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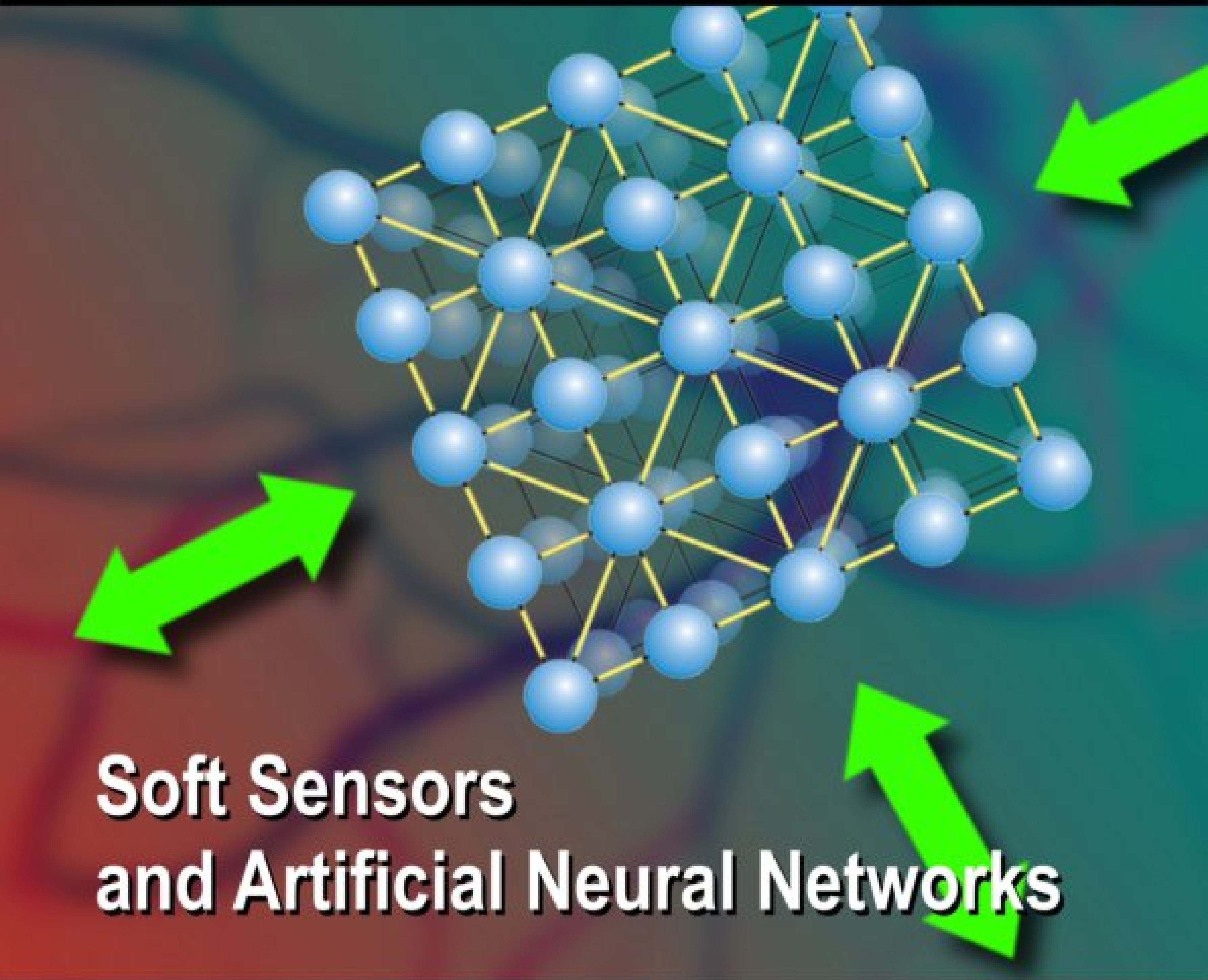

