A dynamic hybrid CDMA/TDMA scheme in mobile ad-hoc networks based on learning automat

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Summery
In this paper, we propose a dynamic code assignment in combination with time slot assignment algorithm. In the beginning, the network is divided into multiple clusters, and then a learning automaton is assigned to each cluster head. Moreover, in proposed CDMA scheme, transmit power for communication between nodes is used as a factor for decreasing code spatial reusability. The proposed scheme allows the network to operate in a collision-free manner, and does not need any centralized control. In proposed TDMA scheme, the portion of assigned TDMA frame to each node is according to its traffic load, and performs dynamically. The simulation results indicate that the proposed scheme performs better than the similar methods and other CDMA/TDMA method with power control in terms of performance metrics.
Keywords:
Code Assignment; Slot Assignment; TDMA; CDMA; Glomosim.

1. Introduction

A Channel is commonly called to communication way that each user is connected to the network through it. This channel must be such that the interference is minimal among desired user with other users in the network. So, the channels should be Orthogonal. The most common methods for creating this orthogonality are: use of different channel frequencies, use of different time slots in frequency band and use of distinct codes. These methods are known as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA) respectively.
CDMA is a spread spectrum multiple access scheme which a transmitter broadcasts the information signals using of a spreading code in a wide range of band. A receiver uses of the same code for evaluating received signal. This method provides multiple accesses with simultaneous transmission through different nodes. Moreover, it is employed for reuse of bandwidth and reduce the interferences in the network. One of the most active topics with ad-hoc networks is on the medium access control (MAC) protocols. MAC protocols in ad-hoc networks need to overcome interference problem, adapt to changing topology, coordinate and make efficient use of the limited shared wireless resource and maintain low power consumption, while achieve high data transmission throughput (Yu, Wu, Cheng, & Wu, 2006).

In a CDMA scheme, a share code can be assign to a group of nodes. Many of codes occupy a same channel but only nodes with a share code can aware of each other. In spite of all that, several nodes may occupy same channel if the codes are Orthogonal. In this state, every bit error caused by communal channel interference can control by forward error correction. Each node should have aware of the codes which use it for transmitting and receiving of particular packet in spread spectrum CDMA scheme. Assign a unique code to each transmitter and receiver is impossible because the number of available codes is limited. Therefore, code spatial reuse concept is a good solution for solving this problem (Amirhosein Fathinavid, Maryam Ansari, 2013). In a clustered network, this concept means that can be assigned same code to two or more non-neighboring cluster (Lin & Gerla, 1997). CDMA technology has long been used in cellular networks and is based on a form of transmission known as Direct Sequence Spread Spectrum (DSSS). Using this system, different users are allocated different spreading codes to provide access to the system (Yu et al., 2006).The MAC protocols for WSN can be classified broadly into two categories: contention based (Koubâa, Severino, Alves, & Tovar, 2009) and schedule based (Wu, Li, Liu, & Lou, 2010).
The contention based protocol does not need time synchronization and can easily adjust to the topology changes when some new nodes join to the network or other nodes die after time to life. These protocols are based on Carrier Sense Multiple Access (CSMA) technique and have higher costs for message collisions, overhearing and idle listening. Using adaptive listening techniques cause to improving the sleep delay and overall latency ultimately. The schedule based protocol can avoid collisions, overhearing and idle listening by scheduling transmit and listen periods but have strict time synchronization requirements. However, both contention based and schedule based protocols have their own weaknesses. Hybrid MAC protocol is a grouping of at least two kind of medium access control methods. It can combine the strengths of contention based and schedule based protocols (Ma, Leung, & Li, 2014).
In TDMA scheme, a single channel is shared in point of time. So, use of channel is divided among multiple hosts. In traditional TDMA protocol, multiple access is

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controlled using time division, namely, each node of networks is assigned with different time slot. When a node's time slot arrives, it transmits a packet. In this manner, each host access to a channel only for period of time, called time slot, periodically. A TDMA frame has known as a set of periodically repeating time slots (Wang, Zeng, & Yu, 2008). During one time slot, the whole of bandwidth is accessible. It is possible that more than one time slot assigned to a specific host in each frame. The main task in TDMA scheduling is to allocate time slots depending on the network topology and the node packet generation rates. TDMA is a collision-free scheme because a channel exists only for a given host at a time. The most important problem in TDMA is synchronizing a number of independent centralized hosts. For solving this problem, we can use of guard band as a good solution for eliminate the effect of propagation delay among hosts. Guard band or guard interval is a period of time that no channel assigns to any host. Moreover, each node only transmits once in a TDMA period to avoid packet collisions (Wang et al., 2008).

One of the advantages of TDMA MAC protocol is that wasting energy is reduced, because the interference between adjacent wireless links is guaranteed to be avoided. The other advantage is that TDMA can solve the hidden terminal problem without extra message overhead because neighboring nodes transmit at different time slots.

There are many studies in point of code assignment and TDMA protocols. Meybodi and Akbari Torkestani have designed a CDMA/TDMA scheme with dynamical frame length for clustered wireless ad-hoc networks (Akbari Torkestani & Meybodi, 2010). In this scheme, inter cluster collision-free communications are organized based on TDMA method. Moreover, they have used of CDMA scheme for organization all connections in the network.

