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An Energy Efficient Protocol Increasing Wireless Sensor Networks Lifetime Using Clustering Technique

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ABSTRACT

Wireless Sensor Networks (WSNs) have been predicted to be in all domains in the near future. However in order to reach this scenario, researchers are finding a solution to some difficulties which are slowing down the wide spread use of these networks. One the activity done by WSN that consumed the most energy is the number of packets sent/received. In order to reduce this and to ensure WSN successful operation, hierarchical clustering protocols have been developed. -TEEN and WBM-TEEN: two hierarchical routing protocols, based on nodes clustering and improving the well-known protocol Threshold sensitive Energy Efficient sensor Network protocol (TEEN) are presented . This improvement is accomplished in a way such that each cluster is node balanced and the total energy consumption between sensor nodes and cluster heads is minimized by using multi-hops intra-cluster communication. Simulation results (using NS2 simulator) show that the proposed protocols exhibit better performance than Low Energy Adaptive Clustering Hierarchy (LEACH) and TEEN in terms of energy consumption and network lifetime prolongation.

Keywords: Wireless sensor networks ; Hierarchical routing protocols; Clustering; Energy- efficiency; TEEN.

1.INTRODUCTION

Wireless sensor networks, composed of a huge number of cheap sensor nodes, are widely used in various fields such as environmental monitoring, traffic monitoring, disaster salvage, target tracking, security monitoring, industrial control and monitoring, home automation and defense [1, 2]. Sensor nodes which integrate sensing, computing and communicating functions can communicate with each other via wireless radio. As the transmission range of sensor node is short, wireless sensor networks are multi-hop networks. Sensor nodes act as both data generator and data router. Wireless sensor nodes are power-constrained devices, long-distance transmissions should be kept to minimum in order to prolong the network lifetime [3, 4]. Thus, direct communications between nodes and the Base Station (BS) are not encouraged. Furthermore, clustering is an effective method to reduce energy consumption of sensor nodes in large wireless sensor networks. Thus sensor nodes are grouped into clusters in which one of the nodes is designated as cluster head [5]. A cluster head collects data from other wireless sensor nodes in its cluster, directly or in a multi-hop manner. Typically, data collected from nodes of the same cluster are highly correlated. Data can be fused during the data aggregation process thus reducing the consumption of energy. The fused data will be then transmitted to the base station. This hierarchical network is organized in layers: the lower layer consists of sensor nodes in each cluster for intra-cluster communication, and the upper layer consists of Cluster Heads (CH) for inter-cluster communication [6]. An effective approach to improve efficiency is to arrange the network into several clusters, with each cluster electing one node as its cluster head. The rest of the paper is organized as follows: section II presents the problems encountered in the routing protocols when the network is scaled up. In section III, the routing hierarchical protocol LEACH is discussed. In section IV, we introduce the routing protocol TEEN which is the basis of our proposal. The first improvement of protocol TEEN (WB-TEEN) is described in section V. In section VI, a second improvement of TEEN (WBM-TEEN) is presented. discusses the simulation results and analysis, and finally we present our conclusion in section VIII.

2. PROBLEM STATEMENT

When studying the routing problem in WSN, a lot of constraints must be taken into account. Indeed, as the number of deployed nodes increases, the problem becomes more complex. The basic routing protocols (in which all nodes are considered homogeneous and communicate directly among themselves without any other intermediary) operate in a satisfactory manner when the density of the network is small but when this density increases (thousands of nodes), these protocols lack efficiency. In order to increase network scalability, the hierarchical topologies were introduced. The WSN is then partitioned into subsets of nodes facilitating the management of the network and ensuring a better energy resource management [7]. Therefore the basic routing protocols do not support the network scalability attribute. A solution to this problem is to adopt the hierarchical routing and the clustering organization. A hierarchical network is based on the concept of standard-node/master-node where the standard nodes deliver their messages to their master which then delivers them to the base station (sink). The hierarchical topologies were introduced for the purpose of distributing the nodes on several levels of responsibility. The task of routing is entrusted to certain nodes called 'master nodes' or Cluster-Heads (CH). The CHs can be special nodes, with powerful resources or similar to the simple standard nodes, periodically elected depending on their residual energy level [8]. In the hierarchical topologies, during the packets routing, an aggregation of the data may be carried out by the CH. This will reduce the number of messages circulating in the network, thus implying a reduction in energy consumption [9, 10]. Hierarchical routing protocols have then been designed to ensure efficient use of energy by reducing the number of messages sent to the sink. They are classified according to the following two approaches: chain-based approach and cluster-based approach. However, the energy consumption of sensor nodes is asymmetric. Cluster heads consume more energy than the other nodes due to their roles that are receiving data from cluster members, aggregate data and sending it to the base station. The energy consumption of cluster heads is affected by the number of cluster members and the distance from the base station. In order to optimize the energy consumption of cluster heads, we must equilibrate cluster members among clusters.