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New Load Balancing Algorithm for LEACH Protocol (F-VCH LEACH)

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Abstract: Wireless Sensor Networks WSNs have recently witnessed many improvements in Clustering and routing protocol, whereas Clustering protocols provide dynamic method for saving energy consumption. Energy considerations pose one of the most critical constraints in WSN that increase the network lifetime. Low Energy Adaptive Clustering Hierarchy protocol (LEACH) is being proposed for Energy conservation in WSN and offers one of the most common clustering-based protocols aiming to reduce the energy consumption. However, LEACH protocol suffers from the bottleneck problem experienced by cluster head absence which is lead to unbalanced and uncontrollable clusters in the network.

In this paper we introduced a Four-Vice Cluster Head algorithm in LEACH protocol called F-VCH LEACH protocol that elects four Vice Cluster Heads with the cluster head in each cluster aiming to prolong the cluster lifetime in the entire network. F-VCH algorithm has been implemented and evaluated using OMNET++ simulator. Comparative analysis and results extraction was performed with the traditional LEACH protocol. Simulation results proved that F-VCH LEACH protocol has high performance in energy saving for the network. *Copyright © 2012 IFSA.*

Keywords: Wireless sensor networks, LEACH protocol, F-VCH LEACH, OMNeT++.

1. Introduction

Wireless Sensor Networks and their challenges have become a favorable subject in academic research areas, WSN is attractive for various purpose applications including environment monitoring, air pollution monitoring, forest fires detection and greenhouse monitoring. Wireless Sensor Networks WSNs [1, 2] consist of thousands small sensing devices called sensors. These sensors are distributed usually randomly over a wide region (sensor field) to communicate together in different distances, and these sensors are installed to collect useful information such as environment home automation, measure the temperatures and military wars and commercial Markets, etc. It is also utilized to gather data from remote places where it's hard to reach; each sensor node gathers the final data and sends it back to one base station [3].

In wireless sensor environment all nodes are homogeneous and energy constrained and the base station is fixed and located in a far distance from sensor place [4].Wireless sensors are known for easily and rapidly deployment and densely with less installation cost, and this type of networks utilize a broadcasting communication and not a point to point communication whereas failure of a single node does not affect on the network [1]. Because the sensor nodes contain a huge amount of data for wireless network or direct to end users for processing for this reason automated method required to aggregating the final data into a set of meaningful and useful information, as well as to avoid information overload, data aggregation also is known as data fusion. It can combine several unreliable data measurements to produce more accurate signal by enhancing the common signal and reducing the uncorrelated noise [4].

The above features ensure that WSNs can be implemented in many applications and environments such as temperature measurement, commercial markets, civil flight and military uses. In military uses, the sensor networks can be used for military command, the rapid deployment, self organizing, control and communications. It can also be used to monitor patients, health monitoring for example, and other applications including product quality and monitoring disaster areas, etc., and expected applications in coming years [2, 5, 8].

WSNs have few limitations similar with the devices that have limited memory, low communication bandwidth and less processing power, which make them not able to be used for application in the sensor networks and in addition the energy efficient supply plays a very important role in WSNs where the nodes inside it are limited by battery longevity. For this reason many energy efficient protocols have been proposed and designed for these types of wireless sensor networks such as clustering, routing and topology control, to increase the wireless network lifetime and to provide better energy for each wireless sensor in the network that should be considered when we develop routing protocols for WSNs [2, 5, 6].

In recent years many researchers explored the routing and clustering protocols in wireless networks and they proposed different clustering and routing protocols for sensor networks because the routing protocols which are used for ad hoc networks and wireless ad hoc networks are not appropriate or useful for this type of networks, also they are not suited to execute the previous solutions on sensor networks for ad hoc networks with some important additional modifications. [6-8].

