Agent-based Framework for Personalized Service Provisioning in Converged IP Networks

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Abstract. In a global multi-service and multi-provider market, the Internet Service Providers will increasingly need to differentiate in the service quality they offer and base their operation on new, consumer-centric business models. In this paper, we propose an agent-based framework for the Business-to-Consumer (B2C) electronic market, comprising the Consumer Agents, Broker Agents and Content Agents, which enable Internet consumers to select a content provider in an automated manner. We also discuss how to dynamically allocate network resources to provide end-to-end Quality of Service (QoS) for a given consumer and content provider.

Keywords: agent-based B2C e-market; Quality of Service; Internet business environment; provider selection

1 Introduction

Internet service providers (ISPs) and IP-based telecom network operators are turning towards new business opportunities in a global multi-service and multi-provider market. With consumers typically having several multi-purpose end-user devices, the number and variety of personal, work, and home related services offered will also grow. As “plain broadband” wired/wireless Internet access is likely to become a commodity in the next 10 years or so [1], the ISPs will have to differentiate in the service quality they offer, and base their operation on new, consumer-centric business models. Such models involve a number of actors involved in service delivery, from the user (consumer of the service) to the end service provider, where the selection of the service provider is a non-trivial issue, considering an electronic market (e-market) with a number of service providers offering the same or similar service. The challenge is twofold: first, how to select “the best” service provider, given the user preferences and semantic service descriptions; and second, once the selection is made, how to dynamically allocate network resources on an end-to-end basis. The main contribution of this paper focuses on the first issue by proposing a novel agent-based framework for service provider selection. This process is based on service discovery which considers not only the semantic matching, but also the price and reputation of the service provider, in which it differs from other approaches found in literature. Section

2 gives the problem formulation, while Section 3 presents the model. We discuss the second issue, end-to-end Quality of Service (QoS) in Section 4. Section 5 concludes the paper.

2 Roles and Relationships in the Electronic Market

There are a number of actors present in the Internet business environment who need to establish relationships in order to provide consumers with converged services. An actor may take on a number of roles in a particular scenario, and furthermore a number of actors can play the same role. The key roles and relationships, shown in Fig. 1, include *Consumer*, *Access Line Provider*, *Primary Service Provider* (PSP), *Internet Service Provider* (ISP), *Content Provider* (CP), and *Transport Provider* (TP) [2].

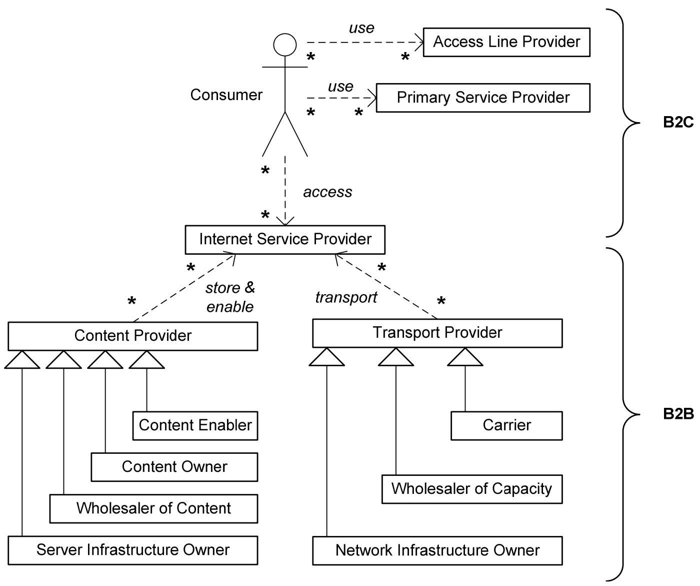

Fig. 1. Roles and relationships of actors in the Internet business environment

The *Consumer* is a role which typically represents the human user. The *Access Line Provider* is a role representing the owner of the access line. The ISP, in the most general sense, is a business entity providing a user with service(s). To differentiate between the responsibilities of an ISP which involve dealing with (e.g., multimedia) content, and those related to managing the transport of the content over the network infrastructure, we introduce the roles of CP and TP, respectively. The role of ISP as CP will be relevant for the first problem addressed in this paper – the selection of the service provider, while the role of TP will be relevant for the second issue – ensuring the end-to-end QoS. From now, we will refer to CP and TP, instead of just "ISP", to disambiguate roles. The PSP is an ISP which provides to a consumer the service of Internet access and consequently has a business relationship with that consumer. It may be noted that a particular consumer can have multiple PSPs, but only one PSP can be active at any one time. By adopting the "one-stop responsibility" concept [3], the PSP is also perceived as being responsible for coordinating the QoS negotiation and adaptation process, while further relying on the services of sub-providers in order to secure an end-to-end service and quality level to the consumer. Fig. 1 also shows the relationships between roles as Business-to-Customer (B2C) and Business-to-Business (B2B).

