Distributed Routing Protocol in Wireless Sensor Networks through Mimetic Algorithm and Time-Sharing Approach to Select Cluster Head

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ABSTRACT:
Wireless sensor networks include sensor nodes communicating each other through wireless links for effective data collection and routing. These wireless nodes are of limited processing power, memory, communication range, channel band width, and battery capacity, from among which the most important is limited capacity of batteries which are unchangeable, under many conditions. The limitation encourages designing efficient protocols in terms of energy consumption. Using clustering is one of the methods to optimize energy consumption. On the other hand, a technical challenge in successful expansion of wireless sensor networks and their exploitation is effective usage made of limited channel band width. To overcome the challenge, one of the methods is dividing schedule of channel usage through TDMA method (Time-Division Multiple Access) so that each cluster head node creates a schedule for transmission of data from member nodes of the cluster through TDMA. Accordingly, in the paper, a distributed routing protocol based on clustering through usage of mimetic algorithm and time-sharing approach is proposed; and, it is capable of optimizing energy consumption and throughput rate, as well as reducing delay. The simulation results are indicative of better performance of proposed method, compared to IEEE 802.15.4 Standard.

KEYWORDS: Wireless Sensor Network, Clustering, Memetic Algorithm, Time-division Multiple Access, IEEE 802.15.4 Standard.

1. INTRODUCTION

Recently, wireless sensor networks have turned to important field in science and research. Wireless sensor networks are communication networks with various characteristics, including intelligent sensors; and, they are capable of information and communication processing. Wireless sensor networks have different applications, based on capabilities of these sensors. These networks are widely used to monitor datasets. Considering variety of these applications, sensors can be of different characteristics in network. Sensor networks may include hundereds or thousands of nodes; and, it may be required for them to be deployed in remote or dangerous environments. For efficiency purposes and easier application, their locating and deployment have to be simple, also. On the other hand, sensors are usually not capable of charging their batteries; so, software and hardware structures have to be used with consideration of their level of energy consumption [1]. Wireless sensor networks may be of different characteristics, based on their application. Most of sensor networks need a radio transmitter to communicate between sensor nodes and sensor-based programs. Moreover, communication between the nodes is very limited; therefore, each node in the network separately needs energy to consume. Different algorithms based on various approaches have turned to important research subjects for optimizing energy consumption in wireless sensor networks. Wireless network clustering is one of the techniques used in wireless sensor network which increases life cycle of the network, and efficiency in terms of data collection. As far as number of nodes in these networks are usually high; communicating based on clustering and hierarchical routing is an effective plan for communication. In a network based on clustering, usually there are two types of nodes called cluster head and cluster members. When hierarchical route is specified by clusters and cluster heads, communication would be established between nodes and sink. In this routing method, cluster members have to only communicate with their own cluster heads. In some of

applications also, the communication between members in a cluster could be taken into consideration. on the other hand, cluster heads have to communicate with other clusters and members of their own cluster. During every communication, cluster members have to just send their own data to the cluster head; and, they have no need to know the entire topology. This would be resulted in simpler data collection and reduction of energy consumption. Other tasks such as finding destination address, computing the shortest rout, and sending message through shortest route have to be performed by cluster heads. To design efficient networks and increase their life cycle, selecting cluster heads is of high importance. Clustering is of high advantages, such as network scalability in wireless sensor netwoks. It also is capable of localizing the route existing within the cluster; and, this way size of routing table inside the node would be reduced [2]. Moreover, clustering can keep communication band width intact; because, It makes intercluster interaction domain limited to cluster heads, and prevents exchange of unwanted messages [3]. Also, cluster head can keep data collected by sensors in its own cluster; so, number of relay packets would be reduced [4]. Clustering makes reuse of band width possible; and, it can increase system capacity. Through usage of clustering, resource allocation would be improved and energy consumption would be controlled, more easily [5]. Accordingly, in the paper effort has been made to deal with clustering in wireless sensor network and to propose a hirerarchical routing protocol based on clustering, through memetic algorithm. This protocol is capable of precisely specifying time intervals allocated to sensor nodes for transmission of data so that energy consumption in this kind of networks would be optimized.

2. RELATED WORKS

Till present time, many studies have been performed to reduce energy consumption in sensor network. However, clustering has been introduced as an efficient method in this respect; and, a number of studies performed in this respect are dealt with in this section. An energy efficient routing algorithm based on harmony search algorithm has been proposed by Zeng and Dong [6]. Their algorithm tries to solve routing problem in wireless sensor networks, through harmony search algorithm. In such algorithm, harmony memory encoding has been optimized based on routing characteristics of wireless sensor networks; and, an effective local search method has been proposed to improve search capability and to increase convergence speed and accuracy of routing method. In [7], an unequal clustering protocol including coss-layer hybrid routing based on ACO (ant colony optimization) and fuzzy logic have been presented by Gajjar et al. for wireless sensor networks. The algorithm includes three protocols for selection of cluster head, clustering, and intercluster routing; and, it uses fuzzy logic along with such inputs as remained amount of energy, number of neighboring nodes, and quality of communication link as for selection of cluster head. To prevent hot spot problem, the algorithm uses unequal clustering method in which those clusters closer to the base station are smaller than those of farther clusters. It also uses ACO-based method for intercluster multi-path routing which is energy efficient for routing from cluster head to base station. Integrated separation has been suggested by An et al. [8] that made expansion in topology control method and designing data routing for clustering method, through usage of limited sources of sensor nodes and increase of network's life cycle. Through a clustering algorithm, routing based on a small world model has been suggested by them so that the problems of unreasonable selection of cluster head and unequal energy consumption would be overcome. Cluster heads have been selected by them, with consideration of energy and degree of each node in the network. In [9], cluster-based client/server data aggregation routing protocol (CBA) has been proposed by Pour Roustai et al. which devides the network into a set of data-drivern clusters. Then, it creates a tree spinal column and transfers the results from each cluster to the sink. Proposed protocol has been aimed at maximizing energy efficiency and accuracy of data aggregation, in addition to minimizing end to end delay. Based on the results, satisfactory performance has been observed, compared to MR-LEACH and DDiFF (direct diffusion) protocols. Dynamic data-driven clustering gives CBA the capability for collection and aggregation of desirable data samples with no consideration of distribution model and/or heterogeneity. CBA reduces energy consumption due to the point that, clusters are formed through lightweight Hamming Distance technique. Moreover, through technique of directing collision, number of control packets would be reduced. A reliable routing protocol based on new GBRR network has been presented in [10] by Meng et al., through clustering and routing characteristics based on network that have been deployed to expand sensor networks and create adaptability for them. In dense large scale fields, cluster routing has been implemented to solve additional load problem in cluster heads so that optimization advantages would be obtained. Also, in combination with greedy algorithm, holes and obstacles' problems would be solved so that the network becomes reliable. GBRR routing protocol has been presented to study reliability of node to node link quality in WSN. Using energy-efficient technology, the strategy uses the mechanism of common path answer to create clusters based on virtual network around nodes of next step in selected routes; and, this would be

