Chapter 7
Architectures for Collective Self-aware Computing Systems

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Abstract This chapter aims to discuss the architectural aspects relevant to collectives of self-aware computing systems. Here, collectives consist of several self-aware computing systems that interact in some way. Their interactions may, potentially, lead to the formation of a self-aware collective of systems. Hence, the chapter defines different types of interactions that can link systems into a collective and then discusses the conditions under which self-awareness can be achieved within such collectives. Furthermore, the chapter identifies some of the most relevant architectural concerns that occur when linking multiple self-aware systems into a (self-aware) collective and defines these in the form of a generic meta-architecture for collectives of self-aware systems. Architectural concerns can represent both static and dynamic aspects of system collectives. Static concerns include the self-awareness levels of systems in a collective; the system interrelations, such as competition and cooperation; and...
several organisation patterns for systems in a collective, such as hierarchy or peer-to-peer designs. Dynamic concerns address changes that may occur over time, with respect to the above-mentioned aspects, based on the experience and learning of systems within the collective. More advanced topics discuss the manner in which the creation of collectives from interrelated systems can be applied recursively, adopting different architectural choices and combinations at each level, and potentially leading to a wide range of variations in the resulting self-awareness characteristics. The chapter concludes by indicating the main contributions and targeted beneficiaries of this chapter and points to the most important challenges to address in future research.

7.1 Introduction

7.1.1 Chapter Overview

Chapter 6 discussed architectural considerations related to individual self-aware systems. The present chapter takes this discussion further by considering multiple self-aware systems that come together to form a collective. The key architectural aspects and the associated questions include:

- What are the types of relations that can link self-aware systems within a collective (e.g., cooperation, competition or usage)?
- What are the most common organisation patterns for defining the roles and interactions among systems in a collective (e.g., hierarchy, peer-to-peer or stigmergy)?
- What are the causality relations between the levels of self-awareness of individual systems (local scopes) and those resulting for an entire collective (global scope)?

The above concerns are both orthogonal—in that various combinations are possible, in principle—and interdependent—in that the way in which one aspect is instantiated may depend on the choices made for the other aspects. For instance, a hierarchical organisation is defined differently depending on whether the participating systems are linked via cooperation or competition relations; also, the exact organisational roles would depend on the self-awareness level of each system.

Most of the architectural concerns discussed here, notably including the relation types and organisation patterns, are not necessarily specific to self-aware systems. They can be found across related domains such as artificial intelligence, multiagent systems, robotics, autonomic and organic computing systems (cf. Chap. 8). However, since these solutions reoccur across all these domains, they will also, most likely, be relevant when designing self-aware systems.

Also, it is important to note that this chapter does not aim to address the algorithmic aspects of how self-awareness functions, such as knowledge sharing and distributed decision-making, can be achieved within the collectives of self-aware systems. Some of these algorithmic concerns are tackled in Chap. 13. Here, instead, we