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Fuzzy Logic Method for Enhancement Fault-Tolerant of Cluster Head in Wireless Sensor Networks Clustering

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Key words: Wireless sensor networks; clustering, cluster head selection, fuzzy logic system, fault-tolerant

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Abstract: Wireless sensor network is comprised of several sensor nodes which have been organized in terms of their application requirement. They recognize incidents, collect and transfer information. This type of network is in the exposure of the numerous challenge depending on the network surroundings. Environmental factors, typical breakdowns and hardware/software problems influence the network operation directly. Perhaps, the routing protocols of simple structures, the destruction of one node or some is not so sensible whereas in the clustering structure the destruction of a cluster head can induce the loss of information of some nodes in the network. The recommended protocol, hence, pursuits a way to increase the fault-tolerant of the cluster head in the cluster network. At first, paying attention to the improvement of the cluster structure and producing a balance in the density of the cluster cause to postpone the death time of the cluster head node and lessen the collision and prevent networks cutting into fragments due to the lack of the energy balance in clusters. The innovation in this stage is formed by using two fuzzy logic systems. One in the phase of evaluation of the cluster head chance and the other in the phase of producing balance and the nodes migration to the qualified clusters to increase balance in the clusters, In the next stage, the focus is on the recognizing and repairing the cluster head fault by checking the vitality of the cluster head node and also determining the backup node in time slices using fuzzy logic system. Increasing the network life time and reducing the number of the dropped packages of the network as a result of simulation demonstrate that the recommended method has acted more successfully than the existing clustering algorithms and algorithms which use fault-tolerant system.

INTRODUCTION

In recent years, wireless sensor networks are widely improved. The sensor nodes have capable of wireless communication and computing capabilities[1]. The recent advances in the electronic industry and communication have made the production of multi-purpose, low cost and low energy-consuming sensor nodes in small dimensions and the feasibility of connection in the short distance possible. Wireless sensor network is transferred to an area in order to sense the different types of physical data from the environment. Then sink assesses the information that are sensed by the sensor. Too restricted computational, storage and power capabilities are the properties of the nodes. A technique that makes the network longevity longer is clustering. In a clustering protocol, the nodes that are near to each other geographically are organized into virtual groups named “clusters”. A node that is chosen as a cluster head lie in its neighboring nodes as a cluster member[2]. The nodes have restriction of energy and cannot be recharged. Fault-tolerant is a significant challenge in the wireless sensor network. Fault tolerance is an equally important issue for long run operation of the Wireless sensor network[3]. One of the most signification wireless sensor networks requirement is referred to as fault tolerance. It makes sure the correct network continuation performance even when some components fail. As a matter of fact, due to sensor node feature, radio communications and hostile environment in which these networks are transferred, fault tolerance is necessary in this type of network[4]. Furthermore, within many Wireless sensor networks, the cluster head are usually selected among the normal sensor nodes that can die because of this additional work load. Many researches[5-7] have suggested the use of some special node called gateways or relay nodes. This gateway and relay node provided with extra energy, these gateways are regarded as the cluster heads and have the responsibility of the same performance of cluster heads. But the gateways are also operated by battery and therefore have power limitations. When a sensor is ruined as a result of the energy shortage, colliding with the surrounding objects due to the diffusion of the first signal in the environment or surrounding interferences like noise; The management of its covering environment must be assigned to another sensor[8-10]. Nodes that die quickly lead to less precise information in that area[2]. In such case, the basic problem is which neighboring sensor is elected for the dropped sensor management to choose the adjacent sensor, a fuzzy Logic system can be used so that backing up the fault-tolerant could maximize the reliability of the network. Fault management can be divided in three groups: the fault-discovery, the fault result recognition and fault correction[11, 12]. The rest of the paper is organized as follows:

