Efficient Clustering based Genetic Algorithm in Mobile Wireless Sensor Networks

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Abstract**—Mobile Wireless Sensor Networks (MWSNs) has significant applications that provide free moving for sensor nodes and flexible communication with each other. MWSNs perform many improvements in energy consumption, network lifetime, and channel capacity than static WSNs. The MWSNs need more sophisticated routing protocols than static WSNs due to the unfixed topology based on nodes mobility. This paperpresents an Improved Mobility based Genetic Algorithm Hierarchical routing Protocol (IMGAHP) to handle the packet delivery ratio problem in MGAHP and maximize the network stability period. The proposed protocol is based on two main points. Firstly, utilizing the optimization process (Genetic Algorithm (GA)) to detect the optimum location of Cluster Heads (CHs) and their numbers. Secondly, reassigning timeslots allocated for sensor nodes which moved out of the cluster or didn't have data to send, to nodes registered in secondary Time Division Multiple Access (TDMA) schedule or new joined mobile nodes. Several experiments are implemented on the proposed IMGAHP protocol using the Matlab simulation program to appraise and compare it with MGAHP and other previous protocols. It is shown from the results that the proposed IMGAHP gives preferable enhancement in packet delivery ratio, energy efficiency, and network lifetime than all previous protocols.**

Keywords—MWSN, genetic algorithm, TDMA, CH.

I. INTRODUCTION

MWSNs consist of hundreds to thousands of tiny battery-powered sensor nodes that have the ability to move within the networks. The mobility of these nodes can be occurred by equipping the nodes with mobilizer to change their location or can be attached to transporters such as robots, vehicles, or animals. It is obvious that the mobile network has many advantages than static ones such as increasing channel capacity and lifetime, reducing energy consumption during communication, and reducing energy holes by relocating nodes after initial deployment to achieve the desired energy. In the beginning, the concept of the sensor network, underlying a fast-deploying feature and random topology, is originally associated with applications of the military environment and inaccessible disaster scene. However, as the more recent exploration of MWSN, special interests on the commercial applications in hot areas are raised while hot areas are the area with high density. There are many applications that utilize mobility in WSNs such as habitat monitoring, wildlife tracking, sensor network-based adaptive navigation systems, parasitic mobility, medical protection, and catastrophe response [1-4]. In atypical applications, mobile nodes can combine with fixed nodes to form the MWSN while other applications need completely mobile nodes. These fixed nodes can be distributed in certain locations and can be provided with a specific power but the mobile nodes can move in a random manner and are constrained with the available residual power. The mobile nodes do not consume power in transmitting and receiving data only, but they consume moreenergy in nodes mobility especially, when they move outside the allocated area and the routing process needs to be reconstructed quickly.

There are various types of mobility in MWSNs such as mobile sink only [5], mobile sensornodes only [6-18], or jointsink and sensor nodesmobility[19]. The limited power, radio capability, and storage area due to the small size of the nodesleads to developing many clustering routing protocols in static WSNs to utilize this limited energy and resources. These clustering protocols depend on grouping the nodes into clusters and aggregating the sensed data of each group before sending them to a higher level. The static routing protocols are unable to be utilized in MWSN because they did not consider node movement after clustering. The unfixed network topology of MWSN makes the network more sophisticated than the static one,hence it repeatedlyneeds to reconstruct the links between nodes.Many previous MWSN routing protocols depended on generating a random number and compared it with a threshold value to determine the cluster heads on the network. These protocols are not proficient in reducing energy efficiency, ensuring connectivity and balancing the load because of the random selection of the CHs and the idea of dividing the network into fixed clusters.

However, searching for the optimal CHs nodes instead of random selection process and demonstrating the mobility of the mobile nodes in the MWSNs becomes a hard issue and can be considered as a Nondeterministic Polynomial-time hard (NP-hard) problem. Subsequently, MGAHP was proposed to save the energy dissipated in the network, prolong the lifetime and guarantee the connectivity of the MWSNs [18].Nevertheless this protocol had less efficient performance in packet delivery ratio than MACRO and CBR-Mobile protocols.Therefore an IMGAHPis proposed to solve this problem and improves the performance of MGAHP. Theessentialconcept of the proposed IMGAHPconsists of two concepts, the first one is calculating the optimum location of CHs and their numbers by using Genetic Algorithm (GA) [20, 21] like the MGAHP, this occurs in the cluster building phase. In the second concept, if the CH discovers that any sensor node didn't have data to send in its allocated timeslot or moved outside the allocated cluster, it will reassign this timeslot to another sensor node from any one of two allocated databases. These databases are produced to occur the mobility and traffic adaptively. Each timeslot is allocated for two sensor nodes to send the sensed data, hence each node sends its data efficiently based on the strength of the received signal. This is the main improvement in the proposed IMGAHP protocol over MGAHPwhich occurs in the data transmission phase.

This paper is arranged as follows: In Section 2, related work is introduced. The preliminaries and problem formulation are explained in Section 3. Improved MGAHPisdemonstrated in Section 4. Performance and simulation results are illustrated in Section 5. Finally, the conclusions are included in Section 6, followed by more relevant references.

II. Related Work

Although there are many routing algorithms deal with static WSNs such as Genetic Algorithm-based Energy-Efficient adaptive clustering hierarchy Protocol (GAEEP) [22]. This protocol depends on usingGA to find the best number of CHs and their optimum locations in static WSN. The GAEEP efficiently prolong the lifetime and improve the stable period of WSN.

So much talk about static WSN algorithms and begin to outline the MWSN routing algorithms. The first routing algorithm which supports mobile nodes isLow Energy Adaptive Clustering Hierarchy Mobilealgorithm (LEACH-M) [6]. It depends onemphasizing that the MobileSensorNodes(MSNs) connected to their CHs within its allocation time in TDMA schedule. EachMSNreceives a request data from CH during each TDMA schedule. If a node does not receive any request during two consecutive TDMA, it is considered that this node is no longer connected to its allocated CH. This node begins to search for another CH to join with it by broadcasting a cluster join request message. The CH that hears this message, sends cluster join ACK message to this mobile node confirming it that they are connected. However, the number and location of CHs are still randomly selected, the LEACH-M algorithm is not efficient in terms of network lifetime, data delivery ratio, and dissipated energy.

LEACH-Mobile-Enhanced algorithm [7] is an enhancement for the LEACH-M algorithm. The selection of CH in LEACH-ME depended on the mobility factor of nodes while the lowest one becomes the CH. The movement number of each MSN outside the cluster represented the mobility factor. It is computed by multiplying the mobile node's velocity with the time required for each node to move from its location to another location. This algorithm needs an extra timeslot for that calculation and also consumes more energy.

The Cluster-Based Routing protocol (CBR-Mobile) is investigated in [8] and supports mobility in WSN by adapting the traffic and mobility. The CBR-Mobile algorithm enables the CHs to reuse unused timeslots for the MSNs to their clusters. Each CH in the network maintains two database schedules that contain its members to achieve mobility adaptation. This enables quick connection of the broken nodes with another CH which leads to maximum delivery ratio and minimum average delay. Comparing this algorithm with LEACH-M algorithm, it is found that CBR-Mobile algorithm diminishes the packet loss and consumes more energy.

