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Modified LEACH for Necropolis Scenario

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***Abstract* – A modified version of LEACH routing protocol has been implemented and simulated in Castalia simulator to verify if it was good to manage a WSN dedicated for necropolis. Simulation results seem to show the valence of our idea.**

I. INTRODUCTION

A Wireless sensor network (WSN) consists in a collection of a big numbers of sensor nodes, up to some thousands, spatially distributed in an environment able to monitor physical quantities and able to communicate wireless among each other and to a sink node [1-3]. Then this last deal with making the data available outwardly as Fig. 1 shows.

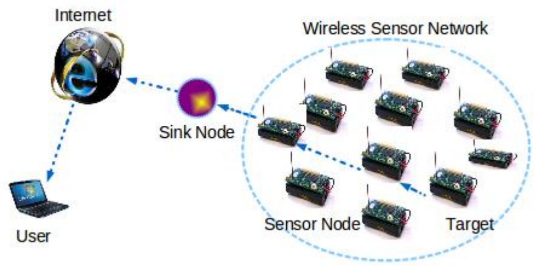

Fig. 1. Typical architecture of a WSN.

The elective application fields for WSN are surveillance [4,5] and monitoring of environmental parameters [6] in many different scenarios as agriculture [7,8], medicine [9], human health [10], aerospace [11,12] but they are also used in military domain [13] or in factories for the check of the machinery health [14-16]. An emerging application field is the surveillance or monitoring of some parameters, typically mechanical quantities, in cultural heritage sites [17-21].

For WSNs, the transmission reliability is fundamental. In fact, when a node sends a packet to the sink node, it may lose the packet during the routing process due to environmental effects, interference between nodes, instable link or other reasons. Therefore, a robust routing algorithm to ensure correctness of data transmission is vital to the WSNs.

In this paper, we propose a modified version of the Low Energy Adaptive Clustering Hierarchy routing algorithm as possible routing protocol for particular archeological site as the necropolis. Simulation results seem show the validity of our strategy.

II. SCENARIO

Considering all possible variables that can be taken into account when designing a wireless network as reliability or the energy efficiency, it does not exist the "perfect" WSN, but it is possible to find the best solution for the scenario under study. Therefore, the description of the operative scenario is fundamental [22,23]. In our case, we considered a necropolis that is a wide archeological site where are distributed high cultural interest tombs, as, e.g., the Etruscan Necropolises of Cerveteri and Tarquinia [24]. As Fig. 2 shows a typical tomb is a low building partially inserted in the earth and partially out, sometimes monumental, cut in rock and topped by impressive tumuli (burial mounds).

Fig. 2. Typical group of tombs that can be encountered in an Etruscan Necropolis (left side). In the top right side, sculptures placed inside a tomb while, the picture in the bottom right side shows a wall painting inside a tomb.

Many of them are extremely impressive and artistically important for the carvings placed inside them or for the wall paintings of outstanding quality.

The necropolis contains thousands of tombs organized in a city-like plan, with streets, small squares and neighborhoods. The site contains many different types of tombs: trenches cut in rock; tumuli; and some, also carved in rock, in the shape of huts or houses with a wealth of structural details. These provide the only surviving evidence of Etruscan residential architecture. The necropolis are famous for the 200 painted tombs, the earliest of which date from the 7th century BC. These two large Etruscan cemeteries reflect different types of burial practices from the 9^{th} to the 1^{st} century BC, and bear witness to the achievements of Etruscan culture. Which over nine centuries developed the earliest urban civilization in the northern Mediterranean.

From a WSN topology point of view, a scenario like this can be optimally represented as that shown in Fig. 3 where the sensors inside a tomb form a cluster that can communicate to the outside using a cluster head. The cluster head collects the information coming from the local "tomb" sensor network and sends the data to the outside.

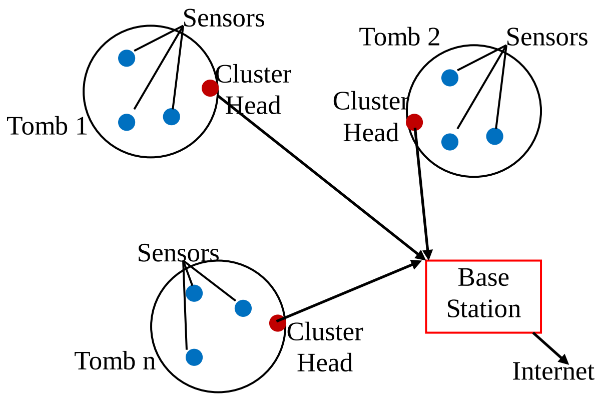

Fig. 3. Typical architecture of a WSN for a necropolis scenario.

