Chapter 2
State of the Art

Abstract This book addresses three different areas: network management, autonomic or self-* properties, and peer-to-peer. Indeed, the key of the work developed here is the integration of those three areas. Therefore, understanding the start of the art associated with each area is of crucial importance to comprehend how their integration can be accomplished. In a first moment, this chapter presents the current research status of each area. In a second moment, current investigations are examined in order to show the relationship among those areas, i.e., autonomic computing/self-* properties and network management, peer-to-peer and network management, and, finally, all three areas together.

Keywords Network management · Autonomic computing · Peer-to-peer · Autonomic and Self-* network management · Peer-to-peer network management · Autonomic and Self-* and Peer-to-peer network management

2.1 Background

As emphasized in Chap. 1, the investigation of new approaches and alternatives for developing network management solutions has gained attention over the years. For this reason, Sect. 2.1.1 shows the approaches and alternatives developed so far. Instead of listing isolated works, this section shows, initially, the types of taxonomies proposed in the literature, that try to classify the proposed network management approaches. Then, the most popular approaches found in the literature are described. Finally, it is presented the discussions of the network management community about the problems left unsolved by those approaches and the expectations for further alternatives.

In the sequence, basic concepts related to autonomic computing and self-* properties are presented. Autonomic computing and self-* properties comprise an area of research that is used in different fields of computer science, (e.g. business [41],

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data bases [123], and cloud computing [57, 78]). In addition, there are no standard definitions of terms and models. Therefore, discussions, terms, and concepts related to autonomic/self-* properties applied to network management field are described in Sect. 2.1.2.

Finally, the description of current research related to peer-to-peer is presented in Sect. 2.1.3. Peer-to-peer is employed in different contexts, is associated with different levels of abstraction, and interpreted in distinct manners [8]. Thus, the objective of this section is to clarify the contexts and concepts where P2P appears.

2.1.1 Network Management Approaches

On network management community, there are no standardized classification or taxonomy of network management approaches. Over the years, some attempts to organize those approaches were proposed. For examle, Martin-Flatin et al. [70] proposed a simple and an enhanced taxonomies. The former is based on the organization criterion and divides the network management approaches in: centralized; weakly distributed hierarchical; strongly distributed hierarchical; and strongly distributed cooperative. The later is based on four criteria and presents seven categories. Schönwälder et al. [90] introduced a taxonomy very similar to the previous one. However, the authors categorized the network management approaches considering solely the number of managers used on the system. This taxonomy has four management categories: centralized; weakly distributed; strongly distributed; and cooperative. Pavlou [80] defined a taxonomy based on the different ways of executing a management task. The proposed taxonomy organizes management approaches, frameworks, and protocols in three levels.

The aforementioned taxonomies have in common the presence of different types and levels of distribution. In fact, with the challenges that were emerging over the years (e.g., number of managed elements, heterogeneity, reliability), and the evolution of the network management area, it has become a common sense on the network management community the fact that, in general, distributed approaches are more suitable than centralized ones. For instance, during the meeting of the Network Management Research Group (NMRG) of the Internet Research Task Force (IRTF), in October 2006 [91], one of the main issues listed by researchers, vendors, and operators was the definition of new distributed approaches for network and service management. Below, the common distributed network management approaches are presented.

Mobile Agents. This approach enables the migration of the management code from the managers to the managed network elements. Mobile agents are able to execute an on-demand and customized distribution of the configuration and management programs [31, 98, 109].

Management by Delegation (MbD). Goldszmidt and Yemini [38] proposed this distributed network management approach. The key concept behind MbD is the employment of delegated-agents that are responsible for executing management tasks on the devices instead of bringing data from the devices to the network management platform-based applications. In this sense, delegation can be used to move management functions to the data rather than move data to these functions. Originally the management functions were customizable scripts, that were written in “ah doc” manners. Schönwälder et al. [90] introduced the employment of Management Information Base (MIB) [73] for the definition of such scripts, so called ScriptMIB. Based on MbD approach several investigations were developed [85, 101].

