2nd Hellenic Conf. on AI, SETN-2002, 11-12 April 2002, Thessaloniki, Greece,
Proceedings, Companion Volume, pp. 451-462

Designing Agents with Multi-attribute Preference Models for Intelligent Telecommunication Services

Nikos Manouselis, Demetrios Sampson[1]

Advanced eServices for the Knowledge Society Research Unit
Informatics and Telematics Institute (I.T.I.)
Center for Research and Technology – Hellas (CE.R.T.H.)
Kyvernidou 1, 546 39 Thessaloniki, Greece
Tel: +30 31 868324 int. 214
Fax: +30 31 868324 int. 213
{nikosm, sampson}@iti.gr

Abstract. In this paper, we present a multi-criteria decision aid methodology optimizing the performance of Service Provider Agents in a Virtual Private Network, according to the Specifications posed by the Foundation for Intelligent Physical Agents (FIPA). We enhance the basic protocol steps for a service brokering procedure, and apply the methodology to a specific case of Network Providers: the Internet radio services providers.

1 Introduction

In order to be competitive, telecommunication service providers need new technologies that facilitate the rapid introduction of services in a cost-effective manner. Services engineering is a new discipline in which the telecommunications sector addresses the technologies and engineering processes required for service creation [10]. Across the world, numerous telecommunication service providers combine service elements from different network providers in order to provide a single service to end customers. The ultimate goal of all parties involved is to find the best solutions available in terms of quality of service and cost. The increasing demand for on-line customer configurable services and on-line provisioning of services requires systems and networks that are capable of co-operating on different levels and that transcend conventional business and national boundaries. The application of intelligent agents to the complex domain of telecommunications management networks is gaining greater recognition as multi-agent systems offer a variety of advantages over traditional software architectures. Network technologies and customer requirements are rapidly changing, and approaches based on agents' intelligence and cooperation are well suited to keeping pace with these dynamic situations [8].

---

[1] Corresponding author

Telecommunications infrastructures are a natural application domain for the distributed software agent paradigm. Telecommunications management control centers employ sophisticated techniques to aid decision making on how the network should be configured and operate [20]. Hayzelden and Bigham [17] provide an extended overview of the application of agent technologies in several sections of the telecommunications domain. Interesting applications include Cooperative Problem Solving for Network Management [26], HYBRID [25], Management by Delegation [14,15], Service Management [3], Tele-MACS [16], IMMuNe [9], and under the Advanced Communication Technologies and Services (ACTS-http://www.focus.gmd.de/research/cc/ima/acts-d5-ac/) set of projects, IMPACT [2], ABROSE [1], FACTS [5] and MARINER [22]. The development and provision of harmonized Europe-wide public telecommunication networks and services by furthering science and research in the field of information and communication technologies is supported by EURESCOM, with several projects addressing problems associated with highly customized multimedia and mobile services and new concepts for effective network and service management, from an agent-based view. More information can be found at [4]. There are also several economic-based approaches to network management and resource allocation, like the *agoric* system of [23], and the work of Kuwabara *et al.* [19] and Gibney and Jennings [11,12]. Most of the above projects give solid results regarding the communication infrastructures of agent-based systems, and provide the necessary dynamic architectural models to study and propose advanced personalized services and support user mobility (the mobile agents paradigm is extendedly applied – see [10,17] for details).

The dynamic Virtual Private Network (VPN) service is a telecommunications service provided to users that want to set up a multimedia connection with several other users. Traditional network management frameworks are based upon fixed management functionality and fixed interaction interfaces that cannot easily satisfy the flexibility and complexity that the dynamic multimedia VPN service demands. Agent technology is very promising in this domain since it facilitates automatic negotiation of service contracts and subsequent configuration of those services, thus enhancing the provisioning process for both users and administrators of dynamic multimedia VPN services.