3. ROUTING PROTOCOL LEACH

LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the most popular hierarchical protocols [11]. This protocol adopts the Time-driven model and uses a distributed clustering (the formation of clusters and the election of the cluster-Heads are realized at the node level). LEACH assumes that the nodes are homogeneous and the routing of packets to the base station is done in a single hop via the cluster-heads as shown in Figure 1

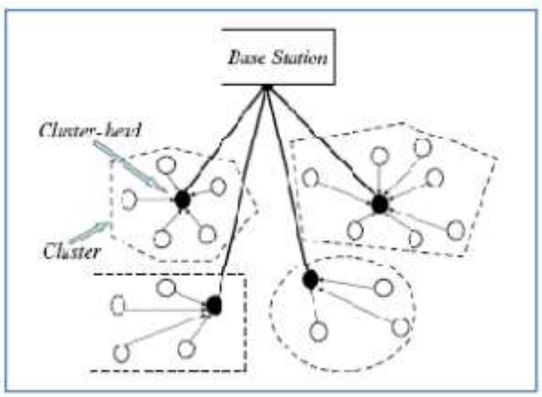

Figure 1. Communication Architecture of protocol LEACH

The nodes have the possibility to become cluster-Head on the basis of election probabilities. By using Time Division Multiple Access (TDMA) (protocol allowing to access the communication medium), protocol LEACH is intended for time-driven applications. So, in this type of application, data are propagated in a periodic way. However, this kind of protocol is unsuitable for event-driven applications where a reactive behavior is necessary for the proper functioning of the system. TEEN (Threshold sensitive Energy Efficient sensor Network protocol) [12] is a routing protocol developed for modeling LEACH in order to meet the requirements of event-driven applications.

IV. ROUTING PROTOCOL TEEN Manjeshwar and Agrawal [12] have proposed a technique of clustering called TEEN for critical applications where the change of certain parameters may be sudden. The architecture of the network is based on a hierarchical grouping at several levels (Fig. 2) where the closest nodes (to each others) form clusters. Then the process of clustering goes to the second level until the base station is reached

