Chapter 19
Energy-Efficient Mobility Heuristics for Maximizing Network Lifetime in Robotic Wireless Sensor Networks

Regis Anne W.
Sri Krishna College of Engineering and Technology, India

ABSTRACT

In a static wireless sensor networks (WSN), the fundamental issue is the formation of energy hole in the sink's immediate locality. The solution to the energy-hole problem can be resolved by incorporating mobile entities like mobile robot (MR) into the network. This chapter proposes three strategies that exploits the mobility of the MR to overcome the energy-hole problem resulting in optimized energy usage across the network and thus maximized network lifetime. Firstly, the energy hole problem using MR is formulated as an optimization model to maximize the sojourn time of the MR at each node and a MR-ranking heuristic that ranks the critical node to be serviced is proposed. Secondly, MR-optimal scheme that finds the optimal path for the MR is formulated and designed. Thirdly, Multi-MR cooperation approach is proposed where multiple MR's collaborate to service the critical nodes. Adequate experiments have been performed to analyze the performance of the proposed schemes. The proposed methods ensure uniform energy distribution and prolonged network lifetime.

INTRODUCTION

The rapid proliferation of smart sensors with advancement in wireless communications is stimulating the growth of Wireless Sensor Network (WSN) across diverse fields, including commercial and military applications. The distributed network of smart sensors collects and forwards multidimensional observations of the environment that is processed and analyzed by field experts to take valuable decisions. Due to the self-organizing nature of WSN, they can be established in hostile and inaccessible terrain or where the physical placement is not possible. The WSN can penetrate into such environment and can monitor

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and report an event which otherwise would not be feasible. A major challenge affecting the network lifetime in static WSN is the unbalanced energy consumption resulting in energy-hole formation. In a static WSN, the fundamental issue is the formation of energy hole (Li & Mohapatra, 2007; Wu et al, 2008) in the sink's immediate locality. It is due to many-to-one traffic pattern in WSN, where the sensors close to the sink have to transfer data back and forth between neighborhood nodes. As a result, the nodes close to sink deplete their energy quickly resulting in energy hole formation, a phenomenon referred as hotspots (Luo et al., 2006; Marta & Cardei, 2009) or sink neighborhood problem. This problem also leads to unbalanced energy consumption across the network resulting in lesser energy efficiency. The solution to the energy-hole problem can be broadly classified into static energy conservation solutions and mobility based solutions as shown in Figure 1.

Incorporating mobile entities like Mobile Robot (MR) into WSN can alleviate the energy-hole problems and can introduce new opportunities (Regis, 2017). The Institute of Electrical and Electronics Engineers (IEEE) Society of Robotics and Automation's Technical Committee: "A 'networked robot' is a robotic device connected to a communications network such as the Internet or Local Area Network. The network could be wired or wireless, and based on any of a variety of protocols such as Transmission Control Protocol, User Datagram Protocol, or 802.11. Many new applications are now being developed ranging from automation to exploration." There are two types of MRs (i) In Tele-operated robots, commands and responses are sent and received to control and coordinate the robots and (ii) In Autonomous robots, the robots adapt, learn and make decisions based on the information from the network. The Robotic Wireless Sensor Network (RWSN) is defined as an autonomous networked multi-robot system

Figure 1. Energy Hole Mitigation Approaches