Policy Based Network Management (PBNM). The goal of policy-based management is to govern the behavior of a system based on the definition of high level policies [95]. One of the most accepted architecture for PBNM was defined by the Internet Engineering Task Force (IETF) [118]. This architecture is composed of four main components: policy tool, policy repository, Policy Decision Point (PDP), and Policy Enforcement Point (PEP). The policy tool is the administrator front-end from where the management policies are defined and edited, to be then stored in the policy repository for future use. When deploying a policy, the policy tool signs the PDPs to retrieve the policy from the repository and translate it to configuration commands on the PEPs (e.g., network interfaces, queuing disciplines) located inside the network devices. This approach has been employed in multiple network management scenarios [6, 119].

Multi-agents. According to Timm et al. [106] multi-agent systems are composed of heterogeneous agents that are generally self-motivated and act to fulfill internal goals, but may also share tasks with others. There is no global or centralized control mechanism and agents have to reason to co-ordinate their actions, plans, and knowledge. Such agents are also referred as intelligent agents [110]. In general, the employment of multi-agents enables the decomposition of network management tasks into sub-tasks that are executed by the agents spread along the network [66].

Peer-To-Peer. Since 2003, the use of P2P in network management solutions, also called as P2P-based Network Management, has been explored by several proposals [39, 97]. The major advantages of using this approach are the scalability, availability, reliability, and connectivity of the network management solutions. The details about the employment of P2P in network management are presented in Sect. 2.3.

In addition to the approaches listed above, there are technologies that contributed for the evolution and dissemination of distributed network management. Examples of distributed network solutions developed based on such technologies are: Web-based network management platforms [9]; CORBA-based solutions to enable distribution and remote invocation of management tasks [93]; and Web service-based network management used to enable interoperability among heterogeneous and distributed network solutions and compositions [77, 86, 112]. In fact, Web, CORBA, and Web services (WS) have become well established technologies employed in network management solutions. Furthermore, new emerging technologies and concepts (e.g., overlays [102], Mashups [15], and virtualization [116]) have been investigated in order to enhance the development of network management solutions.

Despite the diversity of approaches and technologies employed so far in network management, what remains is the feeling that the solutions developed so far are not able to properly fulfill the current needs on network and services management.

For example, mobile agents failed, according to Stadler [96], because at the time they were investigated the basis of Distributed Artificial Intelligence (DAI) area could not deliver important issues for the network management field (e.g., interdomain negotiations and failure detection). In contrast, MbD and PBNM became very popular approaches, but they suffer from scalability and reliability limitations. To overcome the problems of the earlier approaches, multi-agents (which are an evolution of research on DAI [117]) and P2P started to be investigated. They do have the potential to provide fully distributed solutions able to tackle the challenges of network and service management area. However, they were employed so far to build up management platforms and not management applications. In summary, the members of the NMRG of IRTF [91] highlighted that some of the desirable topics to be investigated on the design of future network and services management approaches are: fully distributed solutions (e.g., P2P); change the focus from data structures and protocols towards algorithms; increase the efforts on developing cooperative management solutions; and the investment of research on self-* technologies for network management.

2.1.2 Autonomic Computing and Self- Properties*

Since the first time that the term autonomic computing was used until now, many points of view and definitions were formulated [19, 54, 100]. In fact, there are no standardized definitions concerning the terms autonomic communications, self-management, and self-* properties. For example, Kephart's and Chess's vision of autonomic computing [54] omits the notion of communication. In contrast, Bouabene et al. [19] proposes an autonomic computing approach that explicitly considers communications.

