interval using averaging the number of energy utilization and calculating the energy utilization per second in the last Δt seconds. The actual value of $Er_i(t)$ is computed by using the familiar exponential weighted moving average algorithm used to the values of the drain rate $Er_i(t-1)$ and $E_{curr,i}(t)$,

$$Er_i(t) = \lambda . Er_i(t-\Delta t) + (1-\lambda) . E_{curr,i}(t) \tag{2}$$

In eq. (2), Δt indicates the previous time instant and $Er_i(t)$ indicates the Energy drain rate. Using eq. (3), the current $Er_i(t)$ is computed.

$$Er_{curr,i}(t) = \frac{E_i(t) - E_i(t-\Delta t)}{\Delta t} \tag{3}$$

Interference metric: It is exploited to detect the failures. A dependable connect needs not merely a SIR received level (SIR_{rx}) maximum adequate to precisely decode the information (with SIR_{th}), although the least functional signal power $Q_{rx,min}$. It is stated in eq. (4).

$$I = Q_{rx,min} : SNR = \frac{Q_{rx,min}}{Q_{noise}} = SIR_{th} + \Delta SIR \tag{4}$$

In eq. (4), NR represents Signal to Noise Ratio (SNR), $Q_{rx,min}$ represents least received power.

Congestion Status: The CS_i metric is exploited to explain the congestion status of a node i, which is proportional to the queue length of the node, the number of forwarded data packets and the remaining energy of node.

$$CS_i(t) = c.P_i^{unit}(t) + d.S_i^{unit}(t) \tag{5}$$

In eq. (5), c and d indicates the positive weights, $S_i^{unit}(t)$ indicates node unit forwarding packet number at the present time step, $P_i^{unit}(t)$ indicates queue length of the node unit at the present time step. Algorithm 1 exhibits the explanation of the Backup Routing establishment technique.

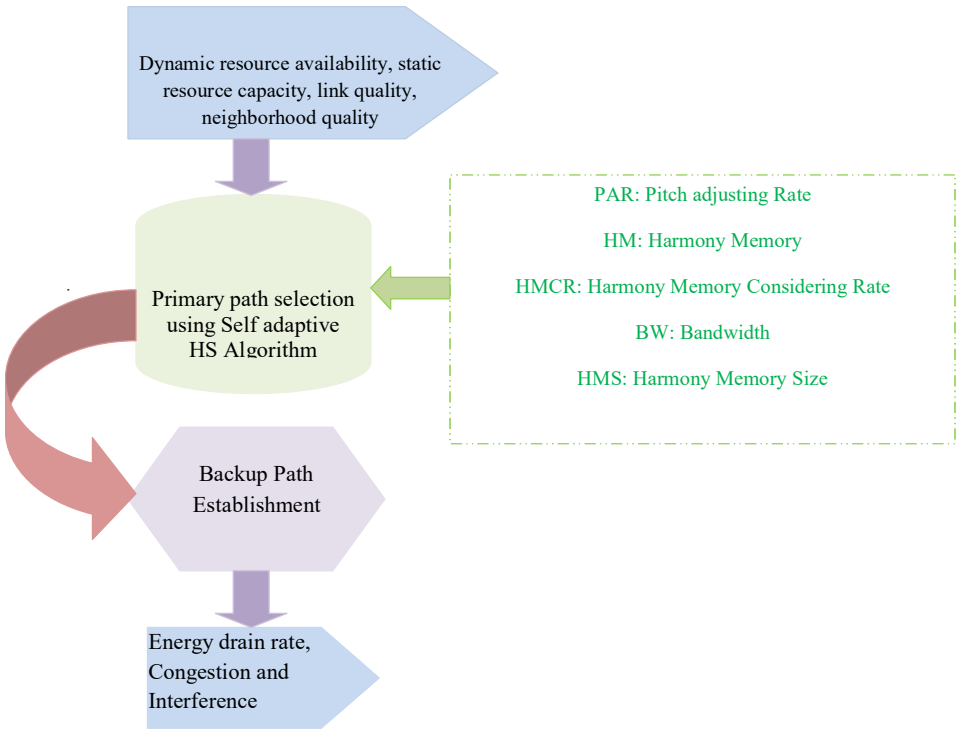

Fig. 1. *Schematic illustration of the proposed algorithm for QoS routing protocol*

Algorithm-1: Parameters of Backup Path Establishment

S – Sender,
R -Receiver,
N_i, $i = 1,2,....,k$ Intermediate nodes,
PE model,
$PEth$ – threshold value for PE function,
RFN

Begin
Set up the primary path among S and R
S transfers the data towards the receiver via the connected primary path.
Every N_i beside the primary path calculates PE
If $PE(N_i) > PEth$, subsequent
N_i transfer a PFN to S
S chooses the subsequent optimal path established
S restarts the transmission to R via the backup path
End if
End

3.2 Self-Adaptive Harmony Search Approach for Primary Path Selection

In this section, the schematic illustration of the adopted backup route establishment for the QoS routing protocol is presented. The developed method includes 2 significant steps like a) backup route establishment, b) primary route establishment. In the primary stage, a self-adaptive harmony search is used to discover the routes. A backup routing protocol is established in the subsequent stage. Moreover, the possible network breakdown, and node, is recognized and backup routing is started. Hence for the recognition of failures, a path evaluation model is decided [9] on the basis of the metrics interference [8], congestion status and energy drain rate [7], are evaluated. Formerly failure is identified, back up routes are recognized and transmission is redirected on these backup routes.