An adaptation on CBR-Mobile algorithm is Enhanced Cluster-Based Routing algorithm developed for Mobile WSNs (ECBR-MWSN) [9]. It consists of five phases, initialization, cluster formation, CHs selection, data transmission, and rerouting and clustering. ECBR-MWSN algorithm depended on selecting the CHs with special specifications such as lowest mobility factor, highest residual energy, and minimum distance to sink node. This algorithm has better performance than LEACH-M and LEACH-ME in network lifetime of MWSNs and energy-efficient by making a balance in energy consumption. Mobility and traffic adapted cluster based routing for mobile nodes protocol[10]is improving onCBR-Mobile that supports mobility of sensor nodes in an energy-efficient manner and maintains maximum delivery ratio and minimum average delay.

Mobility Adaptive Cross-layer Routing (MACRO) algorithm is introduced in [11] to decrease the amount of flooding by using the approach of route discovery. The principle of discovering the most reliable routes for flowingthe packets considers the node's mobility and link quality. However, the MACRO algorithm diminishes the amount of flooding, the end to end delay increases which appears largely in dense networks because of the changes in the MWSN topology frequently.

Mobility Based Clustering algorithm (MBC) [12] selects the CHs randomly depending on the mobility and residual energy of nodes at each round. The basic idea is building more appropriate paths between the mobile nodes and the elected CHs which depended on the stability of each link taking into consideration the connection time of building the clusters. The data of each node are sent to the BS via inter-intracluster communication. This algorithm has some troubles such as link breakage and dropping of the packets.

The basic idea of Cluster Independent Data Collection Tree (CIDT) [13] is organizing a preferable Data Collection Tree (DCT). There are many factors that affect on choosing the data collection and CHs nodes such as nodes mobility, remaining energy, connection time, received signal intensity, and finally, cluster dimension. The CIDT gives better performance in link stability, packet delivery ratio, energy exploitation, and delay. The modification of CIDT algorithm is called Velocity Energy-efficient and Link-aware Cluster Tree (VELCT) algorithm [14]. VELCT considers the locations of CHs in building the DCT to alleviate the problems in CIDT such as delay in tree construction, coverage, and mobility. In this protocol, each data collection node gathers the data from the closest CHs and sends it to the BS via upper level.

A modular mobile node that capable of using different sensor nodes according to the mission needs is shown in [15]. The mobile sensor node has been combined with an existing static network, adding elasticity and range to it and transforming it into a Hybrid Wireless Sensor Network (H-WSN).There are many other protocols that deals with mobility in dense MWSN such as [16] or deals withlarge-scale WSNs[17].

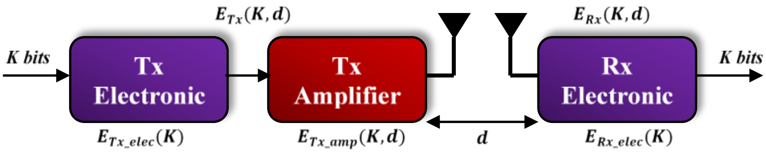


Fig. 1. The model of radio energy dissipation [22].

MGAHP[18] isbased onutilizing GA optimization process [20, 21] and presenting a hierarchical routing protocol.In the set-up phase of the MGAHP protocol, the sink node determines the optimum location of CHs and their numbers and assigns the membernodes attached with each CH. While in the steady-state phase, the CHs collect the sensed data from sensor nodes, aggregate them, and transmit the final message to the sink node.The problem of MGAHP protocol is achieving a less efficient packet delivery ratio than MACRO and CBR-Mobile protocols since eachmobile node must wait for two consecutive timeslotsuntil it receivesa data request message from CH to join a new cluster.

III. PRELIMINARIES AND PROBLEM FORMULATION

A. Preliminaries

To establish the proposed IMGAHP, the following assumptions are considered for network model:

- The network composes of sink node and N MSNs distributed randomly in $(X \times Y)$ sensor field.
- The sensor nodes are mobile and the sink node is a static and resource-rich device.
- The sensor nodes in WSN are homogeneous that means that they have equal beginning energy and data processing.
- The radio channel is symmetric that means that the node needs the same power for transmitting and receiving any message for the same distance.
- The model used for discussing the energy dissipated at nodes in the connection process is a simple radio model shown in Fig. 1 to compare it with previous protocols [6-14].

The network radio model consists of a transmitter that dissipates energy in radio electronics and power amplifier, and a receiver that dissipates energy in radio electronics as shown in Fig.1. Theradiohave power control for expending the minimal desired energy to reach the destined recipients and tuning off to obviate receiving dispensable transmissions. Therefore, two models of the channel [11] are used here (multipath fading and free space) that depend on the transmission distance to discuss the proposed IMGAHP. The dissipated energy when a k -bits packet is transmitted for a distance d is

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) = k * E_{elec} + k * \varepsilon_{amp} * d^n \quad (1)$$

also, the dissipated energy inreception this packet is

$$E_{Rx}(k) = E_{Rx-elec}(k) = k * E_{elec} \quad (2)$$

where, $E_{elec} = 50$ nJ/bit is the energy dissipated in the RX or TX circuits per bit.ε_{amp} define the amplification factor depending on the distance.$\varepsilon_{fs} = 10$ pJ/bit/m^2 is the loss coefficient for free space.$\varepsilon_{mp} = 0.0013$ pJ/bit/m^4 is the multipath loss coefficient. $d_o = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}}$ denotes the threshold distance.If $d < d_o$, $\varepsilon_{amp} = \varepsilon_{fs}$ and $n = 2$ for free space model, else, $\varepsilon_{amp} = \varepsilon_{mp}$ and $n = 4$ for a multipath model where n is the path loss. Whilethe mainconcept in the proposed IMGAHP is receiving the data which are supposed to be correlated from MSNs and aggregate it in the CH.The techniques for combining these sensed correlated data signals and converting them to a single data packet are used. Therefore, the dissipated energy inmerging$m$ packets of k –bits for apacket is

$$E_{agg}(k) = mkE_{DA} \quad (3)$$

where $E_{DA} = 5\,n$J/bit/signal is the energy of data aggregation. Assuming the MWSN is split into L clusters while each onecontains$m_i (i = 1,2,3,\ldots.,L)$ MSNs. Each MSNtransmitsthe data to the respective CH once per frame and the CH aggregates these data and generates data packet with length k –bits. Therefore, the dissipated energy in intra-cluster communication for a mobile node number l with CH number i is

$$E_{MN-i}(l,k,d) = kE_{elec} + k\varepsilon_{amp}(d_{l-i})^n \quad (4)$$

where d_{l-i} is the distance fromMSN number l to its joinedCH number i. Furthermore, the dissipated energy generated from intra-cluster and inter-cluster communication in each CH is

$$E_{CH}(i,k,d) = kE_{elec}m_i + kE_{DA}(m_i + 1) + kE_{elec} + k\varepsilon_{amp}(d_{i-BS})^n \quad (5)$$

where, d_{i-BS} is the distance fromthe sink node and the i^{th} CH node.

B. Problem Formulation

This section studies the problems that affect the MGAHP protocol and how the proposed IMGAHP changes the behavior of the networkfor adaptingto the changes in its intrinsic properties due to mobility such as the offered load and scalability. The drawbacks in MGAHP is:

- Packet delivery ratio in MGAHP is not efficient, while the packet loss increasesquicklywith increasing the number of MSNs.
- MSNs in MGAHP wait for two consecutive timeslots until joining a new cluster.

