

## Chapter 8

# Mitigation of Hot Spots on Wireless Sensor Networks: Techniques, Approaches and Future Directions

**Fernando Gielow**

*NR2 – Federal University of Paraná, Brazil*

**Michele Nogueira**

*NR2 – Federal University of Paraná, Brazil*

**Aldri Santos**

*NR2 – Federal University of Paraná, Brazil*

### **ABSTRACT**

*The use of Wireless Sensor Networks (WSNs) has increased over the past years, supporting applications such as environmental monitoring, security systems, and multimedia streaming. These networks are characterized by a many-to-one traffic pattern. Hence, sensor nodes near to the sink have higher energy consumption, being prone to earlier deaths and failures. Those areas overloaded with high traffic rates are called Hot Spots, and their emergence creates and expands energy holes that compromise network lifetime and data delivery rates, and may result in disconnected areas. This chapter provides an overview of techniques to mitigate Hot Spot impacts, such as the uneven distribution of sensors, routes that balance energy consumption, sink mobility, and the use of unequal clustering. Further, it depicts the approach for achieving mitigation of sink centered Hot Spots. Finally, this chapter presents conclusions and future research perspectives.*

## **INTRODUCTION**

Improvements on wireless networking have highlighted the importance of distributed systems in our current society. Wireless Sensor Networks (WSNs) have been envisaged to support different applications, such as environmental monitoring, security systems, military systems, industrial control and others (Potdar, 2009). WSNs consist of tiny devices with the capability of communication and sensing. Batteries power these devices, limiting the network lifetime and their processing power due to not only size but also energy constraints. In order to obtain effective communication among sensor nodes and satisfy application requirements, the establishment and maintenance of routes from a data source to a base station (or sink) is necessary.

Energy consumption is different on each sensor node of a WSN. Nodes distributed in a homogeneous way suffer a funneling effect due to the many-to-one traffic pattern. This traffic pattern characterizes most of the data gathering applications. As sensors get close to the sink, the number of routes decreases, overloading some areas with data traffic and triggering a gradual process that creates and expands an energy hole around the sink (Bi, 2007). These areas, overburdened with high traffic rates, are called Hot Spots. Their emergence is common, but countermeasures must be taken in order to mitigate their impacts, or else, network performance can be severely harmed.

Balancing network-wide energy consumption is crucial for routing protocols on WSN. The emergence of Hot Spots can compromise the network lifetime, data delivery rate, and may even disconnect sensors of the network. These aspects are destructive for the network performance, impacting the quality of services and applications, which should be preserved. Hot Spots have their nature bounded with routing and, therefore, they must be addressed at the routing layer.

Several works have analyzed the impact of Hot Spots in WSNs. In (Perillo, 2005), authors evaluated strategies proposed to mitigate Hot Spots. The use of the sink mobility approach to manage energy at nodes was examined in (Thanigaivelu, 2009). In (Sesay, 2006), authors analyzed the use of different parameters to detect Hot Spots, such as buffer occupation, packet loss and link layer contention. In order to mitigate Hot Spots, different approaches have been used. In (Liu, 2008), energy balance was modeled as a particle swarm optimization problem by redefining the particles fly rules for the routing optimization. In (Wu, 2006), Wu and Chen proposed the uneven distribution of sensor nodes in the network, deploying more nodes close to the sink. DAR (Bi, 2007) uses a slightly different technique, which tries to establish longer routes, enforcing a more balanced participation of nodes. Over the last years, unequal sized clustering has been extensively employed to mitigate Hot Spots. For instance, UCR (Chen, 2009) and EECRP (Xi-Rong, 2009) decrease the cluster size close to the sink, creating more possible routes to reach it.

Albeit there are many protocols intending to mitigate Hot Spots, they all have distinct disadvantages. The suitability of them is compromised due to unrealistic assumptions and operations and, the analysis of performance was not accurate enough to prove their efficiency. Also, backbone maintenance is hardly concerned. This creates energy-efficient routes that do not relay packets correctly. This chapter presents a general discussion about different techniques to mitigate Hot Spots on WSN. Its goal lies in presenting an overview of existing solutions, emphasizing open issues. Finally, we describe the proposed energy-efficient architecture capable of mitigating Hot Spot effects without performance degradation of network operations, and a new routing protocol called RRUCR, based on the proposed architecture.

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