An Intelligent Channel Assignment Approach for Minimum Interference in Wireless Mesh Networks Using Learning Automata and Genetic Algorithms

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Abstract

Multi-radio multi-channel WMNs are innovative technical kind of WMNs, i.e., the nodes with multi radios and numerous channels for communication. In wireless mesh routers of WMNs, multiple network interfaces caused due to multiple channels typically increases the network throughput, i.e., in multi-channel WMN, whenever two neighboring nodes transfer information using the similar channel, they might interfere with one another and eventually decreases the throughput. Thus, there is a need for an effective approach to reduce network interference and significantly enhance throughput. This paper primarily concentrates on issues of multicasts channel assignment in WMNs to diminish the interference in the network. The adaptive decision-making strategy of learning automata and strong searching capability of the genetic algorithm is employed in this approach. The methodology combined multicast tree construction and channel assignment, to evade that channel assignment could not function well with the specific multicast tree. In this paper, the initial multicast tree construction by learning automata and the optimal channel assignment is performed by genetic algorithm. The experiment outcomes for the suggested methodology is carried out using NS2 and performance efficiency is matched with LAMR, LCA, and GA based multicast channel assignment approach and suggested higher performance using packet delivery ratio, an end to end delay, throughput and total cost.

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1 Introduction

Throughout, the preview few decades, there is a growth in the numerous internet users that tend to the expansion of applications and tools using huge network devices to fulfill the customer needs. These resources are given to customers through diverse kinds of networks such as wired or wireless. Towards this, distinct forms of networks are evolving to be a novel dominant technology known as wireless mesh networks (WMNs). These networks are a distinctive kind of ad hoc network which is self-configured, self-curing, and cost efficient. In addition to this, WMN has numerous benefits compared to conventional wireless networks like robustness, better coverage, lower up-front price, and flexibility in maintenance and deployment [4–8]. Nowadays, WMNs are considered as one of the most significant technology for constructions of wireless equipment as they are evolving. WMNs form the pillar for the subsequent generation transmission in domains with higher population density, and commercial offices are integrating with recent techniques like IEEE 802.11 Wireless LANs (WLANs), LTE/4G and 5G over a unique framework.

WMN working with multi channels and multi radio are therefore denoted as MCMR WMNs [21, 22]. In this network, the cost of each node is not a concern and hence, every node may have many radio interfaces typically lesser than or equivalent to a number of accessible channels [9–11]. In this way, the nodes can transfer and receive data through dissimilar channels concurrently [12]. The efficiency of these MRMC WMNs is primarily defined using features such as the network topology, effective Channel Assignment (CA) and Routing Protocols. The Literature on approaches for channel assignment problems in MRMC WMNs has been investigated considerably for unicast communications. In the current survey, most of the assignment issues in WMNs primarily concentrates on multicast communication.

Multicast communications are beneficial in transforming data amongst different physical tools like wireless sensors [23]. The controlling devices gather and accumulate the data packets received from physical devices and transmit to numerous devices or customers. Additionally, when these controlling devices receive packets, they disseminate them to certain targeting devices or customers. The multicast nodes could transmit similar information flow to several targets deprived of generating the replicated flow and wasting bandwidth. Thus, the eventual intention of the minimal interference channel assignment approach is to allot transmitting channels to wireless machines appropriately as to diminish network interference amongst nodes.

One of the topmost challenge existing in both wireless and wired communication through multicast is the network interference caused among different machine equipment. In wireless mesh routers of WMNs, multiple network interfaces caused due to multiple channels typically increases the network throughput, i.e., in multi-channel WMN, whenever two neighboring nodes send data using the similar channel, they might interfere with one another and eventually minimize the throughput. Thus, there is a need for an effective approach as to diminish network interference and significantly augment the throughput. The better approach to diminish interference in WMNs is to alloy diverse channel to every wireless machine in place of using similar channel. Nevertheless, there would not be sufficient channels available to employ in the similar time period. So, an effective channel assignment technique is essential to reduce the whole network interference. Thus, in this paper, a multicast tree construction and intelligent channel assignment are performed using learning automata and genetic algorithm respectively. The aim is to explore for lower cost routing trees where the channel assignment produces minimal interference.