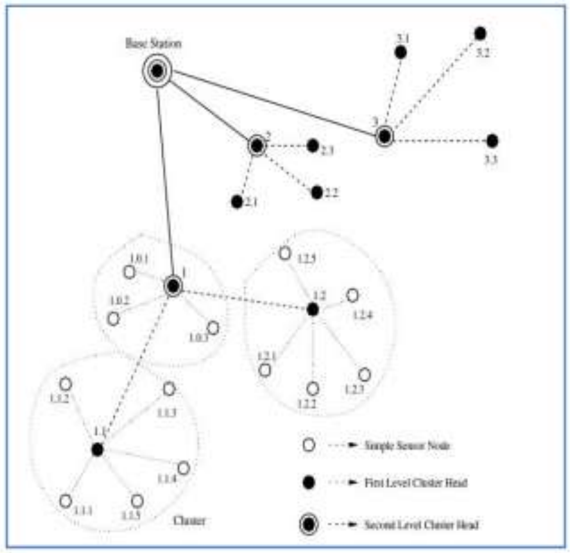

Figure 2. Hierarchical Clustering TEEN

After the formation of clusters, each cluster-head transmits, to its members, two thresholds: HT (Hard Threshold), which is the threshold value of the monitored parameter and a Soft Threshold ST representing a small change in the value of the monitored parameter. The node, that detects the occurrence of this small variation ST, transmits an alert message to the base station indicating this change. Therefore, the soft threshold will reduce the number of transmissions since it does not allow the transmission if there is little or no change in the value of the monitored control parameter [12]. At the beginning, the nodes listen to the medium continuously and when the value captured from the monitored parameter exceeds the hard threshold, the node transmits the information. The value captured is stored in an internal variable called SV. Then, nodes have no longer to transmit data unless the current value of the controlled parameter becomes greater than the hard threshold or differs from the SV value by a quantity greater or equal to the Soft threshold value. Since the transmission of a message consumes more energy than data sensing, energy consumption by TEEN protocol is then less important than in proactive routing protocols or protocols that transmit data periodically such as LEACH [11]. However, the main disadvantage of this protocol is that if the thresholds HT and ST are not received, then the nodes never communicate, and no data will be transmitted to the end users; therefore, the base station would be unable to know the nodes that have exhausted their energy.

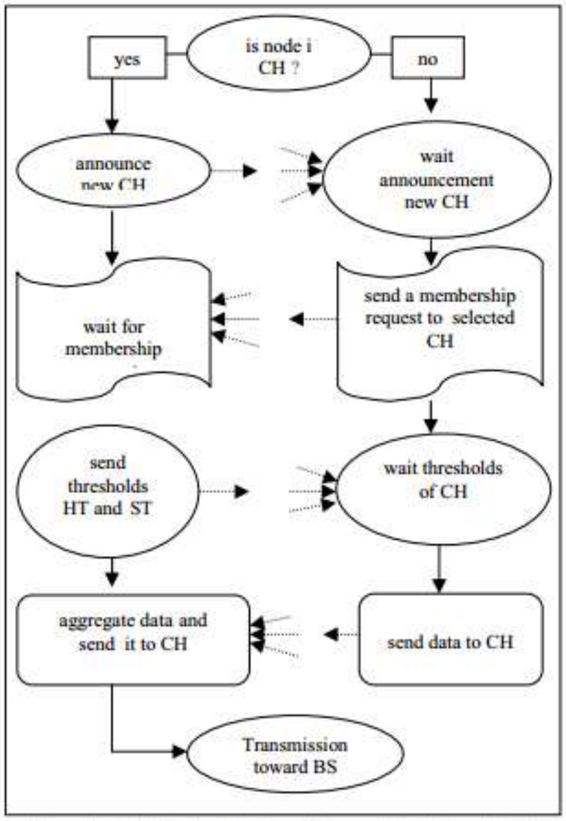

Figure 3. Initialization, Search and Transmission Stages in TEEN

4.Algorithm of TEEN protocol

The algorithm works in rounds. Each round is made up of an initialization phase, a search phase and a transmission phase as shown in Fig. 3. The initialization phase is composed of two sub phases: an announcement phase and groups organization phase. B. Simulation The following parameters and the corresponding value are used for the simulation purpose:

TABLE I. SIMULATION PARAMETERS

Parameters	Values
Surface of deployment	(0 ,0) ×(100,100)
Position of the base station	(50,175)
Number of seasors	100
Initial energy of a sensor	2 Joules
Period duration (round)	20s
Duration of simulation	3600
Number of clusters	5
Size of control package	8 Bytes
Size of packets	512 Bytes

1) **Energy consumed**:
Fig. 4, shows that protocol TEEN consumes less energy than the protocol LEACH: The reason is that in the reactive TEEN protocol, soft threshold reduces the number of transmissions in contrast with the proactive protocol LEACH where data are transmitted.

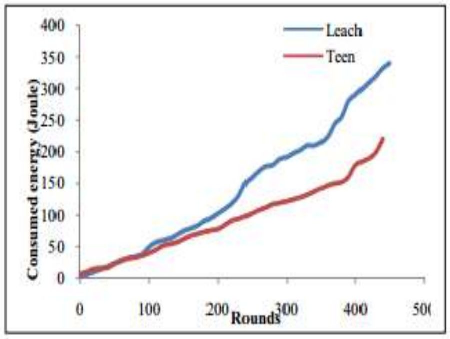

Fig 4:Energy Consumption Between LEACH And TEEN

2) **Duration of network life**:
Fig. 5 represents the number of nodes alive as a function of simulation time. In the protocol LEACH, at the moment t=460, all nodes are dead but this happens at later time (t=560) in protocol TEEN.

