A COMPARATIVE STUDY OF ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

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ABSTRACT

The efficiency of sensor networks strongly depends on the routing protocol used. Most of routing protocols might differ depending on the application, mode of functioning and network architecture. Overall, the routing techniques are classified into three categories based on the underlying network structure: flat, hierarchical, and location-based routing. In this paper, we analyze three different types of hierarchical routing protocols: LEACH, TEEN, and PEGASIS. Furthermore, the paper investigates the power consumption for all protocols. Simulation results show that PEGASIS reduces overall energy consumption and improves network lifetime over its comparatives.

Keyword : sensor routing, performance comparison, LEACH, TEEN.

دراسة مقارنة ل(routing protocol s) في شبكات المتحسس اللاسلكي

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الخلاصة:

تعتمد كفاءة شبكات المحسس بقوة على routing protocol المستخدم واغلب routing protocol تختلف بالاعتماد على التطبيق ونمط العمل ومعمارية الشبكة ، عموما routing protocol تصنف الى ثلاثة اصناف اعتمادا على تركيب الشبكة التحتي flat, hierarchical, and location-based routing في هذا البحث نحلل ثلاثة انواع مختلفة routing protocol كالاتي LEACH, TEEN, and PEGASIS علاوة على ذلك تم التحقق من استهلاك الكهربائي لكل protocol ومن نتائج المحاكاة تبين routing protocol اقل استهلاك للطاقة ويحسن من عمر الشبكة بالمقابل مع قريناتها

INTRODUCTION

A wireless sensor network consists of light-weight, low power, small size of sensor nodes. The areas of applications of sensor networks vary from military, civil, healthcare, and environmental to commercial. Example applications include forest fire detection, inventory control, energy management, surveillance and reconnaissance, and so on. Due to the low-cost of these nodes, the deployment can be in order of magnitude of thousands to million nodes. The nodes can be deployed either in random fashion or a pre-engineered way. The sensor nodes perform desired measurements, process the measured data and transmit it to a base station. The base station collects data from all the nodes, and analyzes this data to draw conclusions about the activity in the area of interest. Base stations also can act as gateways to other networks, a powerful data processor or access points for human interface. They are often used to disseminate control information or to extract data from the network [1].

Figure 1 shows the schematic diagram of sensor node components in which sensor nodes are shown as small circles. Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional like the mobilizer). The same figure shows the communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed.

Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s). A base-station may be a fixed node or a mobile node capable of connecting the sensor network to an existing communications infrastructure or to the Internet where a user can have access to the reported data [3].

Almost all of the routing protocols can be classified into two main categories; based on network structure or based on the protocol operation. Depending on the network structure, different routing schemes fall into this category. A sensor network can be non hierarchical or flat in the sense that every sensor has the same role and functionality. Therefore the connections between the nodes are set in short distance to establish the radio communication. Alternatively, a sensor network can be hierarchical or cluster-based hierarchical model, where the network is divided into clusters comprising of number of nodes. Cluster head, which is master node, within each respective cluster is responsible for routing the information to other cluster head. Another class of routing protocols is based on the location information of the sensor nodes either estimated on the basis of incoming signal strengths or obtained by small low-power GPS receivers or even by combination of the two previous methods. Location-based protocols use this information to reduce the latency and energy consumption of the sensor network.

RELATED WORK

Hierarchical routing performs energy-efficient routing in WSNs, and contributes to overall system scalability and lifetime. In a hierarchical architecture, sensors organize themselves into clusters and each cluster has a cluster head, i.e. sensor nodes form clusters where the low energy nodes are used to perform the sensing in the proximity of the phenomenon. The less energy constrained nodes play the role of cluster-heads and process, aggregate and forward the information to a potential layer of clusters among themselves toward the base station. In this section, we introduce three cluster based scheduling mechanisms

LEACH Protocol

Low energy adaptive clustering hierarchy (LEACH [4]) is a clustering – based protocol that utilizes randomized rotation of the cluster – heads (CH) to evenly distribute the energy load among the sensor nodes in the sensor network. It assumes that the base station is fixed and located far from the sensors and all nodes in the network are homogenous and energy – constrained. The main energy saving of LEACH protocols comes from the combination of data compression and routing. In LEACH the operation is divided into rounds, during each round a different set of nodes are cluster-heads (CH). Nodes that have been cluster heads cannot become cluster heads again for P rounds. Thereafter, each node has a 1/p probability of becoming a cluster head in each round. At the end of each round, each node that is not a cluster head selects the closest cluster head and joins that cluster to transmit data. The clusters heads aggregate and compress the data and forward it to the base station, thus it extends the lifetime of major nodes. In this algorithm, the energy consumption will distribute almost uniformly among all nodes and the non-head nodes are turning off as much as possible. LEACH assumes that all nodes are in wireless transmission range of the base station which is not the case in many sensor deployments. In each round, LEACH has cluster heads comprising 5% of total nodes. It uses Time Division Multiple Access (TDMA) as a scheduling mechanism which makes it prone to long delays when applied to large sensor networks. **Figure 2** shows the communications in LEACH protocol [2,3].