1.1 Organization of the Paper

A brief introduction to Wireless Mesh Network is given in this section. Survey on existing approaches in Wireless Mesh Network is given in Sect. 2. The proposed optimal channel assignment algorithm using learning automata and genetic algorithm is briefly explained in Sect. 3. The experiment outcome and its analysis are given in Sect. 4, followed by conclusion given in Sect. 5.

2 Literature Survey

Similar to mobile ad-hoc networks (MANETs) [1], WMN is likewise a kind of self-constructing wireless network. Nevertheless, there are three significant variances amongst themselves. Initially, nodes in MANETs move frequently whereas mesh routers are usually static. Subsequently, in MANETs entire mobile nodes function in peer-to-peer manner and every node transmits packets for another nodes, whereas in WMNs a hierarchy is built where the mesh routers constructs a pillar and mesh clients could merely employs its related mesh routers. Then, a mobile node in MANETs is usually armed with a single radio whereas the mesh router in WMNs is armed with minimum of two radios.

In previous years, the numerous scholars addressed the issue of multicasting and channel assignment for wireless communication. In [8], Level Channel Assignment (LCA) multicasting methodology is proposed the methodology in two phases. Initially, it builds a multicast tree depending on the breadth-first search (BFS) approach to reduce hop count distances amongst the source and receivers. Subsequently, it employs a methodology to allot channels for reduction of interference. Tabu search and disseminated greedy approach for channel assignments was suggested in [6]. In this approach, the scholar addressed the issue of channels assignment for network transmission with the intension to reduce the complete network interference. They introduced a semi-definite platform construction for optimization issues to attain a lower bound on the entire interference that minimizes with the maximum number of radios.

Furthermore, it is observed from decades that the intelligent computational approaches are likewise robust to offer multicast routing and channel assignment [16–18]. In [16], the multicast tree construction employing Tabu search approach is given. In [17], genetic algorithm is employed for the construction of multicast tree. Varied length chromosomes and their genes are employed for encrypting issues. The crossover operator interchange fractional chromosomes at location autonomous crossing places and the mutation operator conserves the genetic discrepancies of the population. Genetic algorithm is widely employed resolving the QoS multicast issues in numerous wired multimedia networks [2] and optical networks [3].

More recently, In [18], multicast routing and channel assignment employing computational intelligence approach is given. This study introduced an integrated standard that comprises of problem creation, the outcome illustration, the fitness evaluation, and channel assignment approaches. Particularly, the concentration is on the issues channel assignment for multicast construction in MCMS WMNs. Channel assignment issues for multicast construction has merely investigated in [8, 24, 25]. In [25], a novel channel assignment approach known as unidirectional channel assignment strategy (UCAS) depending on uni-directional connection prototype, and an effective greedy

vertex coloring approach known as breadth first vertex coloring (BFVC). In [8], MCM approach was illustrated and in [24] channel assignment approach known as minimal interference MCMR multicast (M4) approaches was illustrated.

The capacity aware link scheduling and channel assignment was proposed in [7]. In this approach, the scholar introduced the issue of channel assignment to be a linear programming (LP) problem in addition to the restrictions and further build the connections and channel assignment matrices. These matrices are formed with the support of suggested measures. Lastly, link and channel assignment are accomplished depending on the introduced measures. In [13], the centralized load-aware assignment approach is suggested however this approach to stable in nature and needs complete network knowledge prior to assigning the channel. In this approach, the initial multi-channel multi-hop wireless ad-hoc network framework is evaluate that could be constructed through standard 802.11 hardware using the armed nodes with numerous Network Interface Cards (NICs) working on diverse channels. In [14, 15], a multiple channel WMN framework is presented which is known as Hyacinth that holds every mesh network node using several 802.11 NICs. A distributed approach is suggested that uses merely localized traffic load data to enthusiastically allot channels and to re-route packets, and matches its efficiency in contrast to a centralized approaches that employs the similar functions. When matched to these approaches, the suggested algorithm, UBMR-CA, builds the multicast tree vigorously having the utility, i.e., an amalgamation of load, capacity, and interference. The utility fluctuates with time and is further employed for channel assignments.