The Foundation for Intelligent Physical Agents (FIPA – www.fipa.org) was formed in 1996 to produce software standards for heterogeneous and interacting agents and agent-based systems. FIPA provides a fully detailed analysis and design of a VPN agent-based system for network management and provisioning [7]. This specification includes all parameters necessary for the implementation and provisioning of telecommunication services based on VPNs, and has significant advantages in this context. In this paper, we introduce a methodology for equipping FIPA specified agents with advanced personalization services for their users. Using techniques and methods from Multi-Criteria Decision Making (MCDM) we enrich the Decision Making modules of the agents in a way that they provide:

1. Multi-attribute description of the offered services, and methods for calculating and selecting the service provider that maximizes a total utility measure;
2. Tools for multi-issue negotiation on services described by multiple attributes;

3. Dynamic multi-attribute preference models that aid in real-time re-configuring the provided services, in order to meet with user specific needs and desires; and
4. Advanced level of personalization since each user expresses preferences upon qualitative criteria, which describe a service apart from the quantitative ones.

This paper is organized as it follows: Section 2 presents the system roles and functionalities of an agent-based VPN, and focuses on the communication protocols between these roles; in Section 3 the methodology for enhancing the protocols with multi-attribute preference models is introduced, and in Section 4 an application of the methodology in the case of Internet radio service providers is studied; finally, in Section 5 some conclusions are stated.

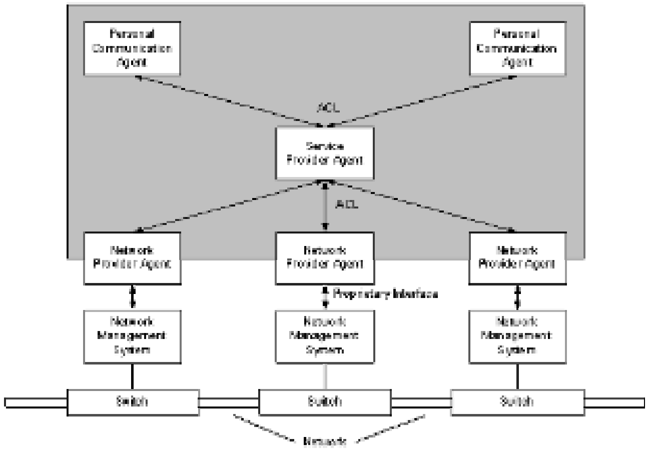

Fig. 1. Virtual Public Network Multimedia Service Reference Model (source: FIPA)

2 System Analysis

The VPN service provides a virtual private network over which multimedia applications can be executed. Virtual Private Networks allow any valid remote user to become part of a corporate central network, using the same network scheme and addressing as users on this central network. Each corporate central network can also be responsible for validating their own users, despite the fact that they are actually dialing into a public network. The VPN service is constructed, maintained and delivered using specialized co-operating and negotiating agents [7]. For actual multimedia systems provisioning the VPN service, three types of agents are used that represent the interests of the different parties involved, according to the specifications imposed by FIPA (Figure 1): a Personal Communications Agent (PCA) that represents the interests of the human users, a Service Provider Agent (SPA) that represents the interests of the service provider, and a Network Provider Agent (NPA) that represents the interests of the network provider. According to the specifications mentioned before, a standard scenario is the following:

1. The VPN service is established by the user who requests the service from their PCA, stating their requirements including the desired quality of service, cost constraints and duration.
2. The initiating PCA negotiates with other PCA's to arrange preliminary conditions such as a time to start the service and terminal details; these initial communications will occur prior to the establishment of the VPN service using traditional network resources, such as the Internet.
3. The initiating PCA will then negotiate with available SPA's to obtain the best service offer available and the SPA will in turn negotiate with NPA's to obtain the optimal solution and to configure the service at the network level.
4. Both SPA's and NPA's communicate with underlying service and network management systems to configure the networks for the service.

