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Collision avoidance and dynamic slot scheduling in multi-hop TDMA based ad-hoc networks using genetic algorithm

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***Abstract*—Collision free dynamic slot scheduling in ad-hoc networks is NP complete problem. In most of the distributed networks, scheduling is performed by cluster heads or relay nodes. A sophisticated method is needed for nodes to perform dynamic schedule on their own and update the state of resources. Recently, neural network and few heuristic approaches are used to solve the problem. In this paper, we propose a heuristic based method on the idea of generating optimal solutions. The arithmetic crossover and cyclic permutation use random generated slot vectors of neighbors, broadcast during the scheduling period to create an initial population. The technique uses elitism to highlight one-hop and two-hop collisions and makes the information usable in finding valid solutions. The operations provide optimal scheduling solutions which are used in next generation. The method increases collision avoidance probability and channel utilization in terms of scheduling maximum transmissions in a TDMA frame.**

***Keywords*—Ad-hoc network, collision avoidance, genetic algorithm, slot scheduling, time division multiple access**

I. Introduction

Ad-hoc networks are mostly decentralized, provide better reliability and reduce connection setup time. On wireless channel, the key issue is to determine who gets to use the channel when all are accessing it simultaneously. An example of five-node network is shown in Fig. 1a which highlights primary and secondary transmission conflicts. Here, nodes N_3 and N_5 can simultaneously transmit to their receivers but nodes N_3 and N_1 cannot because of having N_2 as a common receiver. Irrespective of this primary conflict, collisions can also occur when two or more packets arrive at a node is a single time, though the receivers are different. Based on these transmission constraints, the challenge of dynamic slot allocation has become global coordination of all nodes which participate in communication.

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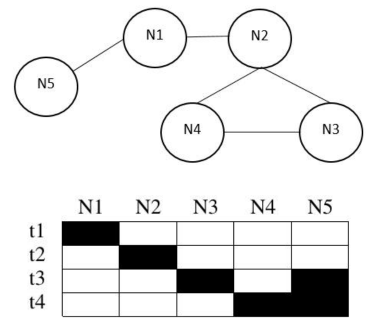

$$C = \begin{bmatrix} 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix} \qquad S_{cf} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{bmatrix}$$

Figure 1. (a) Example of five node ad-hoc network, (b) valid transmission schedule of TDMA frame (c) connectivity and collision free schedule matrix

At link layer, channel access is the serious issue which needs to be considered. Nodes that are involved in sending data, seek for efficient channel access techniques which implicate less errors in terms of collisions. *Time Division Multiple Access (TDMA)* is a good choice specially for voice data, fax, short and broadcast messages. In TDMA, time slots which are assigned to nodes can be fixed or dynamic. In fixed assignment, slot for each node is fixed while in dynamic approach, each frame has one or more slots, assigned to each traffic node. The later approach saves the bandwidth which can be reserved for future use.

The primary objective is to avoid collisions in multi-hop networks and provide dynamic slot schedule of TDMA frame, where many nodes can transmit simultaneously in a single time slot. The secondary objective is to increase network throughput with maximum use of single channel. Once the optimum transmission pattern is decided it can be used for next TDMA cycles. The nodes get dynamic slot assignment depend on application level data and need intelligent exploitation of random search provided with the data to better search the region of good performance in solution space. Heuristic based approaches are commonly used to generate high quality solutions for problem optimization and search problems. Many heuristics based algorithms were proposed which eliminates transmissions constraints but focused more on fixed slot assignment.

In this paper, we modify genetic algorithm (GA) in order to avoid multi-hop collisions and dynamic slot scheduling. Simple arithmetic based crossover and mutation maintain diversity in the solution and reduces computation time. Elitism creates opportunities towards finding a better solution and an additional reverse process generates collision free transmission schedule.

The paper is organized as follows. Section II describes problem formulation. Section III discusses related work in the same field. Section V describe the proposed modified genetic algorithm for collision avoidance and dynamic slot scheduling. Section VI and VII show results and concludes the paper respectively.