resulted in more configuration of nodes in the network so that maximum advantage would be obtained from greedy and environmental transmission, while making sure of node to node connection in data transmission point. Simulation results show that the strategy is capable of data transmission to base station, through effective steps. The project also can avoid holes and obstacles through decentralized transmission. As a result, reduction of packed load due to network uploading would be decreased, compared to similar approach. Two distributed routing protocols i.e. energy-efficient and connection-aware have been proposed by Mehmed et al. in [11]. These protocols are "on hole children reconnection" (OHCR) with local nature and "on hole alert" (OHA) with global nature. Proposed connection protocols keep intact single-phase of deployment and single-path networks with every kind of topology, through energy-efficient method and avoiding topology modification overhead. The authors have put focus on supervision programs in which periodic data collection is necessary; and, these two protocols for these types of networks have been introduced by them so that connection would be maintained and increase of overhead presented by dynamic routing protocols would be avoided. In [12], a fuzzy routing protocol has been proposed by Zahedi et al. based on swarm intelligence. In their proposed method, fuzzy C-means clustering algorithm has been used to cluster all of the nodes inside balanced clusters; then, Mamdani's fuzzy inference system has been used to select cluster heads. The method not only guarantees creation of balanced clusters; but also, it can specify exact number of clusters. In the method, a hybrid swarm intelligence algorithm based on firefly algorithm, as well as thermal simulation have been used to optimize table of fuzzy rules in their proposed algorithm. Proposed method has been mainly aimed at increasing network's life cycle based on its various applications. Clustering routing algorithm for wireless sensor network has been presented by Li et al. [13] so that energy would become balanced and network life cycle would be increased. Routing algorithm presented computes number of proper heterogeneous nodes and selects cluster heads at every run. In their method, all of sensor nodes are divided into two types. First type includes those nodes that transfer data to sink through heterogeneous node; and, the remaining nodes are from type two. Moreover, common nodes at every turn would be clustered by LECH-C. Performance analysis and numerical results show that presented routing algorithm can increase network's life cycle. Also, it can significantly create balance in energy consumption. Energy balancing algorithm and unequal clustering has been presented by Liu et al. [14], in which nodes are partitioned to clusters with unequal size; however, each sensor node maintains gradient value so that it would be defined as minimum number of steps for sink. Cluster size would be determined through its cluster head gradient value; and, data collected from cluster members have to follow direction of decreasing gradient to reach the sink. The method is based on wireless sensor network with uniform distribution; however, in some of real data applications, sensor's uniform distribution is not possible, either technically or practically. Energy consumption balancing method in clustered wireless sensor networks have been developed [15] by Ducrocq et al.; and, sensor's clustering algorithm has been selected by them as cluster head based on remained amount of energy, node's degree and density. The algorithm provides sensor with an opportunity to be turned to cluster head; and, it optimizes energy consumption among all of the sensors. The algorithm has been aimed at optimizing time for all of the nodes to remain alive so that application's requirements would be satisfied. In [16], multi-path routing protocol has been presented by Banimelhem and Khasawneh, using the idea of subnetting sensor network into subnets. Inside each subnet, one of sensor nodes would be chosen as the main node responsible for delivery of created data from each node existing in that subnet, and routing of data received from other main nodes in adjacent networks. For each main node, many diagonal paths that connect main node to the sink are stored as routing natures in routing table of that node so that they would be used for routing divisions. However, the method is just suitable for mesh sensor networks. A new hybrid method including static and dynamic clustering operation has been presented by Bozorgi et al. [17] for energy harvesting wireless sensor networks (EH-WSNs). In the method, a centralized distributed approach and multi-purpose routing have been used; and, such criteria as energy level, amount of harvested energy, and number of neighbors in clustering process have been taken into consideration. Probability level of each node to be selected as CH would be specified based on energy status and amount of energy harvested. Those nodes with higher chance level to become CH will have lower delay. The node with lowest delay time compared to its neighbors has been selected as CH. After selection of CH and formation of a cluster, all nodes in each cluster begin sending packets to CH, with consideration of energy-aware multi-purpose routing. Then, these packets would be sent by CH to base station (BS), through multi-purpose routing. Simulation results show that proposed method improves stability and efficiency of the network, compared to other methods.

3. PROPOSED METHOD

3.1. Memetic algorithm

In this section, a brief explanation would be provided about memetic algorithm; then, proposed method for sensor nodes' clustering.

Gene is a part of biological information transferred from one generation to the other. Genes specify physical characteristics such as appearance, shape, body, and all traits inherited from parents. Meme has been introduced by Dowkins (1979), through a genetic comparison, in terms of cultural evolution. Meme is a cultural or behavioral element transferred by non-genetic factors from one generation to the other. In fact, meme includes every trait and behavior learnt through experience and imitation during life of a creature; and, it would be replicated among creatures. This replication has no genetic nature and reproduction operators have no effect on it.