Lujuan Ma and et.al in (Ma et al., 2014) have proposed a hybrid TDMA/CDMA mac protocol for wireless sensor networks. The proposed scheme allows the network to operate in a collision-free manner, and takes advantage of broadband property provided by CDMA. The main features of this hybrid protocol are high throughput and low latency. Gerla and Tsai have presented a scheduling scheme to access CDMA/TDMA channel for clustered multi-hop wireless network (Gerla & Tzu-Chieh Tsai, 1995). Also, they have proposed distributed algorithm for clustering the network. Lin and Grela have proposed a scheme based on CDMA/TDMA for multimedia support in a self-organizing multi-hop mobile network (Lin & Gerla, 1997). Yang and Chang (Chang, 2003), have designed a dynamic code assignment algorithm for hybrid multi-code CDMA/TDMA. In this method, traffics have considered appropriate for mobile users. In (Akaiwa & Andoh, 1993), Akaiwa and Andoh have presented a dynamical self-organized channel assignment scheme which is called CS_DCA. This scheme is proposed for improve the efficiency of spectrum in a micro-cell TDMA system. Fang et al. have proposed a greedy-based channel assignment algorithm which they have named it GB-DCA for mobile cellular networks (Fang X, Zhu C, 2000). GB-DCA protocol decreases the probability of call blocking and increases the overall network traffic transportation. Wu in (C-M., 2007), has introduced a CDMA/TDMA scheme for clustered ad-hoc networks. In this scheme, CD-GBA method is used to control of collision-free assignment code. Navaie and Yanikomeroglu have formulated optimal downlink resource allocation problem in a cellular TDMA/CDMA network by using an application-based approach (Navaie, K. and Yanikomeroglu, 2006b). Moreover, they have formulated packet transmission in a TDMA/CDMA network as an optimization problem (Navaie, K. and Yanikomeroglu, 2006a). Kanazaki and et al. (Kanzaki et al., 2003), have proposed a TDMA slot assignment protocol for improve the operation of channel, in which excessive of not allocated slots is controlled with change the frame length dynamically. Wang (Wang et al., 2008), extracted the node throughput in TDMA wireless ad-hoc network first and then he compared it with node throughput in CDMA/TDMA wireless ad-hoc network. Vannithamby and Sousa in (Vannithamby, R. and Sousa, 2000), have proposed a scheme based on channel disappearing in which the proposed method found the optimization rate of power allocation.

Rekha and Arivudainambi in 2012, have introduced a new safe method based on genetic algorithm for broadcast scheduling problem in ad-hoc networks using TDMA scheme (Arivudainambi & Rekha, 2012). Hedayati and et al., in 2010 have presented a new scheduling algorithm for S-TDMA that it has improved the operation of ah-hoc network significantly (Hedayati, et al., 2010). This improvement has achieved by using of interaction and traffic load. Pawar and et al. in 2012 have proposed a new scheduling algorithm based on clustering which it is named GCF (Pawar, Nielsen, Prasad, Ohmori, & Prasad, 2012) . This algorithm was used for competition graph in inter-cluster and outer-cluster communications among three hops neighboring nodes. Performance of the algorithm improved in point of energy consumption and end-to-end delay. Vergados and et al. (Dimitrios J. Vergados, Aggeliki Sgora, 2012), have proposed a scheduling algorithm for wireless multi-hop networks which is called LB-FFVSA. This algorithm fairly schedules all transmissions regarding to the communication requirements of active streams in point of throughput in each link.

Akbari Torkestani (Torkestani, 2013), has proposed a distributed algorithm based on learning automata for scheduling program in grid networks in 2013. The proposed algorithm synchronizes the schedulers' performance by pseudo-random number generator. In this method, grid computing capacity which is allocated to each scheduler is proportional to the workload. Bruhadeshwar and et al. (Bruhadeshwar, Kothapalli, & Pulla, 2010), have represented a new TDMA protocol that is appropriate for realistic and practical network models. In this scheme, the authors have used of a control phase and a simple data phase for handling some problems such as membership changes within the transmission range and interference range. Some of the advantages of the proposed solution are that no knowledge of the network parameters such as the size or an estimate of the size is used. Prajapati and Ganesan have proposed a fast, adaptive TDMA MAC protocol based on single frequency for wireless sensor networks (Prajapati, Ganesan, 2011). The proposed protocol has two types of sensors: sensor-TDMA and sensor-TDMA with Virtual Cluster Election (VCE). The proposed protocol uses light-weight smart agent as a middleware. Yang and et al. have presented a cooperative TDMA protocol in order to provide corporative transfers through virtual antenna array to obtain the diversity (Chang, 2003). In C-TDMA, each terminal has two tasks: At first, each terminal transmits its data packets during a specific time slot in each frame. Second, the terminal monitors the other time slots in each frame and cooperates with other terminals to resend demolished packets for the reason that channel distortion in previous frames.

The rest of this paper is organized as follows. In the section 2, we discuss the channel assignment problem in the networks. Section 3 represents the learning automata concepts. We describe proposed CDMA/TDMA scheme in section 4. Section 5 demonstrates the simulation results of proposed scheme, also shows the results in comparison with existing methods. Section 6 concludes the paper.

2. Channel assignment problem in ad-hoc networks

There are several MAC protocols for channel assignment in ad-hoc networks. These protocols are divided into two main groups: single channel MAC protocol and multi channels MAC protocol. One of the most important problems in single channel MAC protocol is packets collision. Therefore, there are two types of single channel protocols: Contention free protocols and contention-based protocols. A contention free MAC protocol, not only guarantees that only one node acts to transmit packet at a specific time but also, transfers occur in the individual time slots. So, the collision will be impossible. CDMA, TDMA and FDMA are three famous protocols in this view.In the figure 1, usability of channel is shown. In FDMA, each user has a limited share of bandwidth. The channels are assigned only when they are requested by users. FDMA is a simple algorithmic and does not need any synchronization. In TDMA, the users do not use of given bandwidth in all times. TDMA needs to be careful to synchronize because all users share the bandwidth in the frequency domain. In CDMA, all users occupy certain bandwidth, but this bandwidth is discrete codes which are different from each other. CDMA needs to synchronize among users.

