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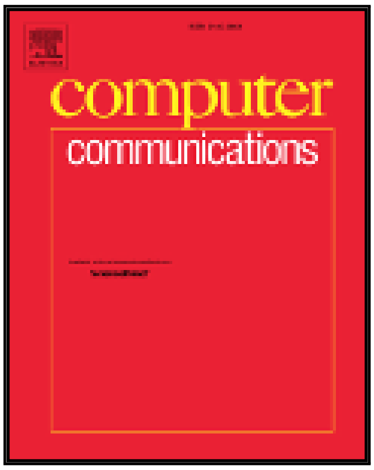


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# Efficient On-Demand Multi-Node Charging Techniques for Wireless Sensor Networks

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**Abstract**

This paper deals with wireless charging in sensor networks and explores efficient policies to perform simultaneous multi-node power transfer through a mobile charger (MC).The proposed solution, called On-demand Multi-node Charging (OMC), features an original threshold-based tour launching (TTL) strategy, using request grouping, and a path planning algorithm based on minimizing the number of stopping points in the charging tour. Contrary to existing solutions, which focus on shortening the charging delays, OMC groups incoming charging requests and optimizes the charging tour and the mobile charger energy consumption. Although slightly increasing the waiting time before nodes are charged, this allows taking advantage of multiple simultaneous charges and also reduces node failures. At the tour planning level, a new modeling approach is used. It leverages simultaneous energy transfer to multiple nodes by maximizing the number of sensors that are charged at each stop. Given its NP-hardness, tour planning is approximated through a clique partitioning problem, which is solved using a lightweight heuristic approach. The proposed schemes are evaluated in offline and on-demand scenarios and compared against relevant state-of-the-art protocols. The results in the offline scenario show that the path planning strategy reduces the number of stops and the energy consumed by the mobile charger, compared to existing offline solutions. This is with further reduction in time complexity, due to the simple heuristics that are used. The results in the on-demand scenario confirm the effectiveness of the path planning strategy. More importantly, they show the impact of path planning, TTL and multi-node charging on the efficiency of handling the requests, in a way that reduces node failures and the mobile charger energy expenditure.

*Keywords:* Sensor networks, wireless energy transfer, mobile charger scheduling, magnetic resonance coupling

## 1. Introduction

Current applications of wireless sensor networks (WSNs) use tiny sensor motes that are powered by miniaturized on-board batteries with limited capacity. This scarceness in energy resources considerably constraints the network lifetime and makes energy efficiency a challenging objective to achieve. A plethora of energy conservation solutions have been proposed in the literature [1]. These solutions can only slow down the energy dissipation, but are unable to guarantee their perpetual functioning. Energy harvesting solutions have been recognized as a sound alternative [2], where ambient energy such as solar, vibrational, wind energy, etc., is used to recharge the sensor nodes. However, the major drawback of these solutions is the high uncertainty associated with the harvested energy, which often shows an erratic behavior. For example; in solar harvesting systems, the energy output of the charger depends on the amount of solar radiations received at the panel, which varies with the time of the day and weather conditions. Research developments in wireless energy transfer technology opened up perspectives for more reliable and deterministic energy provision in WSNs. Kurs et al. [3] developed a new technique called magnetic resonant coupling that enables efficient and stable energy transfer between two devices through mid-range distances (e.g., 2 m). Furthermore, such wireless energy transfer is omnidirectional, i.e., it does not require a line of sight between the charging and receiving nodes. Recent research effort has been focusing on the concept of using a mobile charger that roves the network and charges the sensor motes wirelessly. In most existing