Literal definition of meme is "a part of civilization in which genes play no role in being inherited to the next generation". By biologists, gene is defined as the unit of transfer of physiological characteristics such as color of eyes, hairs, and etc. from parents to children. By psychologists, meme is defined as the unit of transfer of behavioral characteristics including fierceness, traditionalism, and etc. from parents to children. According to psychologists' perspective, a person born in an illiterate family does not necessarily remain so till the end of his/her life. For improvement, he/she can achieve some skills from his/her surrounding environment; however, according to biologists, chromosome genes are fixed and unchanged from the moment of birth to death. Memetic algorithm (MA) is based on this idea. Contrary to genetic algorithm considering no change happening in people from the moment of birth to their end of lives (presence in reproduction process for next generation), a person in memetic algorithm can promote his/her level of competency in one generation with a behavior called imitation.

Some examples from meme are:

- Positive and negative traits in a society having their root in a cultural reality. They do not take advantage of genetic concepts.
- Fashion dress: latest fashion dresses are resulted from ideas provided by fashion designers.
- Sciences: scientists communicate about their own points of view to improve knowledge.
- Literature: novels and poems published by authors and poets which would be resulted in an imitation to be made of one literary style or work.
- Music: in addition to musicians, even birds imitate each others' musical melodies.

Similarities between genes and memes:

- Genes would be transferred from on chromosome to another (reproduction); and, memes would be transferred from one brain to the other (imitation).
- In genetic evolution period and during life, best genes and best memes will survive, respectively.

Differences between genes and memes:

- Numbers of genes are pre-specified. For example, white parents will have white children; however, number of memes can by no means be estimated till beginning of one's life.
- Usually, genes are fixed in various generations; however, memes are repeatedly changed during a life cycle.
- Optimization and modification become possible through memes; however, it takes several generations for genes to do so (evolution as a miracle takes place during a long period of time).

According to Dowkins, memes are more existential than genes; because, genes in a person would be destroyed after his/her death (especially if he/she has no offspring or family). However, there is no death imagined for memes; and, they would be transferred from one person to another (like viruses). In fact, host person is composed of high volume of positive and negative memes. Combination of these memes for example in a human will led to literacy, sobriety and dignity, egoism, pride, stupidity, and/or arrogance in him/her. Some memes are learnt or imitated by a person during his/her life. Anyway, all of these memes would be replicated by the person, and not destroyed by his/her death. Exactly due to the same reason, self-giving people die but devotion still exists and/or despite death of many criminals, crimes are still present in human societies.

Some of the problems with genetic algorithm as mentioned below have caused meme concept to be used, in addition to gene:

- ✓ Like many other meta-heuristics, genetic algorithms in first steps of their execution identify well state space of the problem in which global and local optimums are located; however, they are very slow in continuing their path towards global optimum.
- ✓ Second main problem with genetic algorithm is lack of their stability. That is, quality of answers resulted from various executions of algorithm could be very different and even unreliable.

From among many mechanisms presented as for solving meta-heuristic search algorithms; combining strategy has gained a special status. Combining strategy

is resulted from using global and local search methods in problem solving process. Memetic algorithms are the most famous members of the family which are resulted from combination of genetic algorithms and a local heuristic search.

The idea of using meme concept to design a meta-heuristic algorithm has been first suggested by Moscato. He proposed that, using a local search operator in the body of genetic algorithm (after mutation operator), a child would be granted with the opportunity of living after his/her birth. Memetic algorithm has many similarities with genetic algorithm; and, their main difference is in optimizing population of each generation after implementing recombination and mutation operators. To do so, a local search with pre-specified neighborhood radius would be performed around the chromosome related to the born child in the state space of the problem, against each person born in the society. Memetic algorithm like the genetic one has been used to solve many of continuous and discrete optimization problems and wide range of real world problems. Memetic algorithm pseudocode is shown in Fig. one. Important features of memetic algorithm are:

- Local search would not be performed on all of the members in population so that speed and efficiency in memetic algorithm would be increased. Due to the same reason, usually small population of fit children would be introduced to local search operator, after mutation operator.
- Memetic algorithms would be divided into two important Lamarckian and Baldwinian memetic algorithms.
- If chromosome y would be the result of local search operator on chromosome x, and fitness(y)>fitness(x) (supposing that a maximizing problem is going to be solved); in Lamarckian memetic algorithms, chromosome x would be replaced with chromosome x. However, under the same conditions, in Baldwinian memetic algorithms, only fitness of chromosome x would be replaced with fitness of chromosome y. In fact, in Baldwinian memetic algorithm, only reproduction operators are permitted to change chromosomes.
- Convergence speed in Lamarckian memetic algorithms is higher than that of Baldwinian memetic algorithms; whereas, searching capability of Baldwinian memetic algorithms is much higher than that of Lamarckian memtic algorithms.
- Special characteristic of Baldwinian memetic algorithms is lack of change of chromosome's genotype in life-stage (local search) of algorithm. The characteristic leads to fitness improvement of local optimum neighboring points. This would be resulted in changes applied in fitness landscape in these points; and, some parts of fitness with hedgehog nature would become smooth, and search space would be more easily navigated by the algorithm. In many papers and books, smoothing (simplifying) of fitness landscape by local search engine based on Baldwin theory is called Baldwin effect.
- Instead of placement of new answer in local search engine (Lamarck theory), or lack of answer placement (Baldwin theory), this placement could be done through a P_L probability. This way, if P_L=1, Lamarckian memetic algorithm would be resulted; and, if p_L= 0, Baldwinian memetic algorithm would be the result.
- Adaptive memetic algorithms take advantage of a set of search methods, instead of using only one fixed local search engine. In these types of algorithms and giving one merit to each of local search methods (based on their success level in improving chromosomes' fitness), a proper local search method could be used with consideration of state space of the problem and what the algorithm requires in each generation. In adaptive memetic algorithms, advanced local search engines have learning possibility [18].
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```
Function MA(problem) returns a state that is a local optimum
Input: Populationsize, Problemsize, Pcrossover, Pmutation, MemePopsize
Output: Sbest