In a directed graph $G(V,E)$, a communication network is experimented, whereas V indicates the group of nodes indicates the routers and E indicates the set of edges which indicates the connections among the routers. For a network aiding multiple QoS metrics, every edge (i,j) is linked with four independent metrics of possessing numerical value from zero to one. The values of dynamic resource availability, static resource capacity, neighborhood quality, link quality, are set.

Self-adaptive Harmony Search approach for route discovery: In this primary path chosen approach, self-adaptive Harmony Search is used to discover the probable number of routing paths on the basis of the link metrics [11].

Initialization: Initially, the population is initialized. The values of dynamic resource availability, static resource capacity, neighborhood quality, link quality.

Fitness model: In the network, the fitness model for each route is on the basis of several parameters such as node's dynamic resource availability, static resource capacity, link quality, and neighborhood quality, in such a manner which it fulfills set of QoS requirement. Every parameter is allocated with a weight. These weighted parameters are integrated into a single function that is called a fitness model. The fitness model should least the total cost TC and it is computed by exploiting the eq. (6).

$$TC = \sigma * SRC + \gamma * DRA + \delta * LQ + \lambda * NQ \quad (6)$$

In eq. (6), NQ indicates neighborhood quality, SRC indicates the static resource capacity, LQ indicates link quality, and DRA indicates dynamic resource availability.

The Harmony Search approach is an intelligent optimization algorithm. Its concept is obtained from music relating to the application. In this optimization process, each N -dimensional best solution is considered as one attractive harmony, and this optimization process is considered as the musician's enhancements.

The PAR and HMCR impact the local and global searching effectiveness, correspondingly. The BW and PAR influence the convergence speed in the multi-objective optimization issue. Hence, the rational parameter configuration is pivotal to the effectual operation of the approach. In existing HS, the parameters are constant values. To raise the searching effectiveness of the Harmony Search, a new enhancement concept that is variable approach parameters is presented [10]. This approach has known the self-adaptive HS method. Incomplete parameters of the proposed algorithm deviate with the search number for the enhancement of the convergence effectiveness [12]. It can be stated as below:

$$\begin{cases} PR(t) = PR_{min} + (PR_{max} - PR_{min})\left(\frac{t}{NI}\right) \\ B(t) = B_{max} \exp\left[Ln\left(\frac{B_{min}}{B_{max}}\right)\left(\frac{t}{NI}\right)\right] \end{cases} \quad (7)$$

In eq. (7), $PR(t)$ indicates the PAR value for the iterative variable t, PR_{min} and PR_{max} represents the present extreme value of the PAR, $B(t)$ indicates the BW value for the iterative variable t, B_{min} and B_{max} represents the present extreme value of the BW, and NI indicates the utmost search number.

In the proposed method, BW and PAR deviate as stated by the stated rules. Nevertheless, the solution assessment information as stated by the objective model is not contemplated. Moreover, the fine-tuning of HMCR is not contemplated in the proposed algorithm; it could evade the local optimum. To enhance these issues, the parameters are stated as below:

$$\begin{cases} HR(t) = HR_{min} \exp\left[\chi(t) + \left(\frac{t}{NI}\right) Ln\left(\frac{HR_{max}}{HR_{min}}\right)\right] \\ PR(t) = PR_{min} + (PR_{max} - PR_{min})\left(\frac{t}{NI} + \chi(t)\right) \\ B(t) = B_{max} \exp\left[\chi(t) + \left(\frac{t}{NI}\right) Ln\left(\frac{B_{min}}{B_{max}}\right)\right] \end{cases} \quad (8)$$

In eq. (7), $HR(t)$ indicates the HMCR value for the iterative variable t, HR_{min} and HR_{max} represents the present extreme value of the HMCR, $\chi(t)$ indicates the feedback factor for the iterative variable t, the feedback factor $\chi(t)$ records the evaluation information for the iterative variable t, and the $\chi(t)$ as stated below:

$$\begin{cases} t < 3 \Rightarrow \chi(t) = 0 \\ t < 3 \Rightarrow \begin{cases} \chi(t) = -\exp\left(-\left|\rho(t-1)\rho(t-1) > 0\right|\right) \\ \chi(t) = \exp\left(-\left|\rho(t-1)\rho(t-1) \le 0\right|\right) \end{cases} \end{cases} \quad (9)$$

$$\rho(t-1) = \frac{r(t-1) - r(t-2)}{r(t-2)} \quad (10)$$

In eq. (10), $\rho(t-1)$ indicates the search consequence deviation ratio for the iterative variable $t-1$, and $r(t-1)$ indicates the search result for the iterative variable $t-1$.