Our proposed agent based framework addresses the many-to-many relationship between Consumer and ISP in the B2C electronic market, as shown in Fig. 2. The roles are modeled by using an agent paradigm [4], as follows: 1) the *consumer representation* is represented by a Consumer Agent, 2) the *content provisioning* is represented by a Content Agent, and 3) the *brokering* between Consumer Agents and Content Agents is represented by a Broker Agent. The Broker Agent belonging to a certain ISP offers not only its own content (acting as a CP), but also the content offered (advertised) by other ISPs or CPs to which this ISP has established business relationships, as shown in Fig. 2.

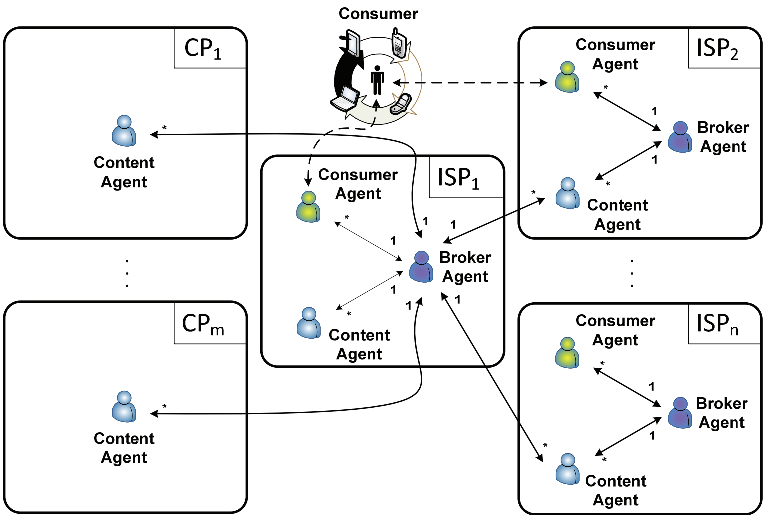

Fig. 2. The proposed agent framework for B2C electronic market

The issue of selecting a content provider has significant implications for all aspects of service provisioning. In the multi-provider network, a consumer will typically have a choice of a (possibly large) number of ISPs/CPs for a given content, as shown in Fig. 2. He or she may also have personal preferences regarding service options, device, and/or a particular wireline/wireless access network. We assume that the Consumer Agent containing these preferences is formed at the time of signing a contract with a PSP (e.g., fixed access via xDSL at home, and mobile access via HSPA in a 3G mobile network), and it resides within the PSP. Given all that, it is the task of the Broker Agent to discover the content and select the best match for the particular content request that corresponds to the given consumer preferences. It is also assumed that the scale of the problem is such that it cannot be solved by exhaustively querying all possible CPs.

As a running example we use the following problem, illustrated in Fig. 3: the user (Consumer) wants to view video-clips with Bayern goals from the latest Bundesliga round on her dual 3G/WLAN mobile phone. Her current (active) PSP is ISP_1. There are several CPs offering and advertising their service of providing *video clips of European football matches* (CP_i, ISP_j, ISP_k) to ISP_1. The ISP_1 has a business and technical relationship (SLA [3]) with ISP_j, and ISP_j has one with ISP_k. After receiving the Consumer request for content, the content from ISP_k is selected as the best match (the most eligible content). Then the QoS negotiation and adaptation takes place on end-to-end basis for a given consumer, service, and ISPs involved in service delivery, and having completed that, the service provisioning starts.