The following parties are involved in the provisioning of the dynamic VPN service and use their own negotiation strategies to meet their internal goals (neither of which will necessarily be publicly known):

User. The initiating user will negotiate with a service provider about the terms and conditions of the service to be provided at minimum cost. The receiving user will get a notification from the network provider that his participation is required in the VPN service when it has been established.
Service Provider. The service provider will negotiate with the user about terms and conditions as stated above. The service provider will also negotiate with its network provider in order to find the optimal solution for the provisioning of the service to the customer since the service provider has an interest in maximising its profit.
Network Provider. The network provider will negotiate with the service provider about terms and conditions as stated above and will also negotiate with other network providers for parts of the connection it cannot deliver itself or that can be offered more cheaply than the network provider can deliver since the network provider has an interest in maximising its profit. The network provider will notify the receiving customers that their participation is required once the VPN service has been established.

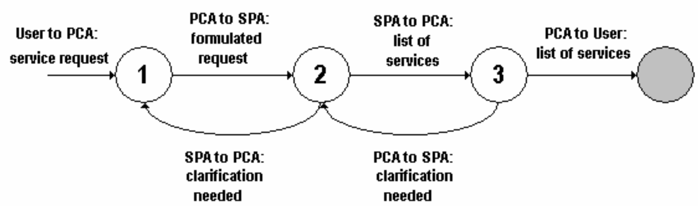

Fig. 2. The simple protocol for service brokering in a state diagram form

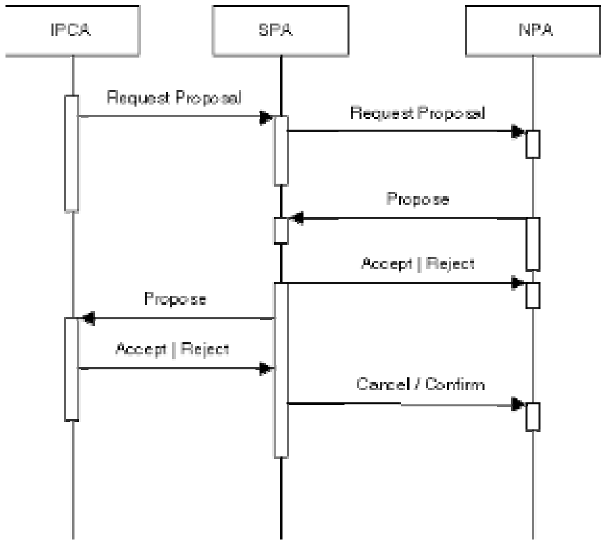

Fig. 3. FIPA Contract Net Protocol (source FIPA)

Let us assume the agent-based system of Figure 1 and a usual brokering procedure [13]. When ready to make a request, the user wants to know all the relevant network providers. The protocol between the PCA and the SPA is given in the sequence below. We suppose that a relevant network provider for the initial request exists in the system and that the user does not know this provider. The brokering steps (Figure 2) are:

1. The user request a service from the PCA.
2. The PCA formulates suitably the request and then forwards it to the SPA.
3. The SPA communicates with the relevant NPAs and accepts offers.
4. The SPA send the list of relevant offers to the PCA.
5. The PCA formulates the list and presents it to the user.
6. The user selects the desired service.

The basic Contract Net [6] service delegation protocol followed between the PCA and the SPA is illustrated in Figure 3. This is not the case of the usual Contract Net because the request-proposal is not multicasted. The general idea is to make a call-for-proposals and then select one proposal. When an agent makes a proposal, it commits to achieve its proposal if it is accepted. In this paper we focus on the construction of the messages (that is the message content and ontology) is such a way that these interactions can be enhanced with multi-attribute preference models, optimizing thus performance and providing personalization. We will describe how this is achieved in the following section.

3 Multi-Attribute Utility Modeling

In order to apply the described method in the specific case under study of Section 4, let us introduce the basic concepts of multi-attribute preference modeling. The general methodology of decision-making problems includes four modeling steps [24], beginning with the definition of the object of the decision and ending with the activity of decision aid. Most of the times the multi-attribute models used are simplified, since the parameters concerning the service are quantitative. In telecommunication services brokering though, existence of various different search parameters poses the need for engaging and handling more complex preference models.