II. Problem Formulation

To demonstrate the effectiveness of collision free dynamic slot scheduling we consider a graph $G = \{N, L\}$ in Fig. 1a, where $N = \{N1, N2, \ldots\ldots, N5\}$ is the set of nodes connected with link L of undirected edges, where $L = \{(N1,N2), (N1,N5), (N2,N3), (N2,N4), (N3,N4)\}$. Each node is directly connected with at least one $(\delta(G) = 1)$ or more nodes if has a link between them and described by an NXN connectivity matrix C, shown in Fig. 1c which is described as

$$c_{ij} = \begin{cases} 1, & \text{if } (Ni, Nj) \, \mathcal{E} \, L \\ 0, & \text{otherwise} \end{cases}$$

In TDMA scheduling, all directly connected nodes can communicate over time slots which may change for each node over the time, denoted by MXN matrix T, describes as

$$t_{mi} = \begin{cases} 1, & \text{if } Ni \text{ transmits in } m \text{ slot} \\ 0, & \text{otherwise} \end{cases}$$

In wireless networks, nodes can transmit in a time slot only if the neighboring nodes which are one or two hop away do not use that time slot. For TDMA approach, the trivial collision free schedule matrix S_{cf} is shown in Fig. 1c. Each row of matrix denotes node and each column represents a single time slot in which nodes can transmit data. According to conventional schedule of a TDMA frame, each node must get a chance to transmit at least once, described in (1).

$$\sum_{m=1}^{M} Ni * tm > 1 \qquad \forall Ni \qquad (1)$$

The objective is to remove multi-hop collisions and creates opportunities for different pairs to transmit in same slot. The problem becomes NP-complete when each node may require more than one slot to transmit data within a frame. Every time node changes its slots selection depending on payload size produces at application level. The slots specification and other control signaling can exchange among nodes using back-off mechanism, contention and probability based approaches, e.g. CSMA/CA, ALOHA etc. Initial fixed mini slots of TDMA frame can also be used for the purpose and can apply bit mapping, binary countdown etc. to exchange required information [1][2].

III. Related Work

Many methods have been proposed for slot assignment depending on different criteria. A modified GA for packet radio network with special crossover and mutation operation is proposed for improvising algorithm efficiency [3]. The improved GA to calculate path bandwidth in TDMA based mobile ad-hoc networks were proposed which focuses on satisfying QoS requirement [4][5]. An energy efficient weighted clustering algorithm for homogeneous ad-hoc network is proposed [6]. An energy efficient multi objective GA for task scheduling is was proposed. The algorithm was designed for cloud computing and handles task allocation to virtual machines [7]. A hybrid grouping and GA based algorithm was proposed to discover regular broadcast plans in wireless mobile environment. It is generally able to solve constrained combinational search problem [8]. A method of resource allocation constraints on data link is proposed to maximize message transmissions [9]. A novel network scheduling approach based on genetic algorithm and time triggered architecture to satisfy transmission requirement in Control Area Network (CAN) of AUV control system is proposed [10].

Generally, all proposed techniques used GA with random initial population rather using significant good quality individuals. Most of the techniques used clusters or relay nodes to perform scheduling operation and focused on optimizing the size of TDMA cycle. Most of the time complex neural networks and annealing approaches are computationally heavy and may not be feasible for time sensitive ad-hoc networks. Our proposed method is focused on improving individuals by avoiding slots which are in collision and schedule them dynamically with less computations. The algorithm uses simple logical arithmetic operations to highlight multi-hop collisions and find possible simultaneous transmission opportunities. The algorithm increases collision avoidance probability with increase in channel utilization.

IV. Genetic Algorithm

Genetic Algorithm (GA) is based on heuristic search which reflects the process of natural selection based on fitness of individuals. Individuals are selected for the reproduction in order to produce offspring of next generation. In GA, each solution is represented by a set of gene joined into binary string, known as *chromosome* which collectively creates population. Each chromosome is itself a solution to given problem and need to get some score, generated by applying the fitness function. There is no fixed rule that a particular function should be used rather depend on problem type. The *crossover* and *mutation* operations are performed to find the fittest chromosome and reproduce a new offspring. These

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operations are applied repeatedly in each generation till the end of finding the fittest individual. The algorithm terminates if the population does not produce offspring which are considerably different form previous generation. At this point it is said that the algorithm has provided a set of solution to our problem. Generally, it is easier to use all valid and invalid members of population but in practice they can produce optimal or non-optimal solution for small problems. In this case, evaluation of fitness criteria, crossover and mutation have major impact on efficiency of genetic algorithm.

