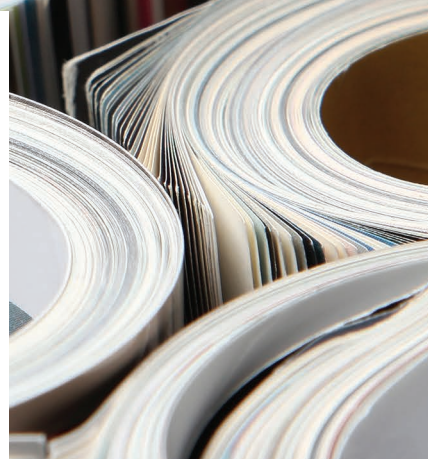

A Novel Hierarchical Two-Tier Node-Deployment Strategy for Sustainable Wireless Sensor Networks

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In recent years, wireless sensor networks (WSNs) have received a great deal of interest from industry and academia due to their low cost, easy-to-deploy characteristics, and ability to accomplish complex tasks. Various civilian and military applications are taking advantage of WSN technology to implement real-time monitoring and/or long-term surveillance tasks in a field of interest (FOI), such as emergency preparedness, soil-moisture monitoring, volcanic-movement monitoring, and border surveillance, just to mention a few. In these kinds of networks, battery-powered autonomous and heterogeneous sensor and actuator devices are deeply embedded into the physical surroundings, and they are equipped with different sensing, computing, and wireless communication capabilities. These autonomous devices collaborate with each other to gather, process, and disseminate valuable information; report the collected information to central servers for further analysis; and make them accessible to interested third parties.

Due to the limited energy capacity of the built-in battery, the working time of the battery-powered sensor node is limited, which, in turn, affects the overall

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effective working time/operation time of the system (i.e., the length of time that both the coverage degree and connectivity of the deployed WSN in the FOI can meet user requirements). Therefore, the limited energy supply is the most critical constraint to a WSN achieving a long-lasting life. Accordingly, solving the problem of improving energy efficiency is the premise for constructing a sustainable WSN, and many approaches have been proposed.

Energy-efficient node-deployment algorithms have been considered an effective approach to reducing network-wide energy consumption while preserving network connectivity. They are typically deterministic-type algorithms that rely on a carefully designed pattern. Because WSNs are normally deployed in remote areas and environments that may be hazardous to human safety, the deterministic-based methods that require manual deployment may not be applicable. Moreover, manual deployment will significantly increase the cost of network deployment. In particular, when the scale of the network is large and/or the terrain structure of the FOI is complex, strictly following the predetermined pattern to deploy the node will significantly increase the complexity of the entire deployment procedure, and this is contrary to the WSN's ease of deployment. Therefore, how to effectively deploy sensors to achieve the objective of reducing system-wide energy consumption, and thereby extend the lifetime of the WSN without increasing the difficulty of WSN coverage and deployment, is an essential problem to be solved in designing a practical, energy-efficient node-deployment algorithm.

To address this problem, unlike most of the existing approaches relying on predetermined deployment patterns, in "A Novel Hierarchical Two-Tier Node Deployment Strategy for Sustainable Wireless Sensor Networks," Azzedine Boukerche and Peng Sun carefully designed a probability density function (PDF)-based, random node-deployment scheme based on rigorous mathematical modeling (*IEEE Transactions on Sustainable Computing*, vol. 3, no. 4, 2018, pp. 236–247). To extend the lifetime of WSNs, their novel approach uses both a regular battery-powered sensor node (RSN) and an energy-harvesting-aided data-relaying node (EHN), which are carefully designed and adopted to perform monitoring and data-transmission tasks, respectively.

> Because EHNs can gain energy from surrounding environments, HTT can maintain the system connectivity nearly permanently.

The authors fully explored the ease-of-deployment property of the random node-deployment method, where RSNs are randomly deployed in the FOI based on uniform distribution to achieve the desired degree of system coverage. Then, based on the newly designed PDF function, the minimum number of EHNs is also randomly deployed in the FOI to collect sensed data from RSNs and forward the gathered data to the data sink, by which the energy consumption of RSNs can be minimized. This, in turn, extends the lifetime of the deployed WSN.

Unlike other existing algorithms, the proposed scheme [hierarchical two tier (HTT)] divides the task of maintaining the degrees of system coverage and connectivity into two independent subtasks (i.e., the sensing subtask for RSNs and the data-relaying subtask for EHNs), by which any problem with the node of one subtask does not affect the execution of another subtask. Furthermore, because EHNs can gain energy from surrounding environments, HTT can maintain the system connectivity nearly permanently. Hence, the system lifetime is affected only by the length of time that the system maintains the desired coverage degree. Because the deployed RSNs do not need to undertake data-relay tasks, their lifetimes can be significantly extended.

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