TEEN Protocol

Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [6] is a hierarchical protocol designed to be responsive to sudden changes in the sensed attributes such as temperature. Responsiveness is important for time-critical applications. TEEN pursues a hierarchical approach along with the use of a data-centric mechanism. The sensor network architecture is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until base station is reached. The model is depicted in **Figure 3**. After the clusters are formed, the cluster head broadcasts two thresholds to the nodes. These are hard and soft thresholds for sensed attributes. Hard threshold is the minimum possible value of an attribute to trigger a sensor node to switch on its transmitter and transmit to the cluster head. Thus, the hard threshold allows the nodes to transmit only when the sensed attribute is in the range of interest, thus reducing the number of transmissions significantly. Once a node senses a value at or beyond the hard threshold, it transmits data only when the value of that attribute changes by an amount equal to or greater than the soft threshold. As a consequence, soft threshold will further reduce the number of transmissions if there is little or no change in the value of sensed attribute. One can adjust both hard and soft threshold values in order to control the number of packet transmissions. However, TEEN is not good for applications where periodic reports are needed since the user may not get any data at all if the thresholds are not reached.

PEGASIS protocol

An enhancement over LEACH protocol was proposed in [7]. The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS). The protocol is a near optimal chain-based protocol for extending the lifetime of network. In PEGASIS, each node communicates only with the closest neighbor by adjusting its power signal to be only heard by this closest neighbor. Each Nodes uses signal strength to measure the distance to neighborhood nodes in order to locate the closest nodes. After chain Formation PEGASIS elects a leader from the chain in terms of residual energy every round to be the one who collects data from the neighbors to be transmitted to the base station. As a result, the average energy spent by each node per round is reduced. Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the Base station instead of multiple nodes. This approach reduces the overhead and lowers the bandwidth requirements from the BS. **Figure 4** shows that only one cluster head leader node forward the data to the BS.

Table 1 shows a comparison between LEACH, TEEN , and PEGASIS routing protocols according to their design characteristics [8].

SIMULATION

In this section we present the simulation results of LEACH, TEEN, and PEGASIS followed by a comparison among the different techniques.

Simulation environment and parameters

To evaluate the performance of the hierarchal routing protocols, we simulated our protocols performance using NS-2 simulator [9] and compared the performance of LEACH, TEEN, and PEGASIS protocols on the basis of energy dissipation and the longevity of the network. The simulation consists of 100 homogeneous nodes and a fixed base station with initial energy of 2 Joule, scattered randomly within a 100x100 units sensor field. Deployed nodes have fixed positions during the entire simulation.

SIMULATION RESULTS AND DISCUSSION

In the first t, we simulate 50 different 100 m x 100 m network topologies with the base station located at least 75 m away from the nearest node. **Figure 5** shows the average energy dissipation of the protocols under study over the number of rounds of operation. This plot clearly shows that PEGASIS has a much more desirable energy expenditure curve than those of LEACH, TEEN, and PEGASIS. On average PEGASIS exhibits a reduction in energy consumption of 40 and 30 percent over LEACH and TEEN, respectively. This is because all the cluster heads in both LEACH and TEEN transmit data directly to the distant base station, which in turn causes significant energy losses in the cluster head nodes. The improvement gained through PEGASIS is further exemplified by the system lifetime graph in **Figure 6**. This plot shows the number of nodes that remain alive over the number of activity for the 100 m x 100 m network scenario. With PEGASIS, all the nodes remain alive for 400 sec, while the corresponding numbers for LEACH, TEEN, and PEGASIS are 10, 40, and 100, respectively.

We conclude that PEGASIS achieves approximately 2x the number of life time compared to LEACH. It approximately achieves 1.2x the number of life time compared to TEEN. TEEN approximately performs 1.6x the number of rounds compared to LEACH. **Figure 7** shows the network lifetime.