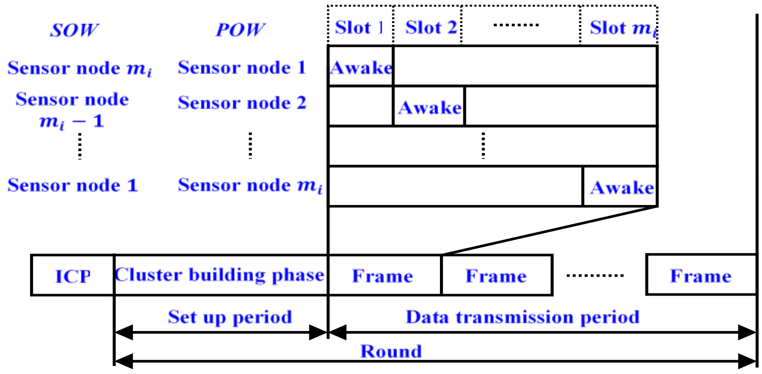


Fig. 2. One round on the operation of the proposed IMGAHP protocol

- The timeslot allocated to MSN is wasted when it moves outside the cluster or does nothave data to sendand the transmitted packet is wasted.

C. *Objective function*

Increasing or decreasing the number of CHs in the MWSN over a certain limit causes energy dispersion. Therefore, the essential concept in the proposed IMGAHP is computing the optimal number of clusters (L) and hence searching for the best location of the (L) CHs $(p = \{(x_1, y_1), \ldots\ldots\ldots, (x_L, y_L)\})$. This can occur by obtaining an efficient number of CHs, minimizingthe total energy dissipated in the network and distributing the load on the nodes uniformly.

Optimization techniques are used to solve such as these multi-objective problems. GA is the type of optimizationthat used in the proposed IMGAHP protocol to solve the two following objectives,

1) *Reducing the aggregated energy:*dissipated in the communication process at the whole network during a round hence it is given by,

$$\text{minimize}\Big(E_{dis} = \sum_{i=1}^{L}\big[\big(E_{CH}(i,k,d) + E_{CHCP}(i,k_{CP},d)\big) + \sum_{l=1}^{m_i}\big(E_{MN-i}(l,k,d) + E_{CHCP-i}(l,k_{CP},d)\big)\big]\Big) \quad (6)$$

where $E_{CHCP}(i, k_{CP}, d)$ is the energy dissipated in Control Packets (CPs) of CH number i and $E_{CHCP-i}(l, k_{CP}, d)$ is the energy dissipated in CPs of MSN number l and the two parameters are calculated in equation (9) and (10).

2) *Calculating the optimal number of CHs:* that minimize energy consumption as follow:

$$minimize \quad (N_{CH} = \frac{L}{N}) \quad (7)$$

Subsequently, the position of optimal CHs $(p = \{(x_1, y_1), \ldots\ldots\ldots, (x_L, y_L)\})$ can be determined by utilizing the IMGAHP protocol which minimizes the following main objective function.

$$min. \quad (F_{\text{MGAHP}}(p) = w * E_{dis}(p) + (1 - w) * N_{CH}(p))$$
$$subject\ to \quad E_{res}(CH_i) \geq E_{avg}; i = 1,2, \ldots..L \quad (8)$$

where E_{avg} represents the average value of the residual energy for all alive MSNs, $E_{res}(CH_i)$ is the remaining energy of the CH number i and $w$represents the weighting factor which has avalue between 1 and 0 and is chosen depending on the observed value of each cost function.

IV. IMPROVED MGAHP

Many previous researchgroup the nodes into clusters to obtain scalability in the network and maximum network lifetimewhile each cluster has a leader called CH.Each CH connects with their sensor members, makes a TDMA, and assigns one-time slot to each MSN and hence causing the previously mentioned problems.

The Improved-MGAHP (IMGAHP) is proposed to find a solution tothese problems by two steps. The first step is calculating the optimum locations of CHs and their numbers which depend on distributing the load uniformly via MSNs and achievingminimum energy dissipation. A Genetic Algorithm (GA) [20, 21]uses in the proposed IMGAHP to define the optimum solution. The second step is to assign two owners (Primary Owner (POW) and Secondary Owner (SOW)) for each timeslot instead of one owner. This leads to improve the stability period, maximize the network lifetime, and make the proposed protocol works adaptively to mobility and traffic. The implementation of IMGAHP consists of many roundspreceded by Information Collection Phase (ICP) which collects the data from the MSNs.Every round consists of the clustering building phase followed by a data transmission phase as shown in Fig. 2. In the first phase, the clusters are organized by utilizing the IMGAHP to determine the best position of CHsand hence the sink node creates two TDMA schedule:- primary schedule and secondary schedule, which each timeslot is assigned for two users. Furthermore, in the second phase, the sensed data are sent through the allocated CHs to the sink node. The flowchart of IMGAHP protocol is shown in Fig. 3.

A. *Information Collection Phase:*

In this phase, the sink establishes the network by determining the nodes number (N), the size of the sensor field$(X \times Y)$, the parameters of the radio model, the initial energy of each node (E_o), and finally the size of one data packet (K). The sink node broadcasts the 'Request Message' containing its ID and its location. The sensor nodes that receive this message and lay in the communication range of the sink, reply to it with sending 'Self Information Message' containing their IDs, locations, and initial energy. Based on the information received from all nodes the sink node determines the number of CHs and their location by the use of IMGAHP protocol via the set up phase and determines the state of the nodes (Ordinary node (ON), MSN, or CH).