3 Proposed Optimal Channel Assignment Approach using LA and GA

An intelligent technique using learning automata and genetic algorithm is introduced in this section to build a multicast routing algorithm with minimal interference within MRMC WMN. Selecting the relaying nodes in WMN to build a multicast routing algorithm is NP problem. The multiple radios present in every node could dynamically be adjusted on multiple channels that makes multicasting in WMN a more complex task. For this purpose, genetic algorithm and learning automata based routing protocol is introduced. The adaptive decision making strategy of leaning automata and strong searching capability of genetic algorithm is employed in this approach. The diagrammatic representation of the suggested methodology in two different phases is given in Fig. 1. The methodology integrated the construction of multicast tree and channel assignment, thus evading that the channel assignment could not function well with the
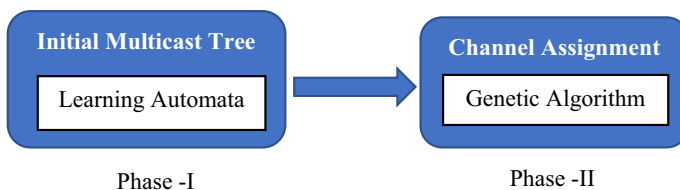

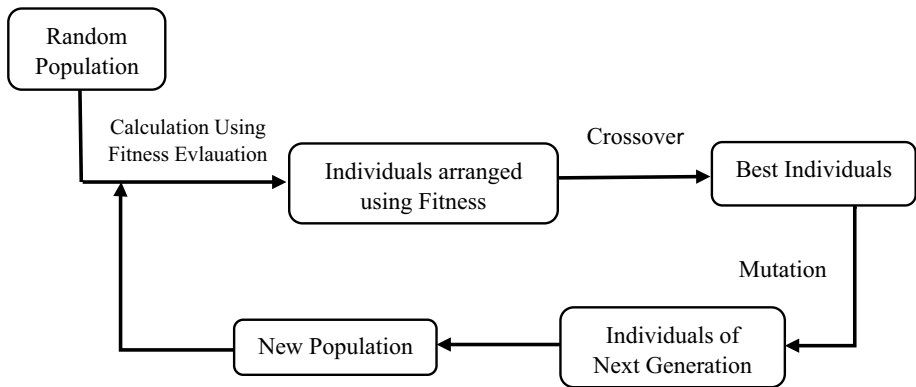**Fig. 1** Block diagram of the suggested approach

Fig. 2 Flow chart of genetic algorithm

defined multicast tree. The proposed approach is developed in flowchart representation as shown in Fig. 2.

- In the initial stage, the multicast tree is build considering available multi radio multi channels using Learning Automata.
- In the second phase, from constructed multicast tree, channel assignment is accomplished with minimum interference using Intelligent Genetic Approach.

3.1 Multicast Tree Construction Using Learning Automata

A Learning Automata (LA) is an adaptive decision-making element which enhances its functionality through learning the selection an optimum event from a finite group of permitted action through recurrently communicating with the arbitrary environment. This estimates the action considered and responds using the reinforcement signals. LA further updates its internal information according to its preferred action and obtained reinforcement signal. The WMN comprises of mesh clients (MCs), mesh routers (MRs), and mesh gateways (MGs). Every MR comprises of some static radio interfaces. Let, WMN is denoted as $G = (V, E)$, where $V = \{v_1, v_2, v_3 \ldots v_n\}$ is the set of MRs and $E = \{e_1, e_2, e_3 \ldots e_n\}$ is the group of edges or communication links in the WMN.

The multicast tree is constructed in a way that there persists a minimal end-to-end delay for fluctuating traffic challenges. Multicast routing is given as the routing from any single node to numerous receiving nodes. The network interfaces cards (NIC) of the mesh nodes is divided into Down-NIC (DNIC) and Up-NIC (UNIC) while every node is merely responsible to assign channels to its DNIC. The LA is residing at the ith DNIC of each mesh node j, referred to as LA_{ij}, decides on which channel, the DNIC N_{ij} should send data to UNIC N_{in}, with n being a member of the node j's one hop downlink neighbors.