The broadness of the term autonomic computing is also a topic of divergence. According to Dobson et al. [29], IEEE and other organizations employ this term to describe "the application of advanced technology on the management of advanced technology". Dobson et al. also listed examples of visions related to autonomic computing, such as organic computing [42], bio-inspired computing [26], self-organizing systems [3], autonomous and adaptive systems [61]. Indeed, the term autonomic computing on Dobson's et al. perspective encompasses all the aforementioned visions [29].

In the literature, there are some initiatives trying to organize the characteristics, concepts, and visions associated to autonomic computing. For example, Hariri et al. [43] and Lin et al. [65] described the characteristics of autonomic computing (both based on the original concept of Horn [45]). They identified eight characteristics associated with autonomic systems: self-awareness, self-protecting, self-optimizing, self-healing, self-configuring, context awareness, openness, and anticipation. Taking the aforementioned characteristics as a comparison basis, Lin et al. [65] presented a list of proposals with different autonomic computing definitions, and which kind of characteristics each one these proposals present. The resulting table shows that a different set of characteristic was covered by those proposals.

The diversity on autonomic computing is not restricted to its definition. Likewise, a different number of theories and technologies have been employed to develop autonomic solutions. Khalid et al. [55] proposed to aggregate the research work focusing on autonomic frameworks, architectures, and infrastructures into seven groups: (i) biologically inspired frameworks and architectures [7, 44], (ii) large scale distributed applications frameworks [84], (iii) frameworks using agent architecture [105], (iv) technique focused frameworks [11, 53], (v) component based frameworks [113], (vi) self-managed service oriented architecture [21], and (vii) infrastructure for injecting autonomicity into non-autonomous systems [56].

Khalid et al. [55] also identified two main design approaches that are followed by the autonomic, self-management proposals. The first one is the *Externalization Approach* where modules enabling self-management lie outside the managed system. The other one is the *Internalization Approach* where the self-management of the application is done inside the managed system. In the authors perspective, externalization approach is more effective because it uses separated modules to let the problem detection and resolution localized in such modules.

In addition to the general discussions about autonomic computing and self-management, there are specific communities developing their own ideas and definitions. For example, after several years of discussion, the network management community seems to be converging into a common understanding of what represent the terms autonomic computing systems and Autonomic Network Management Systems (ANMS). There are two works (one from Samaan and Karmouch [87], and the other from Huebscher and McCann [46]) defining autonomic computing, system, or behavior as a self-managed system presenting the self-CHOP properties, i.e., self-configuring, -healing, -optimizing, and -protection. Based on this autonomic computing description, Samaan and Karmouch [87] also defined the ANMS term as a network management system that employs the autonomic computing concept. Thus, an ANMS must perform management operations following the self-CHOP properties.

In fact, the network management community is depositing efforts on trying to define models, architectures and standards for developing autonomic communication systems. Examples of such efforts are proposals like Focale [100], Autonomic Network Architecture [19], CASCADAS [68], among others. However, none of those proposals has a large acceptance and is recognized as a 'de facto' standard. So, due to the lack of well-established terminologies, models, and architectures, it is possible to observe a proliferation of solutions for specific types of networks and purposes [10, 33, 126]. The investigations of autonomic or self-* solutions applied to network management are detailed in Sect. 2.2.

2.1.3 Peer-to-Peer

The term peer-to-peer (P2P) can be applied to several and distinct contexts. In fact, the analysis of the literature shows that the term P2P can be accompanied with words like system, application, infrastructure, overlay, and networks. According to Androutsellis-Theotokis and Spinellis "it is fair to say that there is not a general agreement on what 'is' and what 'is not' peer-to-peer" [8]. These authors attribute the lack of agreement to the fact that systems or applications are labeled peer-to-peer not because their internal behavior, but due to their external appearance. Despite the fuzzy definitions and terminologies associated with P2P technology, Androutsellis-Theotokis and Spinellis grouped these technologies into: P2P infrastructures and P2P applications [8]. They defined these groups considering only one kind of application, the P2P content distribution, which was the most popular and developed technology at the time their paper was published. However, over the years, other types of P2P technologies emerged. Investigating the literature it is possible to analyze and regroup such technologies as follows.

