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An Energy Balanced Routing Hole and Network Partitioning Mitigation Model for Homogeneous Hierarchical Wireless Sensor Networks

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ABSTRACT

This article addresses the challenges of routing hole and network partitioning often experienced in hierarchical wireless sensor networks (WSNs). This developed model classifies network nodes into sets for effective energy management and formulates two cluster networks namely: switching and non-switching networks. Both networks are considered homogeneous and static WSNs and adopted approaches of residual energy, multi-hop and minimal distance as routing decision parameters. The switching network in addition introduces an energy switching factor as a major decision parameter for the switching of cluster head roles amongst cluster nodes. Network simulation was done using Truetime 2.0 and energy dissipation of the respective nodes and cluster heads was observed against a threshold. Results showed the introduction of the energy switching factor gave a significant energy balancing effect as nodes exhibited uniform energy dissipation. Furthermore, the residual energies for most nodes were above the threshold eliminating the possibility of the presence of routing hole and network partitioning.

KEYWORDS

Clustered Networks, Energy Balancing, Hierarchical Networks, Network Partitioning, Routing Hole, Switching Factor, WSN

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INTRODUCTION

Recent advances in sensing, communication, and computing technologies have driven research in wireless sensor networks to a new level. Potential applications of wireless sensor networks include their use in agriculture, healthcare, security, surveillance, transportation, environmental monitoring, disaster management, industry, smart homes and infrastructure monitoring. A WSN is basically a cluster of sensor nodes with a wireless communication infrastructure intended to sense a physical Phenomenon of Interest (PoI), process the extracted information and communicate with one another to coordinate the intended actions. Every sensor node basically comprises of a transducer, microprocessor, a transceiver and an energy source. The energy source, which is usually a battery, supplies energy to the components of the node and the rate at which it dissipates this energy, depends on the power drawn by the constituent components (Oldewurtel & Mahonen, 2006).

As varied as the applications and benefits of wireless sensor networks, there are still some notable challenges posing this intelligent technology. Sukhwinder et al. (2013) and Karthik and Kumar, (2015) outline some of these challenges to include: security, fault tolerance, architecture, energy, hardware and software issues, design, scalability, data communication, limited bandwidth, quality of service, robustness, time synchronization, limited memory and storage space and deployment. Amongst these, energy constraint ranks tops as a perennial challenge militating against the exploitation and realization of the full potentials of WSNs. The successful deployment of WSNs anywhere that it is useful and economically viable would require stringent energy conservation plans. Energy depletion of the nodes can interrupt communication, affect reliability of the network especially its sensed data (Ndinechi et al., 2007), and in worse case, could cause network partitioning which in turn interrupts monitoring of the PoI. Unlike ad-hoc networks, recharging or replacing of the sensor's battery may be inconvenient, or even impossible in some monitoring environments. Therefore, the key challenge in the design of wireless sensor network protocols is how to maximize the network lifetime, which is limited by battery energy in sensor nodes, while providing the application requirement (Cetin, 2011).

The radio subsystem consumes the largest energy in a WSN node. Decreasing the transmission power of nodes is however not a good energy saving option because of the signal degradation and unsuccessful transmission it introduces to the network. Pottie and Kaiser (2000) in their comparison of computation and communication costs show that transmitting one bit over a distance of 100m consumes approximately the same energy as executing 3000 instructions. It is therefore necessary to reduce energy consumption by seeking for energy efficient pathways for data packets even at the expense of extra data processing. Yan et al. (2016) further explains that transmitting signals, i.e., sending and receiving, takes about two thirds of a node's total energy consumption, while the number of transmitted data packets of a node depends to a great extent on the routing strategy. In other words, an efficient routing protocol can help balance the energy consumption levels among WSN nodes, prolong network lifetime as well as improve the quality of data transmission. Summarily the aim of energy routing protocols primarily bothers on energy conservation for enhanced network lifetime and integrity of data communication.

Most applications of WSNs require that information gathered by the network is delivered to the sink in a multi-hop and energy efficient manner (Ghaffari, 2014). Multi-hop routing which entails data routing to the sink via intermediate nodes generally consumes less energy than the direct or single-hop communication which involves direct communication from a node to the sink. This is because transmission power of a wireless radio is inversely proportional to the square of the distance between the transmitter and the receiver. Multi-hop therefore offers the nodes many possible paths to maintain connectivity to the sink using an optimal communication path.

Most energy efficient routing protocols are designed based on either hierarchical routing or flat based routing network structures (Zaman et al., 2016). The hierarchical routing structure gives better energy and data management than the flat-based routing structures by organizing nodes into clusters. Each cluster has a cluster head (CH) which usually takes the responsibility of relaying data