Population ← InitializePopulation(Populationsize, Problemsize);
EvaluatePopulation(Population);
Sbest ← GetBestSolution(Population);
while ¬ StopCondition() do
  Parents ← SelectParents(Population, Populationsize);
  Children ← ∅;
  foreach Parent1, Parent2 ∈ Parents do
    Child1, Child2 ← Crossover(Parent1, Parent2, Pcrossover);
    Children ← Mutate(Child1, Pmutation);
    Children ← Mutate(Child2, Pmutation);
  end
  EvaluatePopulation(Children);

  MemeticPopulation ← SelectMemeticPopulation(Children, MemePopsize);
  foreach Si ∈ MemeticPopulation do
    Si ← LocalSearch(Si);
  end

  Population ← Replace(Population, Children);
  Sbest ← GetBestSolution(Population);
end
return Sbest;
```

Fig. 1. Mimetic algorithm pseudo code.

3.2. Proposed Method

Proposed method includes two phases of stable clustering or data transmission. In clustering phase, clusters are formed; and, in data transmission phase,

collected data would be transferred to cluster head by sensor nodes, based on schedule. In the paper, operations for specifying cluster heads are supposed to take place in base station or sink. After receipt of energy-related information and also position of network nodes, base station or sink as a powerful central processing unit with unlimited energy is capable of classifying energy classifying them in balanced clusters in terms of total energy consumption and volume of work done, based on memtic algorithm. This is done to the aim of minimizing energy consumption of network as a whole, through proper distribution of structures created from nodes and a number of cluster head all over the network.

After formation of clusters, nodes will recognize their own cluster heads; and, they send their own data based on TDMA schedule determined and sent by cluster heads to nodes to the related cluster head. Each time cluster formation and permanent state takes place, it is called a round. At the end of each round, clustering operation would be performed again; and, new clusters would be selected to play the role of cluster head. In continuation, details of proposed algorithm would be dealt with.

Clustering phase: Initial population of sensor nodes in this phase includes 50 sensor nodes, randomly dispersed in simulation environment. In the base station, number of required cluster heads is set in the program in advance; and, this number specifies chromosome's length. Each gene in this chromosome is identifier of a number of network nodes randomly selected in the phase. Clustering phase include following stages:

Stage 1: Population initialization: random population including 10 chromosomes equal to the number of those cluster heads having gene would be randomly produced. Fig. 2 shows a view of chromosome containing genes with sensor nodes' identifier. According to the Fig. , this chromosome randomly selects nodes with identifiers 47, 30, 20, 10, and 2 from among network nodes, as candidates for becoming cluster head. As far as we are intended to have five cluster head for 50 sensor nodes; five nodes from among nodes would be randomly selected as gene, in the chromosome.

20	30	47	10	2

Fig. 2. A view of chromosome in proposed method.

Stage 2: Evaluation stage of initial population by fitness function: in this stage, quality of answers would be computed through fitness function. That is, fitness of each gene existing in chromosomes in genetic population would be computed through relationship (1):

$$\text{Fit} = \sum_{i=1}^{5}(E_i + \frac{1}{D_i})/5 \quad (1)$$

Where, E is remained amount of energy of i^{th} sensor node, and D is the distance between sink and i^{th} sensor node. Distance to sink would be computed through equation (2):

$$D_i = \sqrt{(xs - xi)^2 + (ys - yi)^2 + (zs - zi)^2} \quad (2)$$

Where, D_i is distance to sink, (xs, ys, and zs) are position of sink, and (xi, yi, and zi) are physical position of i^{th} sensor obtained through GPS.

Stage 3: Achieving best solution: chromosomes would be arranged based on their fitness computed through equation (1); and, best chromosome with highest fitness value would be kept within Sbest array.

Stage 4: Review of termination condition: if 100^{th} round has not been reached, following stages would be followed:

Stage 4-1- Crossover: crossover would be done with probability of higher than 0.5. That is, a random number between 0-1 would be primarily produced. If the number would be equal to 0.5 or bigger than that, crossover would be done. Otherwise, no crossover would be performed. For crossover, two chromosomes existing in initial population with highest level of fitness would be selected as first parent; and, remaining chromosomes would be considered as second parent. Crossover would be done on first and second parents. In crossover process, one random number within the limit of chromosome length (0-4) would be produced and both parent chromosomes would be crossed over at production point in cross form. As shown in Fig. (3), first and second crossover points are selected from first and second parents, respectively; and, children would be created, accordingly.

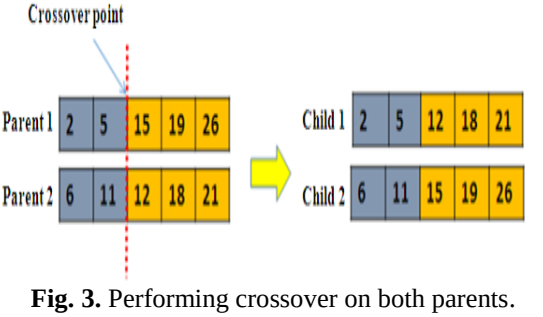

Fig. 3. Performing crossover on both parents.

Stage 4-2- Mutation: with probability level of 0.8, mutation would be performed. That is, a random number would be primarily produced within 0-1 range. If produced number would be equal to 0.8 or bigger

than that, mutation takes place. Otherwise, there would be no mutation. For mutation also, a random number within chromosome length range (0-4) would be produced and considered as index of array/chromosome. In selected box to which random number selected refers, identifier of one of sensor nodes would be randomly placed. That is, the value in the third box would be replaced with identifier of sensor 6.

Fig. 4. Mutation performed on both parents.

Stage 4-3- Evaluating fitness of children produced due to crossover and mutation: quality of answers would be measured again for children through fitness function presented in relationship (1); and, children would be arranged based on their fitness level.

Stage 4-4- Selecting memetic population: children produced in previous generation along with population from previous generation would be placed in memetic population.

Stage 4-5- Performing local search: for each chromosome existing in memetic population, local search would be done. Local search in memetic algorithm is a repetitive process through which answers in neighborhood are considered as current answer to evaluation; and, if they are better answers, current answer would be replaced by them. As far as local search is concerned, if chromosome y is the result from local search operator on chromosome x and $Fitness\ (Y) > Fitness(x)$; then, chromosome x would be replace by chromosome y. That is, if fitness value of a child chromosome would be higher than father, father' chromosome would be replaced by it. The stage corresponds to Lamarck theory.

4-6- Selecting best solution: if 100^{th} round has not been achieved, stages 4-1 to 4-6 would be repeated. Otherwise, in 100^{th} round, population would be arranged based on fitness; and, the chromosome with highest fitness value would be placed in Sbest array. Then, a message declaring turning to cluster head would be sent by sink to identifier of nodes existing in Sbest array.

Stage 5- Formation of clusters: those nodes receiving the above message from sink would be selected as cluster head. Again, these cluster heads produce and send an information message to the nodes within their range, including cluster head identifier, and location of cluster head. Other nodes not being cluster head and receiving such message from other cluster heads sent connection message to the nearest cluster head. The message includes member node's identifier and remaining amount of energy in the battery, as well as physical position of member node.

Stage 6- Scheduling: cluster head nodes receiving connection message act as local control centers to coordinate data transfer among clusters and lack of occurrence of collision between nodes of a cluster. That is, they set a TDMA schedule and send it to cluster members. Based on TDMA, sensor nodes activate radio component just when data are sent; and, other times, this hardware component of node would be off. Using TDMA reduces consumed energy and helps reduction of collisions between data packets.