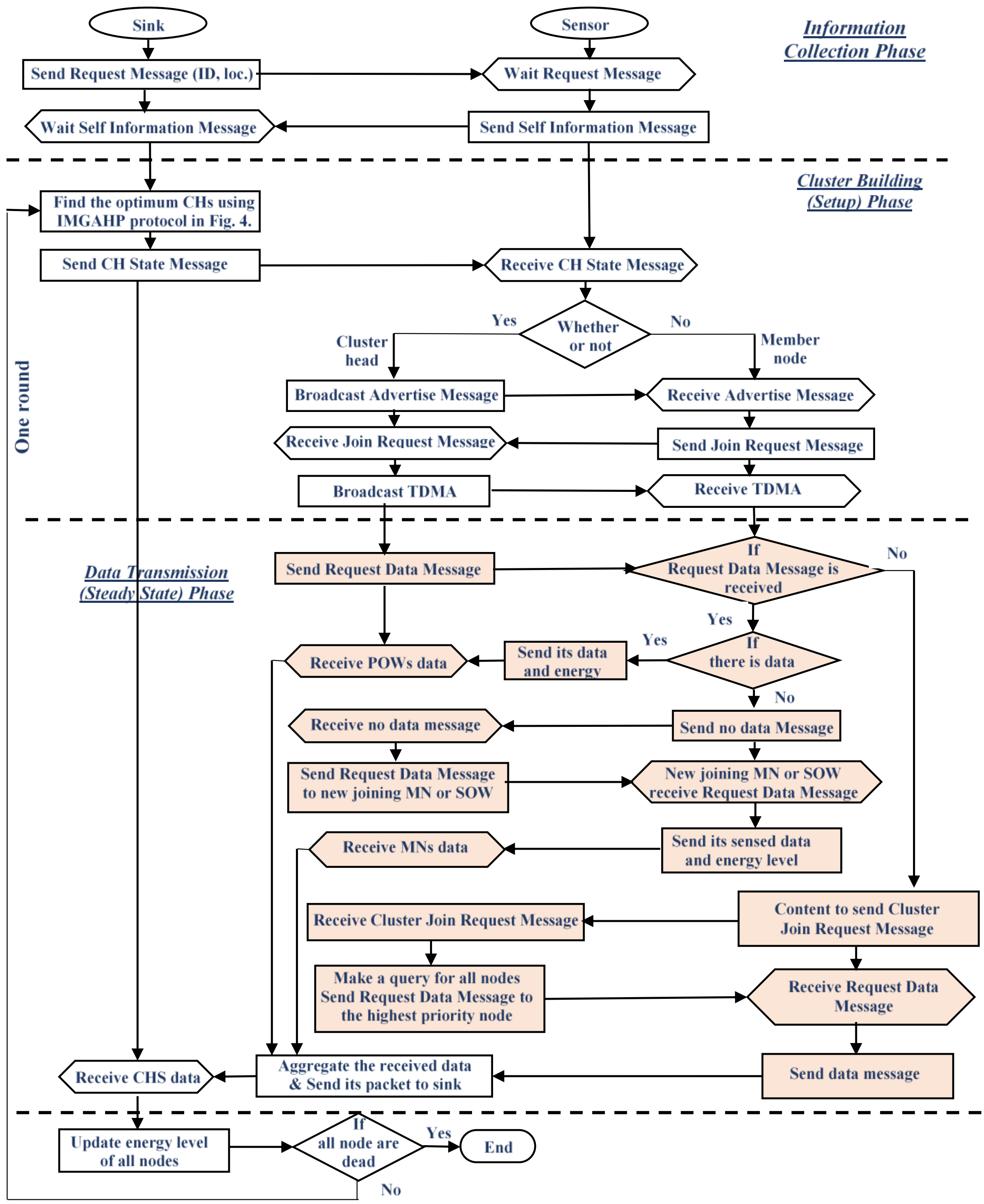


Fig. 3. Operation of the proposed IMGAHP protocol

B. *Cluster Building (Set up) Phase:*

After initialization and collecting self-information of sensor nodes, the sink node utilizes the IMGAHP protocol to find the optimum CHs and their locations which depends on minimizing the energy dissipated in process of communication and overhead CP of all MSNs. The sink node sends 'CH State Message' to the optimized CH to convert its state from 'ON' to 'CH'.Each CHbroadcasts'Advertise Message' to the nodes lies inits communication range containing its IDs to announce them with its states. Every ON can determine the associated CH and transmits 'Join Request Message' to it based on the intensity of the 'Advertise Message' received signal.

After that, every timeslot is allocated for two owners called Primary Owner (POW) and Secondary Owner (SOW), therefore the MWSN can operate with an adaptive manner for traffic and mobility. Furthermore, every CH createsa primary TDMA schedule and transmits it and 'Request Data Message' to the POWs to cognize them with their timeslots and receive their data. Whether the POW does not have sensed data in a certain round, it cantransmit'No Data Message' to its allocated CH.Also whether the POW moved outside cluster boundary, the CH transmits 'Request Data Message' to a new joining mobile node or SOW after waiting until the period of timeout data finished. On the other hand, whether the MSN moved outside the cluster and the 'Request Data Message' didn't transmit to it, this MSN stays until receiving a 'Contention TS Notification Message' from another CH. When the MSNs receive this notification message, they contend on this message and transmit 'Cluster Join Request Message' to that CH. After receiving the new join request from new MSNs, the CH memorizes them in a straightforward database. Therefore, after discovering an empty timeslot, the CH enquires the database to search for the MSN with the height priority and then transmits 'Request Data Message'.

The frame format of the proposed IMGAHP consists of two timeslots kinds; contention-based TS and schedule-based TS. The CH allocates timeslot to each MSN for sending data. The MSN wakes up in the allocated timeslot to transmit its sensed data and after finishing the transmission, it goes to the sleep mode. Contention based TS is the contention period in which the MSNs wake up at the beginning of it and wait for 'Contention TS Notification Message'. While the schedule-based TS is the timeslot that allocated for sending or receiving 'Request Data Message', the sensed data, or 'No Data Message'.

The CPs consume an amount of energy in the CHs selection process which cannot be ignored. So, the IMGAHP protocol considers this dissipated energy for selecting the CHs. The energy dissipated in CPs for CH throughone round comes from receiving the CH state message from sink node, receiving 'Join Request Message' from m_i nodes, broadcasting the'Advertise Message' to the MSNs, and sending the primary TDMA schedule,'Request Data Message', and 'Contention TS Notification Message', which is given by

$$E_{CH-cp}\left(i,k_{cp},d\right)=k_{cp}E_{elec}+k_{cp}E_{elec}\,m_i+4(k_{cp}E_{elec}+k_{cp}\varepsilon_{amp}\,(R_c(i))^n)=(m_i+5)k_{cp}E_{elec}+4k_{cp}\varepsilon_{amp}\,(R_c(i))^n \quad (9)$$

where$R_c(i)$represents the communication range forevery$i$ CH. The energy dissipated in CPs for MSN throughone round comes from transmitting 'Join Request Message' to CH i and receiving 'Advertise Message'the primary TDMA schedule, 'Request Data Message', and 'Contention TS Notification Message', which is given by

$$E_{MN-cp-i}\left(l,k_{cp},d\right)=4k_{cp}E_{elec}+k_{cp}E_{elec}+k_{cp}\varepsilon_{amp}\,(d_{l-i})^n \quad (10)$$

The cluster building phase contains two consecutivestages, CHs selection stagefollowed by the cluster construction stage.

1) *CHs Selection stage:* IMGAHP protocol utilizes GAalgorithm to select the optimum position ofcandidate CHs and their numbers based on distributing the load through MSNs uniformly and reducing the dissipated energy to enhance the stability and lifetime of MWSN. Fig. 4 shows the flow chart of this selecting process using IMGAHP protocol and its details are given below:

a) *Population of Initial Chromosomes:* While CH performs more tasks and consumes more energy than member nodes. The basic concept of proposedIMGAHP is to select CHs from high energy nodes with residual energy

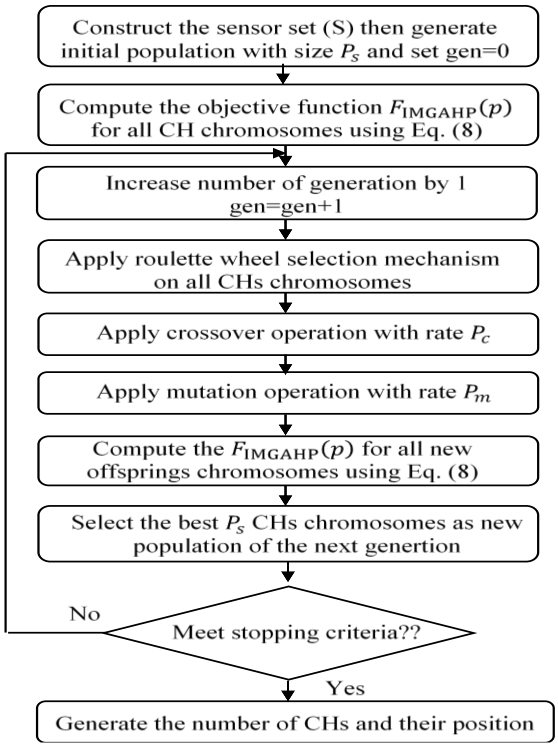


Fig. 4. CHs selection stage for proposed IMGAHP.

(E_{res}) greater than or equal to the average energy (E_{avg}) of all alive MSNs as follow:

$$S=\{s_1,s_2,..,s_{N_S}\}=\{s_l\,|\,\forall\, l\in[1\;\; N_{live}]\wedge E_{res}(l)\geq E_{avg}\} \quad (11)$$

whereN_S is the sensor nodes number in set S and N_{live} is the alive MSNs number. The BS represents the N_S nodes by binary bits which every bit corresponds to CH or ON if it '1' or '0', respectively. Therefore, the initial population that consists of P_s chromosomes $pop=(x_1,x_2,..,x_m,..,x_{P_s})$ are constructed in the BS also while every chromosome contains N_S as shown in table I.