V. Collision Avoidance and Dynamic Slot Scheduling using Modified GA

In proposed algorithm, nodes use control packets in order to exchange slots request and collision free slots schedule with their neighbors. These packets are similar to *Request-To-Send (RTS)* and *Clear-To-Send (CTS)* packets, use in CSMA/CA [9][10]. The control packets are transmitted in slot scheduling period which is divided into *Slot Request (SR)* and *Slot Acknowledgment (SA)* time slots, defined in (2). These control packets are used to exchange chromosomes, offspring in network and inform neighbors about one-hop and two-hop collisions.

$$T_{ctrl\_slots} = T_{SR\_slots} + T_{SA\_slots} \quad (2)$$

Where

$$T_{SR\_slot} = \sum_{m=1}^{M} \sum_{i=1}^{N} Tmi\ Ni \qquad \forall m, i$$

$$T_{SA\_slot} = \sum_{m=1}^{C} \sum_{i=1}^{N} Tmi\ Ni \qquad \forall m, i$$

In $T_{SR\ slots}$, nodes send its slots requirement marked as '1', distributed randomly over all slots. The random slot selection is not fixed and might get changed in next scheduling phase. Each node extracts the bit stream from its neighbors *SR* packets and considers it as chromosomes. The technique not only performs crossover and mutation processes but also removes one-hop as well two-hop collisions using elitism to generate collision free dynamic slots schedule. An additional step allows node to transmit in slots if reserved slots are changed to free slots. However, the contention based scheduling time increases overhead and reduces throughput of the network. In this paper, we are ignoring the contention overhead to focus more on collision free slot scheduling. An another consideration regarding size of bit stream is precisely discussed here that as we increase number of time slots, the size of packets will also increase. To deal with the issue we can use different encoding and compression methods for repeated values e.g. Run-Length encoding, variable length codes etc. [11][12]. For optimized scheduling we consider that each node tries to get collision free time slotted matrix as S_{cf}, defined in section II. To achieve the optimal solution, we modified genetic algorithm, shown in Fig. 2 for collision free dynamic scheduling in multi-hop networks.

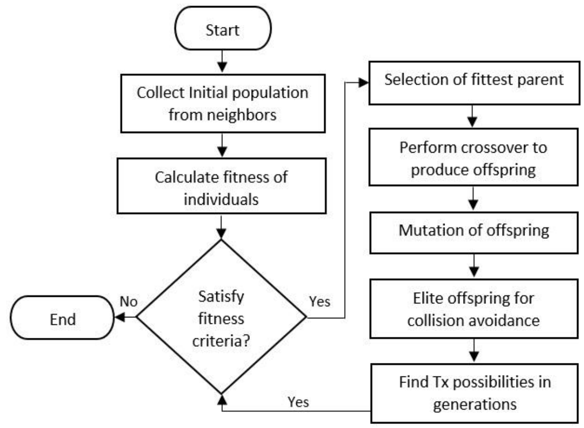

Figure 2. Proposed GA for collision avoidance and dynamic slot scheduling

A. *Initial Population and Selection*

Each node generates a vector of time slots based on the requirement of application data. Nodes create initial population by collecting bit streams from neighbors along with their own bit stream vector. Each vector is represented by a set $C_h = \{C_{h1}, C_{h2}, C_{h3}, \ldots, C_{hi}\}$. These bit streams are considered as chromosomes where each element can be either '0' (means Free) or '1' (means selected). The length of vector depends on the number of data slots which will be used for sending data after the slot scheduling period. The number of data slots varies and not fixed for any node of the network. Each time population changes with different slots requirement in slot scheduling phase.

B. *Fitness Criteria*

The fitness criteria to select best chromosome is maximum number of 1's, defined in (3). The nodes use greedy approach and select its own chromosome if satisfies the fitness criteria itself. Here, we are considering greedy approach due to its property of optimal substructure e.g. largest sum, shortest path etc. In our case it is primary and secondary conflicts.

$$\bigvee_{i:Ci=1} CNi \qquad \forall Ni \quad (3)$$

Therefore, in our proposed design, chromosome having maximum 1s, considered as fittest parent for the optimal solution. Hence, the fitness function is considered as the number of 1s in the chromosomes.

