Volume 5, Issue 1, January 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Survey on Optimizing Energy Consumption in Wireless Sensor Networks

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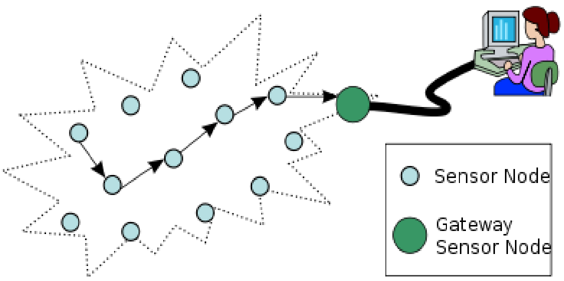
Abstract*— *Clustering is an effective technique that can greatly contribute to overall system scalability, lifetime, and energy efficiency in wireless sensor networks (WSNs). In this paper, we propose an energy efficient clustering algorithm for WSNs based on the LEACH algorithm. LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the most well known energy efficient clustering algorithms for WSNs. The proposed algorithm solves the extra transmissions problem that can occurs in LEACH algorithm.

Keywords*— *LEACH, C-LEACH, Improved LEACH, WSN, Energy Consumption.

I. INTRODUCTION

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links [1–9]. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or is connected to other networks (e.g., the Internet) through a gateway. The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not. This is a traditional single-sink WSN (see Figure 1, left part). Almost all scientific papers in the literature deal with such a definition. This single-sink scenario suffers from the lack of scalability: by increasing the number of nodes, the amount of data gathered by the sink increases and once its capacity is reached, the network size cannot be augmented. Moreover, for reasons related to MAC and routing aspects, network performance cannot be considered independent from the network size. A more general scenario includes multiple sinks in the network (see Figure 1, right part). Given a level of node density, a larger number of sinks will decrease the probability of isolated clusters of nodes that cannot deliver their data owing to unfortunate signal propagation conditions. In principle, a multiple-sink WSN can be scalable (i.e., the same performance can be achieved even by increasing the number of nodes), while this is clearly not true for a single-sink network. However, a multi-sink WSN does not represent a trivial extension of a single-sink case for the network engineer. In many cases nodes send the data collected to one of the sinks, selected among many, which forward the data to the gateway, toward the final user (see Figure 1, right part). From the protocol viewpoint, this means that a selection can be done, based on a suitable criterium that could be, for example, minimum delay, maximum throughput, minimum number of hops, etc. Therefore, the presence of multiple sinks ensures better network performance with respect to the single-sink case (assuming the same number of nodes is deployed over the same area), but the communication protocols must be more complex and should be designed according to suitable criteria.



The main characteristics of a WSN include

- Power consumption constraints for nodes using batteries or energy harvesting
- Ability to cope with node failures .
- Mobility of nodes.
- Heterogeneity of nodes .
- Scalability to large scale of deployment .
- Ability to withstand harsh environmental conditions .
- Ease of use .

Applications of WSN

- Habitat and Ecosystem Monitoring
- Seismic Monitoring
- Civil Structural Health Monitoring
- Monitoring Groundwater Contamination
- Rapid Emergency Response
- Industrial Process Monitoring
- Perimeter Security and Surveillance
- Automated Building Climate Control

II. RELATED WORK

W. R. Heinzelman , A. Chandrakasan , and H. Balakrishnan, "Energy-Efficient Communication Algorithm for Wireless Micro sensor Networks," Proceeding of the 33rd International Conference on System Sciences", pp. 1-10, 2000. Wireless distributed micro sensor systems will enable the reliable monitoring of a variety of environments for both civil and military applications. In this paper, we look at communication protocols, which can have significant im-pact on the overall energy dissipation of these networks. Based on our findings that the conventional protocols of direct transmission, minimum-transmission-energy, multi-hop routing, and static clustering may not be optimal for sensor networks, we propose LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of local cluster base stations(cluster-heads) to evenly distribute the energy load among the sensors in the network. LEACH uses localized coordination to enable scalability and robustness for dynamic net-works, and incorporates data fusion into the routing protocol to reduce the amount of information that must be trans-mitted to the base station.

