

Chapter 1

Sensing Coverage in Three-Dimensional Space: A Survey

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ABSTRACT

Efficient sensor deployment has been one of the most challenging and interesting research areas. The importance and effectiveness of real-world sensing applications, such as underwater and atmospheric sensing, military applications, health systems, and alert systems, which target specific events, raise the need for adaptable design of Wireless Sensor Networks (WSNs). The main challenge in the design of such networks is the optimal sensor deployment, which helps extend the operational network lifetime. Indeed, by maintaining coverage and connectivity with the least number of active nodes and least communication cost, the operable time of the network is guaranteed to be prolonged. The study of two-dimensional (2D) WSNs introduced a significant advancement to the wireless sensor computing technology for different types of smart environments. Nevertheless, 2D WSNs were not sufficient concerning certain applications that require three-dimensional (3D) design. Previous work focused on the design and analysis of various approaches to cover a 3D field of interest, and expanded existing design from 2D to 3D space. Hence, the complexity of such approaches is a major stumbling block. To alleviate this problem, more efficient solutions for the design of WSNs for 3D space deployment have been introduced. By tessellation of the 3D space, which is one of the proposed solutions, researchers studied the partitioning of the space based on Voronoi tessellation by generating identical space-filling cells. Using space fillers cells, which are represented by polyhedra, to model the sensing range of the sensor nodes is assumed to be

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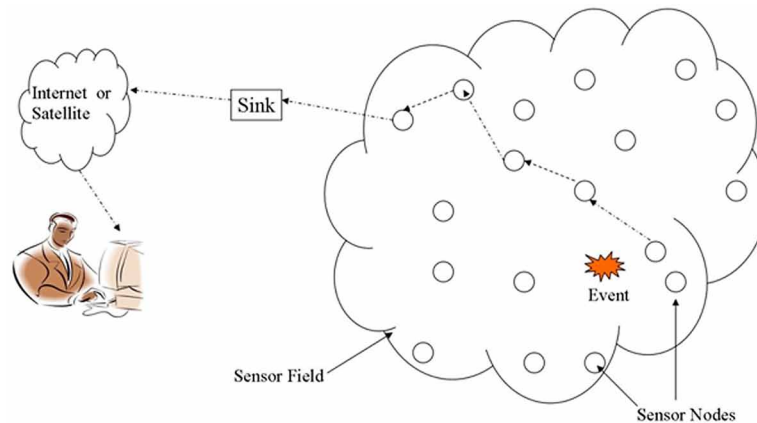
an optimal solution since these polyhedra can fill a 3D space without leaving gaps or overlaps among them. In the existing literature, the coverage problem in 3D space is concerned with finding the polyhedron that can best approximate the spherical sensing range and eliminates gaps without scarifying the network connectivity. Therefore, the latter is directly related to the sensor node placement strategy. This book chapter studies various proposed solutions for the design of 3D WSNs, with a focus on coverage and connectivity. More specifically, it presents several space filling polyhedra, including the cube, truncated octahedron, hexagonal prism, and rhombic dodecahedron. Also, it compares all these space filling polyhedra to cover a 3D space.

1. INTRODUCTION

A wireless sensor network is composed of sensors deployed over a field (or geographical region) of interest. It collects and generates data about specific phenomena, and forwards them to a special node, called the base station (or the sink). Wireless sensor networks (WSNs) have multiple fundamental capabilities due to the functionality of the sensor. A sensor node is a small device that consists of four basic components, which are the sensor, microcontroller, energy supplier, and radio transmitter. These four components coordinate together to achieve the service required by the whole network. The sensors' characteristics are a blessing as they help in the design process of networks for critical missions. However, due to the sensors' limited resources, such as power (or energy), this may cause the network to be vulnerable network, if it is not designed to consider optimal resource allocation. From now on, we use the terms "sensor" and "sensor node" interchangeably.

Sensors can be deployed inside the phenomena to be monitored or close to it, depending on the nature of the events to be detected. The frugal technology for designing and implementing WSNs is an attractive source for a wide range of applications, such as military applications, where sensors can be deployed randomly to detect and monitor military targets, and environmental and home applications, which require deterministic deployment, where the locations of sensors need to be predefined. In addition, acoustic applications are being recently introduced as examples of three-dimensional (3D) WSNs. The features of a sensor node ensure wide range of applications. In particular, the sensors have the ability of

Figure 1. Typical structure of a wireless sensor network



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