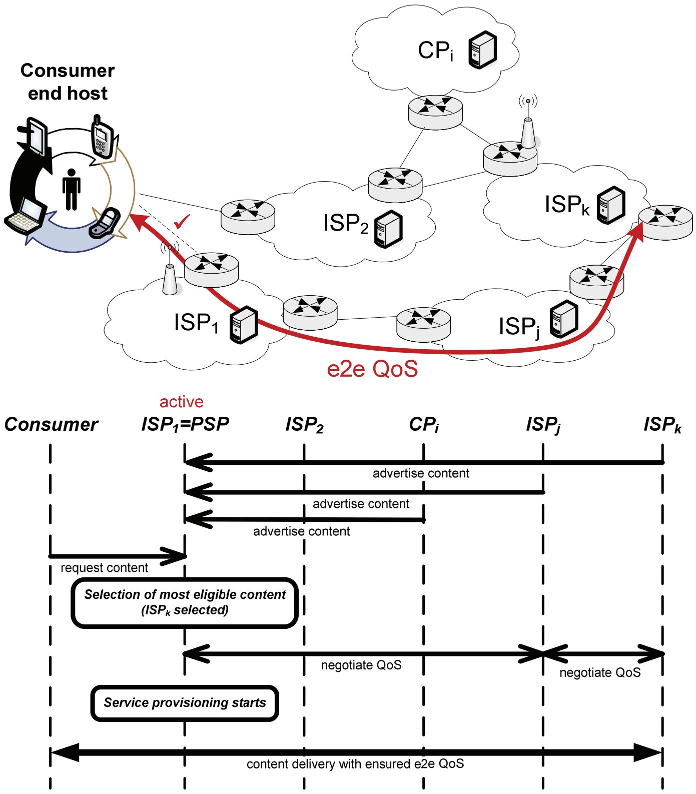

Fig. 3. Problem illustration by example

3 Selection of the content provider

The first step in the process of selecting the content provider is discovery. The state-of-the art discovery mechanisms are based on matching the semantics of resource (e.g., content) descriptions (i.e., semantic matchmaking) [5][6][7], rather than keyword matching [8]. The semantic dimension of resources such as multimedia content has been exploited in order to evaluate "interesting" inexact matches [9].

Most approaches suggested for semantic discovery use standard DL (*Description Logic*) reasoning to automatically determine whether one resource description matches the other. Our discovery mediator in the B2C e-market differs from previous approaches in that it considers the actual performance of businesses which act as ISPs/CPs (with respect to both price and reputation) in addition to semantic matchmaking. The mechanism on which the mediator is based is the Semantic Pay-Per-Click Agent (SPPCA) auction, a novel auction mechanism based on Pay-Per-Click (PPC) advertising auctions [8], but adapted for agent environment and enhanced with a semantic dimension [10].

3.1 The architecture of electronic market for content trading

A description of the proposed agent-mediated B2C e-market architecture (Fig. 2) follows along with a demonstration of how it operates.

The Content Agent. In the proposed B2C e-market agents trade with various types of content (formally defined as a set $\mathcal{IC}$):

$$\mathcal{IC} = \{ic_1, ic_2, \ldots, ic_{|\mathcal{IC}|}\},$$

which is provided by different Content Providers (formally defined as a set $\mathcal{CP}$):

$$\mathcal{CP} = \{cp_1, cp_2, \ldots, cp_{|\mathcal{CP}|}\}.$$

Content Providers are represented in the e-market by Content Agents (formally defined as a set $\mathcal{A}_{\mathcal{CP}}$):

$$\mathcal{A}_{\mathcal{CP}} = \{a_{cp_1}, a_{cp_2}, \ldots, a_{cp_{|\mathcal{CP}|}}\}.$$

An a_{cp_i} represents a cp_i which offers a certain content ic_i that is described by content ontology, whose fragment (describing *video clips of European football matches*) is presented later in this work. Initially, a_{cp_i} wishes to advertise its content (advertised ic_i is denoted as ic_{adv}) at discovery mediator (i.e., the Broker Agent). An a_{cp_i} accomplishes that by participation in the SPPCA.

The Consumer Agent. Consumers of $\mathcal{IC}$ (formally defined as a set $\mathcal{C}$):

$$\mathcal{C} = \{c_1, c_2, \ldots, c_{|\mathcal{C}|}\},$$

are represented on the e-market by Consumer Agents (formally defined as a set $\mathcal{A}_{\mathcal{C}}$):

$$\mathcal{A}_{\mathcal{C}} = \{a_{c_1}, a_{c_2}, \ldots, a_{c_{|\mathcal{C}|}}\}.$$

An a_{c_i} acts on behalf of its human owner (i.e., consumer) in the discovery process of suitable ic_{adv} and subsequently negotiates the utilization of that content. An a_{c_i} wishes to get a best-ranked advertised content which is appropriate with respect to its needs (requested ic_i is denoted as ic_{req}).

The Broker Agent. Mediation between content requesters and content providers is performed by Broker Agents (formally defined as a set $\mathcal{A}_{\mathcal{B}}$):

$$\mathcal{A}_{\mathcal{B}} = \{a_{b_1}, a_{b_2}, \ldots, a_{b_{|\mathcal{B}|}}\}.$$

There is one a_{b_i} located at every ISP and it mediates between c (i.e., $a_{\mathcal{C}}$) to whom this ISP is PSP and all cp (i.e., $a_{\mathcal{CP}}$) which advertised its content at this a_{b_i}. An a_{b_i} enables $\mathcal{A}_{\mathcal{CP}}$ to advertise their content descriptions and recommends the most eligible content to $a_{\mathcal{C}}$ in response to their requests. It is assumed that a_{b_i} is a trusted party which fairly mediates between content requesters and content providers.