The network in clustered-based routing protocol is divided into groups called "clusters". And within each cluster, single node is elected to perform the function of management to be "Cluster Head" (CH); this node (Cluster Head) has the whole responsibility of managing the cluster in its network and transmitting the messages between the sensor nodes in the same cluster. The Sensor nodes (members) in the cluster do not have to broadcast the messages, they only send their requests to the CH, it dose not have to maintain a routing table where this is done by the cluster head maintains the routing table [9]. Based on this in [10] Yong et al proposed a Three-Level Hierarchal Architecture. The lowest level is the member nodes "Agents", then the next level is CH and the highest level is the Manager. In the absence of the CH the manager is responsible to manage the cluster until another member node is chosen (elected) to be "Cluster Head" [10].

WSNs provides a well-known "clustering-based" protocol called "Low Energy Adaptive Clustering Hierarchy " protocol (LEACH), [2] and [5] introduce LEACH protocol to use " randomized rotation "of local Cluster Heads (CHs) to distribute the load of energy between the sensors within the network evenly. LEACH protocol is adaptive clustering protocol and "self organizing". At any time, the sensor nodes elect themselves to be Cluster Heads with a specific probability after that these Cluster Heads send their current status to other sensor nodes (members) within the network, after that each node belongs to the Cluster Head (chosen) which has high signal in its broadcasting message [4]. Also Cluster Head in LEACH protocol is able to distribute energy between the sensor nodes within the network evenly.

Although these clustering algorithms such as LEACH protocol have several advantages but they have potential problems (predictive) in these algorithms. First problem, the Cluster Head is possible to be "bottleneck" of the whole Network because Cluster Head are responsible for many functions and many tasks and at the same time it suffers from heavy loads in each cluster at the whole system. Second problem, if the Cluster Head destroyed (died) in its cluster, the data loss will occur and reformation of the cluster becomes necessary and in such cases it will need more energy and time to bring the cluster back to life.

In this paper we introduce a new algorithm for the most known routing protocol which is used in wireless sensor networks LEACH protocol which is called Four-Vice Cluster Head algorithm utilized in LEACH protocol. The proposed protocol has high performance and response and especially for WSNs and at the same time with restrictive energy, and we will try to overcome the previous problems such as "bottleneck" of Cluster Head

2. Related Work

Heinzelman et al in [2, 5] proposed "hierarchical cluster-based routing protocol" for Wireless Sensor Networks (WSNs), called "Low Energy Adaptive Clustering Hierarchy protocol" (LEACH). LEACH protocol divides the nodes within the network into groups (clusters) and each cluster contains homogeneous Sensor Nodes (SNs). One of the cluster nodes has extra properties (e.g., amount of energy) and is called "Cluster Head" which is responsible of creating a TMDA schedule for the nodes in the whole cluster and transmits all compressed (aggregated) received data from their nodes to the fixed central Base Station [5]. By comparing with the traditional clustering algorithms, LEACH protocol achieves high performance; because all energy distributed between all the nodes in the network evenly.

The system determines the appropriate number of Cluster Heads before the election procedure relying on some parameters, e.g., network topology, costs, etc., and according to these parameters the optimal number of CHs is 5 % of the nodes [2, 5].

In [11] Qing-Hua et al proposed a new protocol for effective tool used to collect the data in different environments in the sparse WSNs called multiple-input multiple-output (MIMO) communication similar to the traditional LEACH protocol but they added new phase to the original phases in LEACH protocol called cluster exchange to solved the important problem when the primary CH cannot find enough secondary cluster heads, which are used to form virtual antenna transmitters with CHs.

Abuhelaleh et al in [12] introduced another contribution on LEACH protocol, called Multihop-LEACH protocol (M-LEACH), which is similar to LEACH protocol almost, but the communication mode between CHs and BS is multi-hop. It selects typical path between Base-Station and Cluster-Head during existing Cluster Heads between them and these Cluster Heads are as a station to transform data between them [12]. Depending on this selected typical path the CH sends data to the nearest CH, also the assigned CH sends data to the nearest CH until it reaches the BS.