Primarily, the LA residing at DNICs of multicast source node denoted as j, are activated simultaneously. The activated learning automaton LA_{ij}, picks an event pertaining to its Action Probability Vector (APV). N_{ij} communicates with UNIC N_{im} where $m \in P(j)$, where denotes a set of one-hop downlink neighbors which have a potential to be actual neighbor of j. Further, a R_{Req} (Route Request) message is generated by multicast source, then the channel chosen by LA_{ij} and index of the associated node are inserted in the fields

C_{list} i.e., Channel List and ID_{list} of the message, respectively. The generated message is further sent by N_{ij} to all N_{im}. This is performed by entire LA present on entire DNICs of multicast source node simultaneously. The LA_{im} present on ith DNIC of every intermediate nodes m is activated upon receiving R_{Req} message at ith UNIC Rim. Then it chooses one of its actions pertaining to APV. The chosen channel and ID of the corresponding node, say m, are appended to fields C_{list} and ID_{list}, respectively. Also the value of TTL i.e Time To Live field of the message is decreased by one and finally the incoming message is sent to all radios N_{ik}, where $k \in P(m)$. The R_{Req} messages are relayed across the ith UNIC and DNIC of network nodes until reach one of multicast receivers. Upon receiving the message in a multicast receiver, the receiver performs two tasks. They are:

- Initially, it acts like an intermediate node such as minimizes the TTL of arriving message and relays it to its one-hop neighbors due to the presence of the other receiver nearby. In this situation, numerous hops from source to the two receivers might be same and thus, the additional duplicate packets are evaded.
- Subsequently, receiver node duplicates the message and changes its type to R_{Rep} (Route Reply). Also, its ID as a discovered receiver node is inserted into field DR of duplicated message and then duplicated message is sent to ith UNIC of multicast source using dijkstra algorithm.

As its feedback mechanism, upon receiving the R_{Rep} message on ith UNIC, the multicast source examines the DR field of the arriving message. Incoming message is discarded in case the R_{Rep} message has been previously received from the receiver node who's ID is inserted into field DR. The reason is that round trip time of the previously R_{Req} message is less than recently arriving message which implies less end-to-end delay. Otherwise, the multicast source sends a Reward message to entire nodes who's IDs is stored in field ID_{list} of the R_{Rep} message which form a new discovered path from the source to the receiver.

Intermediate nodes update their routing tables as well as their APVs according to the learning rule upon receiving the Reward message. In this step, the radio-channel association using the field C_{list} of the Reward message (i.e., the channels previously chosen by the LAs) is tuned too. Multicast source then waits t time steps to receive R_{Rep} messages from other multicast receivers on its ith UNIC. Once the source receives a R_{Rep} message from entire multicasting receivers on all its k UNICs, where $2k$ is the whole number of NICs per each node, above process is terminated. In this case, the initial multicast tree has been constructed and the second phase starts.

3.2 Channel Assignment Using Genetic Algorithm

A link could not be employed for data communication till a wireless communication channel is assigned. To assist these multiple cast transmission on routing tree, a suitable channel need to be used for every connection of tree in order to obtain the minimal interference. In this stage the minimal interference is achieved using Genetic Algorithm (GA). GA is a stochastic metaheuristic optimization approach that builds the genetic standards of Darwinian Theory and Mendelian standard of inheritance. For minimal-interference assignment issue, an intelligent approach is introduced that intends to minimize both conflicts in channel and source utilization. Collection of perpendicular channels like $K = 0, 1, \ldots, k(k \geq 2)$ are provided.

There are several key components in Genetic Algorithm. They are: genetic illustration, population initialization, fitness evaluation, selection, crossover and mutation. Chromosomes are represented using tree data structure. The primary population searches for genetic variations and likewise exploits the information that is priori obtained. Fitness evaluation gives the complete channel variation in multicast tree. Distinction operations like crossover and mutation effectively improves exploration ability. Note that each stage assures that a tree do not interrupt the delay constriction. The population progresses continuously till it converges.

3.2.1 Operation in Genetic Algorithm

1. *Population Initialization*: Every chromosome represents a potential solution. The generic approach is initializing chromosomes in order to discover genetic diversity for every individual, its complete paths are produced arbitrarily. A random path is explored source i to $j \in R$ arbitrarily choosing a node v_1 from $N(i)$, the adjacent of i. Further, a node v_2 from $N(v_1)$ is arbitrarily choosen. This approach is iterated till j is reached. Consequently, an arbitrary path $PT(i,j) = \{i, v_1, v_2, ..., j\}$. As loop is not permitted on constructed multicast tree, the nodes that are priori comprised in the present tree is omitted by restricting the re-occurrence of similar node.