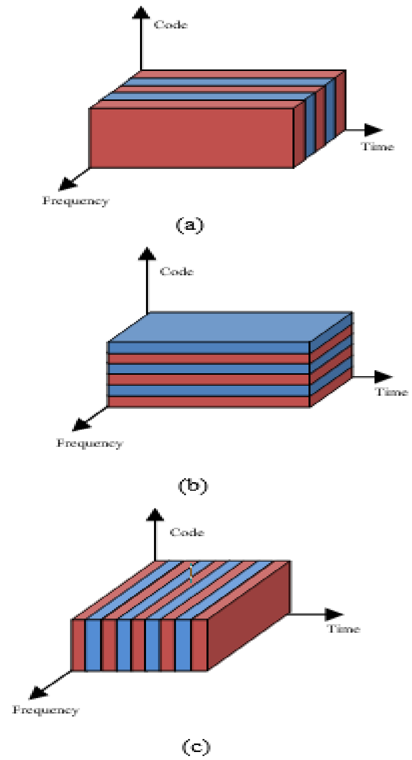

Figure 1. Use of channel in (a) FDMA, (b) CDMA, (c) TDMA

3. Learning automata concepts

Learning process of organisms is one of the new research topics. The end of a learning system is mathematically the optimization of a task which is not perfectly known (Ks Narendra & Thathachar, 2012). A learning automaton is formed of two parts: a stochastic automaton with limited actions and a random environment. A learning automaton is defined as quintuple $SA = \{\alpha, \beta, F, G, \varphi\}$ where $\alpha = \{\alpha_1, \alpha_2, ..., \alpha_r\}$ is a finite set of actions (r is number of automata actions), $\beta = \{\beta_1, \beta_2, ..., \beta_m\}$ is inputs set of automata, $F : \varphi \times \beta \rightarrow \varphi$ is a function to generate new state, $G: \varphi \rightarrow \alpha$ demonstrates the output function which maps the previous state to the next output, and $\varphi(n): \{\varphi_1, \varphi_2, ..., \varphi_k\}$ is set of internal states at the moment n. Environment can be defined by the triple E={α,

β, c} where α={α1, α2 …, αr} represents a finite input set, β= {β1, β2, …, βr} represents the output set and c={c1, c2, …, cr} is a set of penalty probabilities where each element ci of c corresponds to one input action αi. The input of environment is one of the r selected actions. The environments depending on the nature of the reinforcement signal $\underline{\beta}$ can be classified into three models: P-model, Q-model, and S-model. In P-model environments, the reinforcement signal can only take two binary values 0 and 1. In Q-model environment, the reinforcement signal takes its value in the interval [0, 1]. In S-model environments, the reinforcement signal lies in the interval [a, b].
This set with learning automata is named Stochastic Learning Automata. Stochastic learning automata can be demonstrated as quadruple $LA=\{\alpha,\beta,p,T\}$ where $\alpha=\{\alpha_1,\alpha_2,...,\alpha_r\}$ is set of finite actions, $\beta=\{\beta_1,\beta_2,...,\beta_r\}$ is set of automata inputs, $p=\{p_1,p_2,...,p_r\}$ demonstrates the action probability vector of automata and $T=p(n+1)=T[\alpha(n),\beta(n),p(n)]$ is learning algorithm. Relationship between stochastic automata and environment is shown in figure 2. Learning automata randomly selects one action out of its finite set of actions and performs it on a random environment (KS Narendra & Thathachar, 1974).

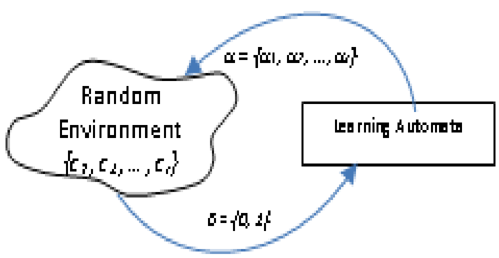

Figure 2. Stochastic learning automata

This automaton operates as follows. Based on the action probability set p, automaton randomly selects an action αi and performs it on the environment. Having received the environment's reinforcement signal, automaton updates its action probability vector based on equation (1) for favorable responses (β(n) = 0) and on equation (2) for unfavorable ones (β(n) = 1).

$$P_i(n+1)=P_i(n)+a(1-P_i(n)) \qquad \textbf{(1)}$$

$$P_j(n+1)=P_j(n)-aP_j(n) \qquad \forall j \quad j\neq i$$

$$P_i(n+1)=(1-b)P_j(n) \qquad (2)$$

$$P_j(n+1)=\frac{b}{r-1}+(1-b)P_j(n) \qquad \forall j \quad j\neq i$$

In equations (1) and (2), a and b are reward and penalty parameters respectively, and r is the total number of actions. For a = b learning algorithm is called LR-P, for a << b it is called LRεP, and for b=0 it is called LR-I. For more information about learning automata the reader may refer to [13, 21]. In the following, we have introduced some definitions which are convergence results of the learning automata.

Definition 3.1. The average penalty probability *M(n)*, received by a given automaton is defined as

$$M(n)=E[\beta(n)\zeta_n]=\int_{\alpha\in\underline{\alpha}}\zeta_n(\alpha)f(\alpha) \qquad (3)$$

Where $\zeta:\underline{\alpha}\rightarrow[0,1]$ determines the probability of choosing each action $\alpha\in\underline{\alpha}$ and $\zeta_n(x)$ is called the action probability.

Definition 3.2. if $\lim_{n\to\infty}E[M(n)]<M_0$ then a learning automaton is said to be *expedient*.

Expediency means that when automaton updates its action probability function, its average penalty probability decreases. This property is defined for operating in a *P*-, *Q*- or *S*-model environment. Expediency can also be defined as a closeness of *E[M(n)]* to $f_l=\min_\alpha f(\alpha)$. Moreover, the learning automaton is called *optimal*, if the average penalty of a taken action is minimized.

Definition 3.3. if $E[M(n+1)\,|\,\underline{p}(n)]<M(n)$ for all *n* and all $p_i(n)$ then a learning automaton is *absolutely expedient*, regardless of environment which it operates on it.

Absolute expediency implies that *M(n)* is a super martingale and *E[M(n)]* is strictly decreasing for all *n* in all stationary environments. If $M(n)<=M_0$, absolute expediency implies expediency.

Definition 3.4. A learning automaton operating in a *P*-, *Q*-, or *S*-model environment is said to be *optimal* if

$$\lim_{n\to\infty}E[M(n)]=f_l \qquad (4)$$

Optimality implies that asymptotically the action for which penalty function attains its minimum value is chosen with probability one.

Definition 3.5. if $\lim_{n\to\infty}E[M(n)]<f_l+\varepsilon$ then a learning automaton is *ε-optimal*. this characteristic is true for all *P*-, *Q*-, or *S*-model environment.

It can be obtained for any *ε>0* by a proper choice of the parameters of the learning automaton. *ε*-optimality implies that the performance of the learning automaton can be made as close to the optimal as desired.