The proposed method uses a self-adaptive parameters modification model that comprises dynamic parameters. Fig. 2 exhibits the best possible solution search procedure of the proposed method.

4. Results and Discussions

4.1. Simulation Setup

In this section, the experimentation of MANET and the simulation outcomes of the developed backup routing protocol were presented. Moreover, the performance evaluation on the basis of the 3 metrics was done.

In order to develop theBackup Route Establishment for QoS Routing Protocol (BREQRP) it has experimented in NS2. For MANETs as the MAC layer protocol, the IEEE 802.11 was utilized. It has the functionality to inform the network layer regarding link breakage. For experimentation, the packet sending rate is deviated as 250,500,750 and 1000Kb. The area size was 1250 meter x 1250 meter square area for 50 seconds of experimentation time. Here, the experimented traffic was CBR. Moreover, the experimentation settings and parameters are explained in Table 1.

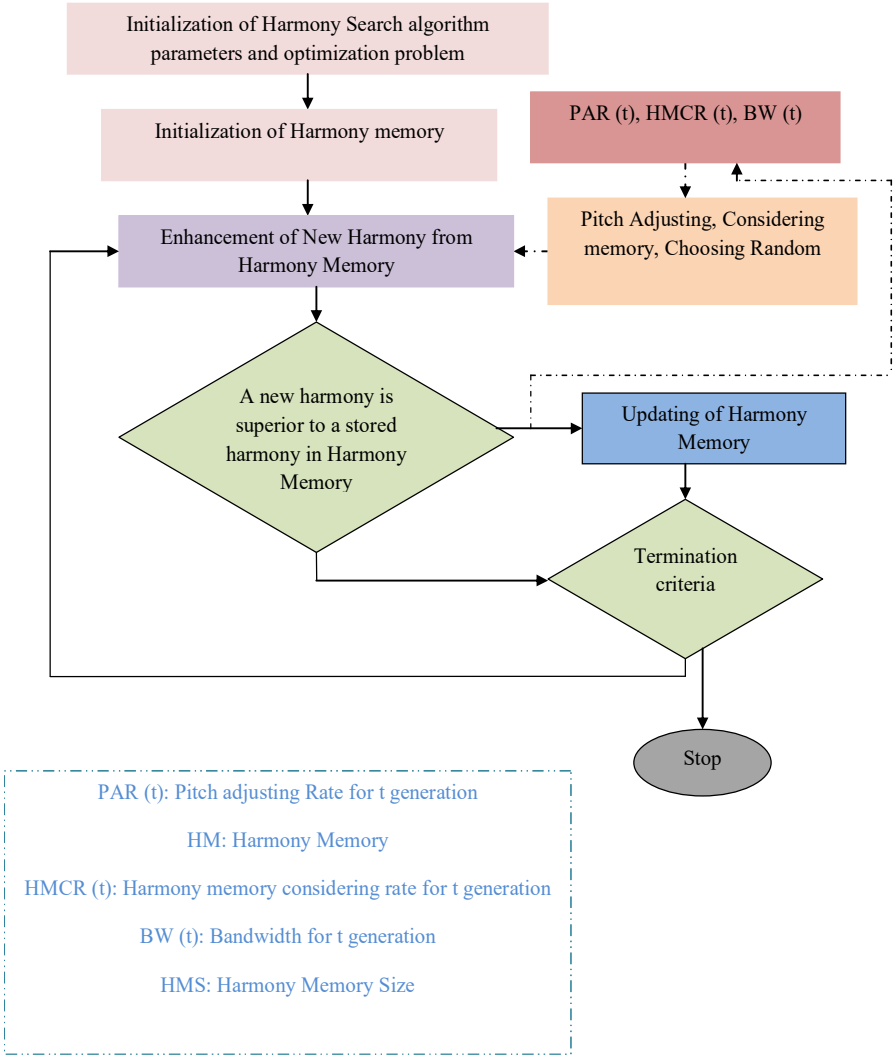

Fig. 2. *Flow chart of the proposed self-adaptive Harmony Search algorithm*

Table 1. *Simulation parameters*

No. of Nodes	30,50,70,90 and 110
Speed	10,20,30,40 and 50m/s
Area	1250 X 1250
Propagation	TwoRayGround
Simulation Time	50 sec
Antenna	Omni antenna
Rate	250,500,750 and 1000Kb
Traffic Source	CBR
MAC	802.11

The performance of the novel protocol chiefly consistent with the following parameters is presented. Moreover, the performance of the proposed method is evaluated with conventional techniques like ABC, PSO, and GWO. Here, the delivery ratio indicates the ratio of the number of packets received effectively and the total number of packets transferred. Moreover, the throughput represents the number of data that can be transmitted from the sources to the destination=. The delay indicates averaged generally surviving data packets from the sender to the receivers.