2. *Selection*: This is significant in enhancing the average eminence of population through transmitting higher quality chromosomes to subsequent iteration. The chromosome selection depends on its fitness value. The selection of pair-wise tournament deprived of replacement [20] technique is used in this paper since it is simple and effective.

3. *Fitness Function*: The quality is assessed accurately using the fitness function. In this paper, a lower cost multicast tree is evaluated to attain minimal interference channel assignment. The aim of this issue is to diminish the above given complete channel variation, as it consequences in enahcing the system output. Amongst, the group of candidate solutions such as multicast trees having identical minimal channel variance value and minimum tree cost is picked. The fitness evaluation merely comprises of total channel conflict. The fitness of chromosome C_i denoting the multicast tree T), referred to $F(C_i)$:

$$F(C_i) = [I_T(f) + 1.0] \quad [8]$$

where $I_T(f)$ is the total channel conflict on the tree T which is given as:

$$I_T(f) = \left| \{(i_c, j_c) \in E_c | f(i_c) = f(j_c), i_c \in E_T, j_c \in E_T\} \right|$$

Here j_c, i_c are the nodes of a conflict graph $G_c = (V_c, E_c)$, function $f(i_c \in E_T) = \{j | j \in K\}$, E_T are links of multicast tree $T(V_T, E_T)$ and $K=\{0,1,2,...k\}$ is the group of accessible channels.

4. Crossover and Mutation: The GA depends on two elementary genetic operations such as crossover and mutation. The crossover accomplishes present outcomes so as to discover good ones. Mutation assists GA in keeping away from local optimum [17]. The form and execution of operations hinges on encrypting and similarly on the issue. The chromosomes are expressed using the multicast tree and single point crossover is employed that exchanges the partial chromosomes at positional autonomous crossing locations amongst two chromosomes [17]. Using the crossover probability, at every iteration,

two chromosomes C_i and C_j are used. In C_i, there is a way comprising of two segments: $(s \xrightarrow{C_i} v)$ and $(v \xrightarrow{C_i} r_i)$. In C_j, there is a way comprising of two segments: $(s \xrightarrow{C_j} v)$ and $(v \xrightarrow{C_j} r_j)$ The crossover interchanges paths $(v \xrightarrow{C_i} r_i)$ and $(v \xrightarrow{C_j} j)$.

The population will perform the mutation operator once crossover is accomplished. Considering mutation likelihood, for every iteration, Ch_i is selected where one receiver r_i is arbitrarily choosen. On the path $(s \xrightarrow{C_j} r_j)$ is chosen as mutation point referred to v. The mutation would substitute the path $(v \rightarrow r_j)$ with a novel haphazard path. All new chromosomes generated using crossover or mutation accept the delay constriction as has priory considered.

4 Experimental Results and its Analysis

The experimental results for the proposed channel assignment approach is wireless mesh network is carried out using Network Simulator-2 (NS2). A 100-node MCMR WMN was randomly generated and used in all conducted experiments. Also, each data point reported in this approach are averaged over the results of ten different runs. In this approach, the efficiency of different methods is measured using end-to-end delay, average throughput, average packet delivery ratio, and total tree cost with the following definitions.

- *Average packet delivery ratio* This is defined as packets obtained for all multicast receivers above the packets sent by the source averaged on entire multicast receivers. This criterion specifies the packets count delivered to the multicast receivers over the packets expected to be received by multicast receivers.
- *Average end-to-end delay* This is given as the average time elapsed amongst packets send using multicast source and receiving the packets to the entire multicast receivers. This criterion is averaged on entire receivers.
- *Average throughput* This is defined as the number of packets obtained by receiver over the needed time to provide the number of packets averaged on entire multicast receivers.

$$\text{Average Throughput} = \frac{1}{|MRS| \times RT} \sum_{i=1}^{|MRS|} NRP(MR_i)$$

where $NRP(MR_i)$ refers to the number of obtained packet at ith multicast receiver. Also $|MRS|$ specifies cardinality of multicast receiver set and RT is the required time to deliver the number of packets.

- *Total cost* This is defined as the number of links forming multicast routing tree.