4. The proposed hybrid TDMA/CDMA scheme

In CDMA scheme, the communication among nodes is created through links. All data packets are transmitted on this links. This action wastes energy so much. So, in proposed scheme we have used energy level of each node as a factor for calculating of link cost. Indeed, unlike previous schemes, proposed scheme uses of a calculated cost for each link based on energy factor. However, the proposed method aims to optimize the slots assignment in clustered networks. In ad-hoc networks, a host can move freely and randomly anywhere. So, the host may leave its cluster and join to another cluster at any time. In such clusters with variable size, use of basic TDMA scheme with a fixed length frame for scheduling channel access is inefficient. This extremely reduces the efficiency of the channel.

We consider an ad-hoc network with N nodes and a set of L links. The links are directional and symmetrical. Each link $l \in L$ has a limited capacity as C1 bit per second. No nodes fully lost its buttery power. On the other hand, topology of the network is not constant. So, the end is management of nodes energy levels before the topology changes. Moreover, each host needs a portion of TDMA frame or a set of time slots according to its traffic load. Therefore, the allocation of equal bandwidth to all hosts reduces channel throughput. The other goal of proposed scheme is to represent a slot assignment scheme with variable frame length. In this part of the algorithm, increasing of channel utilization performs through appropriate time slots assignment to each host according to their traffic loads, so that traffic parameters such as bandwidth, size of data packets, and number of data packets are unknown.

For better recognition of control preferences of transmit power, we have studied two model of transmit power: fixed and variable transmit power. If the transmit power is fixed and cannot be controlled as the fixed number pc in figure 3 – a, then S→D is the shortest and most effective path. On the other hand, if the transmit power is not fixed then send the data packets by intermediate nodes is more effective in term of energy. Because the transmit power for communication between two nodes has an non-linear dependency (p(d) ∝ d2). In figure 3 – b, path S→A→D is more effective than S→D path in term of energy consumption. Because, according to p(d) ∝ d2 we have p(| SD|) > p(| SA|) + p(| AD|). So, node S saves its energy by reducing the antenna power enough to achieve the A not D node.

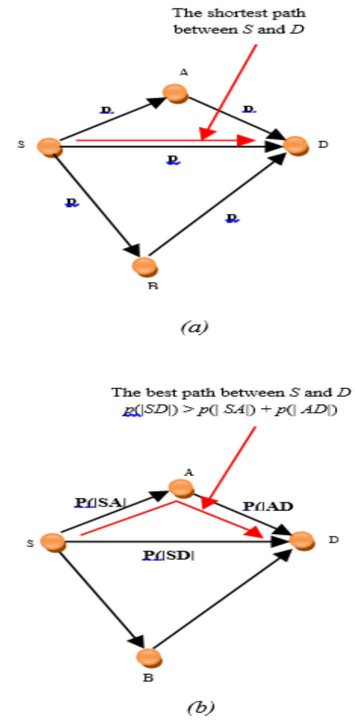

Figure 3. Two models for radio transmit power

The node should calculate consumed energy for calculating the remaining energy power. The consumed energy is including required energy to perform an action when a node sends a message to another node. Energy consumption calculates from equation (5).

$$E_t = E_{elec} \times k + E_{amp} \times k \times d^2$$
$$E_r = E_{elec} \times k \qquad (5)$$

In the equation (5), Et is consumed energy for sending packet and Er is consumed energy for receiving packet, Eelec is consumed energy by radio transmitter or receiver, Eamp is consumed energy by amplifier, k is the number of bytes to be sent, and d is radio range for transmitting.

In the beginning, the network is divided into multiple clusters in which each cluster has a cluster head. A cluster head is responsible for monitor and control of all nodes functionality in its cluster. A learning automaton is assigned to each node in a cluster. Set of actions of learning automata in each node is equal to cluster members. In other word, cardinality of action set in each node is equal to its cluster members. In the beginning of TDMA frame, an unused time slot have reserved for newly entrant hosts in order to transmit control packets for slot assignment or join to the network. So, no data packets are transmitted through this slot. First, all of cluster members are selected with equal probability then TDMA frame is divided into equal parts. The frame portion which is assigned to each host is 1/K that K is the number of cluster members. In this scheme, all learning automatons are LR-P types. Moreover, each learning automata uses a random number generator for selecting one of its actions. All learning automatons initialize their random number generator with same seed. Then, all learning automatons select one of their actions and let to corresponding cluster member during one time slot to transmit its packets, and learning automata rewards to the selected action according to formula 6.

$$p_j(k+1) = \begin{cases} p_j(k) + a[1 - p_j(k)] & i = j \\ (1-a)p_j(k) & \forall j \neq i \end{cases} \quad (6)$$

Now, if selected cluster member dose not have a packet to transmit then it sends a NDATA to all inter cluster nodes and the selected action penalizes according to formula 7.

$$p_j(k+1) = \begin{cases} (1-b)p_j(k) & j = i \\ \left(\frac{b}{r-1}\right) + (1-b)p_j(k) & \forall j \neq i \end{cases} \quad (7)$$

Since the numbers of codes are limited, the assignment of a unique code to each cluster is not possible. So, in this scheme we have used of the code spatial reuse concept. In the proposed scheme, the structure defined in the cluster head node is composed of the following fields.

chi is the ith cluster head, ni represents the number of inter-cluster nodes in ith cluster, N_j^i is number of node j in ith cluster, P_j^i indicates to power of node j in ith cluster and P_{ch_i} is the power of ith cluster. Each node in the cluster sends its energy level to the cluster head. After the cluster head received the packet containing energy from all nodes within the cluster, the cluster head saves this information in defined structure. Then the cluster head calculates cost of link based on formula (8).

$$cost(ch_i) = \sum_{j=1}^{ni} \frac{d^2(N_j^i, ?ch_i}{min(P_j^i ??P_{ch_i}} \quad (8)$$