Stability state or data transmission phase: In this phase, network performance is divided into a number of superframes. In each superframe, all of nodes in a cluster send their data to their own cluster head. Format of superframe would be defined by cluster head, as shown in Fig. 5. The superframe related to beacon interval (BI) would be defined by time interval between two consecutive beacons; and, it includes active and inactive periods (arbitrary). Active period related to superframe duration (SD) would be divided into 16 equally sized time slots, during which data transmission is also allowed. Each active period can be divided more i.e. it can be divided into one contention access period (CAP) and one contention free period (CFP). CSMA/CA would be used along with time slots within CAP. CFP would become activated through application sent from one device to cluster head. As soon as application is received, existence of enough resources would be examined by cluster head. In case of possibility, it allocates time slots applied for. This group of time slots is called guaranteed time slot and exclusively would be allocated to concerned device. One SFP supports maximum 7 guaranteed time slots; and, each GTS could have several time slots. Allocation of GTS cannot reduce length of a CAP to a value lower than specified one by aMinCAPLength constant.

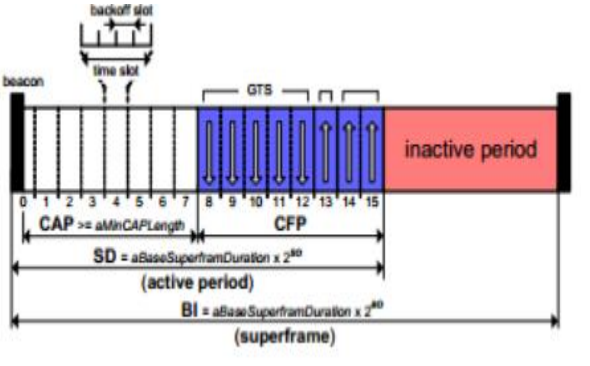

Fig. 5. Superframe structure.

4. PROPOSED METHOD SIMULATION

4.1. Simulation Environment

In the research and to simulate proposed method and comparing it to IEEE 802.15.4 protocol, OPNET 11.5 has been used through which wireless sensor network topology has been modeled; and, the results have been compared. Simulation parameters are shown in table (1).

Considering Fig. 6, network topology in proposed method has been considered with 50 sensor nodes and two scenarios. In first scenario, sensor nodes have been randomly dispersed in the environment based on IEEE 802.15.4; and, in second scenario, nodes randomly dispersed in the environment have been clustered through memetic algorithm. Proposed protocol has been named MABC (Memetic Algorithm-Based Clustering); and, in both scenarios topologies have been supposed to be similar.

Table 1. Simulation parameters.

Parameter	Value
Distribution method of in the area	Random
Simulation environment	1000m*1000m*1000m
Transmission type	CBR
Radio transmission range	250m
Packet size	Bit 1024
Battery model	Constant
Simulation time	200 Sec
Mac layer	IEEE802.15.14
Initial energy	400Jul

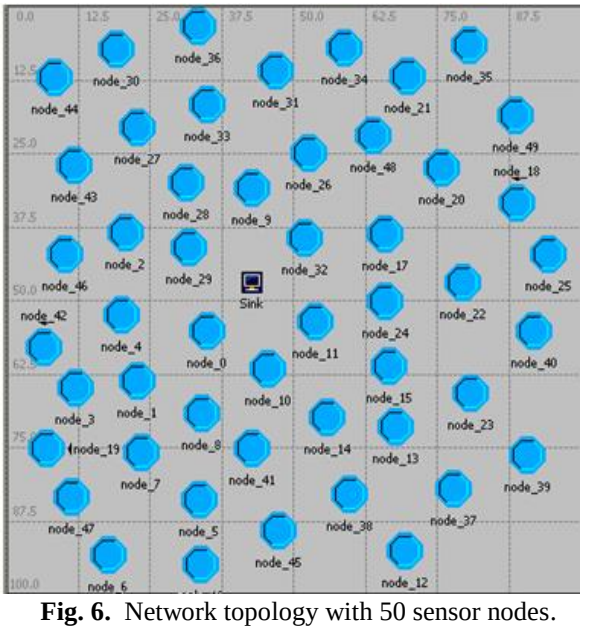

Fig. 6. Network topology with 50 sensor nodes.

4.2. Simulation Results

A Fig. 7 shows comparison made between energy consumed by the network for proposed algorithm's scenario and the one related to IEEE 802.15.4. Vertical axis shows energy consumption and horizontal axis shows simulation time. As it is expected, protocol IEEE 802.15.4 is of highest level of energy consumption. Subnodes do not act consciously and sent collected data directly to the sink node, with no attention paid to the energy consumption level. In proposed method and through clustering with memetic algorithm, those nodes with more energy and less distance would be used to send and transfer data. On the other hand, as far as member nodes also join cluster head node with consideration of their distance; there would be no need to high energy to be consumed to send data from member node to cluster head. Also, due to creation of schedulaer, collision would be prevented and there would be no need for resend of data and more energy consumed.

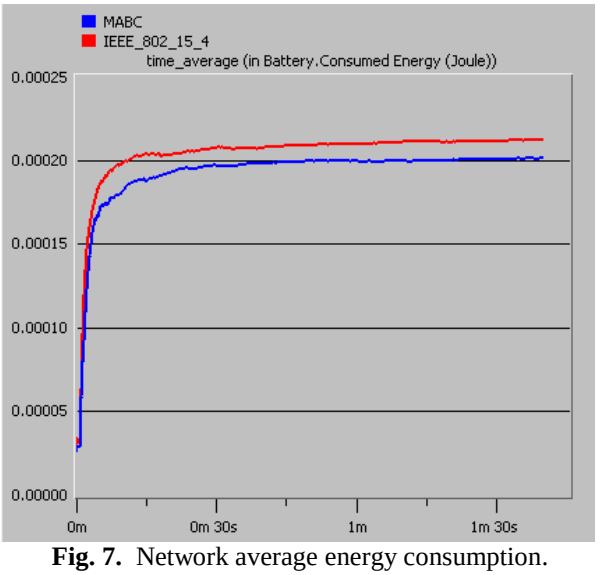

Fig. 7. Network average energy consumption.

Fig. (8) shows comparison made between end to end delay for scenarios based on proposed algorithm and also IEEE 802.15.4. Vertical and horizontal axes show end to end delay and simulation time, respectively. As it is observed in scenario based on IEEE 802.15.4 increase is made in delay; because, some nodes probably cannot complete data transmission due to collision. However, in proposed protocol end to end delay decreased; because, cluster heads are chosen from those nodes with higher level of energy and cluster members join cluster head based on the distance. Also, using TDMA helps reduction of collision in data packets in addition to reduction made in energy consumption; so, there would be no need for data to be resent, and delay to be increased.

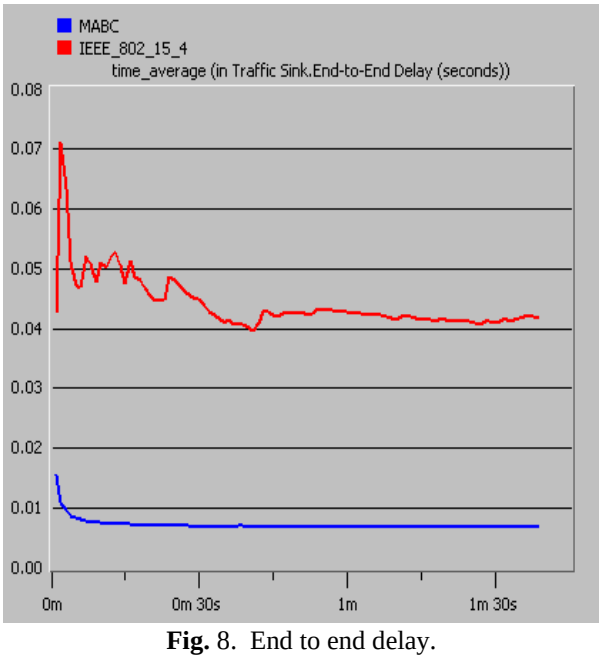

Fig. 8. End to end delay.