The efficiency of the proposed optimal channel assignment approach using LA and GA are compared with the three existing three approaches such as LAMR [19], LCA [8] and GA [20] based approach. The parameters employed for the simulation of the proposed approach is given in given in Table 1. Figures 3, 4, 5, 6, 7, 8 and 9 represents the simulation comparison of network end-to-end delay, data loss, energy consumption, energy efficiency, packet delivery ration, network throughput and cost calculation respectively.

Table 1 Parameters table for the proposed approach

Parameters	Values
Simulation period	150 ms
Coverage area	1000 * 1000
No of nodes	105
No of mesh routers	4
No of mesh gateways	4
No of mesh clients	97
Traffic type	FTP
Agent type	TCP
Routing protocol	AODV
Initial power	1000 J
Idle power	0.1 J
Queue type	Drop-tail
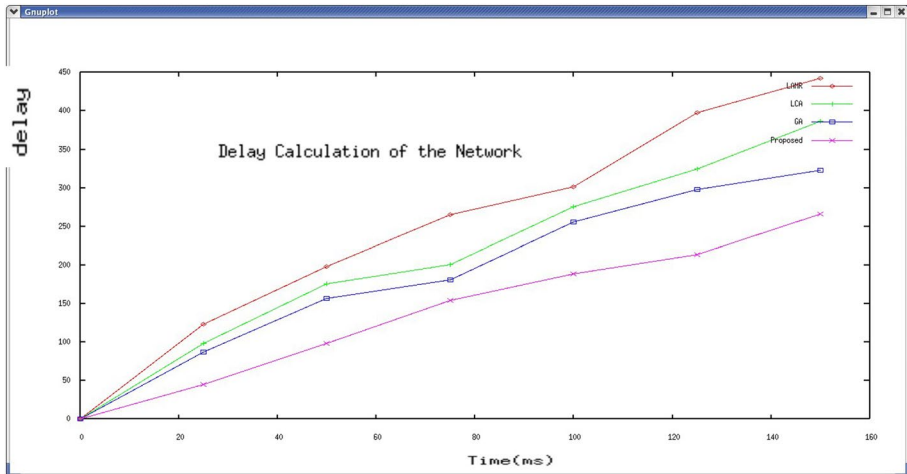
Fig. 3 Comparison of average end-to-end delay

From Figs. 3, 4, 5 and 9, it could be inferred that, the network end-to-end delay, packet information or data loss, network energy consumption and network cost estimation of the suggested intelligent channel assignment algorithm is very less compared to the other existing approach such as LAMR, LCR and GA based Channel Assignment Approach. From Figs. 6, 7 and 8, it can be inferred that, the network energy efficiency, packet delivery ratio and network average throughput of the suggested intelligent channel assignment approach is high when compared to the other approach such as LAMR, LCR and GA based Channel Assignment Algorithm.

The proposed intelligent approach utilized minimum end-to-end delay packets since the time taken to select an optimum path is less compared to other assignment approaches. The average throughput of the proposed approach is more as it attempts to build a multicast tree with minimum contention in every iteration of Learning Automation stage. The proposed
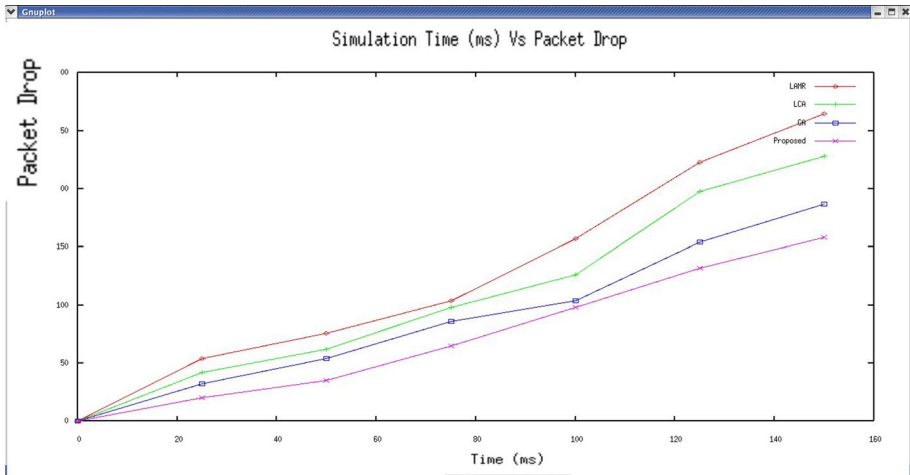
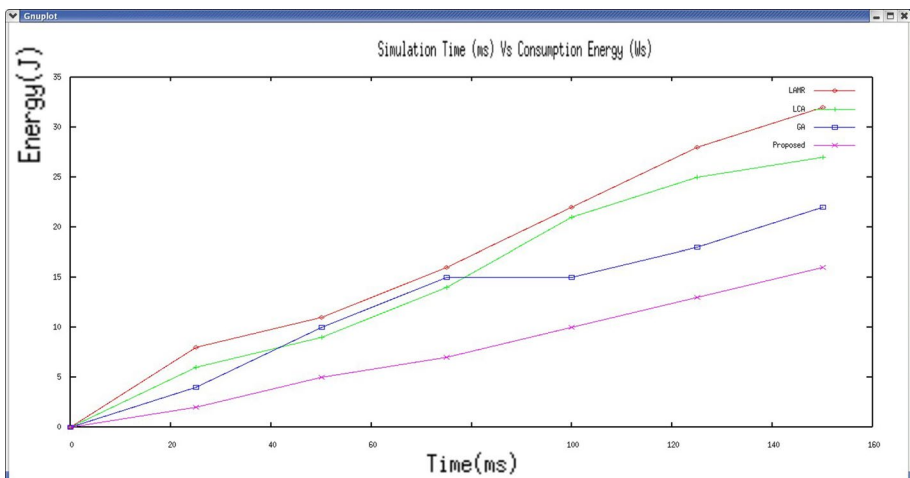**Fig. 4** Comparison of data loss

