Chapter 7  
Self-Optimised Tree Overlays Using Proximity-Driven Self-Organised Agents  

Evangelos Pournaras, Martijn Warnier, and Frances M.T. Brazier  

Summary Hierarchical structures are often deployed in large-scale distributed systems to structure communication. Building and maintaining such structures in dynamic environments is challenging. Self-organisation is the approach taken in this chapter. AETOS, the Adaptive Epidemic Tree Overlay Service, provides tree overlays on demand. AETOS uses three local agents to this purpose (i) to translate application requirements to self-organisation requirements, (ii) to self-organise nodes into optimised tree topologies based on these requirements, and (iii) to control bootstrapping and termination of self-organisation. The evaluation of AETOS in different simulation settings shows that it provides high connectivity in tree overlays optimised according to application requirements.  

7.1 Introduction  
Complex, intelligent, distributed systems in dynamic environments need to adapt continuously. Management is a challenge. Central management of such systems is not often an option; distributed management is required.  
Self-management relies on local management at the level of individual systems, and virtual topologies (overlays) to regulate communication between systems, for example to aggregate global knowledge about the state of a system. Hierarchies often provide the structure upon which distributed management is based. Examples of
domains of applications for which this holds include DNS, multimedia multicasting (Tan et al. 2006), energy management (Pournaras et al. 2009a) and distributed databases (González-Beltrán et al. 2008).

Building and maintaining robust and application-independent hierarchical topologies designed to this purpose is the challenge this chapter addresses, in particular for tree structures. Connectivity in a tree overlay is of key importance. If a node is (temporarily) disconnected, the branches underneath the node are also (temporarily) disconnected from the rest of the system, affecting global performance.

**AETOS, the Adaptive Epidemic Tree Overlay Service**, is the approach proposed in this chapter. AETOS makes it possible to create self-organised tree topologies that are proactively resilient to failures, and reactively self-heal (Chaudhry and Park 2007) the structure built. AETOS (Pournaras et al. 2009b) builds and maintains application-independent robust tree topologies in dynamic distributed environments.

Intelligent software agents are used (i) to translate application requirements to self-organisation requirements, (ii) to self-organise nodes in optimised tree topologies based on these requirements, i.e., reactively reconnecting or rewiring connections to improve robustness, and (iii) to control bootstrapping and termination of self-organisation.

Experimental evaluation of the AETOS self-organisation based on connectivity convergence is presented.

This book chapter is outlined as follows: Sect. 7.2 outlines application domains in which hierarchical topologies are used. It also illustrates the problem and summarises the contributions of AETOS. Section 7.3 illustrates related work on robust tree overlays. Section 7.4 provides a high-level overview of the agent-based approach of AETOS. Sections 7.5–7.7 present the three agents of AETOS: the ‘application agent’, the ‘self-organisation agent’ and the ‘system control agent’ respectively. Section 7.8 illustrates the experimental evaluation of the approach that this book chapter proposes. Finally, Sect. 7.9 concludes this chapter and outlines future work.

### 7.2 Objectives and Contributions

This section discusses the importance of tree topologies for various application domains and identifies the problem of managing application-independent self-organised trees. It also provides an overview of the proposed solution.

#### 7.2.1 Applications

Tree structures are often used in information management for aggregation, search, dissemination and decision-making. Their complexity is usually bounded to a logarithmic function or to the number of nodes in the tree structure. They are also used