Loscrì et al In [7] proposed A "Two-Levels Hierarchy for Low-Energy Adaptive Clustering Hierarchy" protocol (TL-LEACH) which used two different Hierarchy levels for the original LEACH protocol "a Primary Cluster Heads" and "Secondary Cluster Heads". Primary cluster heads create a TDMA schedule for nodes and collect the data from their nodes then transfer these data to Secondary cluster-heads where they transfer data to the BS directly, this technique is better to distribute the energy to the whole network [7]. Each Cluster Head in LEACH protocol communicates with the Base Station directly, no matter the distance between them. But if the distance is too far between them it will consume more energy.

In [4] Heinzelman et al described LEACH protocol as "clustering based routing" protocol and this protocol reduces the amount of energy that it utilized to distribute the load among the nodes in the network. The authors used randomized rotation on their proposed protocol to distribute the load of energy between the nodes to reduce the required energy. Their work shows that LEACH protocol reduces the communication energy eight times compared with direct transmission and minimum transmission energy routing.

Li et al in [13] introduced in WSNs "Energy-Efficient Unequal Clustering " algorithm (EEUC) to distribute the load of energy between cluster heads for data gathering, by dividing and distributing the nodes into clusters in different sizes (unequal clusters) where the clusters that have small sizes are closer to the base station and the clusters that have large sizes are far away from the base station.

The cluster heads in small size cluster can preserve some energy for transmitting data. EEUC protocol improves the network lifetime over LEACH and HEED protocols. In HEED protocol the cluster heads are selected randomly depending on their residual energy, therefore, the node with high residual energy becomes cluster head and the energy consumption is unbalanced in the network therefore, some nodes will die. But this case is avoided in EEUC because the load of energy is balanced between nodes.

Ossama et al proposed an effective protocol called HEED "Hybrid Energy-Efficient Distributed clustering" to support the data aggregation process and maximize the lifetime of the network at the same time [14]. That selects the new cluster head according to residual energy of the node then this node joins the cluster in the network, using this way the communication cost will be minimized.

Another improved scheme presented in [15], called PEGASIS "Power-Efficient Gathering in Sensor Information Systems" which is a greedy chain protocol that minimizes the energy consumption in gathering data process in WSNs. In PEGASIS, each node in the cluster connect only with it's a close neighbor and sends the data to the central Base Station, So it will reduce the amount of energy consumed in the network .And the results shows that PEGASIS has a performance higher than LEACH by minimizing the distance and number of transmissions between the nodes and the base station to keep the energy balanced in the network.

Clustering algorithm of LEACH protocol is very simple but there is no guarantee about cluster heads distribution in the whole network. In [16] Taewook et al introduced new scheme for selecting cluster heads as candidate nodes in each cluster evenly. And their results showed that their scheme is better than LEACH, by reducing the energy consumption and it avoids creating unnecessary redundant cluster heads in small area and also prolongs of the network lifetime. Their method is achieved by number of phases; each phase must start with a set-up phase then followed by steady-state phase. In setup phase: candidate nodes are elected using threshold function, and the number of candidate nodes is more than cluster heads [16]. Then cluster heads are selected during the transmission of advertisement message. Finally, steady-state phase begins: each cluster head starts transmitting aggregated data to the central Base Station.

Shirmohammadi et al have a new "Leader Election with Load Balancing Energy" protocol called LELE in [19] , in this paper, their work was how to choose (elect) the leader (cluster head) by comparing the amount of distributed energy and distance of a node with its neighboring nodes and the node that have the highest energy is chosen as the leader.

In [18] Muneer and Enas introduced a new algorithm called New Energy Saving Algorithm (NESA) which is implemented with LEACH protocol to maximize WSNs life time ,decrease the amount of energy and distribute the energy between the nodes evenly by coordinating activate and sleep nodes in the network according to their residual energy.