4.2. Performance Analysis

Fig. 3 demonstrates the analysis of the proposed method for the delivery ratio with respect to the Rate (Kb). Here, the proposed method is 25% better than the ABC, 29% better than the GWO, and 31% better than the PSO algorithm with respect to the rate (Kb) at 250.

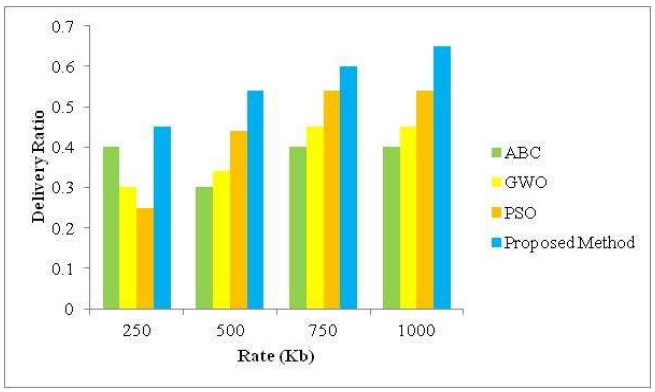

Fig. 3. *Analysis of the proposed algorithm for Delivery Ratio*

Fig. 4 exhibits the analysis of the proposed algorithm for the delay with respect to the Rate (Kb). Here, the proposed algorithm is 15% better than the ABC, 19% better than the GWO, and 21% better than the PSO algorithm with respect to the rate (Kb) at 250.

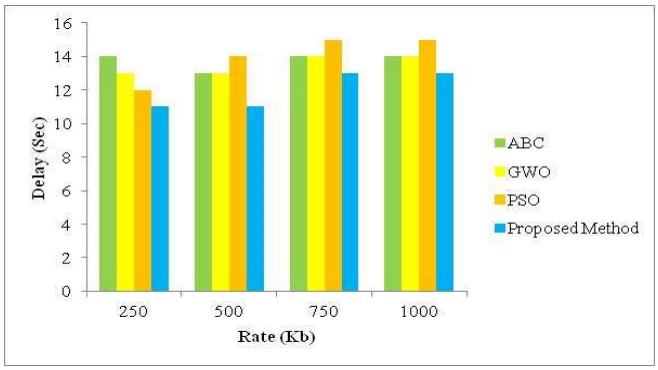

Fig. 4. *Analysis of the proposed algorithm for Delay*

Fig. 5 exhibits the analysis of the proposed technique for the throughput with respect to the Rate (Kb). Here, the proposed algorithm is 16% better than the ABC, 18% better than the GWO, and 16% better than the PSO algorithm with respect to the rate (Kb) at 250.

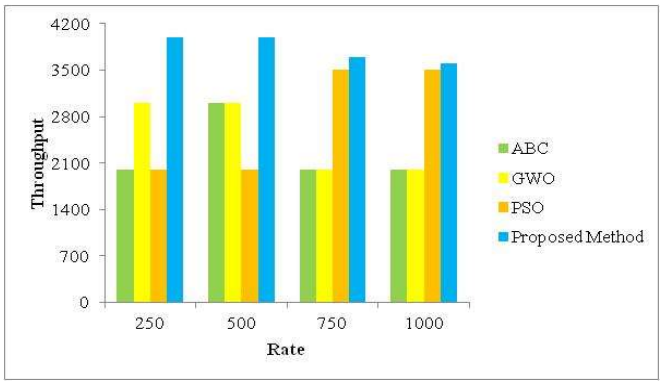

Fig. 5. *Analysis of the proposed algorithm for throughput*

5. Conclusion

For the QoS routing protocol, the backup route establishment was proposed in this paper. By exploiting the two significant stages, the proposed model was done. At the first stage, the main routes were identified exploiting the Self-Adaptive Harmony Search-based routing approach whereas, link quality metrics were integrated. In the next stage, the path evaluation model was used to discover the node failure by exploiting the interference, energy, and congestion. The possible malfunctions of network and node were recognized in this protocol and a backup routing is initiated. While the detection of the malfunction, back up routes were established and transmission was redirected based on these backup routes. Finally, experimentation outcomes exhibit that the proposed protocol has enhanced throughput

and minimized recovery delay. Moreover, the performance of the proposed method is superior to the conventional algorithms with respect to the delay, with respect to the delivery ratio and with respect to the throughput.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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