C. *Crossover and Mutation*

Crossover and mutation steps of GA have high probability of losing best chromosomes. In proposed technique each node selects best parent satisfying the fitness criteria. To cross-breed nodes, perform logical AND with its own random generated chromosome, selected as parent. The AND operation with its own chromosome maintains the integrity of

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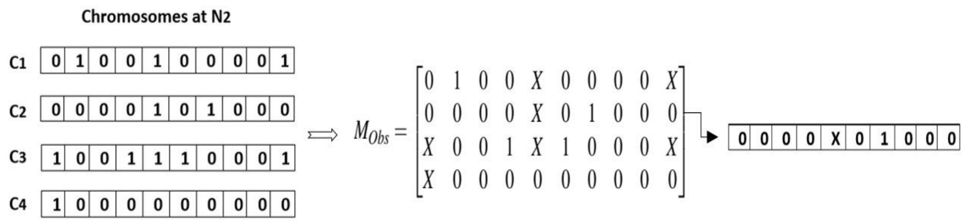

Figure 3. Chromosomes and observatory matrix (M_{obs}) at N2

its own slot selection. The crossover point depends on probability of having value '1' to create offspring. The resultant offspring takes some of the genetic information from both the parents. Hence, the probability to get k success (number of 1's) in n trials (chromosomes) with probability p (1/2=0.5 of getting 1) of success in any trial is defined in (4).

$$\binom{n}{k} p^k (1-p)^{n-k} = \frac{n!\,(p)^k (1-p)^{n-k}}{k!\,(n-k)!} \qquad (4)$$

For mutation process, cyclic permutation is performed to produce offspring having less similarity with its neighbors, defined in (5). For this, the circular left shift of i bits is used, where i is node ID and m is number of time slots.

$$\sigma(Ci) = (i+1)\ modulo\ m \qquad \forall i, m \qquad (5)$$

The circular left shift rearranges the slots, reduces same slot selection probability and maintains the diversity in population.

D. *Elitism for Collision Avoidance*

Elitism is a method which provides an opportunity to copy best chromosomes to a new population. This causes rapid increase in the performance of GA because it prevents losing of best solution. In our case, we elite offspring collected from neighbors including its own offspring. The detailed process is explained by considering same graph G, where nodes have ten slots available for transmissions.

1) One-hop collision avoidance:

In scheduling phase, nodes collect neighbors time slot vector which are offspring. For a given node, each slot of offspring, including its own is marked as either '1/0' or 'X' where '1' means the particular slot is selected for transmission and '0' means the slot is not used by the node. Nodes mark the slots as 'X' if there is a transmission schedule at N_i as well as any of its neighbors. Formally, a TDMA frame is defined as

$$t_{m,i} = \begin{cases} 1/0, & \text{if } t_{m,i} \text{ is reserved /free} \\ X, & \text{if } t_{m,i}\, t_{m,j} = 1 \quad \forall (N_i, N_j)\ \mathcal{E}\ L \end{cases}$$

After elitism for one-hop collisions, each node receives time slot vectors through control packets. The process is explained using an example of same graph G for node N_2. Node N_2 collects time slot vectors marked as X from its neighbors (N_1, N_3, N_4) including its own and generate an observation matrix M_{obs}, shown in Fig. 3. The rows of matrix M_{obs} represent number of nodes and columns represent time slots. The matrix highlights collisions at N_2 but lacks in giving the information about secondary conflicts. At slot t_1, node N_2 is zero whereas N_3 and N_4 are in collision which cannot be identified by other neighbors (in this case N_1) of N_2. When N_2 will send this scheduled vector which also receive by node N_1 then by adapting opportunistic approach, N_1 finds the slot free and schedule its transmission, will result in collision at node N_2. Therefore, in order to deal with the issue, we analyzed the problem in depth and also try to avoid secondary conflicts.

2) Two-hop collision avoidance:

In order to avoid two-hop collisions we add two more notations which is C (collision) and R (Reserved), if N_2 or its neighbors are scheduled at the same slot then the slot at N_2 will mark with C. Now, this will restrict N_1 and N_3 to transmit at slot t_5, as shown in Fig. 4. The addition of checking neighbors conflict avoids collision at slots.