Muneer and Hassan in [20] improved a new protocol, that combines LEACH protocol and Mediation Device (MD) protocol using the proper node scheduling (active and sleep mode) to save energy, it allows the cluster head to be in a sleep mode if there is no data to be sent, Using this approach the efficiency was increased near to 50 % than the traditional LEACH protocol [20].

Tripathi et al presented a new method for cluster head selection in LEACH protocol in [21]; their proposed method balances the energy consumption of every node in a wireless sensor network and their results show that the lifetime of sensor network is enhanced comparing with the original LEACH protocol. Our algorithm F-VCH proposed to elect cluster head and also elect four nodes in same time to increase the network life time that are called cluster head vices instead of one cluster head like their proposed method in [21].

3. Description of LEACH Protocol Algorithm

The algorithm of LEACH protocol is achieved by number of round; each round must start with a "set-up" phase followed by "steady-state" phase (Data Transmission) [2, 5, 17]. In setup phase: initially each sensor node in the cluster has same probability to become a Cluster Head (CH) relying on the amount of energy consumption for each node. And this phase consists of three phases: Advertisement phase, Cluster Setup phase and Steady-State phase respectively. In advertisement phase the nodes need to decide to become a CH depending on the energy consumption for each node in each cluster in the network, then the node which is selected (elected) as CH sends an advertisement message to the rest of nodes in the cluster that it will become the cluster Head in the cluster, during this phase non-cluster head nodes (members) which hear the advertisement message join to a new Cluster Head.

In Cluster Setup phase, non-CH nodes inform their CH that they will be members to its own cluster. The third phase: Schedule creation phases, where CHs keep the number of its member nodes and their IDs also, then CHs create a TDMA schedule for the nodes and send the TDMA table to each member in its own cluster. After that steady-state phase starts [17].

In "Steady-state" phase, each member starts the transmission data to their CH relying on their TDMA, and the transmission data process uses an amount of energy .The cluster members (non-CH) can be slept until their transmission time starts and The Cluster Heads receiver must stay active (turned on) to receive all the data, after that when CH received all data from the nodes CH aggregates these data and send them to the Base Station [5, 17]. For this reason the cluster head is the most important node in

LEACH protocol because it carries all data and is responsible for communication between the nodes in the cluster, and transmit the data from these nodes to one base station and then rebroadcast the reply to all members in that cluster. But suppose if the Cluster Head had been Downed (failure) suddenly for certain reason, the cluster will be without a manager (cluster head) then no transmission data between nodes and base station and no communications between them also then the re-clustering is required, this will cause increasing the cost of the processing and exhausting more energy for election procedure for new cluster head.

Therefore, this paper introduces a new algorithm for LEACH protocol called Four-Vice Cluster Head algorithm, which will be described in the next section to avoid this problem in the original LEACH protocol.

4. Four-Vice Cluster Head Algorithm in LEACH Protocol

Many researchers studies in this type of networks, wireless sensor networks and especially with routing protocols like LEACH protocol that concentrate on improving the performance with excellent results in known factors such as amount of data signals to/from the central base station, the energy and number of nodes, etc., depending on the most important node in each cluster in the whole system which is Cluster Head. The main objective in this paper is to increase the performance of LEACH protocol especially in the clustering scheme, by solving an unexpected problems such as losing Cluster Head suddenly in the cluster that will cause unbalanced network in the system, therefore, this problem will force the system to re clustering the whole network again, But by using our proposed algorithm Four-Vice Cluster Head in LEACH protocol (*F-VCH LEACH*) that uses four vices for each cluster head make the system able to manage and solve this problem.

The proposed algorithm is developed to increase the performance of this type of the clustering algorithm especially in LEACH protocol in WSNs. In this paper we listed four modifications on LEACH protocol, The Details of these modifications will be presented in the following sub-section.

4.1. Four- Vice Cluster Head Algorithm

F-VCH algorithm in LEACH protocol is considered in this research as the new modification on LEACH protocol that allows to execute re-correction process for the system again "a self-correction process", This type of process is proposed a set of nodes (non-CH) are called Vices (Vs).