TABLE I. INITIAL GENERATED CHROMOSOME x_m

Sensor set S	s_1	s_2	s_3	s_4	…	s_b	…	s_{N_S}
Chromosome (x_m)	x_1	x_2	x_3	x_4	…	x_b	…	x_{N_S}
	0	1	1	0	…	0	…	1

b) *Chromosome Selection:* After generation P_s chromosomes population, the selection operation selects the chromosomes that will go through the next operations to produce other chromosomes from the existing population. The basis of the next selection combines the initial chromosomes and the created chromosomes. The type of selection used in proposed IMGAHP is roulette wheel selection which determines the probability of selecting CHs chromosomes commensurate with the value of fitness function $(1/F_{IMGAHP}(p))$. The operation of choosing the more reliable chromosome depends on this fitness value while the chromosomes with higher values are chosen for constructing the next generation population.

c) *Crossover Process:* Crossover and mutation provide exploration, compared with the exploitation provided by selection. Using thecrossover process increases the chromosomes diversitywhile the type of crossover used in the proposed IMGAHP is single-point crossover. In general, crossover deals with binary operators and operates on two parents chromosomes which are selected randomly. The single point crossover chooses point at a random position based on crossover rate P_c from these two parents to exchange the information after that point and hence two children are produced. This operation is repeated until the generation ofN_c children.

d) *Mutation Process:* This stage is operatedforevery chromosome individually with mutationprobability P_m. It depends on changing the bits specified by P_m from 1 to 0 or vice versa. If $P_m = 0.001$ each gene has 0.1 percentage to be mutated.

Example: Two parents CHs chromosomes are considered; each one consists of 10 sensor nodes $\{s_1, s_2, \ldots, s_{10}\}$. The nodes that correspond to ones in Table II are assigned to be CHs and the rest of nodes are ONs. If the crossover point is selected based on P_c to be s_6, the nodes after s_6 in the two parents are exchange, and two children are generated. If the mutation probability $P_m = 0.001$, the node s_4 in the first children is selected to mutate from 0 to 1,and two new children are generated.Due to very low mutation probability, there is no mutation in children 2.

TABLE II. EXAMPLE OF CROSSOVER AND MUTATION

Sensor nodes	Parent1		Parent1	
	$s_1 s_2 s_3 s_4 s_5 s_6$	$s_7 s_8 s_9 s_{10}$	$s_1 s_2 s_3 s_4 s_5 s_6$	$s_7 s_8 s_9 s_{10}$
Parents	1 1 0 0 1 0	1 0 0 0	1 0 0 0 1 0	1 1 0 0
Children	1 1 0 0 **0** 0	1 1 0 0	1 0 0 0 1 0	1 1 0 0
Mutated	1 1 0 0 **1** 0	1 1 0 0	1 0 0 0 1 0	1 1 0 0

e) *Selection of the Optimised Solutions:* The produced children after mutation that generated in the previous step combined withthe beginning chromosomes (parents) are ordered in ascending based on computed objective function values. Then the first P_s chromosomes with minimum values are chosen to be the initial population ofthe next generation.

f) *Stopping Criterion:* the previousstepsare repeated until one of the two following cases is achieved:

- The objective function valuedoesn't change for a specific number of generations.
- The generation numberwhich is increased periodically exceeds the maximum number of generations(Maxgen).

2) *Clusters Construction stage:* After the CHs are selected, the sink node informs them by sending 'CH State Message'.The selected CHs nodes transmit an 'Advertise Message' within its communication range R_c to announce its state to all nodes lays in its range. All CHs consume the same energy in sending 'Advertise Message', while all ONs must be awake to receive this message. Based on the signal strength of 'Advertise Message' received from the CHs, each MSN can determine the nearest CH. The sensor nodetransmits'Join Request Message'to this nearest CH containing its ID to join with it, therefore each CH must make their receiver on all the time to receive this message and also the subsequent data from their connected nodes.The transmission of 'Advertise Message' and 'Join Request Message' uses Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA).

After that, each CH creates two TDMA schedules according to the number of its member nodes by allocating twoowners to each timeslot. The primary TDMA schedule contains the POWs and the secondary TDMA schedule contains the SOWs. Then CH broadcasts the primary TDMA schedule to all nodes in its range to inform its member nodes by it. Each CH creates two databases to adaptively achieve both data traffic and nodes mobility. A new member requests database is the first database and is used for registering the information for all MSNS that want to connect with a new cluster.The secondary schedule databasewhich is used to save the secondary TDMA schedule is the secondary database.

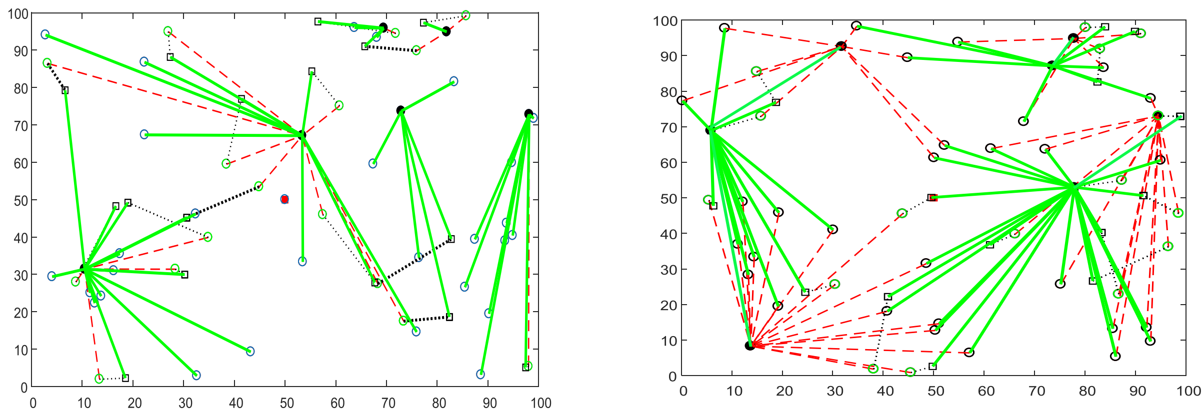
The idea of making two TDMA schedules in the proposed IMGAHP protocol has many advantages such as:-

- The timeslotallocated forprimary MSNsthat moved outsideits cluster boundary ordidn't have data to transmit can be reassigned to another node from new member requests database or secondary schedule.
- It permits the MSNswhichmoved toa new cluster, to join itquickly.
- Efficient exploitation ofbandwidth and timeslots. Furthermore, the longdisconnection period of MSNs from the network can be avoided and thendata loss decreases.
- The primary TDMA schedule will avoid intra-cluster interference between nodes by allowing the member nodes to turn its radio off all-time except at its allocated timeslot, which transmits its data on it. This leads to minimizing the dissipated energy while all the non-CHs nodes are assumed to have sensed data to send to associated CH each frame.

C. *Data Transmission (Steady State) Phase:*

Once the cluster and primary TDMA schedule are created and the POW and SOW for each timeslot are allocated, the data transmission or steady-state phase for IMGAHP protocol begins. The main concept in this stage is the CHtransmission of 'Request DataMessage' to all POW nodes every timeslot.This transmission occurs relative to the primary TDMA schedule to collect the sensed data of MSNs. In case of data traffic, whether the POW possesses data to transmit, it will adjust its power to be minimum to sendthe sensed data back to its CH. Otherwise, 'No Data Message' would be transmitted. After receiving this message at the CH and ensuring that the timeslot is empty, it will inquiry the database of new member requests to designate this empty timeslot to new MSN in the database. Whetherthis database does not have any data, CH will inquiry about the secondary schedule database to designate this timeslot to SOW.