Let us now examine the way such a complex model is constructed [18]. In multi-criteria analysis the set A of potential actions or decisions are analyzed in terms of multiple criteria, in order to model all the possible attributes related to the set A. The clarification of the decision maker's global preferences necessitates the use of a reference set of actions A_R. Usually, this set is: (a) a set of past decision alternatives, (b) a subset of decision actions -especially when A is large- or, (c) a set of fictitious actions consisting of performances on the criteria, which can be easily judged by the decision maker to perform global comparisons. In each of the above cases the decision maker is asked to express his global preferences on set A_R taking into consideration the performances (evaluations) of the reference actions in A_R on all criteria. When we want to model the behavior of the user, we use this previous experience (expressed by the evaluations on the actions in the reference set A_R) in order to predict the evaluations the actions belonging in the real set A.

There are several issues to be addressed when enhancing the Decision Making modules of agents with multi-attribute modeling capabilities. First of all proper ontologies have to be defined, in order for the agents to identify whether the message arriving refers to a "preference" as a single parameter function, or a multiple parameters one. This requires redefinition of all the message contents (even if the messages flow remains untouched (see Figure 3); that is, new languages must be defined for the interacting agents. It is strictly application dependent how these issues are resolved, and beyond the scope of this paper; nevertheless, these are technical matters that have to be successfully solved if such MCDM methodologies are to be engaged by artificial agents.

In order to equip the SPA with a multi-attribute preference model of the user, firstly the preference model of the user is constructed throughout an appropriate procedure [21]; then the brokering procedure takes the following form (Figure 4):

1. The user requests a service from the PCA.
2. The PCA sends a message, which includes the request and the preference model of the user to the SPA.
3. The SPA communicates with the relevant NPA's and uses the preference model to filter the list.
4. The SPA sends the list of proposed services to the PCA.
5. The PCA evaluates each offer using the preference model of the user, and filters the list of offers again.
6. The PCA formulates properly the list of NPA's and presents it to the user.

7. The user selects the desired service.

We should note here that we are mostly concerned with the PCA and SPA interactions. Similar protocols are applied in the SPA and NPA interactions, but describing them in detail is beyond the scope of this paper.

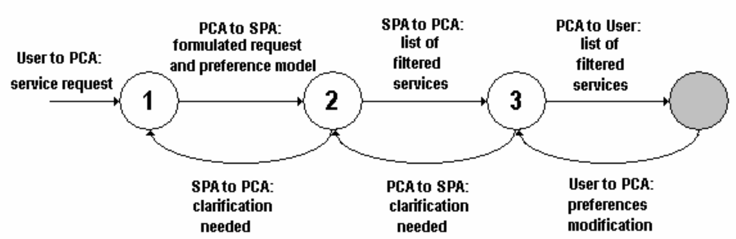

Fig. 4. The service brokering protocol, enhanced with user preference modeling.

4 A Simple Scenario

Let us assume the case of the Internet radio listener. This user is using his personal computer to access the World-Wide Web and to select one or more of radio stations broadcasting through the Internet. The major service brokering problems to be encountered in such a case, are the following:

- Finding a radio station offering a broadcasted program that matches the preferences of the listener.
- Finding a radio station offering a broadcasted signal that complies with the technical specifications defined by the listener, e.g., location, quality of signal, number of maximum connected users, etc.
- Monitoring any changes of the preferences of the user and reformulating accordingly the service brokering parameters.