CONCLUSIONS

In this paper we presented a simulation model for LEACH,EEN , and PEGASIS hierarchical routing protocols. The simulation results show that PEGASIS can greatly prolong sensor network's lifetime when the transmission range is limited. TEEN protocol is well suited for time critical applications and is also quite efficient in terms of energy consumption and response time. It also allows the user to control the energy consumption and accuracy to suit the application.

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Table1. Classification and Comparison of routing protocols in WSNs [8]

Protocols	mobility	Power Requirement	Data aggregation	Location awareness	State complexity	Computation &communication overhead
LEACH	Fixed BS	High power requirement for BS	yes	No	Cluster heads maintains it	Setting up and maintaining cluster
PEGASIS	Fixed BS	High power requirement for BS	yes	No	Very simple	Same as LEACH plus chain setup
TEEN	Fixed BS	High power requirement for BS	yes	No	Very simple	Same as LEACH

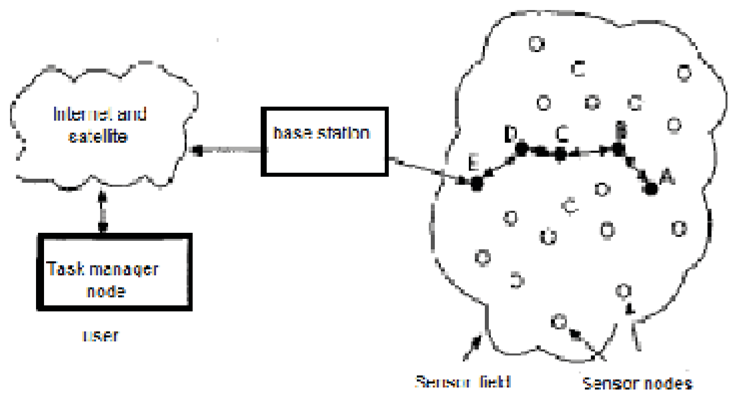

Figure 1. Structural view of sensor network [2]

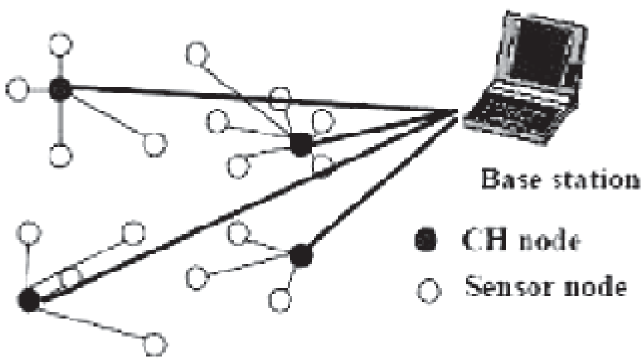

Figure 2. LEACH [5]