III. LEACH ROUTING PROTOCOL

Low Energy Adaptive Clustering Hierarchy (LEACH) [1] is a hierarchical clustering algorithm for WSN. It is a cluster protocol, which includes distributed cluster formation. For each cluster, this protocol selects randomly a sensor node that assumes the role of cluster-head (CHs). In order to evenly distribute the energy load among the sensors, in the network this role is rotated. The CHs have the task to receive and aggregate data coming from the cluster nodes and send a packet to the base station (BS). This allows to compress the total amount of information that must be transmitted to the base station. A TDMA/CDMA MAC is usually used to reduce the possible collisions inside the cluster or between different clusters. In the LEACH, the data collection is centralized and is performed periodically or asynchronously. This makes the protocol particularly appropriate when a constant monitoring is needed as in our case where the monitoring of the environmental parameters requests scheduled measurements.

The typical structure of the LEACH routing topology, is shown in Fig. 4.

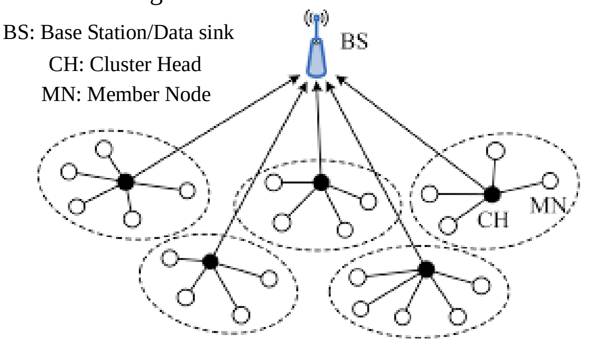

Fig. 4. Typical architecture of a WSN managed by a LEACH routing protocol.

In order to set the WSN, for each round, LEACH protocol first performs a setup phase and then a steady state phase. In the first phase, the clusters are organized and the CHs are selected while in the steady state phase, the data transfer to the sink and to the BS is realized. During the setup phase, a predetermined fraction of nodes, p, elect themselves as CHs. Each elected CH broadcasts a message to the other nodes signaling that they are the new CHs. After receiving this advertisement, the other nodes decide on which cluster they want to belong to and this decision is made on the signal strength of the advertisement. The non cluster-head nodes inform the appropriate CHs that they are a member of the cluster. Fixed the cluster, the CH node establishes a TDMA schedule assigning a time slot to each node that allow him to transmit. Then the schedule is sent with a broadcast to the other nodes of the cluster.

In the steady state phase, the sensor nodes monitor the parameters and transmit data to the CHs. This node, aggregates data and send them to the BS. After a priori fixed time, the network launches a new setup phase to select the new CH. In order to reduce interference from nodes belonging to other clusters, each cluster to communicate uses different CDMA codes.

The strength of a LEACH is the high network lifetime, but, cause its protocol, it usually presents some problems. In fact, LEACH assumes that all nodes can transmit with enough power to reach the BS if needed and that each node has computational power to support different MAC protocols. Therefore, it is not advisable their use to networks deployed in large regions. Secondly, it is not clear how the number of the predetermined CHs is uniformly distributed in the network. Therefore, there is the possibility that the elected CHs will be concentrated in one part of the network. This implies that some nodes will not have any CHs in their vicinity. Furthermore, the dynamic clustering brings extra overhead caused by head changes, advertisements etc., which surely drain the limited energy. At the end, the protocol assumes that all nodes start with the same amount of energy in each round, assuming that a CH consumes the same amount of energy.

Fig. 4 clearly shows as the LEACH routing topology is very similar to the physical topology of our operative scenario (see Fig. 3), suggesting it as a possible candidate to implement a WSN for our scenario, but the drawbacks previously listed introduce severe limitations to its possible use.

IV. CASTALIA SIMULATOR

Castalia is a simulator for WSN, Body Area Networks (BAN) and networks of low-power embedded devices. There are many WSN simulator but Castalia has the great advantage to be open source so researchers may also implement their own algorithms and validate them [25].

In order to overcame the previously drawbacks we simulated the network in Castalia that allows us to modify the LEACH routing protocol. We decided to set the probability that a sensor can became a CH through the management of two parameters the RSSI (received signal strength indicator) and the battery residual energy (BRE). The RSSI concerns to the facility of a node to receive the broadcast signal w.r.t. the other nodes of the same cluster while, the residual energy in the battery concerns the ability of the node to preserve its lifetime. The product between them is necessary because, if we considered only the RSSI, the probability that the node with the highest RSSI is chosen as CH is extremely high strongly reducing the possibility for the other. This would lead a strong reduction of the lifetime of that node. Condition undesirable because would limit the quantity of useful information. Instead, considering the product between RSSI and BRE as variable to set the CH, the probability of selection is more equilibrated. In the case the batteries of the nodes have the same level of energy stored, the highest RSSI of a node highs the probability for that node to be chosen as CH.

This change still allows respecting the existence of the two phases of the LEACH (setup and steady state), but the condition of election of the CHs nodes is no longer just casual, but it is function of the product between RSSI and BRE of the nodes.