In equation (8), Nji ،chi ،Pji و Pchi are represented according to definitions. d2(Nji ، chi) is distance between node j and ith cluster head node. In figure 4, the functionality of clusters is shown. In the figure 4(a) to (d), there are four clusters which are neighbor of each other. Figure 4(a), cluster 1 chooses code 1, cluster 2 chooses code 2, cluster 3 chooses code 3, and cluster 4 chooses code 5. The cluster head 1 rewards its selected code. Because, not only it is against the selected code of cluster 3, but also the cost of cluster 1 is greater than cluster 2 cost. For this reason cluster head 2 is penalized. In figure 4(b), cluster head 2 chooses code 3. This code is common with cluster head 3 code and since the cost of cluster head 2 is greater than cluster head 3, it rewards its code and cluster head 3 is penalized. Figure 4(c) shows that cluster head 3 is penalized because the selected code is 5 and it is common with cluster head 4 code and also the cost of cluster head 3 is less than cluster head 4. In figure 4(d) all the cluster head are rewarded because all selected codes are different. As the algorithm continues, the portion of TDMA frame which is assigned to each cluster member convergences when it has a packet for transmission. The proposed scheme is designed as does not need any centralized control, and it performs dynamically. In this scheme, the portion of assigned TDMA frame to each node is according to its traffic load. Figure 5 shows the pseudo code of proposed TDMA algorithm. Rewarding and penalizing are performed based on learning equations (1) and (2). When a host joins to the network, it broadcasts a JREQ message. Each cluster head receives the JREQ message. Whenever a newly joining host selects a cluster head, it calls join-request procedure. Let pi ={pi1 ,pi2,…,pik-1} be the actions' probability vector of learning automata in ith cluster. When kth host joins to the cluster, the action probability vector updates as equation (9).

$$p_j^i = \begin{cases} \frac{k-1}{k} p_j^i & j \neq k \\ \frac{1}{k} & otherwise \end{cases} \quad (9)$$

Pij indicates the probability of jth cluster member for accessing to channel in ith cluster. Figure 6 shows the clustering process of the proposed scheme. Moreover, the pseudo code of the process is shown in figure 7.

```
for each node in the network
{
        assign a learning automata (LAi) to nodei
        for LAi
          {
                  set a probability vector
                    ={number of   cluster members}
          }
        Si = random (Seed)
        assign a channel to selected  memben where i=number of {Si}
          If selected  memben has packets to transmit then
          {
                  reward {Si}     //increase the portion of bandwidth
          }
        else
          {
                  penalize{Si}          //decrease   the   portion   of
        bandwidth
          }
}
```

Figure 5. The pseudo code of TDMA algorithm

```
for each node in the network
{
        assign a learning automata (LAi) to nodei
        for LAi
          {
                  set a probability vector
                    ={number of   cluster members}
          }
        Si = random (Seed)
        assign a channel to selected  memben where i=number of {Si}
          If selected  memben has packets to transmit then
          {
                  reward {Si}     //increase the portion of bandwidth
          }
        else
          {
                  penalize{Si}          //decrease   the   portion   of
        bandwidth
          }
}
```

Figure 7. The pseudo code of clustering process

When a host leaves a cluster, it broadcasts LREQ message. However, LREQ message can be used for informing the cluster heads when a node leaves the cluster, but proposed scheme needs no message for leaving a cluster. Because the cluster head receives no more packets from leaving host and the portion of TDMA frame assigned to this host approaches to zero after a short period of time. So, the selection probability of this host will converge to zero.
In the next stage, the cluster head randomly selects one of its available codes. Also, each cluster head is informed of its neighbors cluster head selection code by outer-cluster communications. Then, the residing learning automata in the cluster head performs as follows:

- If this code is against to the selection code by its neighbors cluster heads then the learning automata rewards the action proportional to the current code.
- If the cost of cluster head link is greater than cost of neighbor cluster head link which they have selected a same code, the learning automata rewards this action.
- Otherwise, the learning automaton penalizes this action.

The algorithm continues until all the cluster head to be rewarded. The pseudo codes are shown in figure 8.

5. Simulation Results

We have simulated our proposed scheme by Glomosim simulator (Zeng, Bagrodia, & Gerla, 1998) (Bajaj, Takai, Ahuja, & Tang, 1999). For simulation, we need to set some simulation parameters. Some of these parameters are constant for all simulations and some of others are variable from one experiment to the next. The configuration of network is according to table 1. In each host, the arrival rate of new connections is according to Poisson distribution with 5, 10, 15 and 20 connections / min. Furthermore, each host has a particular traffic load.

```
For each chi
{
        cost (hi)=0
        For (j=1 to ni )
        {
              A= d²( Ni, chi)
              B= min (pi, pchi)
              cost (hi) =cost( hi) +(A/B)
         }
         Select one code (Ci) from access code
          For (j=1 to ni)
          {
                        If (Ci <> Cj)
                                Reward (hi)
                        Else
                                                 if
(cost (hi) > cost (hj) && Ci== Cj)
                                Reward (hi)
                        Else
```

Figure 8. The pseudo code of CDMA algorithm

Duration of connection is assumed has exponential distribution with an average of 0.2. The performance of proposed scheme is evaluated based on following metrics:

1. Code spatial reuse: this metric is defined as the frequency of a code that can be used.
   For our scheme, reuse of code space is the average number of clusters that have the same code assigned to them. This metric is necessary for evaluating the code assignment algorithm.
2. Channel spatial reuse: this criterion is proposed for evaluation of the proposed slot assignment algorithm, and is determined as the average number of hosts that they use of same channel.
3. Number of used codes: the number of codes that can be assigned to clusters.
4. Blocking rate: this metric is specified as the number of blocking connections per the total number of requested connections. This metric can be divided into two types:
   - When there is no code.
   - When there is no slot.
5. Waiting time for sending packet: this metric is calculated as the average time for each packet that must wait in the queue before transmitting.
6. Throughput: this is defined as the ratio of the average number of transmitted packets to the total number of received packets in each time slot. Traffic load for the hosts is different in real scenarios. Since, the portion of bandwidth assigned to each host is appropriate to its traffic load in the proposed algorithm, this metric can be optimized.