In this paper we proposed *Four Vices* for each *Cluster Head* in LEACH protocol and these vices are elected with the original cluster head in each cluster when the cluster is created in the system at the first time. After electing the cluster head with its vices in each cluster the cluster head sends a notification message to all nodes (non-CH and non-Vs) in its own cluster to inform them about these new vices.

The main purpose of these vices in each cluster is to take the place of the cluster head if the cluster head failed (destroyed) for particular reason, after that cluster head vices take the place of the original cluster head in the cluster one by one. The First Vice (V1) will announce itself as cluster head and send an a notification message to all nodes in the cluster to inform them about its current status, now if the V1 destroyed for any reason, the Second Vice (V2) also will announce itself as cluster head and sends a notification message to all nodes about its current status, and so on for the Third Vice (V3) and fourth Vice (V4). This algorithm is clarified in Fig. 1.

```
Class ClusterHeadMessage : public ClusterMessage
Start
Define  DepHead[4]  As Integer type
// DeHead is an extra array to store the vice clusterheads
End
```

Fig. 1. Declaring Four Vices in cl_msg_m and Node Files.

So, when a node is given its Cluster Head, it is also given the Vice Cluster Heads to connect to if the cluster head is dead. After that another array is defined to store the incoming vices from the cluster head message as shown in Fig. 2.

```
Define  Dept[4] As Integer type
Set  V= 0
For  V= 0 To Number of Vices -1
Dept[V] =  incoming ClusterHeadMessage*  from DepHead [V]
Set  V=  V+1
End For
```

Fig. 2. Steps for Notification Messages About Four Vices in Node File.

After informing the nodes in the each cluster about these incoming vices using notification messages from the Cluster Head, The Vices will be elected after the Cluster Heads are chosen and distribute them in each cluster as shown in Fig. 3.

```
Set ctr = 0
IF ClusterHeadMessage == Area1.id  Then
For  ctr = 0 To Number of Vices -1      //  Number of Vices = 4
Set DepHead[ctr] = dept[0][ctr]
Set  ctr = ctr + 1
End For
Else IF ClusterHeadMessage == Area2.id  Then
For  ctr = 0 To Number of Vices -1
Set DepHead[ctr] = dept[1][ctr]
Set  ctr = ctr + 1
End For
Else IF ClusterHeadMessage == Area3.id  Then
For  ctr = 0 To Number of Vices -1
Set DepHead[ctr] = dept[2][ctr]
Set  ctr = ctr + 1
End For
Else IF ClusterHeadMessage == Area4.id  Then
For  ctr = 0 To Number of Vices -1
Set DepHead[ctr] = dept[3][ctr]
Set  ctr = ctr + 1
End For
End IF
```

Fig. 3. Steps for Electing and Distributing the Vices in the Network.

Now, the new LEACH protocol (F-VCH LEACH) has the original Cluster Head with its Vices (V1, V2, V3 and V4), which is able to increase the life time of the network without any re-clustering for the system again, but the system will invoke re-clustering process if the four vice cluster heads destroyed in the cluster, the current nodes in the cluster will transmit a message to the central Base Station asking to re-formation clusters to re-balance the system again.

5. Experimental Evaluation and Results Analysis

In this work we used a common simulation in the networks called OMNet++ network simulator to test the original LEACH protocol and Four-VCH LEACH protocol through several experiments , also both of them were compared to show the differences of the performance for each one. OMNeT++ is a C++-based discrete event simulator for simulating various types of networks like ad hoc networks, wireless sensor networks and distributed or parallel systems. The main design features of OMNeT++ simulator are the following:

- Enables simulating large-scale simulations; simulation models are hierarchical, and should be designed from reusable components as much as possible.
- Easy to program, trace, debug.
- The simulation software is modular, customizable and should allow applying simulation models into larger applications.
- Data interfaces are open: it is possible to generate and process input and output files with commonly available software tools.