The problem is modeled according to the methodology described in Section 3. Each service (radio station) will be evaluated on six criteria. In order to demonstrate the difference between the two brokering stages (i.e., the simple one and the one including a negotiation process), we define two different sets of criteria, which will allow us to demonstrate the negotiation capabilities of the protocol. In this simple scenario we do not bother for the consistency of the modeling process, since we want to focus on the way this multi-attribute modeling assists the service brokering process. So let us assume that the criteria g_1, g_2, g_3, g_4, g_5 and g_6 totally describe a radio station (Table 1). Criteria g_1 to g_4 construct the qualitative preference model of the user, whereas g_5 and

g_6 are the criteria the SPA will engage in order to select the appropriate NPAs. In order to simplify the modeling process even more, let us also assume that the descriptors of the musical content of the broadcasted signal can be described by simple one-word constraints (that is one ore more words belonging to a set of musical content descriptors, such as ["Rock", "Pop", "Disco",…]). These constraints are not included in the multi-attribute model, but applied as preliminary search constraints used by the SPA. The point in such a "flexible" search parameters modeling is to clearly demonstrate that multi-attribute preference modeling is a fast and reliable brokering tool which can act in a complementary fashion to the classical brokering procedures.

The reference set A_R on which the radio listener under study will express the first evaluation is depicted in Table 2. Let us follow now the steps of the procedure described in the previous Section. First, the preference model of the specific listener has to be constructed [21] by following the steps given below:

1. The user indicates his area of interest to his PCA ("I'm searching for radio stations").
2. The PCA requires from the SPA a reference set of similar services ("Which are the most representative radio stations at the moment?").
3. The SPA sends to the PCA a reference set of services belonging to the request area of the user (i.e., the set $[R_1 \ldots R_5]$ of Table 2).
4. The PCA presents the reference set of services and requires from the user to evaluate and rank them, by the order he/she would preferably choose them if they were all available ("Try each one of the proposed stations and then assuming they are the only stations available, tell me which you would prefer and why").
5. The PCA requires the desired range of values for the criteria g_5 and g_6 ("What are the values you would accept for criteria g_5 and g_6?").
6. The PCA formulates the preference model of the user (Table 3) according to the evaluations provided by the user in the previous step (that is the evaluations on the reference set A_R and the acceptable range of values for g_5 and g_6 (i.e. $96 \le g_5 \le 320$ kbps, and $10 \le g_6 \le 300$ users).

The values in Table 3 represent the way the different scales of each criterion are conceptualized by the listener. The preference model of Table 3 can be created using an appropriate modeling method. We use one of the most traditional approaches that leads to a functional representation g that can be formed directly from the criteria $g_1, .. g_6$ that constitute A. Thus, the comprehensive preference model is characterized by a unique synthesizing criterion g: $g(a)=V[g_1(a),\ldots,g_n(a)]$, where V is an aggregation function. The function will be in the form:

$$V(a) = \sum p_i g_i(a) \ . \qquad (1)$$

In the specific example we assume that the preference model is directly provided from the user, since we want to focus on how multi-attribute preference models can be handled by agents and not on how these models are constructed (for more regarding this subject see [24], [18], [21]).

Table 1. The consistent family of criteria, where criteria g_1 to g_4 are all qualitative criteria (encoded as values from "1" to "5") based on empirical evaluations, and g_5, g_6 are quantitative ones.

Criteria	Description	Worst Value	Best Value	Step
g_1	Speech	1	5	1
g_2	Advertisements	5	1	1
g_3	Experimentation	1	5	1
g_4	Rhythm	1	5	1
g_5	Quality of Sound (in kbps)	96	320	2
g_6	Maximum number of Connected Listeners	10	300	10

Table 2. The reference set of radio stations used in creating the preference model of the listener, with the evaluations of each radio station upon each criterion.

Reference Set A_R	g_1	g_2	g_3	g_4
R_1	3	4	4	4
R_2	2	3	3	2
R_3	5	1	2	1
R_4	3	2	5	4
R_5	5	5	1	3

Table 3. The constructed preference model.