On the other side, whenPOW moved outside the cluster boundary and does notrespond to the CH,the CHmuststaytill ending theperiod of thetimeout before designating this timeslot to any other MSN. The CH assigns this timeslot to a new node by sending'Contention TS Notification Message' to announce a contention TS. Consequently, the MSNs come from adjacent clustersmust be awakenedat each timeslot beginning so it can receive thisnotification message.



(a) No changing in CH location (b) Changing in CH location

Fig. 5. Sensor field of homogenous network after clustering.

Whether any MSN receives ‘Contention TS Notification Message’, itmustcompete to transmit‘Cluster Join Request Message’ to CHat this period. Otherwise, it will return to sleep mode.The MSNs that don’t join this contention TS, will wait until the next one. Thesesteps will be repeated until all MSNs have associatedwitha new CHefficiently.

If some MSNs does not have the opportunity to join with the contention TSs, they can join the cluster at frame ending. While the CHwill proclaim the updated schedule of TDMA to its cluster members containing the updatedMSNs whichdidnot join the contention TS. Then theseMSNs can join and send their data to associated CH. After the CHs receive all the data from its associated nodes, they modify these data to a single signal and transmit it to the sink node.

V. Simulation Experiment

A. Performance Measurements

The proposed IMGAHP routing protocol uses the following parameters to judge its efficiency:

1) *Network lifetime:* The period from the beginning of the WSN till the termination of the network or death of all nodes.

2) *Throughput:* A vital metric that is used to judge the efficiency of the routing protocol and is the total amount of data sent over the network.

3) *Number of CHs per round:* the number of nodes per round, which will aggregate the sensed information from near nodes, then sent it to the BS directly.

4) *Average Energy Consumption (AEC) per around:* The average energy dissipated when one packet is transmitted from the source node to the sink and is measured by Joule.

5) *Packet Delivery Ratio (PDR):* It measures the ability of the proposed IMGAHP to deliver packets to the destination. It equals the number of packets delivered to the destination perfectly over the total number of packets that are sent.

B. Simulation results

In this section, the proposed IMGAHP protocol is compared with previous protocols MGAHP [18], LEACH-M [6], CBR-Mobile [8], and MACRO [11] using two scenarioswith parameters shown in Table III.

1) *First Scenario:*In this scenario, the IMGAHP protocol is compared with MGAHP and LEACH-M protocol which sensors are assumed to be homogeneous, and each one generates one data packet per round to be transmitted toward the sink. The new member requests database is initially empty and the secondary schedule database is the reverse order of the primary TDMA schedule. To reduce the experimental error caused by randomness, each test was run 5 times and the average was taken as the final result.

a) *Effect of mobility on nodes distribution:* The homogeneous network after clustering using IMGAHP protocol with 50 nodes and centered sink node is shown in

TABLE. III Simulation Parameters of Proposed IMGAHP Protocol under Discussion

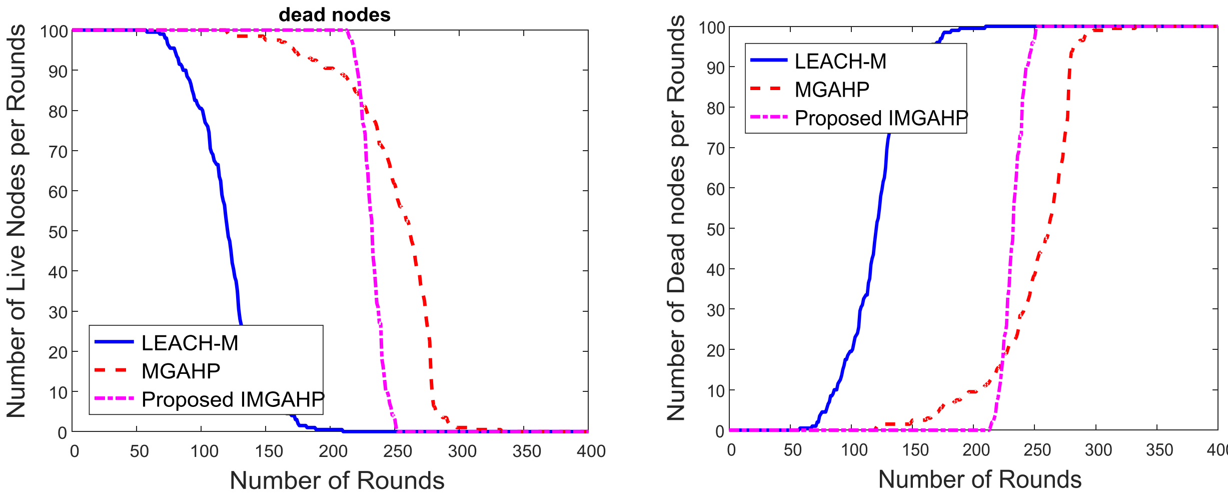
Parameter	**Value**	
	First scenario [6]	***Second scenario [8, 11, 18]***
network size ($X \times Y$)	(200×200) , (100×100)	50×50 m^2
number of nodes (k)	50, 100	100
sink location	(100, 100) , (50×200)	(25, 25)
size of data packet (P)	4000 bits	2000 bits
mobile nodes percentage (P_{mob})	50 %	0–90%
speed of MSNs	5 m/s	0–10 m/s
initial energy of node E_0	0.5 J	0.5 J
energy dissipated per bit in the RX or TX circuits (E_{elec})	50 nJ/bit	50 nJ/bit
energy dissipated in data aggregation(E_{DA})	5 nJ/bit	5 nJ/bit
free space loss coefficient (ε_{fs})	10 pJ/bit/m^2	10 pJ/bit/m^2
multipath loss coefficient (ε_{mp})	0.0013 pJ/bit/m^4	0.0013 pJ/bit /m^4
number of initial population (P_s)	50	50
crossover rate (P_c)	0.7	0.7
mutation probability (P_m)	0.11	0.11
weighting factor (w)	0.9	0.9
maxgen	100	100
mobility model	random waypoint mode	random waypoint mode

Fig. 5. The dashed red line represents the previous intra-cluster communication for the mobile nodes and the green line represents the current intra-cluster communication. It is shown that the mobile node with the green circle moves to another position to be black color square. There are some nodes move inside the cluster however, there are other nodes move outside the cluster and connect to a different CH such as illustrated with dashed bold black line in Fig. 5(a) with no change in CHs locations. Another clustering is shown in Fig. 5(b) after the location of the CHs are changed.

b) *Effect of large scale network:* Now, network lifetime comparisonfor the proposed IMGAHP protocol with LEACH-M and MGAHP protocol isimplemented in large scale network (200×200) m^2 with 100 nodes distributed uniformly and the centralized sink node. These simulations are carried for 400 rounds. Fig. 6(a) represents the relation between the number of alive MSNs and the number of rounds. In the proposed IMGAHP protocol, the stability period, which is the period until the first node dies, is about 230 rounds which is better than the stability period of MGAHP, and LEACH-M that are 120 and 70 rounds with improvement about 48% and 70%, respectively.The network lifetime of proposed IMGAHP protocol,MGAHP and LEACH-M are approximately 250, 300, and 180 rounds, respectively. The network lifetime of the proposed IMGAHPhas more performance than LEACH-M protocol because of utilising the energy efficiently. That is because choosing the optimised CHs depends on Optimization process which selects the best number and locations.