Table 1. the configuration of the network

Network Parameter	Value
Routing protocol	DSR
Mac protocol	802.11
Dimensions of network	1000 * 1000 m^2
Node Placement	Random
Packets size	512 bit
Bandwidth	2 mb/s
Radio range	250 m
Number of nodes	60 – 200
Simulation time	1000 s
Number of codes	4 – 20

Performance of proposed scheme is evaluated based on mentioned metrics in two levels. In the first level, we have simulated and evaluated the performance of proposed

CDMA algorithm and second, the performance of TDMA algorithm is evaluated. Also, the simulation results are shown in comparison with CS-DCA, Hybrid-DCA, LASAA and LACAA protocols. The proposed algorithm uses L_{R-P} learning automata for updating the probability vectors.

In the first simulation, we have investigated the effect of increase the number of assigned codes in comparison with variation of hosts' number. Figure 9 shows these results.

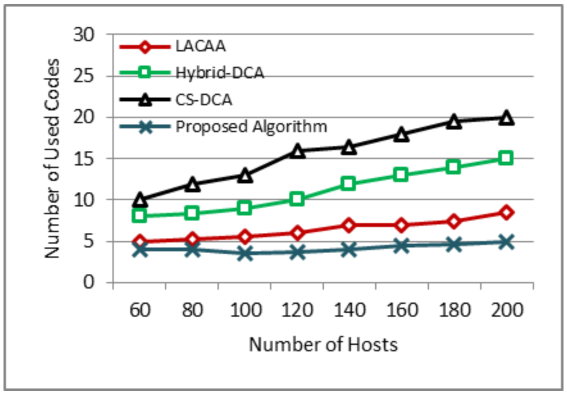

Figure 9. Number of used codes vs. number of hosts

The scheme results show that the proposed algorithm is better than CS-DCA, Hybrid-DCA and LACAA algorithms from the point of used codes. Indeed the proposed scheme uses fewer codes than the other algorithms. The important reason for this behavior is that each cluster-head calculates link cost for all nodes in its cluster, and so one of the two clusters changes its code that have a common code and have a lower cost than the other one. Moreover, the number of used codes has increased with increase of hosts' number.

In the second simulation, the proposed scheme is compared with similar algorithms in term of code spatial reuse for increasing number of hosts. Obviously, that code spatial reuse in four algorithms is increased when the number of hosts varied; however, the proposed scheme has less alterations than the others algorithms. Figure 10 depicts the results. Although, the proposed scheme demonstrates low performance than LACAA for less than 100 nodes, the code spatial reuse in proposed scheme is higher for approximately more than 100 nodes in network than the others. This happens due to different reasons and the most important reason is the process of code assignment, because the learning rules perform based on the sender node's energy level in a specific path. So, the minimum number of codes are assigned to the clusters.

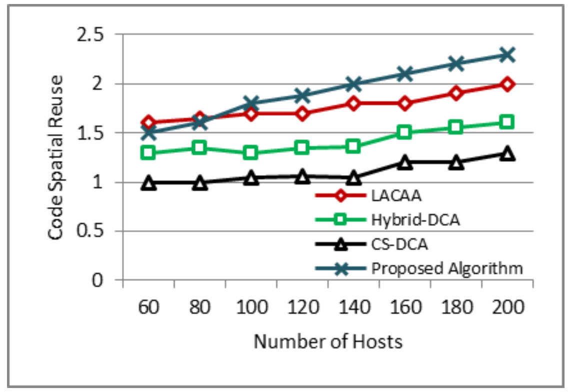

Figure 10. Code spatial reuse vs. number of hosts

We have evaluated the average waiting time for sending data packets due to lake of free codes with variation of hosts' number. These results are depicted in the figure 11. Naturally, when the number of hosts increases the average waiting time increases too. In this test, we have considered the minimum number of codes for calculating the blocking rate. In the second level, we have performed this test based on the lake of free slots versus hosts' number.

The results of simulation in figure 12 show the average of throughput in the network with increase the hosts' number in all algorithms. This figure clarifies that the throughput rate increases by the increase of hosts' number. The throughput rate in all protocol increases with increase of hosts' number of paths. But, the graph's gradient shows high increase for proposed method than the other algorithms. Because, when a host leaves a cluster, the assigned slot to the host is distributed among other cluster members by the proposed algorithm. The important reason for this behavior is the application of learning automata and finding the best path based on energy levels of nodes. In fact, the system learns behavior of finding path by increase of gathered information of learning automata from its environment.

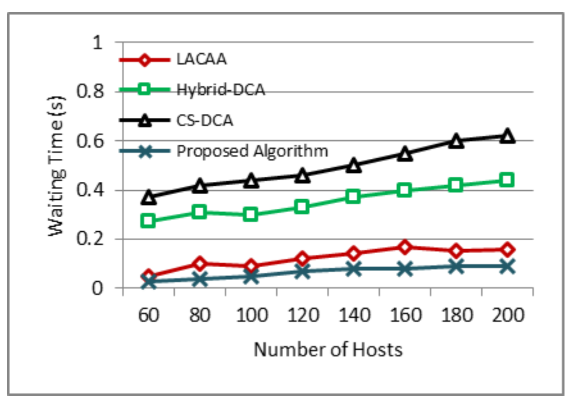

Figure 11. Average waiting time vs. number of hosts due to lake of free codes

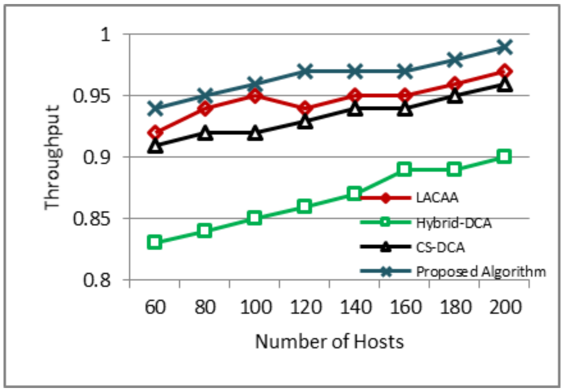

Figure 12. Throughput vs. number of hosts in the network

As we have mentioned before, in the next experiments, we have studied the performance of proposed TDMA algorithms in second level. In the next simulation, the average waiting time versus the hosts' number in comparison with other methods is analyzed. The number of hosts is varied while the number of connections is fixed in this simulation. In addition, a number of time slots is intended one. The figure 13 shows the average waiting time is increased with increase of hosts' number. But our method is relatively more convenient in case of waiting time when there is no slot. So that waiting time difference for 160 to 200 numbers of hosts is zero approximately.