The experiments have been performed on a 2.8 GHz PC, with Intel Pentium 4 processor and 768 MB memory.

5.1. Four Vice Cluster Head LEACH Algorithm

Sensor Nodes are distributed in the network randomly within area (1000 m×1000 m) and the distance between nodes is 15 m and each node in the cluster sends data in every 0.5 seconds. The Probability of cluster head in the cluster equals 0.05. And the following table (Table 1) contains the main parameters used in the simulation environment.

Table 1. Summery of the parameters used in the simulation experiments.

Simulation Parameters	Value
Simulation time	900 s
Packet size	512 byte
Topology size	1000 m × 1000 m
Nodes speed	10 m/s
BS position	Located at 1250 × 750
Packet rate	40 packets/second
Initial node power	5 Micro Jules
Number of nodes	50, 100, 150
Number of trials	10

The network lifetime is very critical point in WSNs depending on the presence of the energy; therefore the energy consumption is the most important factor that affecting in LEACH protocol. So depending on the energy factor we test energy consumption percentage in the whole network for protocols, the traditional LEACH protocol and F-VCH LEACH protocol. The next section shows a set of experiments that been performed to compare the performance of the traditional LEACH protocol and our F-VCH LEACH protocol.

5.2. Simulation Results Analysis

Four failures in different clusters were made to test the energy consumption percentage for the whole network when self-correction process is executed by the system. As we know Re-clustering process in LEACH protocol consumes more energy than F-VCH LEACH protocol, the nodes sends information to the base station asking for reform the clusters again and elects new cluster head again to build new TDMA scheme and the parameters redistributed in the network again. For that it will consume high energy. But by using F-VCH LEACH algorithm the nodes in each cluster joins to the Vice node as a new cluster head if original cluster head failed due to particular reasons. And the new vice will re-built the new TDMA scheme and continues the previous work from the previous cluster head with low energy.

The following figures show the amount of energy consumption of both, LEACH protocol and F-VCH LEACH protocol, better performance was observed by using F-VCH LEACH protocol compared to the original LEACH protocol.

In Fig. 4, the number of node was **50 nodes** and better performance was achieved when the F-VCH LEACH was used four vice cluster heads only, while Re-clustering process was needed in the original LEACH protocol. Also when we have the same parameters but the number of vice cluster heads decreased to 3, 2 and 1. The 3-VCH LEACH, 2-VCH LEACH and 1-VCH LEACH shows better performance than original LEACH protocol.

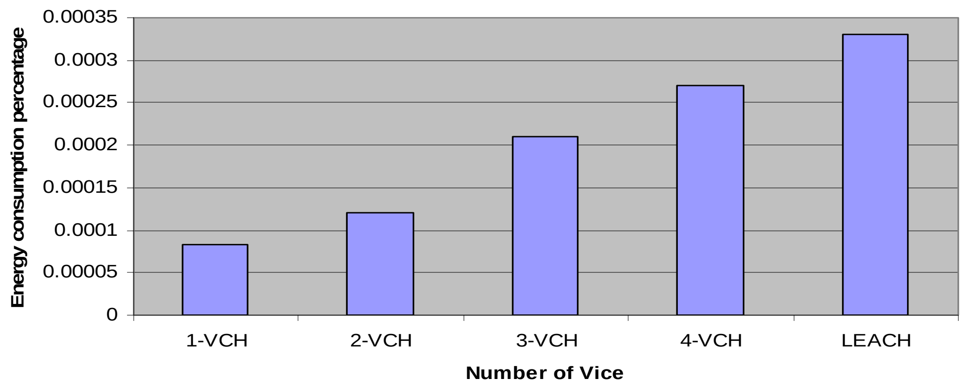

Fig. 4. LEACH Protocol vs. VCH LEACH Protocol.

The next set of experiments in Fig. 5 has been conducted for the same parameters but the number of nodes increased to **100 nodes,** thus, F-VCH LEACH shows better performance than LEACH protocol.

