Chapter 2.7
Hovering Data Clouds for Organic Computing

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Abstract As part of our project AutoNomos, we have investigated traffic information and management systems that motivate the usage of new methods and tools inspired by Organic Computing paradigms. Current traffic monitoring and management approaches with stationary infrastructure lack flexibility with respect to system deployment and have difficulties with detecting unpredictable events (e.g., accidents). One goal of AutoNomos is the development of a distributed and self-organising traffic information and management system without a centralised infrastructure. Our system relies on a GPS-based navigation system and a wireless radio interface; vehicles can gather information about the current position on the road network and form a vehicular ad-hoc network (VANET) to share information about traffic phenomena. In this article, we introduce Hovering Data Clouds (HDCs) as a tool to collect, aggregate and disseminate application-specific data. HDCs evolve in a self-organising manner at locations of relevant data in the system. Although their data is hosted on the nodes, HDCs exist independent of the individual carriers. While HDCs float between physical carriers, their corresponding HDC messages are disseminated in the network by a new effective transport protocol named AutoCast, designed according to Organic Computing paradigms. Finally, we demonstrate that HDCs detect traffic phenomena reliably and propagate them robustly within the network.

Keywords Organic computing · Self-organising systems · Wireless ad-hoc networks · Hovering data clouds

1 Introduction

During the last decades, computing systems have evolved enormously with respect to their processing power, storage and memory. At the same time, the size of these systems continuously decreases resulting in powerful mobile systems. Additional wireless interfaces enable ad-hoc networks consisting of a notable number of these mobile systems. However, with the transition from wired to wireless technologies in computer networks, the complexity of systems increases significantly. Distributed applications built on top of wireless networks must be well designed to work in this difficult and changing environment. Especially ad-hoc wireless communication
between devices with wireless transceivers based on multi-hop topologies is an open research field.

Protocols designed in the past based on simulations solely using simple transmission models and graph-theoretic assumptions fail to work reliably in real field tests. Therefore, systems that flexibly adapt to their environment in order to exhibit robust behaviour are being studied in a number of research programs, among them the Autonomic Networking Initiative and the Organic Computing Initiative. Organic Computing systems are expected to exhibit “life-like” properties, including self-adaptation and self-organisation in the sense of being adaptive to changing conditions. In this article we explore Organic Computing approaches for system design, including protocol design in wireless multi-hop networks.

As a motivating example, we consider traffic monitoring, in particular traffic jams on a highway. Each traffic jam itself has life-like properties and consists of several parts, i.e., front, back and middle region. Although this article focuses on traffic monitoring, there are a number of other scenarios [3] that can be dealt with by our approach. The important aspects are self-organisation and mobility of data, which evolves when phenomena like a traffic jam occur. Hovering Data Clouds are a new concept for creating applications for ad-hoc networks. We show that HDCs are optimised to handle complex and organic phenomena.

The rest of this article is organised as follows: Section 2 discusses work related to our approach. In Sect. 3, the concept of Hovering Data Clouds is introduced as a self-organising entity that is able to migrate seamlessly from one physical device to another. Two major building blocks of HDCs (data aggregation and data dissemination with AutoCast) are discussed in Sect. 4 and Sect. 5. Section 6 presents evaluation results of HDC implementation and applications based on HDCs. The article concludes in Sect. 7 with a summary and future work.

2 Related Work

Research in the field of artificial intelligence builds and investigates self-learning systems that are able to adapt to changes in the environment. These self-learning systems (e.g., neural networks) have intrinsic emergent properties. Particularly in automation, the challenge is to predict the properties of these intelligent systems. Supervised learning is introduced to ensure the correct behaviour of a system in real applications, as the behaviour of artificial-intelligent systems is difficult to predict. These approaches of controlled learning are part of the practical solutions in Organic Computing [9]. A system architecture as introduced in [8] called “Observer/Controller architecture” provides feedback that leads to emergent properties, but also controls the subsystems. The Observer/Controller architecture can be implemented on different layers of a system and helps to develop well-defined hierarchies in a complex system.

Another field of related work is Content-Centric Networking (CCN) [5]. In CCN, information is not bound to a specific physical resource either. A consumer “asks”