3.2 The content discovery model

Fig. 4 presents interactions between a_{c_i} and a_{b_i} which enable content discovery in the proposed B2C e-market. The a_{c_i}, by sending CFP (Call for Proposal) to a_{b_i}, requests two-level filtering of advertised content descriptions to discover which is the most adequate for its needs. Along with the description of requested content ic_{req}, the CFP includes the set of matching parameters (to be explained later) that personalize the discovery process according to the consumer preferences. First-level filtering ($f_1 : \mathcal{IC} \rightarrow \mathcal{IC}$) is based on semantic matchmaking between descriptions of content requested by c_i (i.e., a_{c_i}) and those advertised by cp (i.e., $a_{\mathcal{CP}}$). Content which passes the first level of filtering ($ic_{f_1} \subset \mathcal{IC}$) is then considered in the second filtering step. Second-level filtering ($f_2 : \mathcal{IC} \rightarrow \mathcal{IC}$) combines information regarding the actual performance of cp_{f_1} (cp which offer ic_{f_1}) and prices bid in SPPCA by corresponding $a_{\mathcal{CP}_{f_1}}$($a_{\mathcal{CP}}$ that represent cp which offer ic_{f_1}). The performance of cp_{f_1} (with respect to both price and reputation) is calculated from the previous $\mathcal{A}_{\mathcal{C}}$ feedback ratings. Following filtering, the most eligible content ($ic_{f_2} \subset ic_{f_1}$: $|ic_{f_2}|$=1) is chosen and recommended to the a_{c_i} in response to its request.

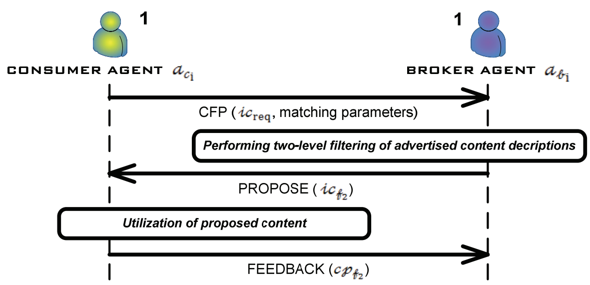

Fig. 4. The a_{c_i} discovers the most eligible content advertised at a_{b_i}

Fig. 5 explains how the SPPCA auction, which is part of the discovery process, operates. The SPPCA auction is divided into rounds of fixed time duration. To announce the beginning of a new auction round, the a_{b_i} broadcasts a CFB (Call for Bid) message to all the $a_{\mathcal{CP}}$ which have registered their ic_{adv} for participation in the SPPCA auction. Every CFB message contains a status report. In such a report, the a_{b_i} sends to the a_{cp_i} information regarding events related to its advertisement which occurred during the previous auction round. The most important information is that regarding how much of the a_{cp_i} budget was spent (i.e., the advertisement bid price $\mathrm{bid}_{ic_{adv}}$ multiplied by the number of recommendations of its ic_{adv} to various a_C). In response to a CFB message, an a_{cp_i} sends a BID message.

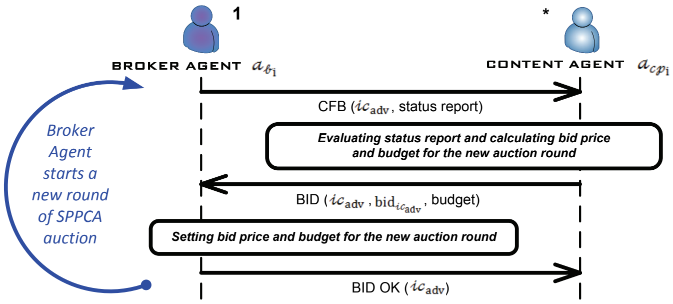

Fig. 5. The SPPCA auction

Semantic matchmaking of content descriptions. In the multi-agent system implementing the proposed B2C e-market model, the Semantic Web technology [11] is used to describe content. Namely, for describing content we use W3C's OWL-S (*Web Ontology Language for Services*), which is an OWL-based (*Web Ontology Language*) (Fig. 6) technology for describing the properties and capabilities of Web Services in an unambiguous, computer interpretable mark-up language.