Figure 14 shows the performance of proposed TDMA algorithm from the point of blocking rate due to lake of slots with variation of hosts' number. In this simulation, the number of slots is limited. Obviously, from the results of simulation shown in the figure 14, the number of blocking connections has decreased with increase of hosts' number. Proposed scheme reserves no slots for new income hosts in a cluster. Furthermore, the selection probability of assigned slots to each host is proportional to its traffic load.

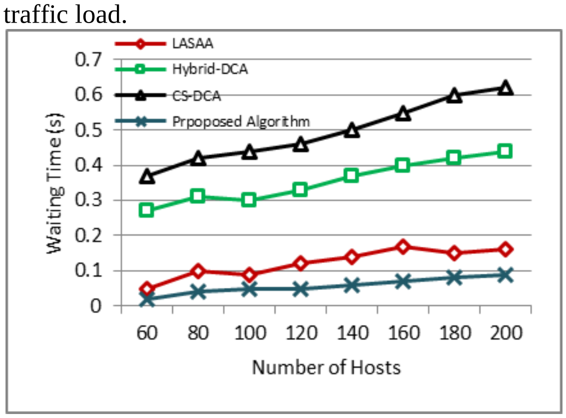

Figure 13. The average waiting time vs. the number of hosts

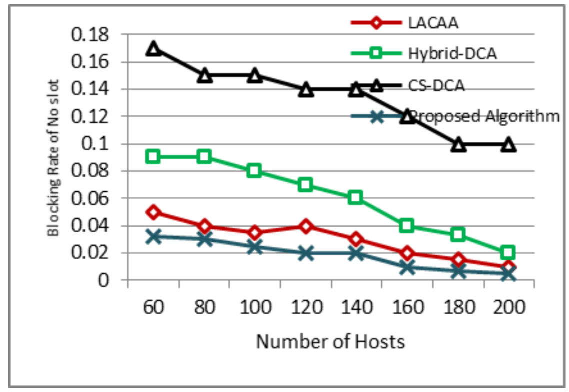

Figure 14. The blocking rate vs. number of hosts due to lake of slots

In the next simulation, we have perused the average waiting time of the network for LACAA, CS-DCA, Hybrid-DCA and proposed algorithm with increase of connections' number. Figure 15 shows the results.

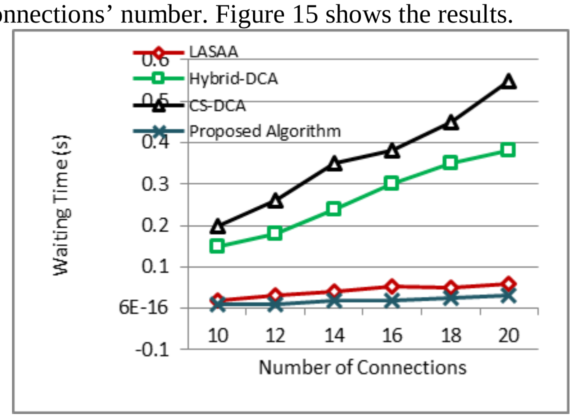

Figure 15. The average waiting time vs. number of connections

As we have expected, the proposed algorithm has lower waiting time than the other protocols. In this simulation, the number of nodes is 100 and the number of clusters is 10. The learning automaton in each node gathers the information from the environment and this causes assignment a time slot to inter cluster nodes to be performed properly when the number of connection increases. So the quantity of average waiting time has not increased obvious more than 0.1.

We have analyzed the performance of TDMA protocols in term of channel spatial reuse, when number of hosts was varied. Figure 16 shows the difference among four protocols from the point of channel spatial reuse in the network. However, channel spatial reuse increases whit increase of number of hosts. But proposed algorithm has better performance than the other algorithms significantly. Because proposed algorithm does not need to reserve a large number of unused time slots for new entrant hosts.

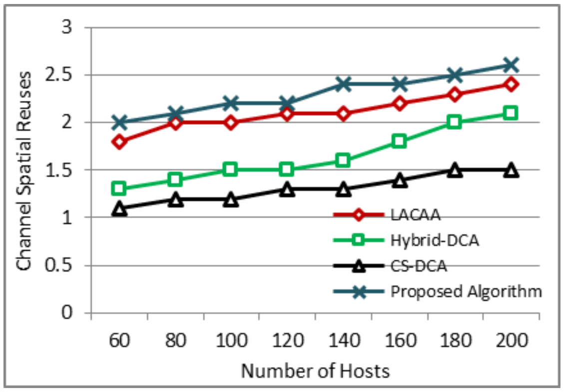

Figure 16. Channel spatial reuses vs. number of hosts

5. Conclusion

In this paper, we have represented a dynamic TDMA/CDMA scheme based on learning automata in MANETs. In the scheme, we have used TDMA scheme for inter cluster communication in which a time slot is assigned to a host when it has a packet for transmitting. In addition, we have used CDMA scheme for outer cluster communication. In both algorithms, learning automata rules are utilized. Moreover, the energy levels of nodes in the network have been used as a factor for saving energy within the network in the proposed scheme. The performance of proposed scheme is compared with three protocols: LACAA, CS-DCA and Hybrid-DCA. Simulation results show that our proposed scheme outperforms other similar protocols in point of evaluation criteria.