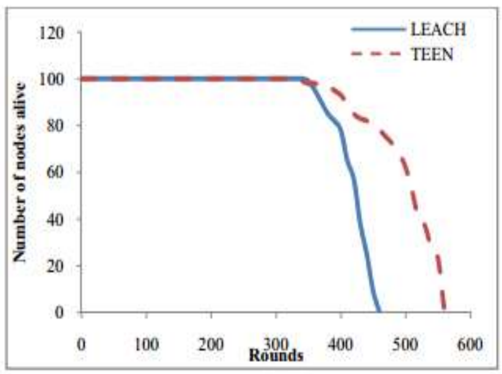

Fig 5:Number Of Nodes Alive In LEACH And TEEN

In LEACH protocol, nodes that are far away from the base station die quickly contrary to the closest ones because of the use of single hop communication. Unlike TEEN that uses the HT and ST thresholds, as well as the use of a multihop communication toward the base station reduces the energy consumption. Therefore maximizing the battery lifetime which implies a longer lifetime of the network.

5. PROPOSED IMPROVEMENTS TO TEEN PROTOCOL

A. Problem Statement

Among the disadvantages of TEEN protocol, we have studied, appears the problem of groups disparity. The random selection of Cluster-Heads in TEEN allows nodes to be self-organized into clusters without spending a lot of energy. However, this does not guarantee to obtain clusters with similar number of member nodes; which causes great energy dissipation. To remedy this inconvenience, we propose the protocol WB-TEEN (Well Balanced TEEN): an improvement of protocol TEEN which enables clusters balancing (avoiding clusters formation with a significant difference in sizes). B. WB-TEEN Protocol The main objective of our proposal is the minimization of energy consumed obtained from the balancing process of clusters (All clusters have almost the same number of member nodes). After being elected CH, a node must inform the other nodes non-CH of its new rank. For this, a warning message ADV, containing the identifier of the CH, is broadcasted to all nodes non-CH. This broadcast is sent in order to ensure that all non-CH nodes have been informed. Each node has to inform its CH of its desire of belonging to the cluster, and sends it a JOIN_REQ message. The CH with the strongest signal (the closest to CH) will be chosen. In case of equal signals, the node randomly chooses their CH. The cluster head calculates its degree, defined by: Degree NN - CHnbr CHnbr + 1 Where CHnbr is a number of cluster heads and NN is a Total number of nodes in the network.