P2P infrastructures. Technologies developed to build underlying conditions and services to support applications. Examples of such conditions and services are: routing and location [25], reputation [89], topology management [2], performance [121], connectivity [49], security [51]. Some of the well-known P2P infrastructures are, for instance, JXTA [120], Pastry [17], and Chord [99].

P2P applications. In general, the proposals of this group are applications that make use of P2P infrastructures. Examples of current popular P2P applications are: file sharing [74]; multimedia streaming [13]; P2P Television (P2PTV) [4]; and searching documents and databases [63];

P2P infrastructures for specific applications. This group of technologies is comprised of investigations that present a very tight relationship between the P2P infrastructure and the application running on top of such infrastructure. Based on the analysis of the literature, it is possible to list some proposals belonging to this group, such as multiplayer games [111]; workflow [37]; Voice over IP (VoIP) [24]; and typical P2P applications such as file sharing [5] and multimedia [71].

Androutsellis-Theotokis and Spinellis [8] also classified P2P applications into five categories based on the purposes associated with the applications. The analysis of recent literature reveals that the definition of those categories is still valid. The five categories are described below.

Communication and collaboration. These applications usually focus on providing direct communication among peers (e.g., instant messaging applications like Google Talk [47]). The possibility of direct communication can enable collaborative behaviors.

Distributed computation. In this category, it is possible to find applications that need to compute massive tasks. For doing this, such applications break-down the tasks into small ones and distribute them among the available peers of the P2P infrastructure (e.g., Seti@Home [58], Rosetta@Home [60]).

Internet service support. This group is composed of applications that use P2P infrastructures to provide services like: video conference (e.g., Qnext [27]), telecommunication (e.g., Skype [64]), Web portals (e.g., Osiris [104]), streaming (e.g., PPLive [81]), among others.
Database systems. The applications of this group are able to use the P2P infrastructure as a database system, instead of a traditional central repository [12].
Content distribution. This is the most popular category of applications. In this case, files are spread along the P2P infrastructure and can be accessed through file sharing or content distribution application (e.g., Mininova [75], eMule [103]).

Some of the major contributions of P2P for the society and for the research community are related to the variety of applications that can be developed exploring (i) the features introduced by P2P infrastructure (e.g., scalability, robustness, and reliability); and (ii) the design concepts behind the P2P applications (e.g., distributed algorithms, collaboration on executing a task, sharing information, decentralization of decisions). Encouraged by the features and design concepts introduced by P2P approaches, the network management community started to explore those approaches on their solutions. The discussion about the use of P2P on network management solutions is described in Sect. 2.3.

2.2 Autonomic Computing and Network Management

The research developed on autonomic computing and self-* properties (or self-star) applied to network management can be divided in two major groups. The first one comprises high level architectures and the second group is related to specific networks, services, and management tasks.

Architectural Approaches. The investigation of architectural approaches for autonomic network management can be divided into two groups. The first one is related to proposals in the context of projects and the second one comprises individual attempts. Some of the main projects devoted to build autonomic network management architectures are described below.

Foundation Observation Comparison Action Learn rEason (*FOCALE*) is an autonomic network management approach that is meant to be built on top of the current established network management environments. The basis of FOCALE are ontologies, policies, and context-aware mechanisms to provide self-knowledge for the autonomic system [100]. FOCALE employs distribution and two control loops: a maintenance control loop and an adjustment control loop.
BIOlogically inspired NETwork and Services (*BIONETS*) project is devoted to address pervasive computing and communication environments. According to Carreras et al. [22], BIONETs is inspired on living world science to deal with the problems of scale, complexity, and diversity for a rather long time. Based on this, a network looks like a living ecosystem, where services play the role

of organisms, evolving and combining themselves to adapt to the environmental characteristics (e.g., network topology, service dynamics).