Literature review: Too many research has been carried out regarding clustering and fault-tolerant so far. the most significant and applied clustering protocols lie upon the wireless sensor network of the LEACH protocol which puts on emphasis on election on electing cluster heads randomly with a fixed probability. In the LEACH protocol, the sensors are accidentally distributed in one area. The time duration of the network activity is divided into some rounds. In the beginning of each round, a number of nodes are selected randomly as the head node and each node produces a casual figure between 0 and 1. In the equation 1 if the figure is less than the quantity of T(n) the mentioned node is elected as the cluster head, and then the cluster heads transfer a message toward all nodes , and then the nodes choose the considered cluster based on the received signal from the cluster heads. P is the proportion of the number of clusters to the number of nodes. R is the figure of the present round and G is the number of the nodes that have not been selected as cluster heads in the previous round[13]:

$$T_{(n)} = \begin{cases} P/\left(1\text{-}p\times\left(r \bmod \left(1/p\right)\right)\right), & n\in G \\ 0, & \text{Otherwise} \end{cases} \qquad (1)$$

In LEACH protocol, a node won’t have any chance to become a head node unless all of the nodes become cluster head a head node unless all of the nodes become cluster head or the external circle is accomplished. Moreover, it won’t have any mechanism to tolerant the cluster head fault. Cluster head election also will be taken place accidentally and it doesn`t have any other parameter. Thus, it is possible that a node with the least energy to become cluster head and the elected clusters also because of their casual nature maybe elected close to each other or elected on the surrounding edges. Cluster Head Election mechanism using Fuzzy Logic (CHEF) protocol uses fuzzy logic to select cluster head with inputs: remaining energy of the node and local distance (total of distance between a specific node and its neighbors within a specified radius)[14]. CHEF doesn`t take inter cluster communication cost for cluster head selection into consideration. Cluster head selection protocol uses distance of cluster centroid from sink, residual energy of node and network traffic as inputs fuzzy logic for cluster head selection[15]. CHUFL is the clustering algorithm and it is the best cluster head election. This algorithm select the best cluster head of fuzzy logic system with three inputs: remaining energy, distance from sink and an accessible ability to the neighboring nodes with radius of R. The focus on the inputs in order to select the cluster head leads to a better function of this algorithm than the different algorithms like the CHEF algorithm in this algorithm no attention has been paid to the cluster density and balance maintenance in the clusters[16]. Although, clustering algorithms have a lot of advantage, they have usually paid no attention to fault-tolerant. All member of the cluster also will lose their connection to sink when an error maybe committed. A mechanism must be considered to discover and repair the fault[17, 18]. The algorithm of FTCD is one of algorithm in the fault-tolerant area it include the two steps of fault recognition and fault finding of the cluster head. In the first step, the clustering inadequacy and defect are indentified. In the next step, the repair and maintenance of the cluster are carried out. This algorithm uses the LEACH base, protocol for clustering .In the fault-recognition phase, an evaluation process of the cluster head situation has been added to TDMA timing that check the vitality of the cluster head in the determined time intervals .In the event of making n error, the nearest node lies in the distance of r/2 from the cluster head and it is selected as the replacing cluster head. The challenge of this algorithm is that it has no other mechanism for selecting the substitute cluster head node; there is also an election probability of substituting node among from the nodes with the less energy[18]. One of the algorithm of fault-recognition is DFCA. In this protocol, maintaining the cluster nodes energy is the major preference. This protocol is of the recognition phase and the fault tolerant of the cluster head nodes. In DFCA, the mechanism of the cluster head election is on the basis of cluster head cost function which has a direct relationship with the remaining energy along with a distance between the sensor node and the cluster head and the distance of the cluster head from the sink. The main challenge of this algorithm is that there is no mechanism for a suitable choice of the cluster head in the first phase. Furthermore, there is no mechanism for filtering worthless cluster head nodes in respect to the density and disbanding the cluster head nodes which have attracted more nodes than threshold .In the phase of the node election that is carried out by the coverless nodes, the remaining energy of the target node is the only considered criterion[3]. The next algorithm is the above-mentioned algorithm in which there are a number of homogeneous sensor with a unique identifier and a rate of identical transfer all of which are interrelated on a network based on radio interchanges. The proposed algorithm calculates and extracts the fault-tolerant extent for each node. Meanwhile each node possesses a current nerve network installed on it. The algorithm ensure that each sensor recognizes the identity of its own neighboring sensor. This algorithm doesn`t have any effectiveness in the environment with higher density[19]. Another presented algorithm in this study is the mentioned algorithm that proposed a distribution method to fight the node fault and uses the movable nodes for recovery. Determining the type and the movement route in this study is innovative and it could have been useful for the heterogeneous movable networks[20]. Another algorithm has been presented to increase the fault-tolerant using fuzzy logic within the wireless sensor networks. In the proposed algorithm when a sensor encounters a problem, the space covered by the sensor remains uncovered. A this missing space is given a cover due to the sensor destruction by the faulty neighboring sensors. In this algorithm, one of the faulty neighboring sensor that is of higher priority to cover the lost space moves toward the faulty sensor so that it would cover the missing boundary .the fuzzy logic has been used to calculate the priority arrangement of the neighboring nodes. The fuzzy inputs are the faulty: node distance from its neighbors, the distance from the cluster head and the remaining energy amount. his algorithm, is proposed in a network that is not clustered, its nodes are movable and the purpose is to cover the lost area. It also has no mechanism to choose the substitute when the sensor is faced with problems[21].