Fig. 9 shows comparison made regarding access made to medium for both scenarios of proposed algorithm and IEEE 802.15.4. Vertical and horizontal axes show delay made in making access to medium and simulation time, respectively. As it is observed in scenario based on IEEE 802.15.4 protocol, there would be an increase in delay of multimedia files; because, in video transmission and due to very high production rate and also explosive property, increase would be made in swarm and collision would be resulted in packets' destroy. In proposed protocol, end to end delay would be decreased; because, cluster heads in clustering would be selected from among nodes with higher level of energy.

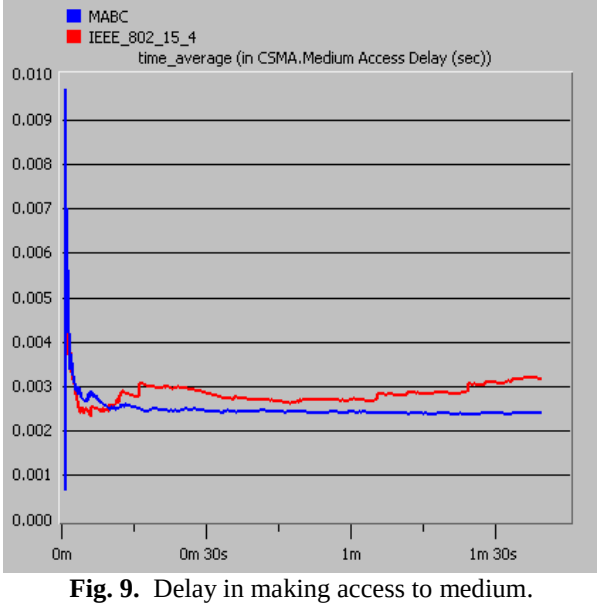

Fig. 9. Delay in making access to medium.

Fig. 10 deals with comparing error rate in data packet for both scenarios of proposed algorithm and the one based on IEEE 802.15.4. Vertical and horizontal axes respectively show error rate in the packet and simulation time. As it is observed, IEEE 802.15.4 protocol has higher error rated; because, signals of data sent by the protocol can collide and received by error. Error rate in packets in proposed protocol is low due to selection of safe paths containing high energy nodes and increase of data to be sent to sink, successfully.

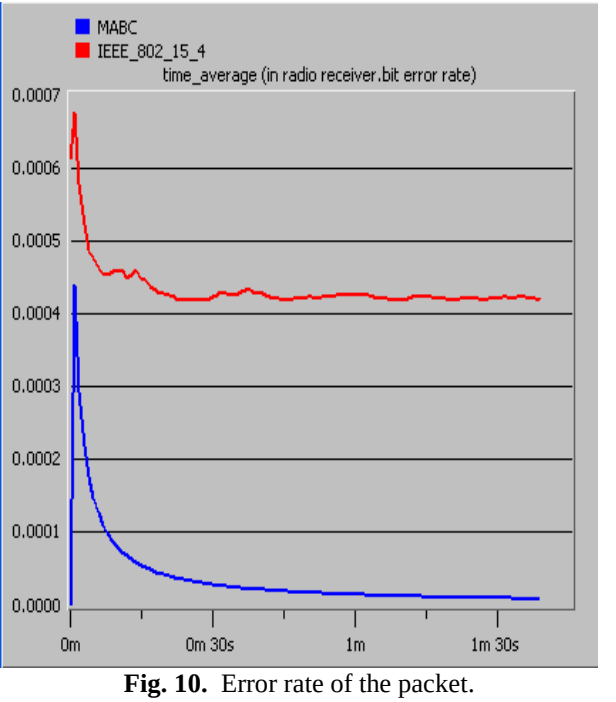

Fig. 10. Error rate of the packet.

Fig. 11 shows throughput rate. Horizontal axis shows simulation time and vertical axis shows number of packets delivered during time (throughput rate). Considering Fig. (11), IEEE 802.15.4. Compared to proposed protocol, number of packet successfully delivered to the sink compared to total number of packets transferred by sensor nodes is low because of swarm created and probability of node becoming off due to energy discharge. However, in proposed protocol and to form clusters, nodes with higher level of energy in the path would be selected and their energy would not be ended soon, till the end of phase. So, no change would be made in stability of the path till the end of data transmission phase; and, number of packets delivered to the sink in proposed method would be higher.

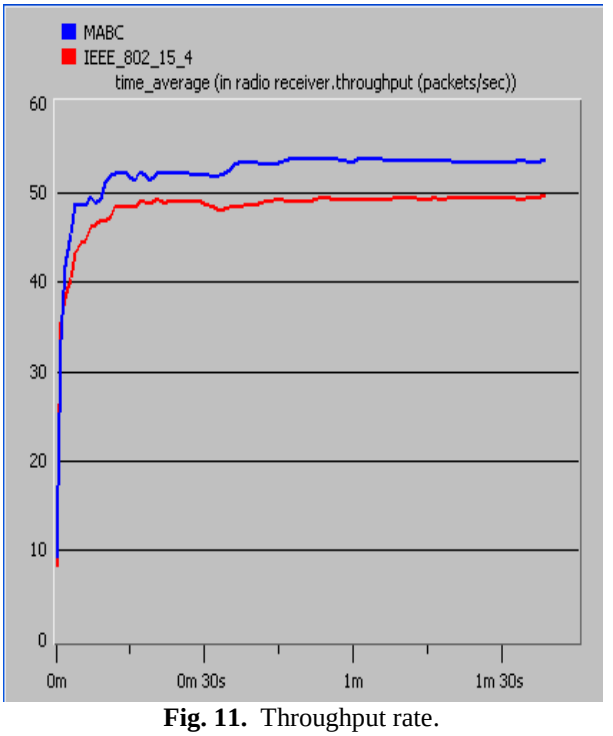

Fig. 11. Throughput rate.

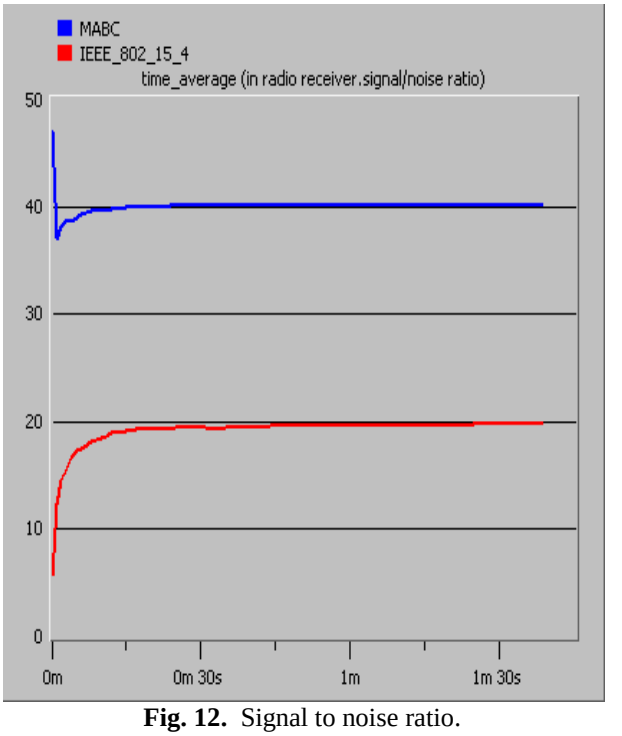

Fig. 12. Signal to noise ratio.

Fig. 12 shows comparison made between ratio of signal to noise for proposed algorithm and IEEE 802.15.4 protocol's scenarios. Horizontal and vertical axes show simulation time and ratio of signal to noise, respectively. Considering the Fig. , IEEE 802.15.4 protocol has lower noise level, compared to proposed protocol; because, instable paths could be used by IEEE 802.15.4 protocol to send data. This way and when data are sent, number of bits suffering from error would be increased and ratio of signal to noise would be decreased. Also, signals of transmitted data by IEEE 802.15.4 may be destroyed due o swarm and chaos created; then, noise level would be probably higher and quality of sent data would be reduced. In proposed method and due to usage made of TDMA which would be resulted in reduction of packets' collision; rate of data loss would be reduced and signal ratio to noise would be increased.

5. CONCLUSION

One of the main objectives of computations is efficient energy consumption in WSNs through provision of mechanisms for improvement of network performance and also reduction of energy consumption so that the network's life cycle would be increased. Except for relying on revolutionary changes made in battery technologies, one of the most important ways to improve system life cycle is clustering. Accordingly, a proper clustering method through memetic algorithm has been presented in the paper. Proposed method includes two stable clustering and data transmission phases. In clustering phase, clusters are formed and in data transmission phase based on schedule, collected data would be transferred by sensor nodes to cluster head. In the paper, operation of specifying cluster heads is supposed to be taken place in base station or sink. Base station or sink as a powerful central processing unit with unlimited amount of energy is capable of classifying information related to energy and position of network nodes (after receipt) in clusters being equal in terms of energy consumption and total amount of work done, based on memetic algorithm. After formation of clusters, nodes will recognize their own cluster heads and send their own data to related cluster head, based on TDMA (Time Division Multiple Access) schedule specified and sent by cluster heads. Each cluster formation phase and permanent state is called a round. At the end of each round, clustering operation would be performed again; and, new nodes would be selected to play the role of cluster head.