Autonomic Network Architecture (*ANA*) is a project whose main objective is to enable networks to scale in size and functionalities. Jelger et al. [48] presented the principles of ANA architecture, and different from traditional approaches, ANA considers that heterogeneity is a basic element of the network. This architecture provides manners to make the network adapts itself to deal with heterogeneous styles and demands.

Component-ware for Autonomic, Situation-aware Communications, And Dynamically Adaptable Services (*CASCADAS*) is an IST project aiming at developing and validating an autonomic framework for creating, executing, and provisioning situation-aware and dynamically adaptable communication services. According to Manzalini et al. [69] the development activities of the project are focused on prototyping a toolkit based on distributed self-similar components characterized by self-* properties.

Autonomic Internet (*AUTOI*) is an European project devoted to investigate the Future Internet, and the main challenge is change from a service agnostic Internet to a service-aware network where autonomic principles are applied for managing the virtual resources. According to Galis et al. [36], AUTOI management system is designed to achieve the following functionalities: embedded network functions, aware and self-aware functions, adaptive and self-adaptive functions, automatic self-functions, extensibility functions, and outlay functions.

4WARD is an European project that aims at investigating a clean slate approach for the Future Internet. This project defined a management paradigm called In-Network Management (INM), whose main goal is to embed self-management capabilities deep inside the network nodes. According to Prieto et al. [82] the INM approach is related to autonomic computing in two ways: the management plane inside the network is self-organizing and exhibits autonomic behavior; and the functions that the management plane offers are either autonomic themselves or building blocks for autonomic management functions.

Self-Management of Cognitive Future InterNET Elements (*Self-NET*) is an European project devoted to investigate the designs and prototypes of the Future Internet throughout the employment of self-management and use of cognitive functionalities. According to Kousaridas et al. [59] Self-NET proposes a generic cognitive cycle model that is composed of monitoring, decision, and execution process. Moreover, the authors proposed a distributed execution of this cycle model which happens to introduce a certain level of orchestration among the monitor, decision, and execution elements of their architecture.

In addition to the aforementioned projects, there are many other initiatives trying to develop autonomic networks and autonomic network management solutions, such as EFIPSANS [32], Autonomia [30], AutoMate [1]. Besides the investigations conducted in the context of projects, there are also independent investigations devoted to create architectural approaches for bringing together autonomic computing/self-* properties and network management [10, 83, 108]. Despite the general concepts and high level architectures, there are several initiatives using autonomic or self-* properties directly defined to specific networks or management tasks. The next section describes some of these initiatives.

Specific Solutions. The analysis of the literature has presented an increasing number of proposals relating autonomic computing and self-* properties to specific network management scenarios and tasks. In this section, these proposals are organized into two groups: oriented to a specific network and oriented to specific management tasks.

- *Proposals Oriented to a Specific Network.* Wireless network community is heavily using self-* properties to solve their management problems. Given the dynamic nature of wireless networks, and the inability of managing this environment in a manual fashion, the research developed for these kind of networks has been exploiting self-* and autonomic concepts. It is possible to find autonomic solutions in a very large range of wireless networks. For example: frameworks for Wireless Sensor Network applications [18], context-aware policies to adapt Mobile ad hoc networks (MANETs) [67], autonomic architecture to autonomously configure accesses points in 4G systems [28], autonomic distributed solution for the management of base stations of Wireless Local Area Networks (WLAN) [92], and self-managed pervasive service middleware [124].
- *Proposals Oriented to Specific Management Tasks.* In the literature, there are several proposals of employing autonomic and self-* properties to design different types of management tasks. Some of these proposals focus, for instance, in: self-organizing management system for core networks [107], combined self-* aspects and monitoring techniques to build a traffic self-monitoring system [23], self-organizing coordination service [113], infrastructure for dynamic deployment and self-configuration of services belonging to an overlay [88], and self-organizing techniques on server virtualization scenarios [115].