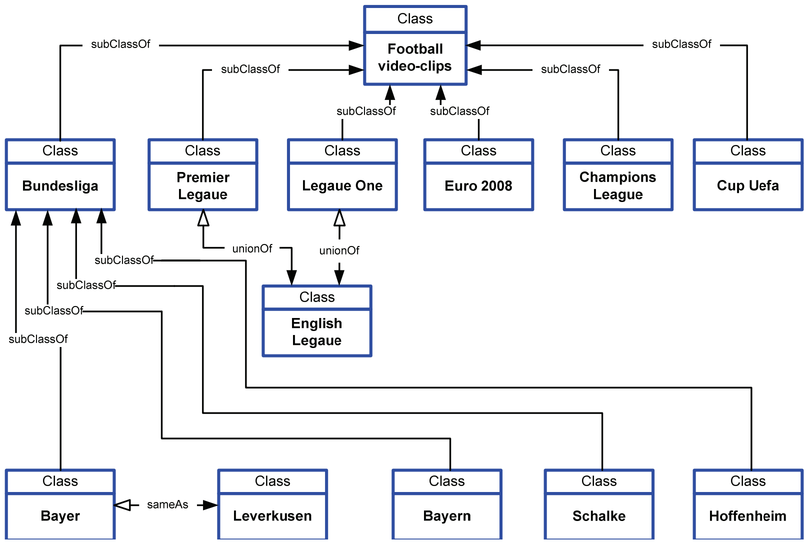

Fig. 6. The OWL ontology fragment describing *video clips of European football matches*

Our a_{b_i} uses OWLS-MX [12], a hybrid semantic matching tool which combines logic-based reasoning with approximate matching based on syntactic IR similarity computations. As the notion of match rankings is very important, OWLS-MX enables computation of the degree of similarity between compared service descriptions, i.e., the comparison is assigned a *content correspondence factor* (M). Namely, the OWLS-MX matchmaker takes as input the OWL-S description of a_{c_i} desired content ic_{req}, and returns a set of relevant content which match the query ic_{f_1}. Relevant content is annotated with its individual degree of matching similarity value (i.e., $M_{ic_{req},ic_{adv}}$). There are six possible levels of matching [12]. The first level is a perfect match (also called an EXACT match) which is assigned a factor M = 5. Furthermore, we have four possible inexact match levels which are as follows: a PLUG-IN match (M = 4), a SUBSUMES match (M = 3), a SUBSUMES-BY match (M = 2) and a NEAREST-NEIGHBOUR match (M = 1). If two content descriptions do not match according to any of the above mentioned criteria, they are assigned a matching level of FAIL (M = 0). An a_{c_i} specifies its desired matching degree threshold (i.e., the M_{min}), defining how relaxed the semantic matching is.

The performance model of content providers. A performance model tracks the past performance of $\mathcal{CP}$ in the B2C e-market. Our model monitors two aspects of a cp_i performance – the reputation of the cp_i and the cost of utilizing the ic that cp_i is offering.

After utilizing the recommended content, an a_{c_i} gives an a_{b_i} feedback regarding cp_{f_2}, both from the reputation viewpoint (called the *reputation rating* ($Q \in [0.0, 1.0]$)) and the cost viewpoint (called the *price rating* ($P \in [0.0, 1.0]$)). A rating of 0.0 is the worst (i.e., the cp_{f_2} could not provide the content at all and/or utilizing the content is very expensive) while a rating of 1.0 is the best (i.e., the cp_{f_2} provides a content that perfectly corresponds to the c_i needs and/or utilizing the content is cost-efficient). The overall ratings of cp_i can be calculated in a number of ways. In our approach, we use the EWMA-based (*Exponentially Weighted Moving Average*) learning [13].

Calculating a recommended ranked set of eligible services. After an a_{b_i} receives a CFP message from an a_{c_i} (Fig. 4), the discovery mediator finds the best-suitable content ic_{f_2} and recommends it to the a_{c_i} in response to its request. The final rating $R_{ic_{adv}}$ of a specific ic_{adv} at the end of discovery process is given by:

$$R_{ic_{adv}} = \frac{\alpha \times \frac{M_{ic_{req},ic_{adv}}}{5} + \beta \times Q_{cp_{adv}} + \gamma \times P_{cp_{adv}}}{\alpha + \beta + \gamma} \times \text{bid}_{ic_{adv}} \quad (1)$$

A higher rating means that this particular ic_{adv} is more eligible for the consumer's needs (i.e., ic_{req}); α, β and γ are weight factors (i.e., matching parameters from CFP message in Fig. 4) which enable the a_{c_i} to personalize its request according to its owner's (i.e., c_i's) needs regarding the semantic similarity, reputation and price of a ic_{adv}, respectively; $M_{ic_{req},ic_{adv}}$ represents the *content correspondence factor* (M), but only ic_{adv} with M higher than threshold M_{min} are considered; $Q_{cp_{adv}}$ and $P_{cp_{adv}}$ represent the quality and price ratings of a particular cp_{adv}, respectively; $\text{bid}_{ic_{adv}}$ is the bid value for advertising an ic_{adv} in the SPPCA auction.