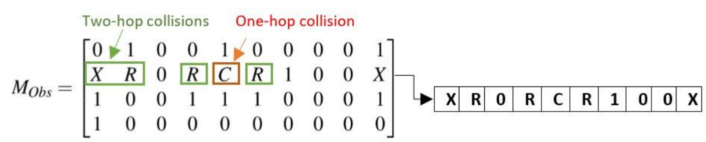

Figure 4. one and two-hop collision avoidance

However, there is still be a possibility that N_2 finds no conflict at the slot but one of its neighbor is scheduled for transmission. These slots will mark with R (reserved), alert neighbors that there is another transmission scheduled at the slot which is two-hop away and could cause collision at N_2, resulting in secondary conflict. The description of TDMA frame elements are

$$ch_{i,m} = \begin{cases} X, & \text{if at least two neighbors slot} = 1 \\ C, & \text{if neighbors and } Ni = 1 \\ R, & \text{if neighbor slot} = 1,\ Ni\ \text{slot} = 0 \\ 1/0, & \text{if slot is selected or free} \end{cases}$$

Using above marking procedure all one-hop and two-hop conflicts have been identified by all nodes. The collision probability now reaches zero because each node is being informative enough about all the conflicts to transmit data. The slots which are identified in collision decrease number of slots for transmission. Therefore, we increase the number of slots usually doubled as nodes with uniform random slot selection for each node of network.

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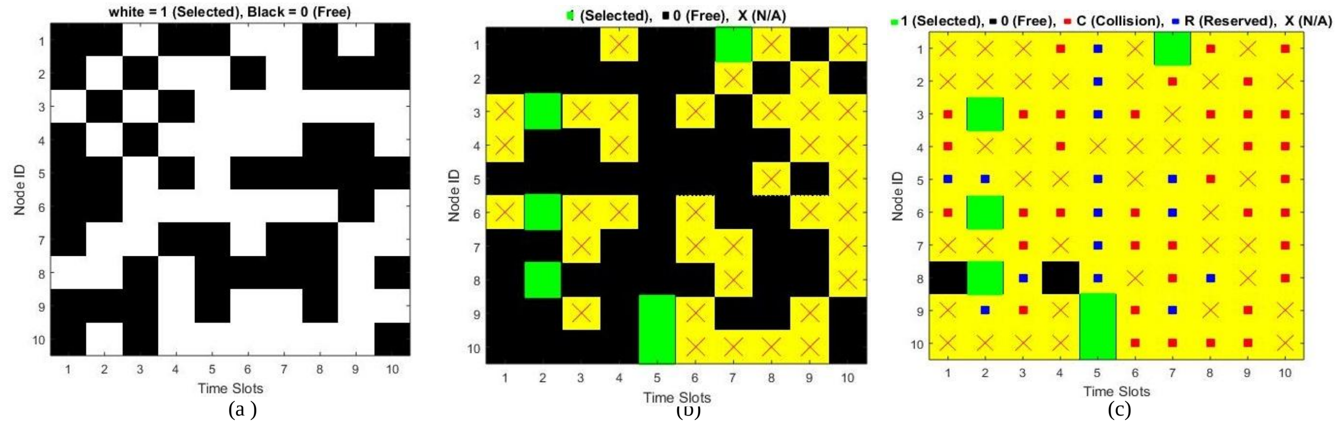

(a) (b) (c)

Figure 5. (a) Selected slots on each node (b) One-hop neighbor collision identification

After collision avoidance, each node keeps neighbor vector to find possible opportunities when gets free slots e.g. t_3, t_8 and $_9$ in above M_{obs} matrix, shown in Fig. 4. In these slots, nodes can overcome the slot wastage occurred due to one and two hop conflicts and try to increase channel utilization. For maximum channel utilization, the resultant vectors of M_{obs} are passed through an additional step, where slots which are marked as 'R', are changed to free slots for dynamic scheduling.