MATERIALS AND METHODS

Proposed protocol; clustering and creating balanced cluster: The problems of the probable clustering algorithm and the weakness in choosing an appropriate and balanced cluster head in the network has assigned one part of our idea to itself in this study. In the proposed protocol, the existence probability of a cluster head with a small number of members approximately reaches to zero. At first, the cluster are created in equilibrium in order to increase the network longevity and prevent its breaking into pieces. In the each period, CH_{opt} is number of optimal cluster head and we will select 2 CH_{opt} .The phases head node election are as follows: In each period, each node creates a random figure between 0 and 1.

If the random figure is less than, P_{opt} the sensor node calculates chance of becoming luster head through a fuzzy system No 1. Then, the node sends other nodes a message including its own identifier and a chance obtained from the first fuzzy logic system. Then, the node waits for the next message of other nodes, if the mentioned node chance is greater than the chance of the other nodes, the node is elected as the cluster head.

The elected cluster head nodes as to their head clustering and member admittance send their own publicity message. After receiving the publicity message of the cluster head in terms of the most powerful received signal, the normal nodes of the network elect the appropriate cluster head which has the nearest distance from them and then send it their own request of membership message. The cluster head nodes send their own identifier list of their own cluster member nodes to the sink[8].

The next phase is the disbanding of the Sparse clusters. The definite number of cluster head is obtained through K = K'/2 equation. In this way, we will have no cluster head with a number of members less than threshold. Innovation in this phase is the election of the suitable and balanced cluster heads in the network. Then, the migration of the disbanding cluster nodes to the appropriate clusters is obtained through fuzzy logic system No 2.

Determining the substitute node: After appropriate cluster formation and definite cluster heads election, determining the backup node is performed through fuzzy logic system No 3. This process is repeated in each period using TDMA because it is possible that the elect backup node in the previous time slot to have lost its own energy in the next time slot due to the energy consuming or a reason of this sort. Therefore, it can't be a good election as the cluster head substitute in the event of fault appearance.

Evaluation fault recognition: One of the network collision which mainly occurs due to the simultaneous transfer of several nodes. Also the use of hierarchy transfer is to diminish the cost of package transition as to the sink. Another way to fight the cluster head nodes defeat in the present article is using the backup nodes. In this mechanism, the candidate node of the cluster head (backup) can substitute the faulty cluster head node when the cluster head node is defeated, In the proposed algorithm, the status of cluster heads are examined in different times slot. In there is no response from the cluster head, the nodes close to the cluster head become sensitive to its performance and send their request if it has not made any mistake. Otherwise, the mentioned nodes can recognize that the cluster head node is faced with a problem.

Fault repair: In the event of the cluster head fault, the node or the deciding nodes introduce the substitute node as the new cluster head. The list of the previous cluster head members is sent to the new cluster head; the system is asked for table scheduling table schedule TDAM. Then, the new cluster head sends a message to the new cluster head. Again, the phase of determining the substitute cluster head for the new cluster head is carried out.