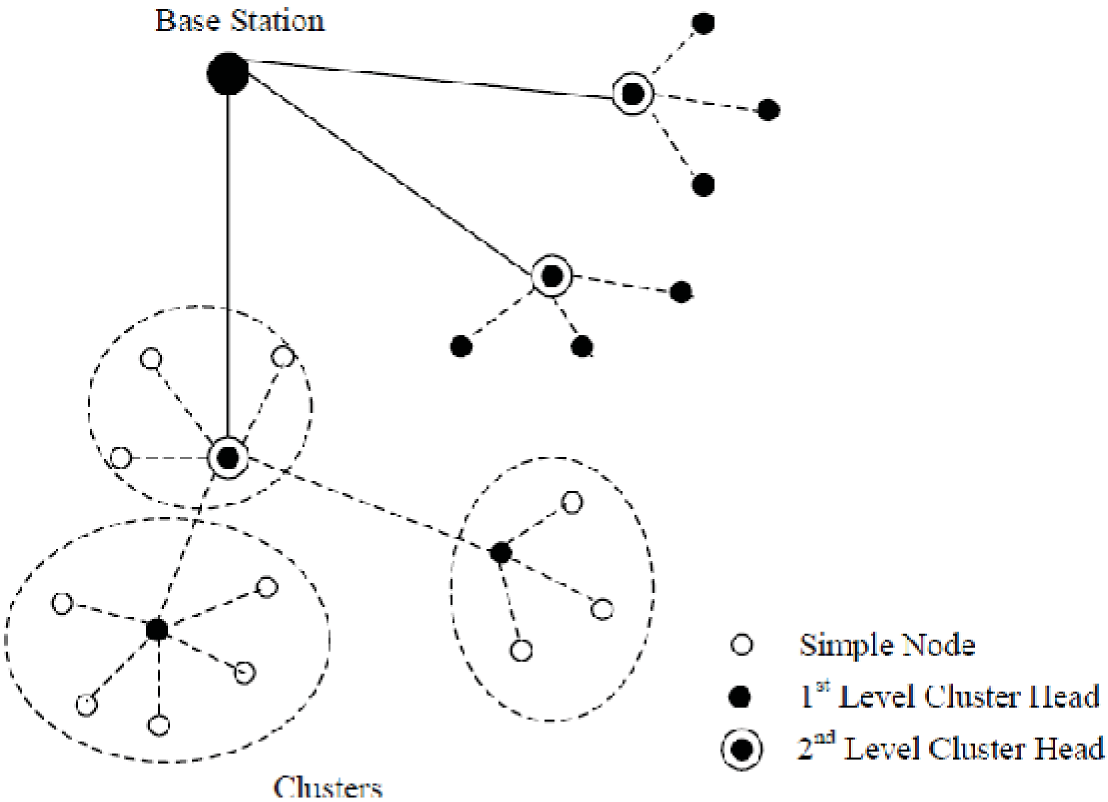

Figure 3.Hierarchical Clustering in TEEN [6]

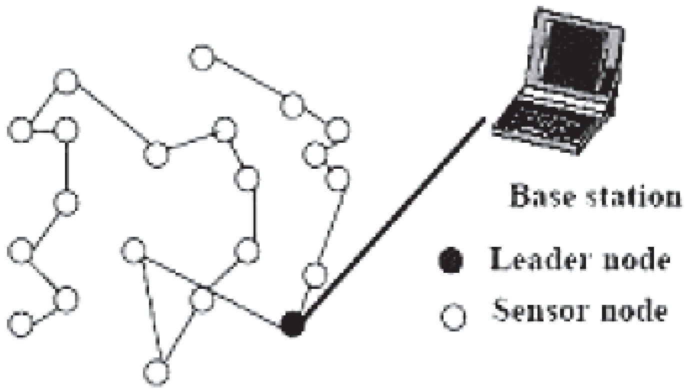

Figure 4. PEGASIS [5]

