THE UNIVERSITY OF DANANG

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NOVELTY OF PHD DISSERTATION

OPTIMIZATION OF ENERGY EFFICIENT ROUTING IN MULTI DOMAINS WIRELESS UNDERGROUND SENSOR NETWORKS

Major: Information system **Code:** 325478

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The dissertation investigates and proposes energy-optimization solutions for wireless underground sensor networks (WUSNs), with the objective of developing routing algorithms and models that enhance energy efficiency under both single- and multi-region monitoring scenarios. The principal contributions are summarized as follows:

- We construct a comprehensive energy-consumption model that explicitly accounts for underground-specific factors— including attenuation, dielectric constant, soil moisture, and soil erosion—by incorporating them into the path-loss function used for routing. Building on this model, the dissertation formulates a closed-form objective function to enable optimal cluster-head selection and joint clustering of underground and aboveground nodes. This design reduces the through-soil propagation distance and thereby optimizes the network's overall transmission energy.
- We introduce a new clustering protocol, FCM-WUSN, which extends the classical FCM algorithm. In this framework, μ_{ij} denotes the membership degree of node i to cluster j, while V_j represents the cluster centroid obtained via an analytical solution derived from the aforementioned objective function. The proposed routing algorithm is consistent with the adopted loss model; after each round, it updates node states to avoid redundant iterations involving energy depleted nodes in subsequent rounds. The routing scheme is validated through simulations across

multiple scenarios, including increases in the number of sensing nodes and variations in the proportion of nodes buried at a depth of 25 cm from 10% to 30% of the total deployment.

- With the problem of monitoring multiple observed areas of interest, the dissertation models an wireless underground sensor network with multi-region coverage as a multigraphs, in which relay nodes serve as inter-graph connectivity attributes linking the component graphs. It introduces a new node metric defined on the graph that aggregates energy level, coordinates, neighborhood-influence factor, communication radius, and a domain membership index. Consequently, forwarding decisions between any two sensors are no longer based solely on spatial proximity and residual energy; they are informed by a richer set of attributes.
- To address multi-areas routing in such networks, the dissertation develops a novel routing mechanism based on hash table. The method not only discovers near-optimal paths efficiently, but also improves network wide energy utilization by continuously updating the topology and excluding nodes with depleted batteries, thereby significantly extending system lifetime. Experimental results demonstrate that the proposed algorithm prolongs network lifetime by more than 2.1 times compared with established baselines such as PEGASIS and HLEACH. Moreover, the algorithm's flexibility and strong scalability are validated across diverse network sizes and sensor deployment distributions.

The dissertation's contribution lies in leveraging multigraph theory together with the optimization of a mathematic objective function. This research direction is applicable to routing in wireless underground sensor network for both single-region and multi observed regions settings going forward.