The first fuzzy logic system: Determining the proposed protocol cluster head: In order to determine the head clustering chance among from the candidate nodes, the first fuzzy logic system with three inputs are used. The inputs: The remaining energy of the node n (first input), the distance from the sink (second input), the output: the head clustering chance of the

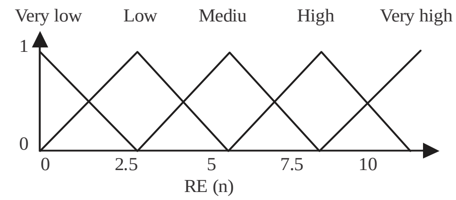

Fig. 1: Remaining energy of node

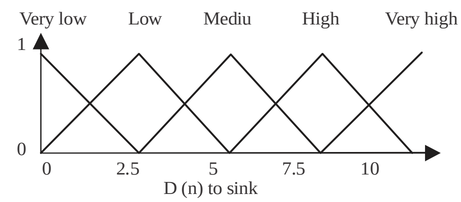

Fig. 2: Distance form the sink

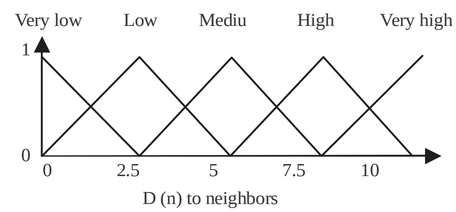

Fig. 3: Distance form the neighbors

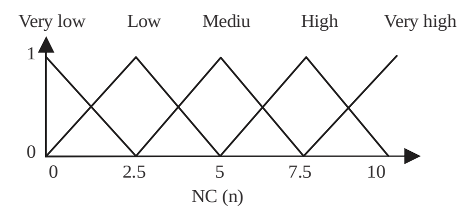

Fig. 4: Node cost

node n. The distance parameter depends on the mean of the nodes distance in the neighboring radius are shown in Fig. 1-4[16].

The fuzzy logic System inputs are demonstrated in form of the following fuzzy diagram and each sensor node cost is calculated by equation 2 and 3[22]. The cost of each sensor node in time slot is [0,1]. In this way, the head clustering chance for all the candidate node is calculated and the node with the greater node cost (more chance) and highest f(n) would be selected as the cluster head:

$$NC = \frac{\sum Rule_i \times C_i(NC)}{\sum Rule_i} \quad (2)$$

$$f(n) = NC \quad (3)$$

The second fuzzy logic system: The stable status of the proposed protocol: After disbanding the private

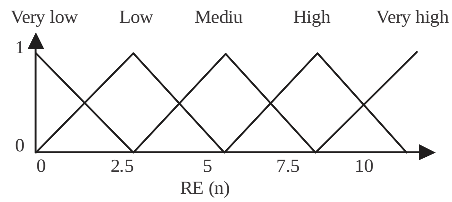

Fig. 5: Remaining energy of node

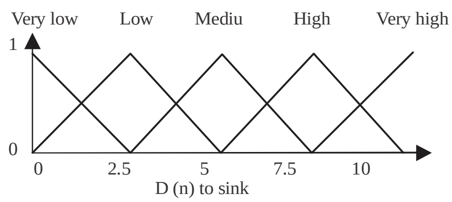

Fig. 6: Distance form the sink

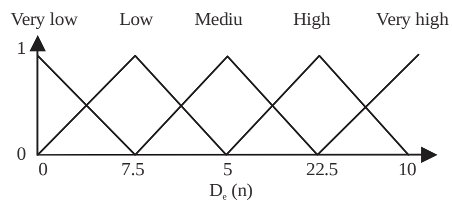

Fig. 7: The density of the clusters

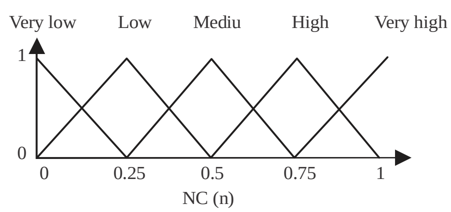

Fig. 8: Node cost

nodes, the nodes resulted from the protocol nodes disbanding use the second fuzzy logic System in order to migrate to the existing clusters and to select the best cluster. The usable fuzzy logic system in this stage comprises three inputs and one output. The inputs: The most remaining energy and the distance from the cluster and the density (the number of the clusters numbers). The output: the cost for electing the best cluster head, are shown in Fig. 5-8. As it is inferred from the fuzzy logic system and the proposed triangle model, each input parameter of fuzzy logic system consists of a triangle diagram. In each diagram, regarding the existing triangles other values in y axis can be assigned to the behavior of one parameter in variable values of X axis. Each point on the axis contains two values on Y axis. In the density diagram, the density ratio can be placed in 5 level: very low, low, medium, high, very high. The density of each cluster can be put in one of these levels or at least in the