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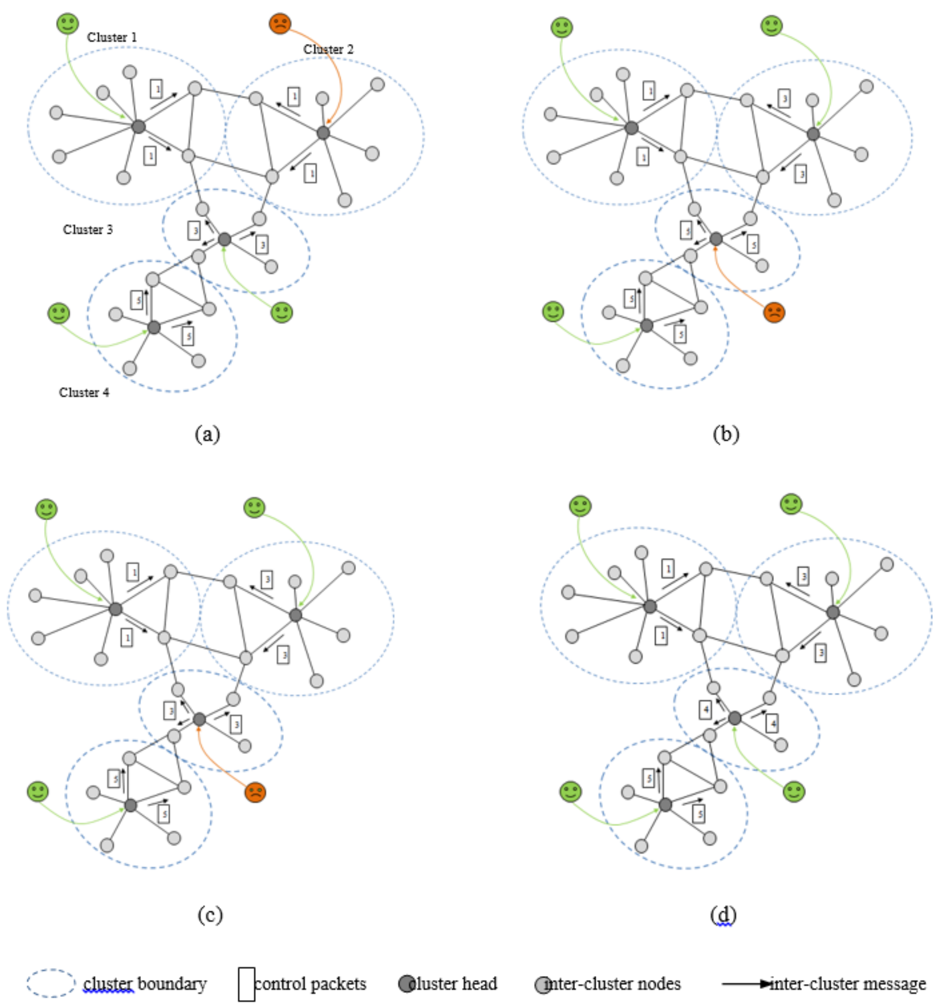

Figure 4. Functionality of clusters in network.

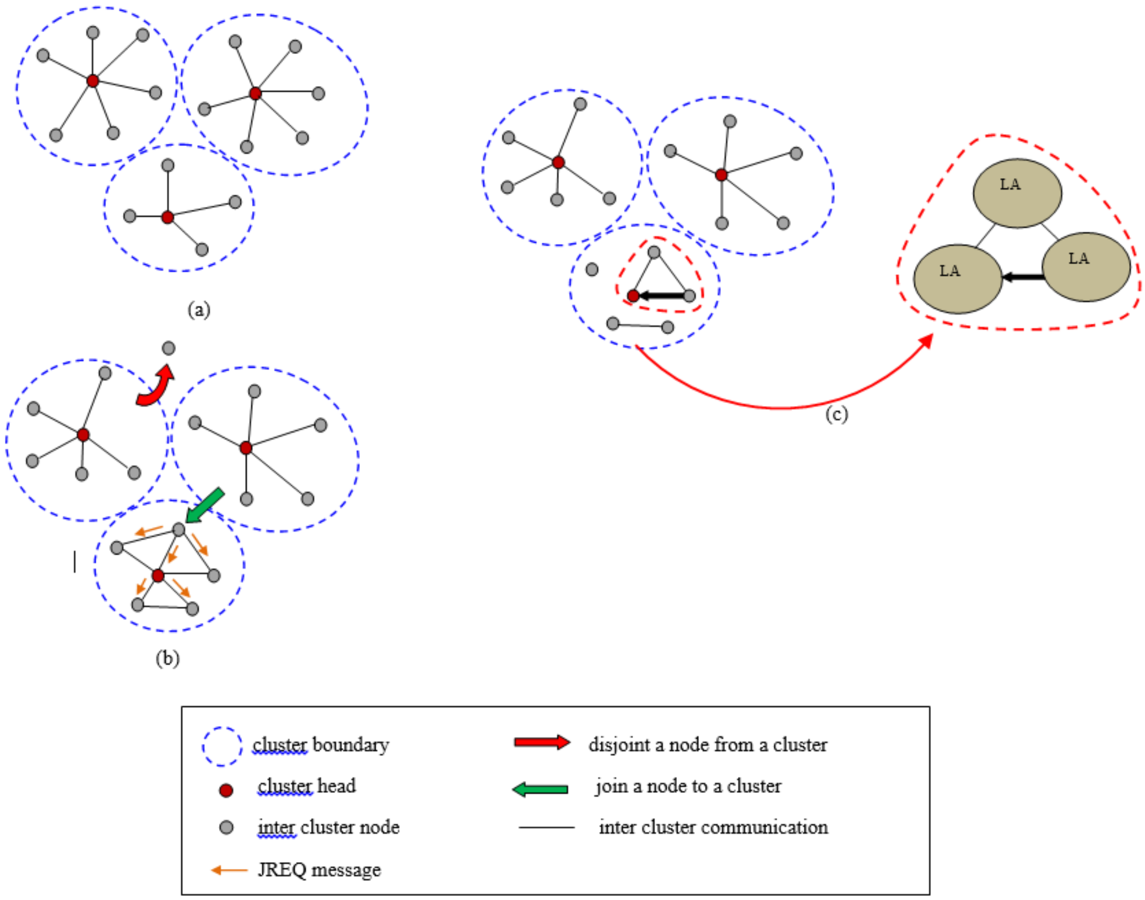

Figure 6. (a) shows he clustering process, (b) shows the clustering after specific period and disjoining a node from one cluster and joining to another cluster, (c) shows learning automata function to send data packet to cluster head.