Scale of g_1	$u(g_1)$	Scale of g_2	$u(g_2)$	Scale of g_3	$u(g_3)$	Scale of g_4	$u(g_4)$
1	0	**5**	0	**1**	0	**1**	0
2	0	**4**	0.7	**2**	0.1	**2**	0.3
3	0.5	**3**	0.8	**3**	0.2	**3**	0.5
4	0.8	**2**	0.9	**4**	0.3	**4**	0.7
5	1	**1**	1	**5**	1	**5**	1

The brokering procedure takes now the following sequence of steps:

1. The user requests a service from the PCA. ("I'm looking for a Rock or Pop radio station".)
2. The PCA sends a message, which includes the request and the preference model of the user to the SPA. ("The user wants a Rock and/or Pop radio station and I send you the preference model".)
3. The SPA communicates with the relevant NPA's and uses the preference model to filter the list. ("I am looking for providers which can offer to a user radio stations described by the constrains-keywords 'Rock' and/or 'Pop' ", and with specific values for criteria g_5 and g_6.)
4. The SPA uses the preference model of the user in order to negotiate the most interesting offers of the NPAs.
5. The list of probably relevant NPA's is sent to the PCA. ("These are the proposed radio stations").

6. The PCA evaluates each product using the preference model of the user (Table 4) and, if needed, requests extra information or clarification from the SPA.
7. The PCA formulates properly the list and presents it to the user.
8. The user selects the desired service.

Table 4. After the first evaluation a list of the radio stations that satisfy a certain condition (here the first N=11 stations are selected) is evaluated again using extra information provided by the user (here the re-evaluation formula $u_{new} = u_{old} \cdot 60\% + u(g_5) \cdot 30\% + u(g_6) \cdot 10\%$ is used). The way the re-evaluation formula changed the utility "scores" of the radio stations is depicted in the two Utility columns of this table. In the last column, the final weak-order ranking from which the proposals to the user are going to be chosen is presented.

Radio Stations	g_1	g_2	g_3	g_4	g_5	g_6	1st Utility	Final Utility	Final Ranking
R17	4	1	4	5	128	50	0,775	0,5217	4
R8	4	4	5	2	128	100	0,7	0,4939	5
R15	5	3	4	4	256	20	0,7	0,6377	2
R25	4	4	5	2	128	100	0,7	0,4939	5
R14	4	1	2	4	96	30	0,65	0,3969	7
R30	5	2	1	4	256	60	0,65	0,6215	3
R4	1	4	5	4	128	200	0,6	0,4684	6
R5	5	1	1	2	320	300	0,575	0,7450	1
R21	4	4	4	3	128	20	0,575	0,3913	8
R23	1	1	5	2	96	100	0,575	0,3760	10
R29	4	3	1	4	128	10	0,575	0,3879	9

Table 4 contains the results of the evaluation procedure for each solution. We notice that apart from the multi-criteria evaluation of each alternative that the MCDM techniques provide, the re-evaluation of the radio stations (maybe based on information changing with time, or private information that the PCA does not wish to reveal to the SPA) provides a slightly different ranking, leading thus to different proposals to the user. The PCA can also monitor the way the user reacts to the proposed products and re-evaluate the model each time the brokering procedure is completed.

5 Conclusions

In Virtual Private Networks, providing intelligent and personalized telecommunication services is a matter of profiling the user's preferences, identifying the available resources and allocating them in the most efficient way. In this paper, we have addressed the theoretical aspects of designing service brokering agents, which are able of creating and manipulating utility models, based on the multiple attributes that describe the service requested. Nevertheless, this is not a process visible to the end user, since it enhances the intermediate brokering infrastructures by equipping facilitator agents with advanced user requirements modeling capabilities. Our aim was to describe the way multi-attribute utility models can be used by brokering agents, such that the discovery and matchmaking procedures are fast and realistic. It is remarked that implementation details are beyond the scope of this paper.