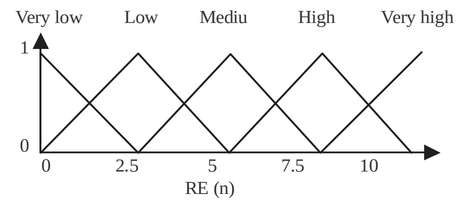

Fig. 9: Remaining energy of node

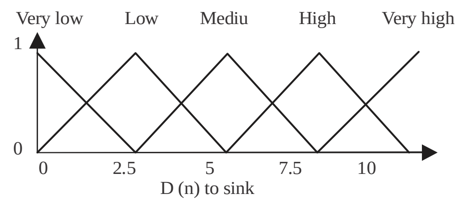

Fig. 10: Distance form the sink

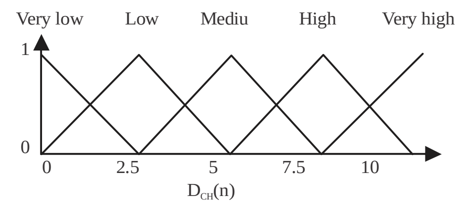

Fig. 11: Distance form the cluster head

two respective levels. NC(n) and f(n) will be calculated from Eq. 2 and 3[22]. The greater node cost (more chance) and greater f(n) causes the node to the cluster with the highest chance migrate.

The Third fuzzy logic System: electing the substitute node: Performing an affective clustering and creating a balanced cluster as much as possible, the appropriate substitute cluster head with a fuzzy system is elected immediately in order to replace the backup node with faulty cluster head when a fault appears in the cluster head. Within the tome intervals of TDMA, the fuzzy system is implemented, so that , the best substitute cluster head is elected. The target fuzzy logic system in this phase includes four input and one output. The inputs: the remaining energy of the node n, the distance to the sink, the distance from the cluster head and the average distance from other cluster heads; output: the cost is for electing the best substitute cluster head are shown in Fig. 9-13. The distance parameter is dependent upon the distance extent which is calculated from Eq. 4:

$$\Delta_x = \nu.\Delta_t \quad (4)$$

Δ_x is the distance of the node from the sink, that is the same $D_{(n)}$ in the fuzzy diagram. The parameter ν is a

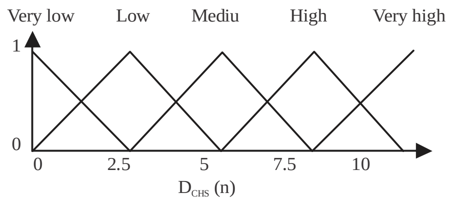

Fig. 12: Average distance form the cluster heads

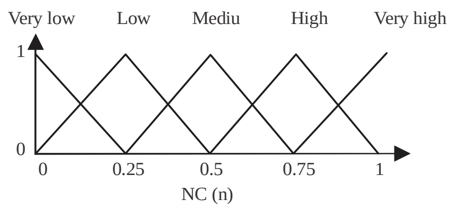

Fig. 13: Node cost

Table 1: Simulation conditions

Parameters	DFCA, FTCD	Proposed
Network size	1000×1000	1000×1000
Antenna	All the way	All the way
Time simulation	1000	1000
The number of sink	1	1
Location sink	Fixed	Fixed
Primary energy sink	1000	1000
The number of nodes	100	100
Position nodes	Random	Random
Status groups	Fixed	Fixed
Primary energy	10 Jules	10 Jules
Energy model	Battery	Battery

fixed variable that is equal to the light speed and is considered as the genuine amount of 299792458 m/sec and an estimated amount of 300 km/sec. The speed of signal is equal to the light speed; the same amount is applicable in our equation. But the parameter Δ_t is equal to the difference of time of one package transition and its received time. In this way, the more the mount of Δ_t , the more distance between the sender and the receiver will be. The average of the distance amount from other cluster head is estimated for the reason that the accessibility extent of the cluster head to the sink to be considered. For sending information when the node has a great distance from the sink and has also low energy and cannot send information, it sends the information by the help of other cluster head. These four Parameter, after entering the proposed fuzzy logic System and performing fuzzy operation and adapting with the rules, change into the fuzzy logic System output that will be regarded as the node cost or the same NC(n) and it will be calculated from equation 2 and 3[22]] and Fuzzy rule base shown in Table 1. At last, the sensor node which has the maximum f(n) amount of the node will be elected as the best candidate node for acquiring the substitute cluster head role.