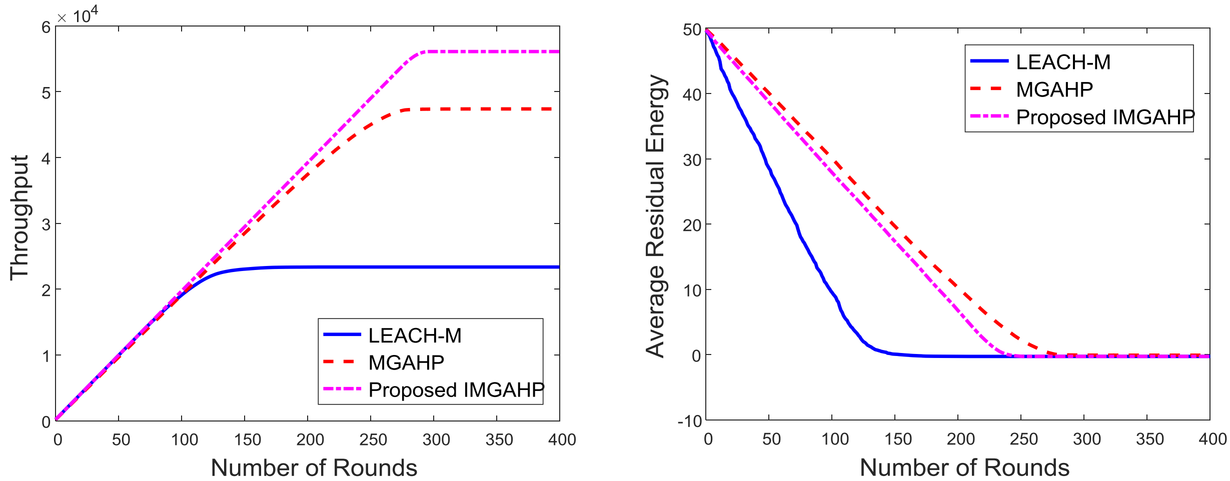
Fig. 6(b) shows the dead MSNs for three protocols. At about 230 rounds, all nodes die in LEACH-M protocol and 12 nodes die in the MGAHP protocol however all nodes are still alive in the proposed IMGAHP protocol. This means that the lifetime of IMGAHP protocol has a great improvement than MGAHP and LEACH-M protocols due to the optimization process and the idea of making each MSN join the new CH within a short time on the contrast of the other protocols while each node must wait for two consecutive timeslots until joining another CH.Therefore, this causes the network to be more balanced in energy load distribution.

As the stability period of IMGAHP protocol is higher than MGAHP and LEACH-M, this implies that the nodes transmit extra packets to BS causing higher throughput. Throughput is the total amount of data sent over the network which includes the packets sent from normal nodes to either their CHs or BS, in addition to packets sent from CHs to the sink. According to Fig. 7(a), the throughput in proposedIMGAHP, MGAHP, and LEACH-M protocols is5.63×10^4,4.75×10^4,and 2.35×10^4, respectively. The proposedIMGAHP has a higher throughput than MGAHP and LEACH-M due to uniform distribution of CH over the sensing field, efficient CH selection of these CHs, and enhanced network lifetime.



(a) Network lifetime graph (b) Comparison of dead nodes.

Fig. 6. Comparing the alive nodes and dead nodes for proposed IMGAHP protocol with MGAHP and LEACH-M.



(a) Throughput (b) Energy consumption.

Fig. 7. Comparison of throughput and energy dissipation between proposed IMGAHP with other protocols

Simulation result in Fig. 7(b) illustrates the decreasing of network residual energy forthe three protocols over rounds.The network residual energy after 100 rounds is 28J, 31 J, and 10 J for the proposed IMGAHP, MGAHP, and LEACH-M protocols, respectively. The energy of all nodes is depleted after 240, 275, and 140 rounds for IMGAHP, MGAHP, and LEACH-M protocols, respectively. Subsequently, the proposed protocol consumes less energy than LEACH-M but consumes more energy than MGAHP due to using some additional control message for computing the new member requests database and secondary schedule database and sending ‘Contention Timeslot Notification Message’ and ‘No Data Message’.

c) *Effect of small scale network:* Another comparison forIMGAHP,MGAHP, and LEACH-M protocols is implemented using the same parameters but in small network size 100×100 m^2 and different sink location (50, 200). Fig. 8(a) shows that the total number of packets that send to CHs and BS in IMGAHP, MGAHP, and LEACH-M protocols are 5.35×10^4 , 4.9×10^4 and 3.6×10^4 respectively. The IMGAHP has higher throughput than the two other. Fig. 8(b) illustrates the decreasing network residual energy of two protocols over rounds, but the residual energy of sensors nodes in proposed IMGAHP and MGAHP protocols decrease more quietly than that in LEACH-M. After 208 rounds; the nodes in MGAHP and proposed IMGAHP are still have24 % and 18% of their initial energy, respectively but, the residual energy of all nodes in LEACH-M is dissipated. This means that the proposed IMGAHP protocol improves the network lifetime and saves the residual energy of the sensor nodes than LEACH-M but consumes more energy than MGAHP.

Fig. 9(a) represents the number of alive sensor nodes during the network duration. The simulation result shows that the first node died after 132, 200, and 232 rounds, and all nodes died after 208, 285, and 261 rounds for LEACH-M, MGAHP, and IMGAHP, respectively. It is clear that the proposed IMGAHP protocol extends the stability period and shrinks the instability period as compared to the LEACH-M by 100 and 47 rounds respectively. This means that the proposed IMGAHP protocol increases the reliability of the clustering process in MWSN. Moreover, it prolongs the stability period more than the MGAHP and LEACH-M protocol by 14 % and 43 %, respectively. This due to that the IMGAHP protocol always selects the CHs from nodes that have energy higher than the average energy of all live nodes.Fig. 9(b) shows the number of CHs that selected in each round using IMGAHP, MGAHP, and LEACH-M protocols. From this figure, it is noticed that the number of selected CHs in each round using IMGAHP and MGAHP protocols changes from 3 to 7. However, in LEACH-M

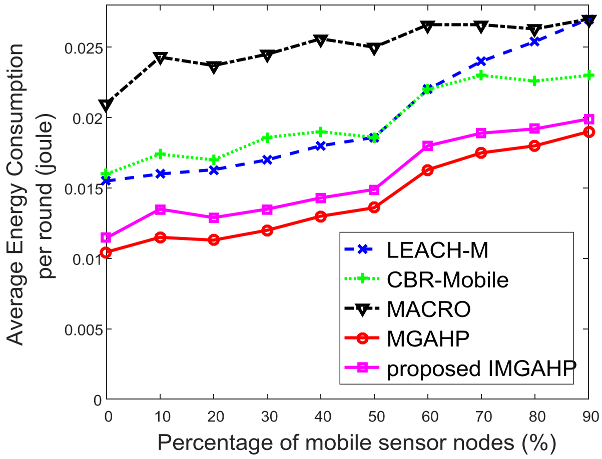


Fig. 10. Percentage of MSNs versus AEC per round.