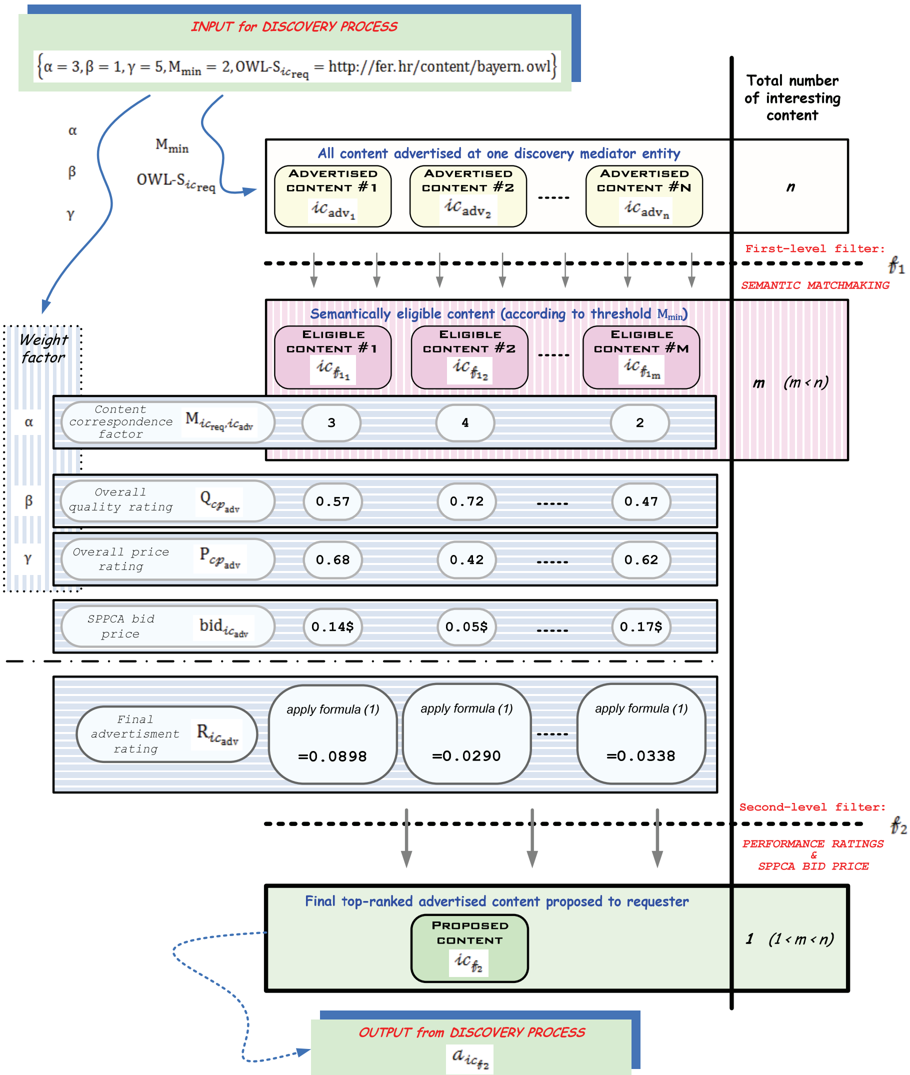

Fig. 7. An example of the discovery process

Since our performance model monitors two aspects of the cp_{adv} performance (i.e., its reputation and price), the $a_{c_{\mathrm{req}}}$ defines two weight factors which determine the significance of each of the two aspects in the process of calculating the final proposal (β represents a weight factor describing the importance of cp_{adv} reputation while γ represents a weight factor describing the importance of content prices at cp_{adv}). Furthermore, an $a_{c_{\mathrm{req}}}$ can specify whether information regarding the semantic similarity of ic_{req} and ic_{adv} is more important to it or information regarding an cp_{adv} performance. Thus, the $a_{c_{\mathrm{req}}}$ also defines parameter α which is a weight factor representing the importance of the semantic similarity between ic_{ic} and ic_{adv}. In our example (Fig. 7) where requested content are video-clips with Bayern goals from the latest Bundesliga round (OWL-S$_{ic_{\text{req}}}$ = http://fer.hr/content/bayern.owl), $\alpha = 3$, $\beta = 1$ and $\gamma = 5$. This means that the $a_{c_{\text{req}}}$ is looking for an inexpensive ic_{adv} and it is not very concerned with the cp_{adv} reputation.