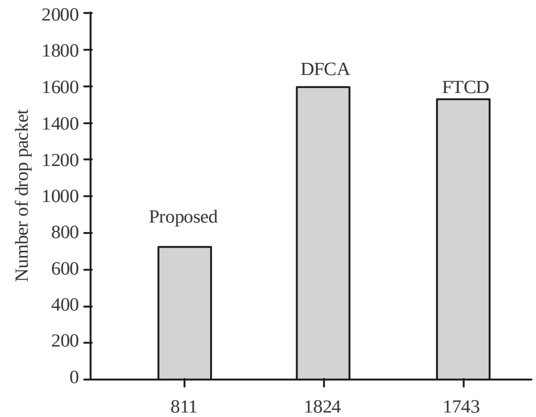

Fig. 14: Number of dropped packets

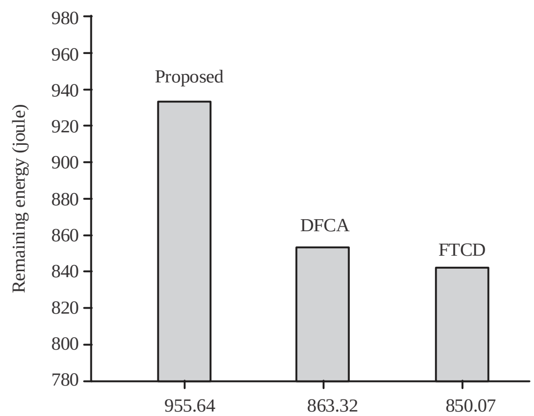

Fig. 15: Remaining energy

RESULTS AND DISCUSSION

In this study, we presented a clustering protocol on the basis of fuzzy logic system with a trend of fault tolerant. We have put the intended idea into practice in the simulation environment of the network that is the NS simulation software 2.34 version and then we have evaluated this study results with the base and similar algorithms. That we have considered the parameters dependent on the clustering mechanism in the network and have tried to balance the cluster head pressure on the highly valuable nodes, it is evident that the death time of the first and the last network node is postponed. In the tests, we have had some sensor nodes make mistakes accidently in the simulation (14 and 15). We want to evaluate to what extent the proposed method and the similar ones can discover this fault and can repair it in the clustering structure, The death tie of the first and last network node is generally and directly related to the life time of the sensor network. The simulation conditions are shown in Table 2. The results obtained from the administered tests on the proposed protocol showed that

Table 2: Fuzzy rule base for the third fuzzy logic system

Antecedent Rules	Remaining Energy $RE_{(n)}$	Distance to sink D(n) to sink	Distance to CH $DCH_{(n)}$	Distance to other CH $DCHs_{(n)}$	Consequent $C_iNC_{(n)}$
Rule1	Low	Medium	Very low	Low	Medium
⋮	⋮	⋮	⋮	⋮	⋮
Rule16	Medium	Medium	Very Low	Medium	Medium