References

1. ABROSE Project, http://b5www.berkom.de/ABROSE/
2. ACTS IMPACT Project, http://www.acts-impact.org/impact/
3. Busuioc M., "Distributed Intelligent Agents – A solution for the Management of Complex Services", IATA'96 Workshop at ECAI'96, Budapest, Hungary, 1996.
4. Eurescom P712 Project: Intelligent Agents and their application to service and network management, http://www.eurescom.de/public/Projects
5. FIPA Agent Communication Technologies and Services, http://www.fipa.org
6. FIPA Contract Net Interaction Protocol Specification, XC00029F, FIPA 2001.
7. FIPA Network Management and Provisioning Specification, XC00082B, FIPA 2000.
8. Fletcher M., Deen S. M., "Agent-based Service Brokerage in Telecommunications Management Networks", International UNICOM Seminar on Intelligent Agents in Communications, London UK, April 1998.
9. Frei C., Faltings B., "Intelligent Agents for Network Management", Intelligent Agents for Telecommunication Applications (IATA'98) Albayrak S., Garijo F. J. (Eds.), LNAI 1437, Springer-Verlag, Paris, July 1998.
10. Gervais M. P., Diagne A., "Enhancing Telecommunications Service Engineering with Mobile Agent Technology and Formal Methods", IEEE Communications Magazine, July 1998.
11. Gibney and Jennings, 1997] Gibney M. A., Jennings N. R., "Market based multi-agent systems for ATM network management", in Proc. of 4th Communications Network Symposium, Manchester, UK, 1997.
12. Gibney and Jennings, 1998] Gibney M. A., Jennings N. R., "Dynamic Resource Allocation by Market-Based Routing in Telecommunications Networks", in Intelligent Agents for Telecommunication Applications (IATA'98) Albayrak S., Garijo F. J. (Eds.), LNAI 1437, Springer-Verlag, Paris, July 1998.
13. Gleizes M.P., Leger A., Athanassiou E., Glize P., "Self-Organization and Learning in Multi Agent Based Brokerage Services", H. Zuidweg et al. (Eds.), IS&N'99, LNCS 1597, pp. 41-54, Springer-Verlag, 1999.
14. Goldszmidt G., Yemini Y., "Delegated Agents for Network Management", IEEE Communications Magazine, Vol. 36 (3), March 1998.
15. Goldszmidt G., Yemini Y., "Distributed Management by Delegation, in the 15th International Conference on Distributed Computing Systems, IEEE Computer Society, June 1995.
16. Hayzelden A., "Telecommunications Multi-Agent Control System (Tele-MACS)", in ECAI'98, Brighton UK, August 1998.
17. Hayzelden A.L.G., Bigham J., "Agent Technology in Communications Systems: An Overview", Knowledge Engineering Review Journal, Vol.14:3, 1999.

18. Jacquet-Lagreze, E., Siskos, Y.: "Preference disaggregation: 20 years of MCDA experience", European Journal of Operational Research, Vol. 130, pp. 233-245, 2001.
19. Kuwabara K., Ishida T., Nishibe Y., Suda T., "An Equilibratory Market-based Approach for Distributed Resource Allocation and its applications to Communication Network Control", in Clearwater S. H. (Ed.) Market-Based Control: A Paradigm for Distributed Resource Allocation, World Scientific, 1996.
20. Liebowitz J., Prerau D. S., "Worldwide Intellignt Systems: AI Approaches to Telecommunications and Network Management", IOS Press, 1995.
21. Manouselis N, Matsatsinis N.F., "Introducing a Multi-Agent, Multi-Criteria Methodology For Modeling Electronic Consumer's Behavior: The Case of Internet Radio", In M. Klusch, F. Zambonelli (Eds.), Cooperative Information Agents V, LNAI 2182, Springer-Verlag, 2001.
22. MARINER Project, http://www.teltec.dcu.ie/mariner/
23. Miller M. S., Krieger D., Hardy N., Hibbert C., Tribble E. D., "An automated auction in ATM network bandwidth", in Clearwater S. H. (Ed.) Market-Based Control: A Paradigm for Distributed Resource Allocation, World Scientific, 1996.
24. Roy B., Multicriteria Methodology for Decision Aiding, Kluwer Academic Publishers, 1996.
25. Somers F., "HYBRID: Intelligent Agents for Distributed ATM Network Management", in IATA Workshop at ECAI'96, Budapest, Hungary, 1996.
26. Weihmayer R., Brandau R., "Cooperative distributed problem solving for communication network management", Computer Communications, Vol. 13 (7), November 1990.