M. J. Handy, M. Haase, and D. Timmermann , "Low Energy Adaptive Clustering Hierarchy with Deterministic Cluster-Head Selection," 4th International Workshop on Mobile and Wireless Communications Network, pp. 368-372, 2002.This paper focuses on reducing the power consumption of wireless micro sensor networks. Therefore, a communication protocol named LEACH (Low-Energy Adaptive Clustering Hierarchy) is modified. We extend LEACH's stochastic cluster-head selection algorithm by a deterministic component.

B. Krishnamachari, D. Estrin, and S. Wicker, "The Impact of Data Aggregation in Wireless Sensor Networks," 22nd International Conference on Distributed Computing Systems Workshops, pp. 575-578, 2002. Sensor networks are distributed event-based systems that differ from traditional communication networks in several ways: sensor networks have severe energy constraints, redundant low-rate data, and many-to-one flows. Data-centric mechanisms that perform in-network aggregation of data are needed in this setting for energy-efficient information flow. In this paper we model data-centric routing and compare its performance with traditional end-to-end routing schemes. We examine the impact of source-destination placement and communication network density on the energy costs and delay associated with data aggregation.

J. N. Al-Karaki, and A. E. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey," IEEE Wireless Communications, vol. 11, **no. 6, pp.** 6-28, 2004. Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation, and wireless communications capabilities. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy awareness is an essential design issue. The focus, however, has been given to the routing protocols which might differ depending on the application and network architecture. In this paper, we present a survey of the state-of-the-art routing techniques in WSNs. We first outline the design challenges for routing protocols in WSNs followed by a comprehensive survey of different routing techniques. Overall, the routing techniques are classified into three categories based on the underlying network structure: flat, hierarchical, and location-based routing. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, and coherent-based depending on the protocol operation. We study the design tradeoffs between energy and communication overhead savings in every routing paradigm.

O. Younis, M. Krunz, and S. Ramasubramanian, "Node Clustering in Wireless Sensor Networks: Recent Developments and Deployment Challenges," IEEE Network, vol. 20, no. 3, pp. 20-25, 2006. The large-scale deployment of wireless sensor networks (WSNs) and the need for data aggregation necessitate efficient organization of the network topology for the purpose of balancing the load and prolonging the network lifetime. Clustering has proven to be an effective approach for organizing the network into a connected hierarchy. In this article, we highlight the challenges in clustering a WSN, discuss the design rationale of the different clustering approaches, and classify the proposed approaches based on their objectives and design principles. We further discuss several key issues that affect the practical deployment of clustering techniques in sensor network applications of selection combining is to monitor all the diversity branches and select the best one (the one which has the highest SNR) for disclosure. Therefore we can say that SC is not a combinatorial method but a selection procedure at the diversity which is available

III. LEACH PROTOCOL

Low Energy Adaptive Clustering Hierarchy ("LEACH") is a TDMA-based MAC protocol which is integrated with clustering and a simple routing protocol in wireless sensor networks (WSNs). The goal of LEACH is to lower the energy consumption required to create and maintain clusters in order to improve the life time of a wireless sensor network. LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station (sink). Each node uses a stochastic algorithm at each round to

determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head, but that using this radio at full power all the time would waste energy.
Nodes that have been cluster heads cannot become cluster heads again for *P* rounds, where *P* is the desired percentage of cluster heads. 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. The cluster head then creates a schedule for each node in its cluster to transmit its data.All nodes that are not cluster heads only communicate with the cluster head in a TDMA fashion, according to the schedule created by the cluster head. They do so using the minimum energy needed to reach the cluster head, and only need to keep their radios on during their time slot.LEACH also uses CDMA so that each cluster uses a different set of CDMA codes, to minimize interference between clusters.
Properties

- Cluster based
- Random cluster head selection each round with rotation. Or cluster head selection based on sensor having highest energy
- Cluster membership adaptive
- Data aggregation at cluster head
- Cluster head communicate directly with sink or user
- Communication done with cluster head via TDMA

This protocol is divided into rounds; each round consists of two phases;
Set-up Phase
(1) Advertisement Phase
(2) Cluster Set-up Phase
Steady Phase
(1) Schedule Creation
(2) Data Transmission