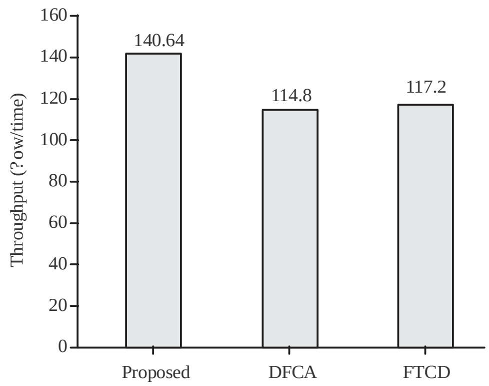

Fig. 16: Throughput

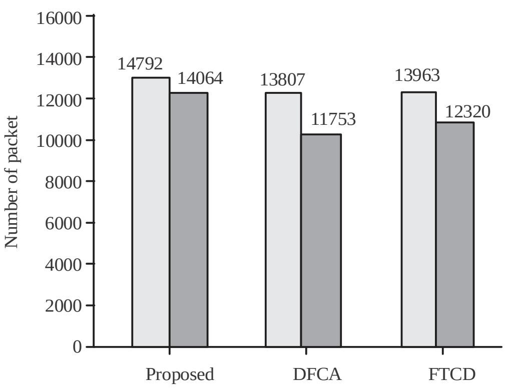

Fig. 17: Number of routing packets

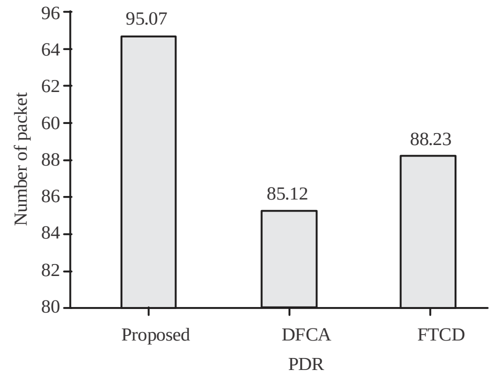

Fig. 18: (FND) First Node Die

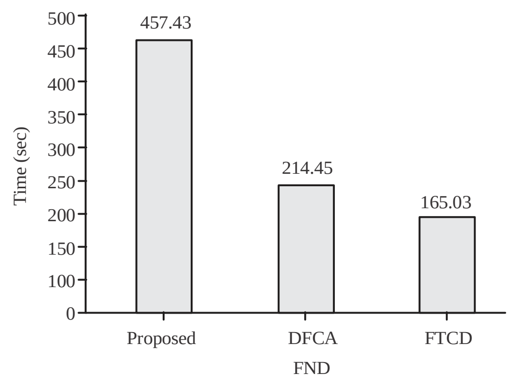

Fig. 19: (PDR) Packet Delivery Rate

the proposed protocol in the important parameters like the remaining energy, the death time of the first node, the number of the network routing packets, the number of dropped packets of the network and the comparison test of the network Throughput in terms of the number of the network current and the packet delivery rate has a better performance than the two protocol of FTCD and DFCA. In the first phase, the appropriate cluster head election creating balance in the cluster, and appropriate election backup cluster head causes can increase in the fault-tolerant and network longevity (Fig. 16 and 17). The reason of superiority of the proposed protocol regarding the death time parameter of the first node as to its compared protocols lies in the fact that the longer this time is the network responsibility load and clusters have been distributed more effectively .The proposed method could have achieved one of its goal that is to delay the death time of the network node. The number of the dropped packets represent the achievement degree of fault0tolerant performance in the network. The less the number of the dropped network packets indicates the best performance of the network in confronting occurred fault and managing it and fighting against it. The proposed protocol presented a better performance in this regard. Increasing the fault-tolerant and electing appropriately the cluster head induce a better information transferring in the network and through put increasing and the high extent of this parameter in the proposed algorithm in comparison to the two other algorithms demonstrates the best network output. The received data over the sent data in terms of the percentage represents the delivery rate of the packets. Surely, the more this percentage rate is, the better network output and performance will be in the cluster head election and fault-tolerant controversy. The proposed algorithm has had better performance in this regard. Chart simulation results for the proposed protocol and protocol FTCD and DFCA shown in Fig. 14-19.

CONCLUSION

The purpose of the study is to present a new way for balanced clustering with a fault-tolerant trend using fuzzy logic system. The node fault-tolerant in the induces reliability maximizing in the network and the network longevity. Moreover, the necessity of the network stability, energy consuming balance creation in the cluster nodes population and management and better access of the cluster heads to the network source are all among the proposed protocol goals. The proposed protocol has been designed on the basis of the present challenges and postpones the death time of the first node in the network, increase the network longevity, an d prevents the networks dismantling. The appropriate number of the cluster members not only prevents any delay in information collection in the cluster head but also disbands the worthless and reclusion clusters.

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