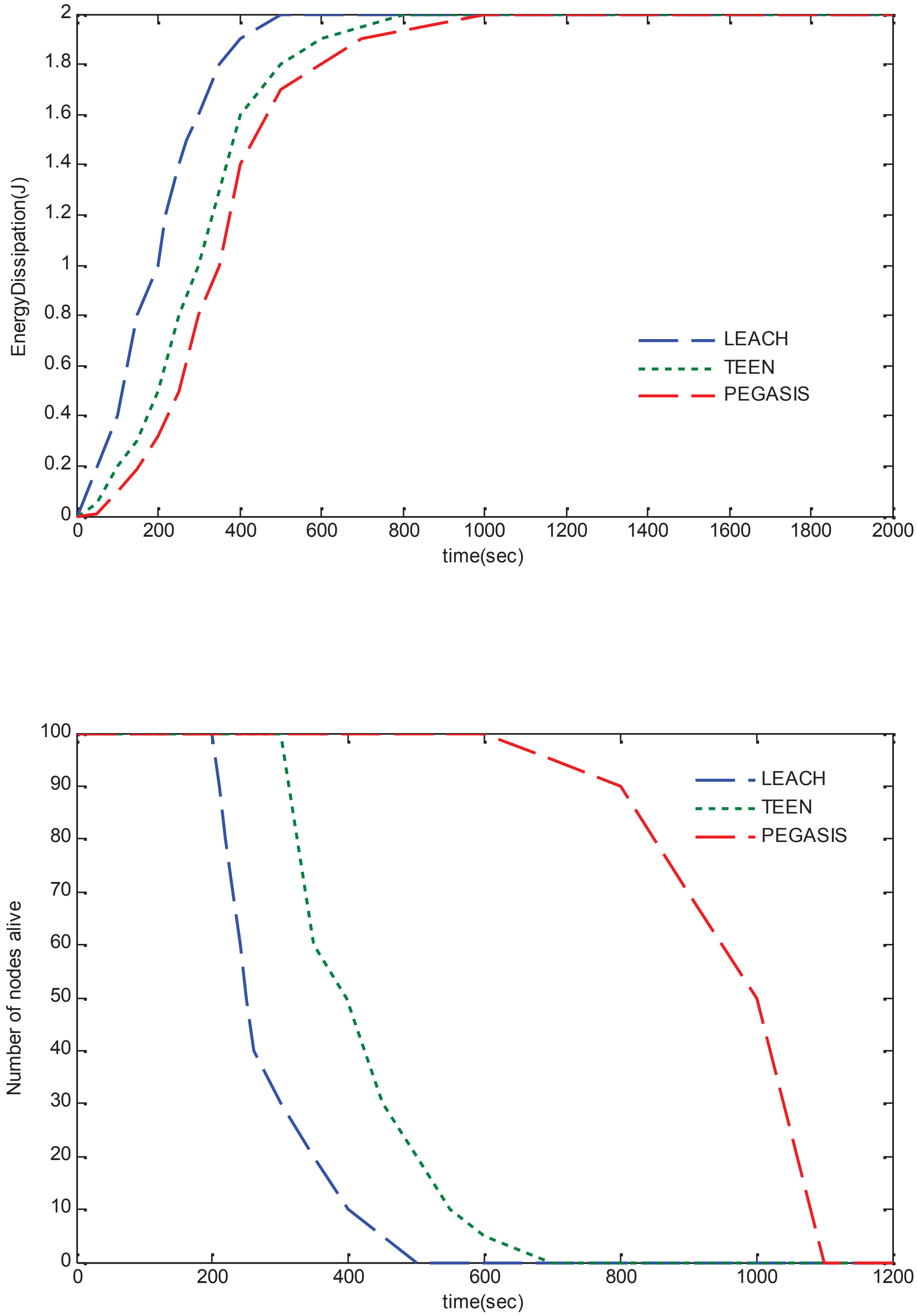

Figure 6 Comparison of the no. of nodes alive

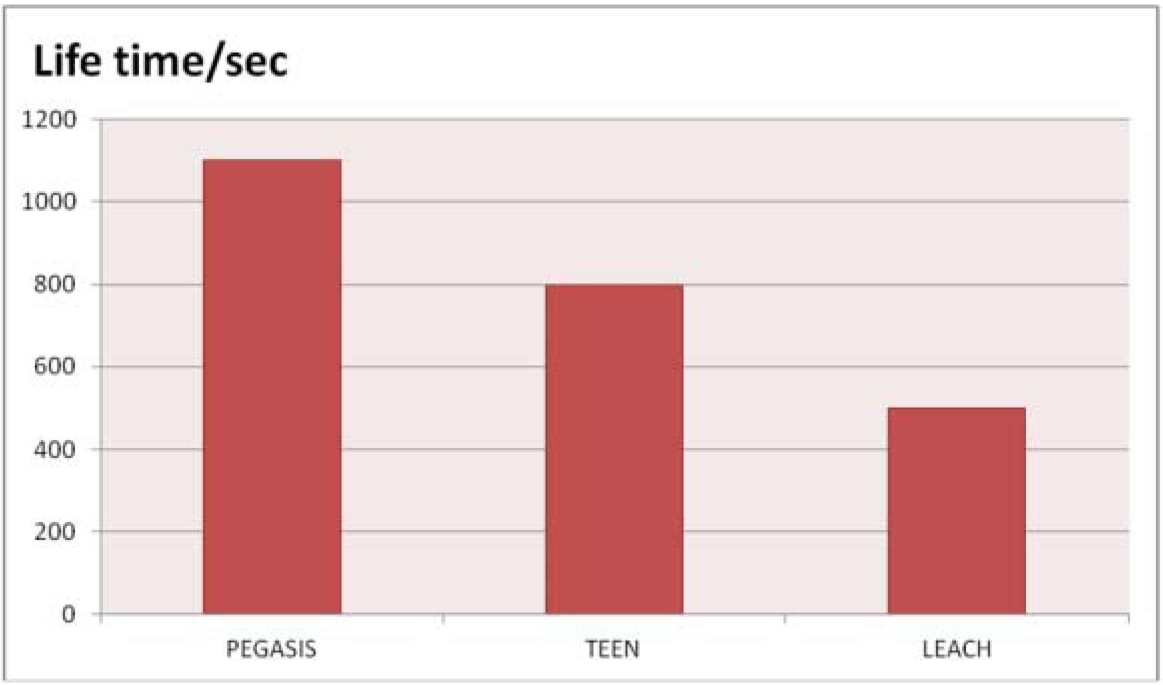

Figure 7 shows the network lifetime