A. Set-up Phase
Each node decides independent of other nodes if it will become a CH or not. This decision takes into account when the node served as a CH for the last time (the node that hasn't been a CH for long time is more likely to elect itself than nodes that have been a CH recently).In the following advertisement phase, the CHs inform their neighborhood with an advertisement packet that they become CHs. Non-CH nodes pick the advertisement packet with the strongest received signal strength. In the next cluster setup phase, the member nodes inform the CH that they become a member to that cluster with "join packet" contains their IDs using CSMA. After the cluster-setup sub phase, the CH knows the number of member nodes and their IDs. Based on all messages received within the cluster, the CH creates a TDMA schedule, pick a CSMA code randomly, and broadcast the TDMA table to cluster members. After that steady-state phase begins.

B. Steady-state phase:
Data transmission begins; Nodes send their data during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy (chosen based on the received strength of the CH advertisement). The radio of each non-CH node can be turned off until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes. When all the data has been received, the CH aggregate these data and send it to the BS.LEACH is able to perform local aggregation of data in each cluster to reduce the amount of data that transmitted to the base station. Although LEACH protocol acts in a good manner, it suffers from many drawbacks such like;
• CH selection is randomly, that does not take into account energy consumption.
• It can't cover a large area.
CHs are not uniformly distributed; where CHs can be located at the edges of the cluster .Since LEACH has many drawbacks , lot of research have been done to make this protocol performs better.

IV. C- LEACH PROTOCOL
LEACH offers no guarantee about the placement and/or number of cluster heads. In [13], an enhancement over the LEACH protocol was proposed. The protocol, called LEACH-C, uses a centralized clustering algorithm and the same steady-state phase as LEACH. LEACH-C protocol can produce better performance by dispersing the cluster heads throughout the network. During the set-up phase of LEACH-C, each node sends information about its current location (possibly determined using GPS) and residual energy level to the sink. In addition to determining good clusters, the sink needs to ensure that the energy load is evenly distributed among all the nodes. To do this, sink computes the average node energy, and determines which nodes have energy below this average .Once the cluster heads and associated clusters are found, the sink broadcasts a message that obtains the cluster head ID for each node. If a cluster head ID matches its own ID, the node is a cluster head . otherwise the node determines its TDMA slot for data transmission and goes sleep until its time to transmit data. The steady-state phase of LEACH-C is identical to that of the LEACH protocol. Based on the LEACH, LEACH-C also organizes the sensor nodes into clusters with each cluster a cluster head and divides a round into set-up and steady-state phases. It differs from LEACH only in that it uses a high-energy base station to finish the choice of cluster heads. In the set-up phase of each round, every sensor node sends its information about energy to

remote BS. Then the BS selects the cluster heads based on the energy information and broadcasts the IDs of cluster heads to other member nodes. This method can make the nodes with more energy and more chance to become the cluster head in the current round. But in this phase, every sensor node needs to send its ID and energy information to remote BS to compete for the role of cluster heads, which causes energy consumption on the long distance transition. In HEED are well distributed across the network and the communication cost is minimized. However, the cluster selection deals with only a subset of parameters, which can possibly impose constraints on the system. These methods are suitable for prolonging the network lifetime rather than for the entire needs of WSN.

V. IMPROVED LEACH PROTOCOL

In LEACH algorithm, some of the nodes have to select cluster heads that, in comparison to them, have a longer distance to the BS. These nodes send their data to a further location and then their data has to go through a long distance to reach the BS. Such transmissions waste the network's energy and are called extra transmissions. In order to solve the extra transmission problem, we are to make a change in the set-up phase of the LEACH algorithm. In this phase, once the cluster heads are selected, the other sensor nodes do not necessarily select the closest node. Among the cluster heads that, in comparison to them-selves, have a shorter distance to the BS, these nodes select the closest cluster head and inform it that it will become a member of the cluster. If such a cluster head does not exist, it will not be the member of any clusters and will send its data directly to the BS.

VI. CONCLUSION

In this paper, we considered a well known energy efficient clustering algorithm for WSNs called LEACH algorithm and proposed a new clustering algorithm based on it. In this new approach, we eliminated the extra transmissions that can occur in LEACH algorithm. In this we compare three algorithms i.e LEACH, C-LEACH, IMPROVED LEACH.

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