In Fig. 6 the parameters stay as before, but the number of nodes increased to **150 nodes**. F-VCH LEACH protocol shows high performance than original LEACH protocol too.

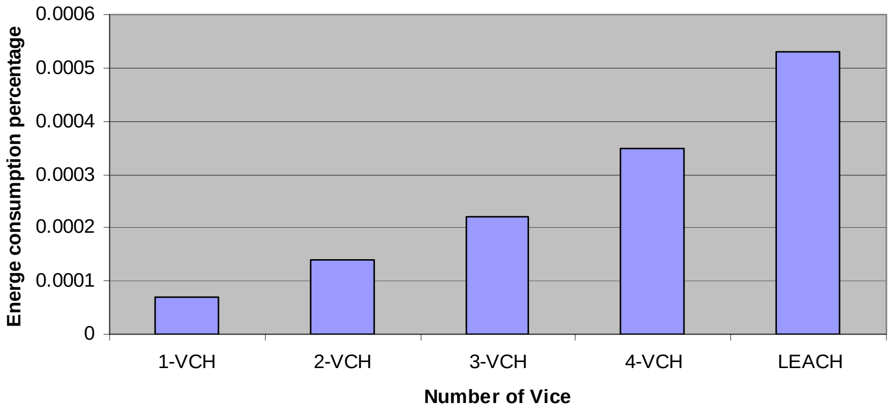

Fig. 5. LEACH Protocol vs. VCH LEACH Protocol.

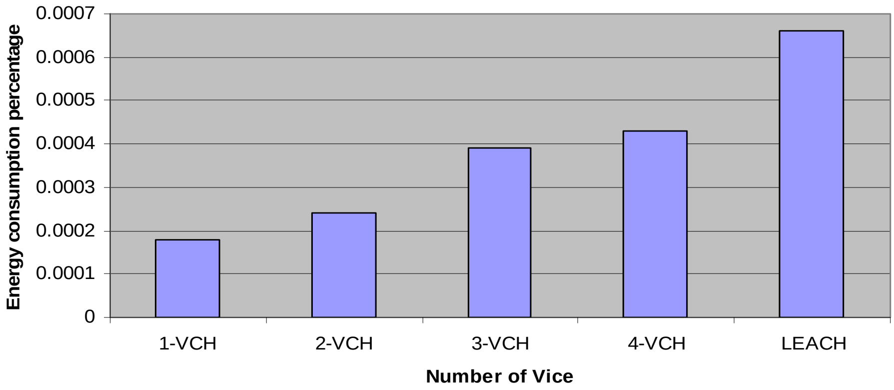

Fig. 6. LEACH Protocol vs. VCH LEACH Protocol.

6. Conclusion

Wireless Sensor Networks WSNs obtained a high improvements in clustering protocols like LEACH protocol due to its features in saving the energy consumption and increasing the lifetime of the sensor networks, many researchers have been proposed many clustering algorithms that aims to increase the network lifetime as long as possible, although most of them faced different types of problems in energy saving problem specially in LEACH protocol.

LEACH protocol is one of important clustering protocols that organizes the sensor nodes in the network into a set of clusters and elects one of them as a Cluster head for each cluster, which has a high responsible of distributing the energy between the nodes evenly and connecting the nodes with each other with one central base station. However, LEACH protocol suffers from bottleneck problem in cluster head absence from the clusters that make the clusters in the network unstable and unbalance.

In this paper, a Four-Vice Cluster Head algorithm in LEACH protocol, (F-VCH LEACH) is proposed to improve the performance of LEACH protocol; by aiming to solve the bottleneck problem faced by the cluster head. Our proposed algorithm aims to solve this type of problems in LEACH protocol by electing Four-Vice Cluster Heads to manage the cluster if the cluster head (manager) failed (died) suddenly for a particular reason and also at the same time increases the lifetime of the cluster in the network.

Our results show better performance than the original LEACH protocol by using F-VCH LEACH protocol.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 8-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

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