V. TEST AND RESULTS

The simulations have been conducted using Castalia. In the first simulation, we tested what can happen comparing the possible configuration: the LEACH routing protocol and its modified version. For the classical LEACH, we assumed that each node can send data to the BS and therefore each node, for each round, has the same probability to become a CH during the setup phase. At the beginning, we consider the energy capacity similar for all nodes. The problem is that, depending on the position inside the tomb, the signal pass through a different number of tufaceous walls thus, for each physical route, we have a different attenuation. Obviously, the signal emitted by the devices placed near the roof or in a position with only one wall to pass through, will be less attenuated w.r.t the other. For these latest, the request of energy for the transmission will be more elevated. In the simulations, we considered two devices that has an additional attenuation of 3 dB and two nodes with an additional attenuation of 6 dB w.r.t the better-placed node. The request of energy for the transmission is one time and half for the node with attenuation 3 dB and two times and half for the nodes with attenuation 6 dB w.r.t the only better placed. These values coming from the analyses of the curves Current Absorption [mA] / RF Power [dB] findable in the datasheets of the transceivers.

For the modified version of the LEACH we triplicated the available energy both for the best-placed node and for one of the nodes that has an attenuation of 3 dB.

The test evaluates the behavior of the clusters studying the lifetime of the nodes and so how many packets sent by the nodes arrive to the BS during the time. The time has been divided in epochs each one equal to a period of one month. The transmission of sensible data happened each time that a measurement is executed by the cluster therefore, the data are not memorized or packed. The number of the clusters is ten and are composed of five nodes each. The starting energy present in the system is the same for all configurations, but the distribution between the nodes is different. For the classical LEACH, all nodes have equal quantity of energy; in the modified version, two nodes have the 33,5% each of energy, while the other three have 11% each of energy. We simulated the network for 20 epochs statistically verifying when the power consumption of the node is so low to prevent the data transmission. The transmission mechanism acts in such a way that we consider equal to one the energy necessary to transmit the information within the cluster and ten times more the energy requests from the CH to send the information toward the BS for the best placed node. For the other, the request of energy is 1,5 times for the node with attenuation 3 dB and 2,5 times for those that have attenuation of 6 dB. For the classical version of the LEACH, all the nodes are possible CHs having the same probability to be elected, but having the same starting energy, an asymmetrical consumption of energy is produced. This leads to a reduction of the time life of the more disadvantage sensors w.r.t. those better placed thus reducing the information that could arrive to the BS. On the contrary, the modified version of the LEACH optimizes the power consumption allowing a more equilibrated power consumes and so obtaining a better managing of the overall energy of the cluster. This is shown in Fig. 5, where the graph shows the overall energy consumptions *vs* epochs for the two routing protocols. It is clear that, even if the power consumption trend is similar for both the protocols, the overall power consumptions of the LEACH is overall higher than the modified version.

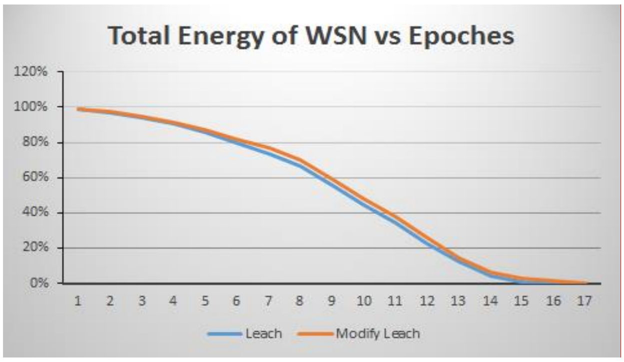

Fig. 5. Total energy of the WSN during the time.

This is reflected in the transmitted information. In fact, the graph of Fig. 6 shows the mortality trend of nodes that, for the LEACH, grows rapidly starting from the 11th epoch while the modified version maintains a good rate of data transmitted for a longer period.

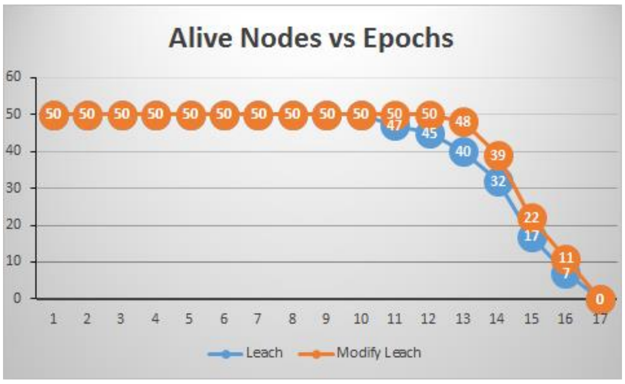

Fig. 5. Mortality trend for the nodes during the time for the two routing protocols.

VI. CONCLUSIONS

Within of the general framework of the Wireless Sensor Network, routing protocols is a topic of great interest because the reliability of the transmission is strongly dependent by them. This is even more true because does not exist an *a priori* best WSN for each kind of scenario. Instead, the designing of a tailored routing protocol obtained by suitable modifying a known protocol, adjusting their characteristics to a specific scenario could increase the overall performance of the network making it good for that operative scenario.

In this paper, we modified the well-known LEACH protocol to make it suitable to manage a WSN for a necropolis obtaining good results by the simulations.

AKNOLEDGMENTS

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