The initiatives presented in this section reveals how much the concepts of autonomic computing and self-* properties span across network management discipline. The influence of those concepts is present from network systems with very restricted conditions (e.g., wireless sensor networks) until very abstract environments (e.g., virtual networks and Service Overlay Networks (SONs)). Moreover, the current amount of projects and the diversity of architectural proposals also indicates that the research in autonomic network management is in expansion and tends to become a "de facto" alternative of network management.

2.3 Employment of P2P on Network Management

In the same way that there are no general agreement about P2P definitions, there are no standard terminology, techniques, and directives of how P2P can be employed on network management discipline. Thus, considering that there are different groups of

P2P technologies, and different purposes on building P2P applications, it is possible to conclude that the employment of P2P on network management solutions can assume distinct forms. Therefore, the objective of this section is to characterize which are the current ways of developing P2P-based network management solutions. To achieve this objective, the main proposals found in the literature are analyzed and compared to the features of groups of P2P technologies and categories of P2P applications presented in Sect. 2.1.3. The conclusion of this comparison is that current P2P-based network management proposals can be organized into two groups. The main criterion for grouping such proposals is the common characteristics explored by the P2P approach and the type of network management tasks employed. The groups are presented as follows.

P2P infrastructure to support general purpose management platforms. This group of proposals is characterized by general purpose P2P-based network management systems. The remarkable feature is the employment of the P2P infrastructures (mainly routing, location, and connectivity P2P infrastructures) to enable a more flexible deployment of a network management system. Examples of initiatives in this group are presented below.

State and Festor [97] defined a P2P infrastructure based on JXTA [39]. The management system explores the advertising messages of JXTA as a manner of exposing the management API of the managed elements to all peers that are part of the P2P management system. In this case, the manager/agent approach is maintained, and through the P2P infrastructure the manager can access the Java Management Extensions (JMX) management agents.

Granville et al. [40] employed both P2P infrastructures and P2P applications to enhance the traditional Management by Delegation (MbD) approach. P2P infrastructure is used to provide the connectivity abstractions, routing, and cross domain communications, while P2P applications, like file sharing and instant messaging, are used to support the human interaction among teams of administrators of their approach. The authors defined a MbD infrastructure composed of Top Level Managers (TLM), Middle Level Managers (MLM), and agents [79]. TLMs are able to use the P2P applications available on the management system to enable the human collaboration. MLMs are responsible for executing the management tasks by contacting the agents. Inspired by the aforementioned work, Fiorese et al. [34] focused their proposal on enhancing the connectivity among TLMs and MLMs by investigating the location issues of P2P infrastructures.

Barsham et al. [14] also followed the strategy of joining P2P infrastructure with MbD. In the case of the work proposed by these authors, a 3-tier hierarchy of peers is composed of TLM, MLM, and Lower level Managers (LLM). The focus of their research is to provide fault tolerance for a P2P-based MbD approach.

Kamienski et al. [52] used P2P infrastructure to provide a better support on the management of policies. The authors kept the same hierarchical concept behind the Policy-based Network Management approach. However, instead of using a Policy Decision Point (PDP), they used Policy Decision Nodes interconnected by a Distributed Hash Table (DHT) network. Through the DHT it was possible to reach and change the policies. In this sense, the P2P infrastructure is used to enable the dissemination of policies inside the management system. The authors aim at providing scalability and fault tolerance for the network management system.

P2P infrastructure to provide specific management solutions. This group comprises the initiatives where P2P is used to solve some specific management tasks and situations. Examples of such initiatives are listed below.

Yalagandula et al. [122] designed a sensing information management backplane that, among other techniques and technologies, employed DHTs algorithms to aggregate and disseminate network and node status information. Web services are used to enable the composition and aggregation of monitored information, and a P2P infrastructure created by the DHTs and overlays is used to expose the WS interfaces and the monitored information. In this context, P2P is used as the main infrastructure to support scalable dissemination of monitored information, and location of the services of the management system.