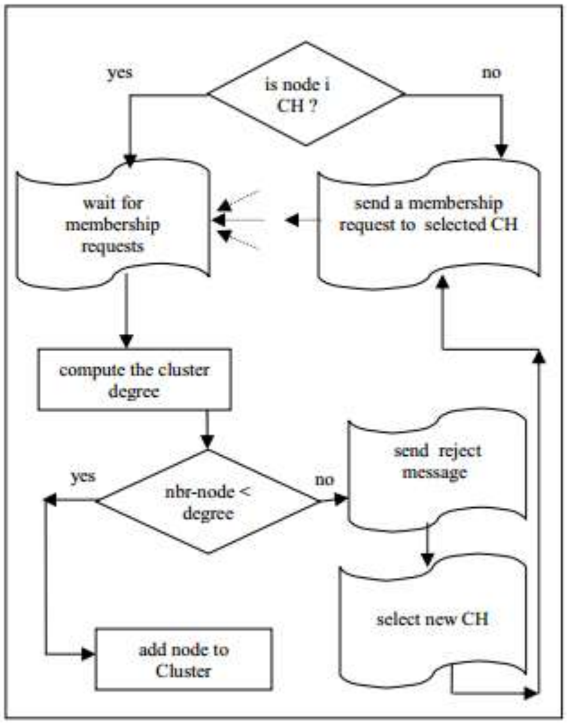

Figure 6. Clustering Stages in WB-TEEN

On the reception of the JOIN_REQ message, if the number of nodes has not reached the degree of the CH, then the node is added to this cluster. Otherwise, the CH rejects the membership request, and invokes the Negative_CH procedure. This procedure, sends a negative message to the node informing it that its request has been rejected. The concerned node then chooses another CH from its list (the following CH) and sends another JOIN_REQ. After the formation of clusters, each CH sends out the two thresholds HT and ST to its members. A. Simulation Results 1) Energy consumption: WB-TEEN protocol consumes less energy than TEEN protocol (Fig.7), since in the protocol TEEN it is possible to have some CHs managing clusters with significant number of nodes, while at the same time, there exists some other CHs managing clusters with only a few nodes, contrary to the protocol WB-TEEN where all clusters have almost the same number of nodes. This load balancing has been achieved by changing the clusters formation rules

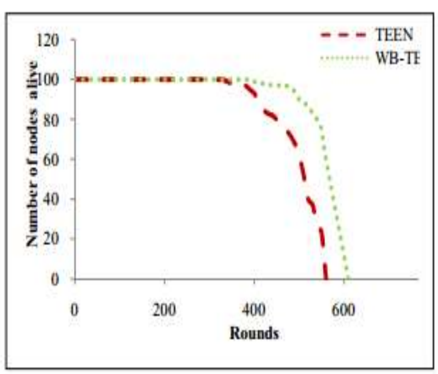

Figure 7. Number of nodes Alive in TEEN and WB-TEEN

Network lifetime: Figure 7 represents the number of nodes alive during the simulation. We note that the protocol WB-TEEN extended significantly the network lifetime compared to TEEN. This improvement is accomplished because the nodes remain alive due to clusters load balancing which prevents the situation where the CHs can be concentrated in a part of the network. Consequently, an energy consumption balancing of the CHs leads to the increase of the network lifetime. This is very important because it contributes to the success of the network mission. In the protocol WB-TEEN, the number of nodes alive at time t=500 is 70 while in the protocol TEEN the number of nodes alive at that time is zero. This result is also important because it allows the network consolidation connectivity and therefore increases its lifetime duration.

6. WB-TEEN WITH MULTI-HOP INTRA-CLUSTER : WBM-TEEN

According to the study we conducted about the protocol TEEN and the proposal protocol WB-TEEN, we conclude that the nodes located further away from the CH die more quickly than the nodes which are closer to the CH. To improve and regulate the energy consumption of distant nodes, we propose to make nodes communicate with their immediate neighbors and not directly with the CH since single hop communication is more costly in terms of energy than multi-hops nodes communication. Our improvement for WB-TEEN protocol is called WBM-TEEN (Well Balanced TEEN with Multi-hop intra cluster communication), which refers to the fact that all nodes in the cluster, communicate with their closest neighbors to send out or receive data. This enables each node to consume little energy amount to reach the CH. The latter transmits all data received from its cluster to another CH on a higher level until the base station is reached. A. Energy consumption Figure 9 shows the energy consumed as a function of simulation time; as illustrated, the protocol WBM-TEEN consumes less energy than WB-TEEN protocol. This improved result is obtained due to the use of multi-hop routing within the clusters instead of a routing with only single hop as in WB-TEEN. This increases the reliability of the protocol by the ability to find an alternate path in case of failure of the used path. In addition, our new proposal WBM-TEEN performs data aggregation at the level of a CH, which reduces the energy consumption. B. Network life time As illustrated in Figure 10, the batteries of the nodes in the protocol WBM-TEEN last longer (100 nodes alive at time t=500) than that of WB-TEN (70 nodes alive at a similar time t=500). In effect, the protocol WBM-TEEN allows a higher rate of energy conservation, since it uses a multi-hop intra-clusters communication.