4 Ensuring End-to-End QoS

Once the consumer, by using the mechanism described in the previous section, selected the CP, the end-to-end QoS needs to be negotiated with her PSP. For ensuring end-to-end QoS, support in the network is needed to negotiate and adapt QoS to match the consumer preferences, service profile, and network capabilities; and thus create a basis for service and price differentiation [14]. A general QoS negotiation scenario involves four steps: 1) a host initiating a service on another host; 2) the addressed host providing a service offer/answer; 3) the initiating host responding to the offer/answer; and 4) service delivery. We assume that all ISPs are QoS-aware, i.e., that they control and administer the necessary infrastructure for providing QoS-based services, regardless of which lower layers mechanisms are used. The selection of QoS provisioning mechanisms in the access and core network is performed in the TPs. Depending on the type of the network, this may involve various service control entities that handle QoS signaling, QoS policy control, and interaction with underlying network QoS mechanisms, as well as typical "support functions" (if and when needed), such as consumer authorization, authentication, accounting, auditing, and charging. During the process of QoS (re)negotiation, signaling flows typically traverse a number of functional network entities along the end-to-end path between communication endpoints, as shown in Fig. 8 [15]. It should be noted that the signaling (control) and data flows are separated, and that the resource managers in the data plane are "vertically" controlled by session control functions, which interface with the end-points and the internal databases related to consumers and services.

In an actual network architecture, functional entities may be mapped to one or more network nodes. The end points are shown as hosts (Host A, Host B) or application servers (Content Server, 3rd party Content/Application Servers). The additional functionality which must be implemented in the host may include, for example: a GUI for consumer preferences management, capability to negotiate session QoS (e.g., SIP (*Session Initiation Protocol*) interface), resource management capability (e.g., DiffServ), and mobility (e.g., Mobile IP’s Mobile Host entity). Having in mind the CP selection procedure described in the previous section, we assume that a Consumer A, attached to the NGN by using Host A, has selected a PSP here shown as PSP Domain (Consumer A), to perform service control functions and offer access to 3rd party applications and services.

This service provider is then responsible for AAA functions (consumer authentication, authorization, and accounting), service provisioning, and maintaining a database for storing consumer-related data. It further interacts with an underlying network provider, for example, a 3G mobile network provider, which provides media connectivity functions. In a real life scenario, a single operator may take on multiple roles, including that of both a service and a network provider.

