Chapter 7

A Performance Evaluation of the Coverage Configuration Protocol and its Applicability to Precision Agriculture

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ABSTRACT

Wireless Sensor Networks (WSNs) have recently emerged as a prominent technology for lots of civilian and military applications in both rural and urban environments. Area coverage configuration is an efficient method to alleviate the nodes' limited energy supply in high density WSNs. It consists in selecting as few active sensors as possible from all deployed nodes while ensuring sufficient sensing coverage of the monitored region. Several coverage configuration protocols have been developed; most of them presume the availability of precise knowledge about node locations and sensing ranges. Relaxing these conservative assumptions might affect the performance of coverage configuration protocols. In this chapter, the authors examine the impact of location errors, irregular sensing ranges, and packet losses on the Coverage Configuration Protocol (CCP). The authors focus more precisely on the impact of using this protocol on a real application: precision agriculture where farmers need to cover the entire terrain with sensors in order to rapidly detect and localize spots requiring chemical treatment.

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INTRODUCTION

Recent advances in wireless communication and Micro Electro Mechanical Systems (MEMS) have led to the emergence of wireless sensor networks (WSN) (Pathan, Hong, & Lee, 2006). A WSN consists of a large number of sensor nodes that cooperate with each other to monitor the physical word. Applications of wireless sensor networks include battlefield surveillance, environmental monitoring, traffic control, smart space, and industrial diagnostics (B. Wang, 2010). Energy conservation is a primary concern in sensor networks because replacement of battery is costly and even infeasible in some applications such as battlefield surveillance. Recent researches have proved that significant energy savings can be achieved by scheduling node duty cycles in high density sensor networks (Popescu, 2008). They aim to select a subset of sensors to operate in active mode and let the remaining in a sleep mode. This essential issue in wireless sensors networks is refereed as the area coverage problem.

Area coverage is a fundamental measure of quality of service (QoS) in sensor networks (Zhou, Liang, Xu, & Xie, 2012). It indicates how well each point in the sensing field is monitored by the sensors. A point in the monitored area can be covered by several sensors at the same time in which case it has a higher coverage degree. The coverage degree requirement depends on the target application (Chen & Koutsoukos, 2007). For instance, a battlefield surveillance application may require a higher coverage degree than an environment monitoring application. Moreover, some applications such as intrusion detection may need an adjustable coverage degree as the coverage degree could be increased when an intrusion takes place.

Over the last decade, several area coverage protocols have been proposed (Dai &Wu, 2003; Tian & Georganas, 2002; Xing et al., 2005; Zhang & Hou, 2005). Most of them are based on geometric algorithms to select the active nodes set. These algorithms assume that the sensing range is a uniform disk and every node knows its own as well as its neighbors' accurate locations and states (Fan & Jin, 2010). These two assumptions are appealing since they make the coverage control protocols easier to design and analyze. However, they may be unrealistic in practical physical environments. Indeed, the sensing patterns of sensor nodes are highly affected by environmental factors (noise, obstacles, rain, wind). In addition, location calculation and estimation are not very accurate (Oliveira, Nakamura, Loureiro, & Boukerche, 2005) as location errors can amount to several meters (J. Wang, Ghosh, & Das, 2010). Finally wireless networks are prone to packet losses which may negatively impact the information collected about neighbors.

Location errors, sensing irregularity and packet losses are common and non negligible phenomena in wireless systems. Thus, there is an urgent need to evaluate the effect of these phenomena on the performance of the area coverage protocols. The coverage configuration protocol (CCP) (Xing et al., 2005) is one of the most well-known coverage protocols in the literature. Several works have already presented a performance evaluation of CCP. However, to the best of our knowledge, none of these works have studied CCP under realistic assumptions. In this paper we first propose to study the robustness of CCP against location inaccuracy, sensing irregularity and packet losses. Then, we focus on the applicability of CCP on a real use case; namely precision agriculture. In precision agriculture, farmers and agribusinesses target to micromanage their fields by applying an efficient and localized soil/plants chemical treatment. They need to cover the entire field with sensors in order to precisely and rapidly localize the area where the chemicals should be dispersed. In this paper, we target to study to what extent famers and agribusinesses can rely on CCP to achieve precision agriculture goals.