VI. Results and Discussion

The proposed technique is analyzed on random ad-hoc network topology where each node gets 10, 20 and 30 slots to schedule their transmissions. The simulation is performed on MATLAB for the network of 10, 30 and 50 nodes. For result showing and detailed analysis a network of 10 nodes is shown, deployed in an area of 400 x 400 meters. Each node has a set of few neighbors listed in table I, along with possible simultaneous transmissions.

TABLE I. EXAMPLE OF A NETWORK WITH POSSIBLE TRANSMISSIONS

Node (N)	Neighbor Nodes	Collision free simultaneous Tx (Scf)
N1	N3,N4,N5,N6,N9	N8
N2	N3,N4,N7,N8,N10	N5
N3	N1,N2,N4,N7,N10	None
N4	N1,N2,N3,N6,N7,N9,N10	None
N5	N1,N6,N9	N2,N7,N8,N10
N6	N1,N4,N5,N9	N8
N7	N2,N3,N4,N8,N10	N5
N8	N2,N7,N10	N1,N5,N6,N9
N9	N1,N4,N5,N6	N8
N10	N2,N3,N4,N7,N8	N5

In scheduling phase, nodes select the slots randomly according to their slots requirement as shown in Fig. 5a. The random selection of slots increases collision probability as each node selects slots without having any knowledge about their neighbor slots. As shown in Fig. 5b, nodes N3, N6 and N8 have got the slot t_2 available for transmission but could result in collision at N4. In this case, N4 is the common neighbor and is not giving any information about the reservation of slots by its neighbors. The issue is resolved in Fig. 5c, where N3, N6 and N8 still got the slots scheduled for transmission but after receiving N4 collision free schedule, will withdraw themselves as found X on N4 at slot t2. The method finds all collisions by identifying slots under collision as well as those which are reserved by neighbors.

The method removes all conflicts but leaving very less slots available for transmission as shown in Fig. 5c. For this, we increase number of slots which increases the transmission possibilities. The algorithm is applied on different topology matrix as shown in table II. As we increase number of slots with same initial random selection the chances of collision become less with increase in reserve and free slots. It can also be seen in Fig. 6b, there are some common slots available for all nodes such as {t_8, t_{11}, t_{15}, t_{18}} and any node can transmit in these slots. The collision free transmissions within these slots are scheduled in different generations, as shown in Fig. 6c. Each slot contains a value of either 0, 1, 2, C, R or X. Any value with entry 0 indicates that the slot is free, with 1 indicates the slot is selected and with value 2 indicates that the slot is schedule for *collision free transmission (CFS).* The technique increases *collision avoidance probability (P_{ca})* with number of generations for a network, as shown in Fig. 8 (using fit curve equation). The optimal dynamic slot scheduling performs over multiple generations only on common free slots with 10, 30 and 50 nodes.

TABLE II. STATISTICS AFTER COLLISION AVOIDANCE FOR (N, M)

No. of nodes	No. of links	No. of Slots	C (%)	R (%)	F (%)
10	22	10	0.78	0.3	0.04
		20	0.25	0.49	0.39
		30	0.11	0.58	1.163
30	58	30	0.86	0.18	0.02
		40	0.43	0.66	0.95
		50	0.19	0.87	2.12
50	98	50	0.67	0.25	0.12
		60	0.34	0.73	0.25
		70	0.17	0.84	3.45

