Chapter 13
On the Design of Self-Organizing Ad Hoc Networks

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ABSTRACT
Self-organization concept has become very important to the vision of pervasive and ubiquitous systems because such systems are expected to be composed by lots of interconnected computing devices immersed in the environments. In particular, general Mobile Ad hoc networks, and their specializations such as Sensor and Vehicular networks can be seen as the main technologies for pervasive infra-structures. These networks were conceived under the self-organization paradigm due to many characteristics such as a high number of devices, dynamic network topology and the need of autonomous operation. Although several mechanism and techniques for achieving self-organizing behavior are already applied, there is still the lack of general methodologies for the design of new self-organizing functions. Thus, this chapter will present an overview of self-organizing networks introducing important functions and techniques, and it will focus on important design aspects that can be useful to new designs.

INTRODUCTION
Mobile Ad hoc Networks (MANETs) (Haas et al., 1999) are an important subject for research as mobile devices (laptops, PDAs, cell phones), wireless networks and applications became widespread during the last decade. For instance, specialized ad hoc networks such as the Wireless Sensor Networks (WSNs) (Pottie & Kaiser, 2000; Akyildiz et al., 2002) and the Vehicular Ad hoc Networks (VANETs) (Kosch et al., 2006) are very active research areas.

A WSN consists of sensor nodes connected among themselves by a wireless medium to perform distributed sensing tasks, and these networks are expected to be used in different applications (Arampatzis et al., 2005) such as environmental and health monitoring, surveillance, and security. A VANET is composed by wireless devices to allow communications among nearby vehicles, or among
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them with the roadside infra-structure, to provide an information system regarding traffic, roads and contextualized events.

Following the vision of Pervasive Computing (Satyanarayan, 2001), we are starting to interact with computing devices around us, many time in an invisible way, and in many contexts such as intelligent homes, factories or transport systems. All these devices are expected to be interconnected to provide a common communication system to access information anywhere, anytime. Thus, it is very clear that mobile ad hoc networks and its specializations are the main technologies to achieve a ubiquitous and pervasive world.

The scenarios where MANETs are applied may be very dynamic. In these networks, topological changes are very frequent. For example, sensor nodes can be destroyed by the environment, nodes can have their energy depleted, vehicles are frequently moving, new nodes can be added or leave the network, or the wireless communication can be intermittent due to interferences or obstacles. Thus, the algorithms and protocols for this kind of network must be able to enable network operation during its initialization, and both normal and exception situations. Besides, many applications require the adoption of a totally autonomous behavior. This is due to the necessity of creating infra-structure in remote places, which can be inhospitable or of hard access, or in consequence of the network scale, which increases the network complexity due to the exponential number of possible interactions among nodes and can make massive or even impossible the execution of management actions by administrators or centralized entities.

In this context, self-organization has become an important concept that has been applied in such large-scale and autonomous network systems. Its main idea is the “achievement of a global behavior through local interactions” (Heylighen, 2002, pp. 1), which leads to networks less dependent of central control and that tend to be scalable, adaptable and, consequently, robust.

In the development of MANETs, several studies have applied the self-organization concept (sometimes implicitly) in specific functions, such as communication and clustering. However, they did not cover a more general and practical view of the concept application that can be used for new designs and developments. Thus, this chapter will present a general view of the concept application to these networks, it will present important functions and techniques applied in the development of these networks, and it will focus on important design aspects that can be useful to new designs.

The rest of this chapter is organized as follows. In the next section, we introduce the self-organization concept and present some fundamental work in literature. Next, we present our main contributions on the design aspects of self-organizing functions by organizing important design ideas in a methodological view. Finally, we present some conclusions and future trend in this promising research area.

FUNDAMENTALS AND RELATED WORK

Self-organization is a well known concept in the literature and it has been employed in different areas such as Physics, Chemistry and Biology (e.g., see Haken, 1983). Its idea is the creation of a coherent global behavior only from local interactions among the system elements (Heylighen, 2002), and its consequent decentralized aspect leads to systems that are more adaptable, scalable and robust. These characteristics have led to the application of the self-organization concept in several computer systems, which are becoming more distributed and composed of many elements. In particular, many examples of self-organization in the computer network are already studied (Zambonelli et al., 2005), varying the scale from microsensor networks to the entire internet, and particular mechanisms achieving self-organization