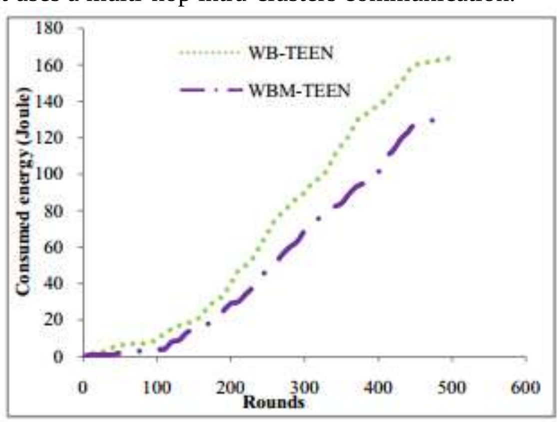

Figure 9. Energy consumption in WB-TEEN and WBM-TEEN

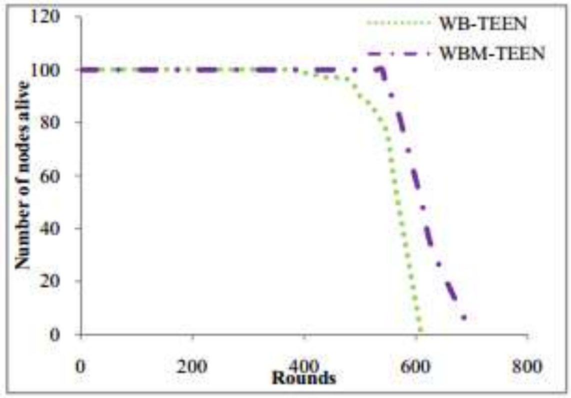

Figure 10. Number of nodes alive in WB-TEEN and WBM-TEEN

7. COMPARISON OF THE PROTOCOLS

B. Energy Consumption

Figure 11 shows a comparison of energy consumption between the 3 protocols. The energy is consumed based on the operations performed such as capture operation, data processing and data communication. For this reason, we tried to optimize the data processing for the protocols, WB-TEEN, WBM-TEEN compared to LEACH. In addition, we have also performed a comparison of energy consumption between the simple nodes, and between the CH and the BS.

C.Network lifetime

Figure 12 shows a comparison of the number of nodes alive between the 3 protocols depending on the time of simulation. Each sensor node must effectively manage its energy in order to keep the wireless sensor network at a consistent operational state. The WSN lifetime is closely linked to the energy use of sensor nodes.

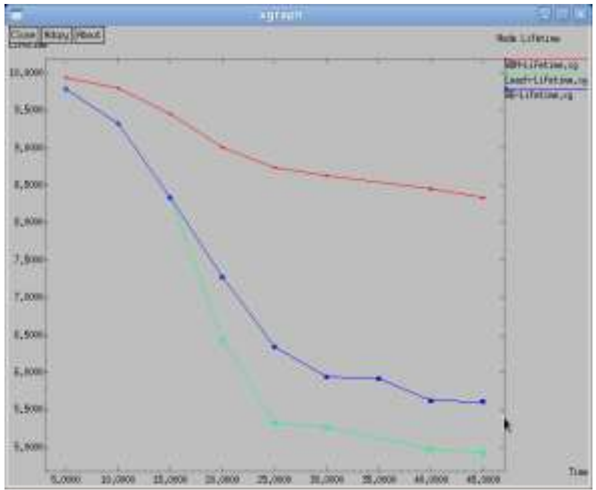

Figure 12. Number of Nodes alive in Various Protocols

8. CONCLUSION

The interest in wireless sensor networks is constantly increasing. Due to their promising development, the applications of WSN tend to invade all areas. However, to make a real change in network domain, WSN have to overcome difficulties which hamper their maturity. Among these obstacles, the energy problem is the most important one. In the meantime of new technology offering us batteries with long duration and auto-rechargeable, providing an abundant and recurrent energy, for now researchers have only to design protocols that optimize the use of that valuable energy resource. In this paper, we are interested in the problem of saving the energy of sensor nodes for different routing protocols, because communication of messages is the most energy consumer activity in WSN. After having studied two well known protocols (LEACH and TEEN) we devised two variants protocols: WB-TEEN and WBM-TEEN which are managing energy more efficiently than their original protocols while keeping their basic principles. The performance of our proposals showed, via simulation (NS2) results, is very convincing since the energy consumption optimization extends the WSN lifetime by more than 40 %

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