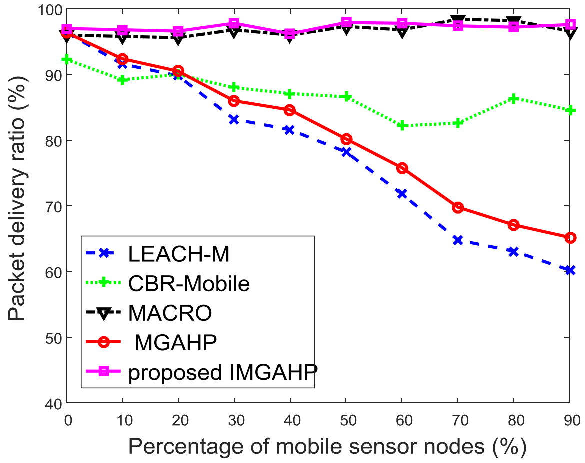


Fig. 11. Changing the percentage of MSNs versus PDR.

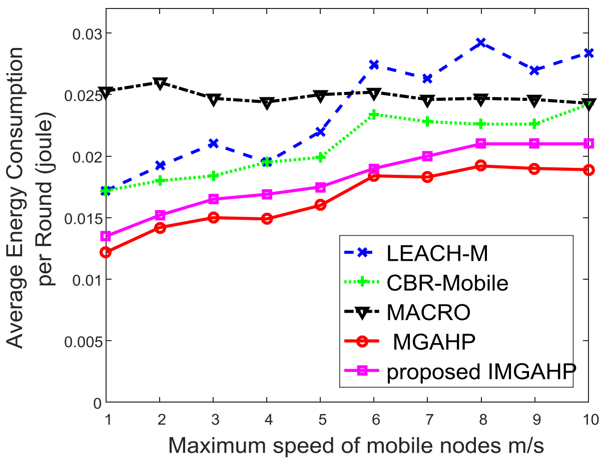


Fig. 12. Maximum speed of MSNs versus AEC per round.

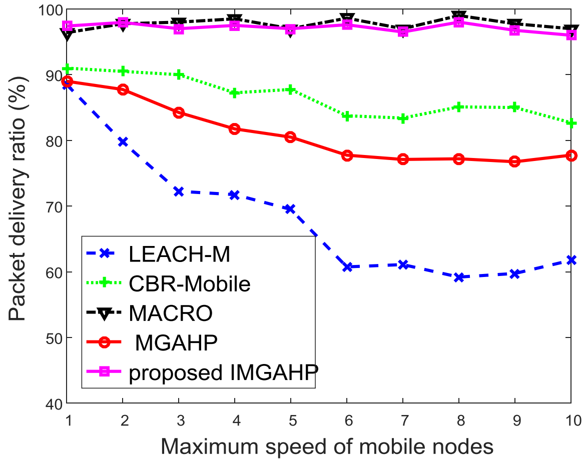


Fig. 13. Changing the maximum speed of MSNs versus PDR

protocol, number of CHs is approximately changes from 0 to 11. Thismeans that the proposed IMGAHP is more uniform than LEACH-M.

2) *Second Scenario:*The effect of changing the percentage of MSNs and maximum speed on proposedIMGAHP protocol attitude are estimatedcompared withMGAHP,MACRO, CBR-Mobile, and LEACH-M protocolsusingthe parameters shown in Table III.

a) *Effect of varying the MSNs percentage:*The effect of changing the percentage of MSNs with average energy consumption per round for proposedIMGAHP,MGAHP, MACRO, CBR-Mobile, and LEACH-M protocols is shown in Fig. 10. The figure shows theincrease of average energy consumptions with increasing of MSNs percentage for all protocols hence the number of MSNs outside the cluster is increased. In LEACH-M and CBR-Mobile protocols, the nodes disconnect from their clusters for a certain amount of time because they moved out of their clusters. Therefore, the energy is wasted because of overhearing the unwanted message since the radio of the nodes is keeping on to can receive control messages. MACRO protocol consumes more energy than LEACH-M and CBR-Mobile. The MACRO protocol gives results approximate to those in the CBR-mobile when the percentage of MSNs increased. When the number of MSNs is 90%, the MACRO protocol and the CBR-mobile gives the same results. The proposed IMGAHP protocol consumes less energy than the MACRO, CBR-Mobile, and LEACH-M protocols due to using a GA for determining the efficient location of CHs and their numbers and distributing them uniformly over the sensing field.The periods of disconnection for MSNs in the proposed IMGAHP are short therefore, these MSNs can reduce the energy by avoiding theoverheadmessage. The proposed IMGAHP consumes more energy than the MGAHP since itusesoverhead messagesto adaptively realize traffic and mobility.

Fig. 11 shows the PDRofthe proposed IMGAHP protocol comparedto previous protocols. It illustrates that PDR reduces in MGAHP, CBR-Mobile, and LEACH-M protocols when the number of MSNs is increased. That is because the MSNs that leave the cluster are increased with increasingthe number of MSNs. The packet loss will increase while the number of MSNs that disconnected from the network will increase. Nevertheless, the performance of PDR for MGAHP is more efficientthan LEACH-M protocol, ithas less performance than MACRO and CBR-Mobile protocols due to the waiting of MSNs for two timeslot failure. This problem is solved in the proposed IMGAHP, while this protocol gives more stable and higher PDR when the MSNs percentage increases due to the idea of assigning two owner to each time slot that leads to adaptive mobility and traffic. Moreover, the figure shows a large improvement in PDR because the MSNs that moved outside the allocated cluster will connect to new cluster during a short time. Furthermore, the timeslots allocated to nodes that moved outside cluster boundary or did not have data to send, will be assigned to a new incoming MSN.

b) *Effect of maximum speed variation:*The average energy consumption per round of all protocols versus MSNs speedisillustrated in Fig. 12. The figure shows that the average energy consumption for the MGAHP, CBR-Mobile, and LEACH-M protocols increase with increasing MSNs speed because the frequent moving of the mobile nodes increases the disconnected periods and then increases the energy consumption. Here the CBR-Mobile has a better AEC performance than LEACH-M. The MACRO protocol consumes more energy than LEACH-M in a lower speed while in the higher speed the MACRO protocol has better ACE performance. The MGAHP protocol has the best ACE performance compared to all protocols as it consumes the lowest energy. The proposed IMGAHPsaves the energy consumption compared with MACRO, CBR-Mobile, and LEACH-M protocols while the disconnected nodes can connect to the network again within a short period. However, it consumes more energy than MGAHP since it uses more overhead messages.

The PDR of all protocols versus the speed of mobile nodes isillustrated in Fig. 13. The figure shows that with increasing MSNs speed in MGAHP, CBR-Mobile, and LEACH-M protocols, the PDR is decreased. That's because increasing the speed makes the nodes move from their clusters searching for other clusters frequently and this leads to frequent nodes disconnection and reduces the PDR. As seen also from the figure, the proposed IMGAHP protocol gives thebest PDR performance and offers the highest and more stable PDR with increasing the maximum speed of mobile nodes due to achieving mobility and traffic adaptively.

VI. Conclusion

Mobile wireless sensor network becomes more popular and important in recent days because it has many advantages than static one. MWSNs can increase the channel capacity and lifetime of the networks and reduce energy consumption during communication. They also can reduce the energy holes by relocating nodes after initial deployment to achieve the desired energy. In this paper, an IMGAHP has been illustrated to enhance both the packet delivery ratio and the lifetime of MWSNs. The proposed IMGAHP is energy-efficientand more reliable protocol comparing with (MACRO, CBR-Mobile, and LEACH-M protocols). However, MGAHP protocol is the best protocol in saving energy consumption but it has less efficient performance in packet delivery ratio than MACRO and CBR-Mobile and protocols. It is shown that the proposed IMGAHP protocol overcomes this problem and achieves the highest and most stable packet delivery ratio on account of using some more energy compared to MGAHP.

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