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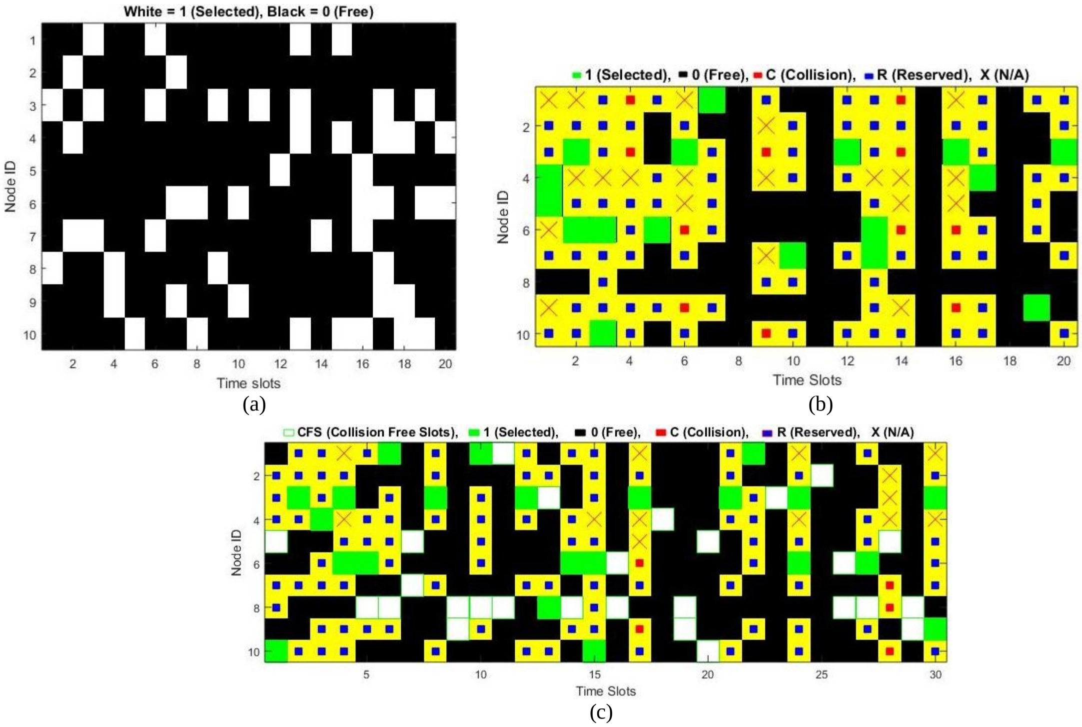

Figure 6. Multi-hop collision avoidance (a) over 20 slots (b) over 30 slots (c) collision free dynamic slot schedule for 30 slots

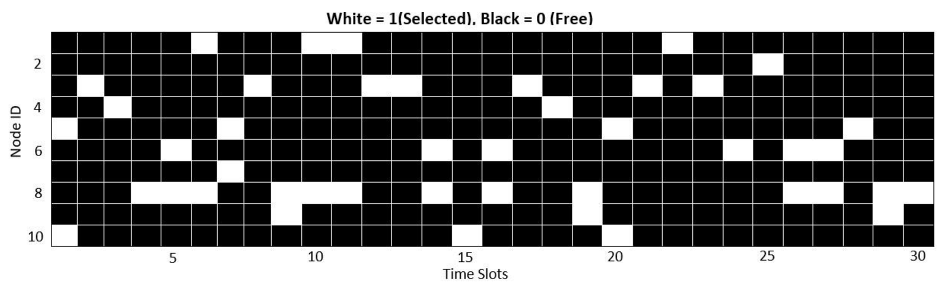

Figure 7. Collision free dynamic schedule with multiple simultaneous transmissions over 70 generations

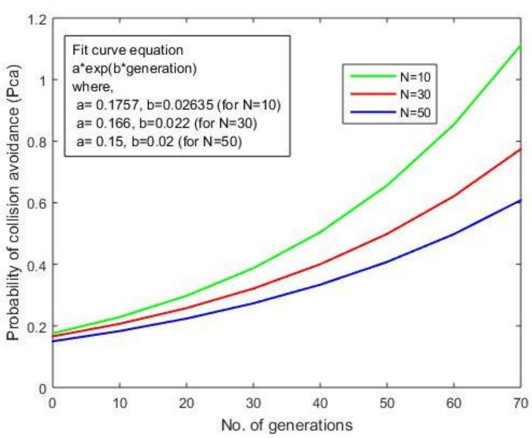

Figure 8. Improvement in collision avoidance probability over 70 generations for N=10, 30 and 50.

It is observed that for 30 and 50 nodes, the algorithm uses more than 70 generations because of random connectivity among them and the number of slots available for trnsmissions.

The method provides multiple slots to a node and schedule transmissions according to the possibilities marked in *Scf*. When an additional step is applied in which all reserved slots are marked as '0' (free) then nodes can transmit in these slots as shown in Fig. 7. Now, each node gets a chance to transmit data and most of the slots favors simultaneous transmissions. The benefit of using the approach is that all nodes know their free slots and can use the same schedule pattern for next data phase. This reduce bandwidth wastage by having simultaneous transmissions. The algorithm runs in an iterative manner until all nodes send their data. The slots which are not accommodated in one cycle are scheduled in next frame cycle while keeping the data stored in node buffer.