Zhou and van Renesse [125] employed a structured P2P infrastructure (by using DHT algorithms) for helping on the maintenance of connectivity information about IPv6 and IPv4 networks. The authors established that the core network will keep being IPv4, while the edges will be IPv6 networks. To solve the connectivity problem, the authors proposed that egress gateways from IPv4 networks use DHTs in order to keep routing tables with information able to handle the mapping between the two types of networks. Leng et al. [62] also proposed a P2P infrastructure to address the connectivity problem between IPv4 and IPv6 networks. In this work an unstructured P2P network was used to distribute Tunnel End Point (TEP) information among the IPv4 gateways. Analyzing both proposals, in the light of P2P technologies, it is possible to say that the authors used P2P infrastructures in order to build a content distribution application to disseminate routing information and enhance the connectivity between end points.

The predominant feature on the proposals analyzed above is the employment of P2P infrastructures to enhance the underlying conditions of the network management systems. Very few initiatives use the concepts behind the P2P applications in order to enhance the execution of the network management task itself. During the analysis of the works described above, it was recurrently mentioned the cooperation among the peers of the P2P-based network management infrastructure. However, it is was never clear what exactly the authors meant with the term cooperation. In most of the cases, this term indicated a connectivity relation between the peers rather than a joint operation to solve a problem. Indeed, the literature shows that P2P infrastructures are being well explored to build network management infrastructures, while management applications keep on being developed following traditional hierarchical network management approaches.

2.4 Autonomic/Self-*, Peer-to-Peer, and Network Management

As presented in the previous sections, there are several proposals joining autonomic or self-* properties and network management, as well as, P2P and network management. Nevertheless, when all these topics (i.e., autonomic/self-*, P2P, and network management) are put together it is possible to observe that there are no clear proposals fully merging those topics. For example, Prieto et al. [82] and Franzke et al. [35] mentioned that nodes of INM approach (in 4WARD Project) would follow a P2P interaction model. However, no precise details and definition were described relating self-* properties and P2P for executing the in-network management defended by the authors. The same lack of clear definition, related to the employment of the three topics, happens to the proposal presented in BIONETs project [22, 76]. Some of the few initiatives joining autonomic/self-* and P2P techniques for network management are described and analyzed as follows.

Binzenhöfer et al. [16] employed P2P overlays to address fault and performance management. Their architecture aims at providing generic connectivity tests and Quality of Service (QoS) monitoring in a distributed and self-organized system that is based on the Distributed Network Agents (DNAs) [50]. The distributed infrastructure is achieved by the employment of overlays formed by structured P2P networks (using DHTs) on top of the monitored network. In this sense, groups of DNAs composing a DHT are able to communicate to: exchange monitoring information; and ask for other DNAs to execute tests on the monitored network in order to find eventual failures. The self-organizing property is related to the maintenance of the distinct overlays that might be defined during the execution of this environment [50]. In this sense, the self-* property is not directly related to the network management task being executed (i.e., monitoring and QoS tests) but it is related to the maintenance of the P2P overlays. In addition, the authors described that the decision of which peer will belong to a monitoring/testing overlay is given by random choice or by human definition [16]. This description emphasizes that the management task being executed does not reveal a truly self-organizing behavior. An example of self-organizing behavior would be the management P2P overlay itself discovered which are the suitable peers to form and execute a monitoring or test request.

