Introduction

The Internet network is a difficult network to control because of its initial design where only one service class exists: the *best effort* service, which requires the network to do the best it can for all the users. It is an excellent solution for keeping the connection costs low since control is done at the terminal machine, PC or other mobile terminal level.

On the other hand, for land or mobile users, the Internet network is not always the most convenient solution. In fact, each network application must be able to move data packets with a quality of service which guarantees an adequate performance for the application. In order to achieve this, innovations in the last few years have made routers and network protocols more complicated by introducing, for example, priorities between the different moving flows. The main disadvantage is the increase in network complexity thus making it harder to manage and control. Furthermore, the optimization of network resources based on user requirements is not well managed, thus leading to a waste of network resources which can become costly.

After the propositions failed to introduce quality of service to users at a reasonable cost, network research specialists have focused on new opportunities in order to go back to end control for quality of service and to optimize network resources. In addition, newly implemented technologies are also designed to guarantee communication security and user mobility management.

At this point, these new technologies mainly come from the artificial intelligence world. This research leads to the emergence of a whole environment of intelligent software entities within an architecture that is adaptable to a particular context and environment. We use the term “intelligence” to recall the adaptation capacity shown

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by an entity. An intelligent entity is then an entity which is able to adapt to a context, to a particular environment and/or to events that may never have been encountered.

This research is an extreme innovation at present but it is difficult to implement because it calls for competences coming from both the networking and artificial intelligence worlds. The pairing of these two domains will lead to:

– a dynamic and intelligent control of local equipment;

– a global control of the network in a cooperative way;

– a more autonomous network management;

– a better guarantee of end-to-end quality of service.

The technology used, on which these new adaptable and even autonomous networks are based, mainly comes from new research on intelligent agents and multi-agent systems. This technology is tested today in widely diverse areas: computer-aided design, social behavioral simulation, intelligent management of distributed systems, image recognition, etc. This research has demonstrated the efficiency, reliability and robustness of multi-agent systems for the dynamic control of complex and distributed systems. IP network infrastructures now appear as a natural application domain for software agents in general and particularly for cooperative software agents. Despite the hesitations from certain players in the field, this technology is slowly finding its place in telecommunication networks.

Multi-agent technology is an innovation of the last 10 years emerging from several research fields: symbolic artificial intelligence, the theory of control and distributed artificial intelligence. The quick development of this technology is due to the necessity for new solutions and new mechanisms to resolve complex problems. This technology is slowly becoming key as computer systems increasingly become distributed, interconnected and open. In such environments, the capacity of software agents to plan their actions and goals, to cooperate and negotiate autonomously with others, and their capacity to respond in a flexible and intelligent way to dynamic and unpredictable situations will help to reach a significant improvement in the quality and performance of software systems.

The final challenge of all these studies is to make the network completely autonomous.

This book is designed to show the different aspects that the research conducted has uncovered until now in order to reach this ultimate goal of autonomy. The

different integration studies conducted have mainly focused on the management and control aspects in the IP network field, whether wireless or not.

Chapter 1 gives an overview of network management and monitoring aspects and of artificial intelligence techniques and control which may be considered in this context. The evolution from expert systems to mobile agents via multi-agent systems is presented briefly.

The first form of intelligence integrated to the network, although not directly based on artificial intelligence concepts, is addressed in Chapter 2 through the notion of active networks. The active network is used here to reach an active control of the quality of service in an IP environment and thus ensure an adaptive management.

Chapter 3 explains in more detail the concepts of Chapter 1 on agent aspects and their adequacy in dealing with the problem discussed after putting an emphasis on IP management problems. The possible applications for artificial intelligence-network pairing are also addressed: simulation, quality of service, continuity of services, congestion control, monitoring, topology maps or routing.

Chapter 4 presents an advanced approach in terms of wired or wireless network management called policy-based management. The use of intelligent agents in this context is discussed. A new application is highlighted, i.e. the service contract negotiation between a client (mobile or not) and a service provider, and between two service providers.

From Chapter 5 onwards, the agent concept based on artificial intelligence is enhanced by multi-agent systems and associated platforms. Their evaluations, which are often considered as the weak point of these systems, are addressed.

Chapters 6, 7, 8 and 9 together form a coherent group of studies conducted in the LIP6 laboratory of UPMC (University of Paris 6) and at LM2S of UTT (University of Technology, Troyes) among others. Advanced research on artificial intelligence has been conducted particularly in behavioral management (behavior based on human behavior) from DiffServ network elements (nodes, routers, etc.). This research has been able to prove that the use of intelligent agents in the analysis and management of DiffServ networks enables us to understand failures in a more precise way and thus to be able to significantly optimize these networks (Chapters 6 and 7).

Research projects have mainly focused on the multi-agent simulation of IP networks and have led to the creation of a simulator which makes it possible to analyze networks that support DiffServ QoS and intelligent agents. This piece of software can simulate any type of model (network or not) and, although it is still new, it has serious advantages (changing parameters during simulation, portability, reliability) which ensure an ongoing research as well as its use in the industrial field (Chapters 8 and 9).

The advantage of this technology is the consideration of active elements leading to the operation of networks. All the parameters can dynamically change in time and space. These new parameters have never been considered in a modeling, simulation and control context before.

Chapter 10 addresses a particularly crucial problem that is the management of mobility in the 3rd and 4th generation. Here again the use of agents in this context brings significant added value, particularly in the VHE (virtual home environment) domain.

Chapter 11 completes the previous chapter by integrating the concept of learning within the problem of dynamic allocation of radio resources, which are particularly expensive and therefore are imperative to optimize. Learning is without a doubt the ultimate intelligence step since it is this step that will enable the systems concerned to adapt to an environment and to be able to attain the concept of autonomy.

Finally, Chapter 12 somewhat integrates the different aspects discussed throughout this book and presents a possible example of architecture which combines concepts of management and control, of policy-based management, of active network and of mobile code in a DiffServ environment thus leading to an automation of the different control points.

All the studies presented in this book mark a step in the research conducted on embedded intelligence in a telecommunication network environment. The ultimate step will lead to an autonomous network, which is considered as one of the most important undertakings for the next 10 years in terms of telecommunications. Even though the main activity is currently in research, we should still mention the emergence of the first start-up (Ginkgo Networks) devoted to the autonomy of agent networks at the end of December 2004.