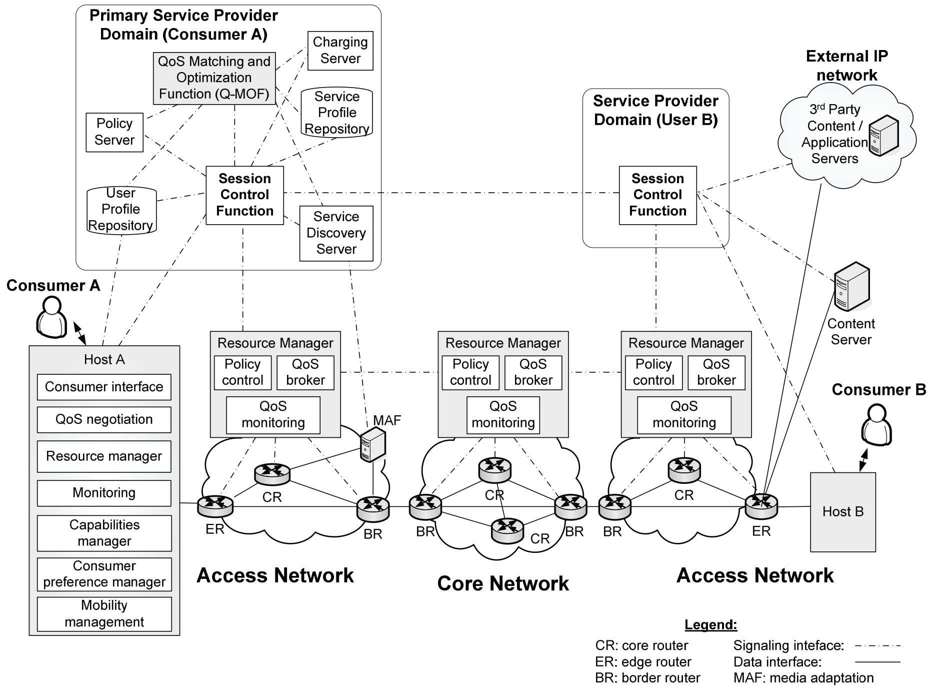

Fig. 8. End-to-End QoS provisioning

While the initial service matching and resource mapping may be based on QoS classes and SLA, more advanced mechanisms are needed to take into account dynamic changes in service profile (e.g., consumer willingness to pay for the service), network capabilities (e.g., due to handover), and service parameters (e.g., types of media streams comprising the service). Although the architecture proposed here is generic, in our previous work we considered a converged IP-based network based on 3GPP IP Multimedia Subsystem (IMS) [16]. In a pure-IP approach, SIP can be applied for session signaling, Diameter for policy control and AAA, and any QoS enabling mechanism may be applied at the network layer, including those for IP QoS interconnection [14][17][18].

5 Conclusion

In this paper, we proposed an agent-based framework for the B2C e-market where interactions between Consumer Agents, Broker Agents and Content Agents enable Internet consumers to select the most eligible content provider in an automated manner. The main benefit of the proposed approach is that in a situation with many ISPs/CPs offering the same or similar content, the user could not search for the content manually, nor exhaustively, nor could the best match be found based solely on semantic descriptions. Finally, we have discussed how end-to-end QoS could be negotiated once the content provider is selected.

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References

1. Anderson, J.Q., Rainie, L.: The future of the Internet II. Technical report, Pew Internet and American Life Project (2006), http://www.pewinternet.org
2. Podobnik, V., Lovrek, I.: Multi-Agent System for Automation of B2C Processes in the Future Internet. In: 27th IEEE Conference on Computer Communications (INFOCOM) Workshops, pp. 1–4. IEEE Press, Phoenix (2008)
3. ITU-T Recommendation E.860: Framework of a service level agreement (2002)
4. Podobnik, V., Jezic, G., Trzec, K.: Towards New Generation of Mobile Communications: Discovery of Ubiquitous Resources. Electrotechnical Review 75(1-2), 31–36 (2008)
5. Sycara, K., Paolucci, M., Anolekar, A., Srinivasan, N.: Automated Discovery, Interaction and Composition of Semantic Web Services. Journal of Web Semantics 1(1), (2004)
6. Li, L., Horrock, I.: A Software Framework for Matchmaking Based on Semantic Web Technology. In: 12th International World Wide Web Conference (WWW), pp. 331–339. ACM, Budapest (2003)
7. Keller, U., Lara, R., Lausen, H., Polleres, A., Fensel, D.: Automatic Location of Services. In: Gómez-Pérez, A., Euzenat, J. (eds.) ESWC 2005. LNCS, vol. 3532, pp. 1–16. Springer, Heidelberg (2005)
8. Jansen, B.J.: Paid Search. Computer 39(7), 88–90 (2006)
9. Di Noia, T., Di Sciascio, E., Donini, F.M., Mong, M.: A System for Principled Matchmaking in an Electronic Marketplace. International Journal of Electronic Commerce 8(4), 9–37 (2004)
10. Podobnik, V., Trzec, K., Jezic, G.: Auction-Based Semantic Service Discovery Model for E-Commerce Applications. In: Meersman, R., Tari, Z., Herrero P., et al. (eds.) OTM 2006. LNCS, vol. 4277, pp. 97–106. Springer, Heidelberg (2006)
11. Leuf, B.: The Semantic Web: Crafting Infrastructure for Agency. John Wiley & Sons, New York (2006)
12. Klusch, M., Fries, B., Sycara, K.: Automated Semantic Web Service Discovery with OWLS-MX. In: 5th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS), pp. 915–922. ACM, Hakodate (2006)
13. Luan, X.: Adaptive Middle Agent for Service Matching in the Semantic Web: A Quantitive Approach. PhD Thesis, University of Maryland (2004)
14. Briscoe, B., Rudkin, S.: Commercial models for IP quality of service interconnect. BT Technology Journal 23(2), 171–195 (2005)
15. Skorin-Kapov, L.: A framework for service-level end-to-end quality of service negotiation and adaptation. PhD Thesis, University of Zagreb (2007)
16. Skorin-Kapov, L., Mosmondor, M., Dobrijevic, O., Matijasevic, M.: Application-level QoS negotiation and signaling for advanced multimedia services in the IMS. IEEE Communications Magazine 45(7), 108–116 (2007)
17. Howarth, M.P., et al.: Provisioning for interdomain quality of service: the MESCAL approach. IEEE Communications Magazine 43(6), 129–137 (2005)
18. Masip-Bruin, X. et al.: The EuQoS System: A Solution for QoS Routing in Heterogeneous Networks, IEEE Communications Magazine 45(2), 9–103(2007)