Fig. 5 Comparison of energy consumptions

approach utilizes available channel pool such that minimum interference multicast tree is constructed and hence, the average packet delivery ratio rises with increasing the number of available channels.
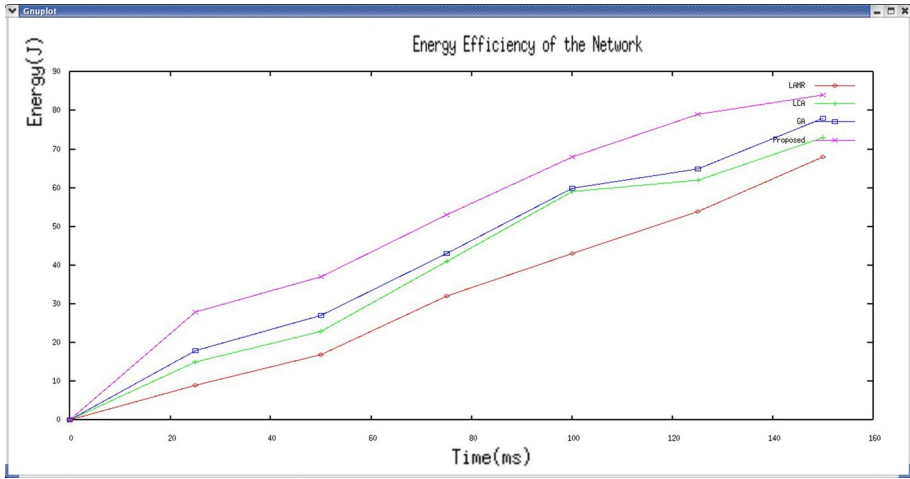
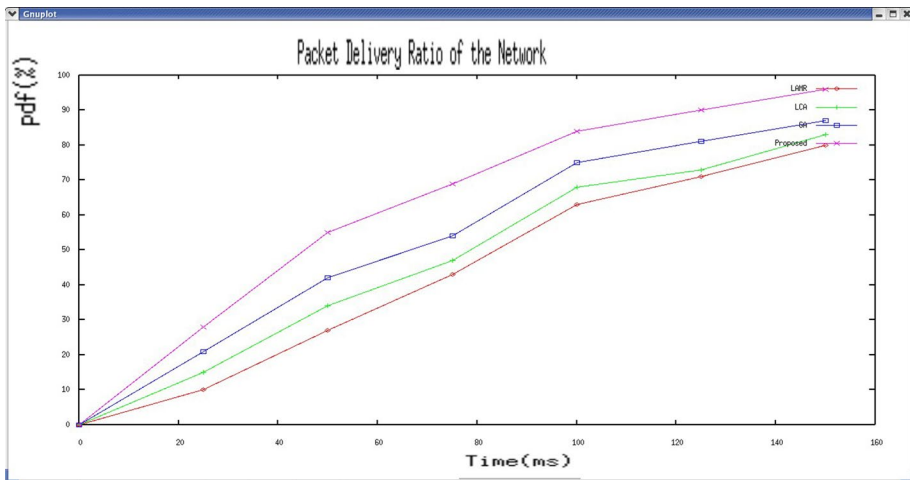**Fig. 6** Comparison of energy efficiency