VII. Conclusion

In ad-hoc wireless networks, nodes in same communication domain face primary and secondary collisions. The proposed method provides provision of accessing the channel in collision free manner using heuristic approach. It is based on efficient searching algorithm which relies on reproductive selection criteria. The algorithm works on two major issues of TDMA based ad-hoc network. For collision free slot scheduling, nodes broadcast their chromosomes in scheduling phase. These chromosomes are basically random slot selection depend on the application level data in scheduling phase. The exchange of their temporal initial generated chromosome keeps each node updated about their neighbor selection. Crossover and mutation are performed to find optimal solution for dynamic slot scheduling. Using the broadcast offspring, nodes perform elitism to avoid multi-hop collisions. The method also performs opportunistic schedule by changing the state of reserved slots for possible simultaneous transmissions over multiple generations. The proposed technique gives benefits in terms of scalability as nodes update the state of slots in distributed manner. It also reduces collision probability and perform dynamic schedule to all nodes of the network.

References

[1] H.-W. Ferng, C. Setiadji, and A. Leonovich, "Fair round robin binary countdown to achieve qos guarantee and fairness in wlans," Wireless Networks, vol. 17, no. 5, pp. 1259–1271, 2011.

[2] L. L. Peterson and B. S. Davie, Computer networks: a systems approach. Elsevier, 2007.

[3] G. Chakraborty, "Genetic algorithm to solve optimum tdma transmission schedule in broadcast packet radio networks," IEEE Transactions on Communications, vol. 52, no. 5, pp. 765–777, 2004.

[4] R. Gunasekaran, S. Siddharth, R. Muthuregunathan, R. Srivathsan, and V. Uthariaraj, "An improved parallel genetic algorithm for path bandwidth calculation in tdma-based mobile ad hoc networks," in 2009 International Conference on Advances in Computing, Control, and Telecommunication Technologies. IEEE, 2009, pp. 220–226.

[5] M. Vaezi, Z. Ding, and H. V. Poor, Multiple access techniques for 5G wireless networks and beyond. Springer, 2019.

[6] H. Qi, F. Liu, T. Xiao, and J. Su, "A robust and energy-efficient weighted clustering algorithm on mobile ad hoc sensor networks," Algorithms, vol. 11, no. 8, p. 116, 2018.

[7] Bindu, GB Hima, K. Ramani, and C. Shoba Bindu. "Energy aware multi objective genetic algorithm for task scheduling in cloud computing." *International Journal of Internet Protocol Technology* 11.4 (2018): 242-249.

[8] Tsiligaridis, J. "A Grouping Method and a Genetic Algorithm for Discovering Regular Plans in Wireless Mobile Environment." *Proceedings of the International Conference on Wireless Networks (ICWN)*. The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (WorldComp), 2019.

[9] W. Sun, W. Xie, and J. He, "Data link network resource allocation method based on genetic algorithm," in 2019 IEEE 3rd Information Technology, Networking, Electronic and Automation Control Conference (ITNEC). IEEE, 2019, pp. 1875–1880.

[10] S. Majidi and R. Obermaisser, "Genetic algorithm for scheduling timetriggered communication networks with data compression," in 2019 IEEE International Conference on Industrial Cyber Physical Systems (ICPS). IEEE, 2019, pp. 373–379.

[11] G. Bianchi, L. Fratta, and M. Oliveri, "Performance evaluation and enhancement of the csma/ca mac protocol for 802.11 wireless lans," in Proceedings of PIMRC'96-7th International Symposium on Personal, Indoor, and Mobile Communications, vol. 2. IEEE, 1996, pp. 392–396.

[12] E. Ziouva and T. Antonakopoulos, "Csma/ca performance under high traffic conditions: throughput and delay analysis," Computer communications, vol. 25, no. 3, pp. 313–321, 2002.

[13] S. Kondo, S. Kadono, M. Hagai, and K. Abe, "Variable length coding method and variable length decoding method," Aug. 21 2018, uS Patent App. 10/057,602.

[14] C. McAnlis and A. Haecky, Understanding compression: Data compression for modern developers. " O'Reilly Media, Inc.", 2016.

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