Brunner et al. [20] proposed the Ambient Network (AN) concept that is based on the composition of different networks in order to gain connectivity. The authors suggested that a P2P-based network management approach could be able to handle the network compositions of the AN concept in two manners. One manner is related to the topological composition between management systems of ANs, and the second is associated to the creation of the connectivity conditions required to compose two ANs. In this case, P2P technology is used for the maintenance of the hierarchical management overlay, and for pooling and sharing management information within and across heterogeneous composed networks. Simon et al. [94] detailed the employment of P2P approach to enable the composition of ANs. It is not discussed on both works how the management tasks running inside the composed networks should exactly work. Apparently, the management tasks would be executed in an hierarchical fashion, where super peers (i.e., managers) request for peers (i.e., agents) the execution of some task. So, P2P technology is used to support the connectivity across domains, provide scalability of the network management system, and disseminate information. Besides the employment of P2P, self-management is also incorporated in Ambient Networks. Mathieu et al. [72] proposed the self-management of contexts associated to the overlays of AN. The authors defined the Service-aware Adaptive Transport

Overlays (SATOs) for ANs. A SATO is created for delivering a certain requested service. The self-management of SATOs is accomplished throughout the collection of distributed context associated to users and networks, and the assignment of dedicated nodes to analyze the collected information. Based on this information, SATOs can be deployed and adapted. Analyzing the works related to AN, above listed, it is possible to identify that there is not a clear and direct connection between P2P and self-management devoted to constitute a management solution for the Ambient Network concept. The presence of P2P is very strong on the management of ANs, however, self-management is more related to the users perspective, rather than to the management of ANs.

Fallon et al. [33] employs a P2P approach to self-form network management topologies targeted to accomplish specific network management tasks. A hierarchical model based on Network Elements (NE) is employed. The NEs are grouped into clusters, and these clusters form P2P overlays that can be arranged hierarchically according to the requirements of the management task to be executed. One conclusion that is possible to be inferred from this work is the fact that the cooperation among the NEs performing a management task is not provided by their proposal, solely the connectivity of such NEs is provided (i.e., the arrangement of the NEs in an overlay). The self-forming property is associated to the process of preparing the network management infrastructure. Based on parameters associated to the NEs, the clusters are formed, maintained, and self-optimized in the presence of changes. The parameters can be changed dynamically by direct operator intervention, automatically using policies, and because of changes on the network status [33]. Analyzing the proposed work it is easy to distinguish the relationship between the self-* properties and the P2P management overlay. In the same way, it is possible to identify the integration between the management overlay and the execution of a management task. However, it is not easy to understand the influence of the self-* properties on the execution of the network management task. Indeed, at a first glance, the network management task, considered by the authors, is modeled taking into account the cooperation provided by the P2P management overlay, but no self-* properties are considered to be part of the network management task.

Besides the initiatives presented here, there are other proposals concerning the joint use of self-* and P2P and/or overlay [3, 114]. However, those proposals are not directly related to network management, but they address the management of the P2P and/or overlay network itself. Therefore, this book aims at bringing knowledge to issues involving the joint use of self-* properties and P2P to contribute with the development of an alternative for designing network management task solutions.

2.5 Summary

This chapter presents an overview of the state of the art regarding network management, autonomic computing, peer-to-peer, and the relationship among these three research areas. First, the discussion about network management approaches available in the literature is presented. Analyzing the discussion and the output of them it is possible to verify the majority presence of distributed network management approaches, and the indication by the NMRG-IRTF that more investigations are necessary on this area. Indeed, the research community understands, as a common sense, that distributed solutions are more suitable to handle the current scenarios where network management is employed. In the sequence, a review of the definitions associated with autonomic computing and the current research status of P2P is presented. Some of the main architectural approaches for autonomic and network management are presented as well as some individual initiatives to develop self-* properties applied to network management. The diversity of contexts and areas is one of the characteristics of research on autonomic network management. Considering the P2P scope, this chapter presents the types of investigations and how they are related to network management, and once again, the broadness of the solutions is a remarkable feature. This chapter is closed with the discussion about the proposals related to: autonomic or self-* properties applied to network management; P2P employment on network management; and finally the combination of autonomic or self-* properties and P2P on network management.

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