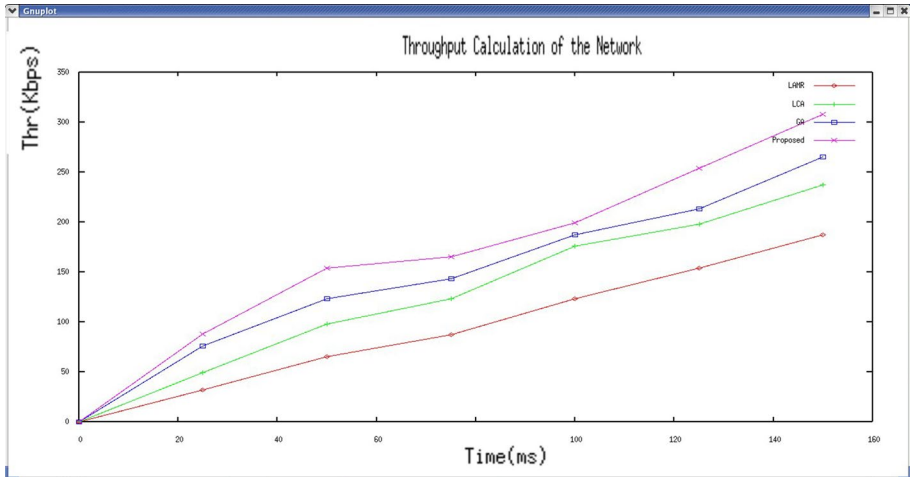**Fig. 7** Comparison of packet delivery ratio
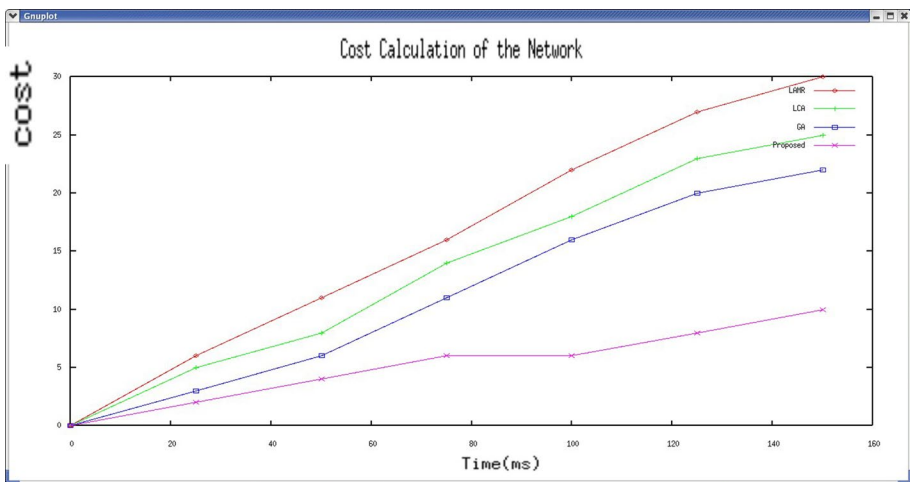
Fig. 8 Comparison of network throughput

Fig. 9 Comparison of cost calculation

5 Conclusions

In this paper, an intelligent channel assignment approach using learning automata and genetic algorithm is introduced so as to reduce network interference caused due to MRMC WMN and to significantly enhance network throughput. Better ways to minimize interference is to allot diverse channel to every wireless machine instead of employing the similar channel by constructing an optimum initial multicast tree. Thus learning automata is employed for multicast tree construction and genetic algorithm for channel assignment. The performance of the proposed approach is simulated using NS2 and performance measures like packet delivery ratio, end to end delay, throughput and total cost is matched with LAMR, LCA and GA based channel assignment approaches.

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