Proposed method along with IEEE 802.15.4 protocol have been simulated in OPNET; and, simulation results such as consumed energy, end to end delay, signal to noise ration, probability of successful transmission of data to sink, and throughput rate have been extracted to study how the proposed method performs. In general, it was observed that proposed method shows better behavior than IEEE 802.15.4 because of selection of those paths with nodes of higher energy level. Also, general efficiency of network has been improved by proposed method; and, increase has been made in reliability of packet delivery. A topology causes better usage of channel's band width and guarantees lack of collision. On the other hand, member nodes in the cluster in all of time intervals except for that related to them would go to sleep which in turn would be resulted in saving energy.

REFERENCES

[1] Heinzelman, W. B., Chandrakasan, A. P., & Balakrishnan, H., "**An application-specific protocol architecture for wireless microsensor networks"**. *IEEE Transactions on wireless communications*, Vol. 1(4), pp. 660-670, 2002.

[2] Akkaya, K., & Younis, M., "**A survey on routing protocols for wireless sensor networks**." *Ad hoc networks*, Vol. *3*(3), pp. 325-349, 2005.

[3] Younis, M., Youssef, M., & Arisha, K., "**Energy-aware management for cluster-based sensor networks**." *Computer networks*, Vol. 43(5), pp. 649-668, 2003.

[4] Dasgupta, K., Kalpakis, K., & Namjoshi, P., "**An efficient clustering-based heuristic for data gathering and aggregation in sensor networks"**. *In 2003 IEEE Wireless Communications and Networking*, 2003. WCNC 2003., Vol. 3, pp. 1948-1953, IEEE, 2003.

[5] Kwon, T., & Gerla, M., "**Clustering with power control"**. In *MILCOM*, Vol. 2, pp. 1424-1428, 1999.

[6] Zeng, B., & Dong, Y., "**An improved harmony search based energy-efficient routing algorithm for wireless sensor networks**." *Applied Soft Computing*, Vol. 41, pp. 135-147.

[7] Gajjar, S., Sarkar, M., & Dasgupta, K., "**FAMACROW: Fuzzy and ant colony optimization based combined mac, routing, and unequal clustering cross-layer protocol for wireless sensor networks**." *Applied Soft Computing*, Vol. 43, pp. 235-247, 2016.

[8] An, J., Qi, L., Gui, X., & Peng, Z., "**Joint design of hierarchical topology control and routing design for heterogeneous wireless sensor networks**." *Computer Standards & Interfaces*, Vol. 51, pp. 63-70, 2017.

[9] Ardakani, S. P., Padget, J., & De Vos, M., "**CBA: A cluster-based client/server data aggregation routing protocol**." *Ad Hoc Networks*, Vol. 50, pp. 68-87, 2016.

[10] Meng, X., Shi, X., Wang, Z., Wu, S., & Li, C., "**A grid-based reliable routing protocol for wireless sensor networks with randomly distributed clusters**." *Ad Hoc Networks*, 51, 47-61, 2016.

[11] Mohemed, R. E., Saleh, A. I., Abdelrazzak, M., & Samra, A. S., "**Energy-efficient routing protocols for solving energy hole problem in wireless sensor networks**." *Computer Networks*, Vol. 114, pp. 51-66, 2017.

[12] Zahedi, Z. M., Akbari, R., Shokouhifar, M., Safaei, F., & Jalali, A., "**Swarm intelligence based fuzzy routing protocol for clustered wireless sensor networks**." *Expert Systems with Applications*, Vol. 55, pp. 313-328, 2016.

[13] Li, C., Bai, J., Gu, J., Yan, X., & Luo, Y., "**Clustering routing based on mixed integer programming for heterogeneous wireless sensor networks**." *Ad Hoc Networks*, Vol. 72, pp. 81-90, 2018.

[14] Liu, T., Li, Q., & Liang, P., "**An energy-balancing clustering approach for gradient-based routing in wireless sensor networks**." *Computer Communications*, Vol. 35(17), pp. 2150-2161, 2012.

[15] Ducrocq, T., Hauspie, M., & Mitton, N., "**Balancing energy consumption in clustered wireless sensor networks**." *ISRN Sensor Networks*, 2013.

[16] Banimelhem, O., & Khasawneh, S., GMCAR: "**Grid-based multipath with congestion avoidance routing protocol in wireless sensor networks**." *Ad Hoc Networks*, Vol. 10(7), pp. 1346-1361, 2012.

[17] Bozorgi, S. M., Rostami, A. S., Hosseinabadi, A. A. R., & Balas, V. E., "**A new clustering protocol for energy harvesting-wireless sensor networks"** *Computers & Electrical Engineering*., Vol. 64, pp. 233-247, 2017.