An Agent-Based B2C Electronic Market in the Next-Generation Internet

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ABSTRACT

In a global multi-service and multi-provider market, Internet Service Providers (ISPs) will increasingly need to base their operation on new consumer-centric business models. In this article, we present an agent-based framework for the Business-to-Consumer (B2C) electronic market, comprising User Agents, Broker Agents and Provider Agents, which enable Internet users to select an ISP in an automated manner.

INTRODUCTION

In the late 1980s, when Mark Weiser introduced the concept of ubiquitous computing (also referred to as pervasive computing), it was just a vision for the 21st century (Weiser & Brown, 1997). Meanwhile, continual advances in wireless technologies and telecommunication systems, in conjunction with rapid proliferation of various types of (portable) devices, have made Weiser's vision a technical and economic viability. Weiser's ideas are becoming a reality as the new generation of ICT-based (*Information and Communication technology*) systems evolve. The next-generation Internet, the most prominent example of such a system, creates heterogeneous environments populated with diverse types of ubiquitous communication-enabled devices in need of specific services. Consequently, such an environment requires efficient mechanisms which can match demands (requested services) to supplies (available services), anywhere and anytime. The focus of this article is on creating an agent-based framework for service provider selection in the next-generation Internet.

BACKGROUND

The evolution of the Internet

The Internet emerged in the early 1970s, as a small network interconnecting just a few computers. As the Internet grew through the 1970s and 1980s, many people started to realize its potential. Nevertheless, the Internet did not experience real proliferation until the invention of the World Wide Web (WWW or simply Web 1.0), a service provisioned through the Internet infrastructure. Web 1.0, as a global information medium enabling users to read and write via computers connected to the Internet, became the bearer of the digital revolution in the 1990s which was a major catalyst of globalization and an important driver of economic prosperity. Consequently, all further Internet evolution after the invention of Web 1.0, is

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characterized as Web X.0, in spite of the fact that the WWW is just one of many Internet services. Web 2.0, also called "the Social Web", is no longer simply about connecting information, but also about connecting people through various forms of social networks (e.g., Facebook (*http://www.facebook.com*), MySpace (http://www.myspace.com), or LinkedIn (*http://www.linkedin.com*)). The phrase "Web 2.0" was coined a couple years ago when the social networking phenomenon was recognized, having more than half a billion users world-wide in 2007, employing it on a daily basis for both personal and businesses uses (Reid & Gray, 2007). Web 3.0, also called "the Semantic Web", is the next stage in the evolution of the Internet in which it will become a platform for connecting knowledge. Web 3.0 is an evolutionary path which will enable people and machines to connect, evolve, share, and use knowledge on an unprecedented scale and in many new ways make our experience of the Internet better (Davis, 2007). One of the most promising Web 3.0 technologies, besides the Semantic Web, are intelligent software agents which can utilize semantically annotated information and reason in a quasi-human fashion.

Stakeholders in the Internet domain

There are a number of different stakeholders present in the Internet domain (see Figure 1) who need to establish strategic partnerships in order to provide end-users with Internet services, integrate information and transport services. A stakeholder may take on a number of roles in a particular scenario, and a number of stakeholders can play the same role.

Figure 1. Roles and relationships of stakeholders in the Internet domain.

Examples of roles include the following (Fischer & Lorenz (European Telecommunications Consultants), 2000) (Podobnik & Lovrek, 2008):

- *User*: An Internet service user, having at his disposal one or more devices (e.g., mobile phone, laptop, digital TV receiver) attached/able to connect to the Internet.
- *Access Line Provider:* Provides telecommunication access to service consumers (e.g., an operator providing wireline access through a local loop or a mobile/wireless access operator).
- *Internet Connection Provider:* Provides network layer access to the Internet and its services (e.g., an operator with entry points to the Internet).
- *Internet Service Provider (ISP):* Facilitates integrated services for the consumers (e.g., a company offering IPTV service).
- *Service Broker*: Provides simplified filtering and access to a vast number of services available on the Internet (e.g., search engines).
- *Network Infrastructure Owner:* Provides transmission lines (e.g., telecoms or cable TV operators).
- *Carrier*: Provides a transport service for data traffic (e.g., companies which buy bandwidth from a Network Infrastructure Owner).
- *Wholesaler of Capacity:* Provides lower-cost transmission and storage capacity (e.g., large ISPs selling capacity to smaller ISPs).
- *Server Infrastructure Owner:* Provides storage capacity and server functionality (e.g., companies owning "server farms").
- *Content Owner:* The owner of information or service in its original form (e.g., a movie producer).
- *Content Enabler:* Converts information to a format appropriate for Internet-based transmission.
- *Wholesaler of Content:* Provides low-cost content.

Figure 1 also differentiates relationships as being Business-to-Customer (B2C) or Business-to-Business (B2B).

AN AGENT-BASED B2C ELECTRONIC MARKET IN THE NEXT-GENERATION INTERNET

The problem: how to select "the best" Internet service provider?

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 (Anderson & Rainie, 2006), the ISPs will have to base their operation on new business models. Such models involve a number of stakeholders engaged in Internet service provisioning, from the user (i.e., consumer of the service) to the service provider. The selection of the service provider is not a trivial issue, assuming an (e-market) hosting a number of service providers offering the same or similar service. Our main challenge is the following: how to select "the best" ISP, given a set of user preferences.

The proposed solution: An agent-based B2C electronic market

Prompt growth of the WWW and the rapid rise of e-commerce have provoked dynamic and extensive research aimed at developing efficient e-market models. Electronic commerce (e-commerce) comprises a broad range of issues including advertising, ontologies, on-line catalogs, intermediaries, security, trust, reputation, law and payment mechanisms (Guttman, Moukas, & Maes, 1998). Considering we aim to solve the problem of ISP selection given user preferences, in this article we are primarily concerned with B2C e-markets and the following stakeholders from the Figure 1: *users*, *service broker* and *ISPs*.

Intelligent software agents

In a multi-agent system (MAS) implementing the proposed B2C e-market, intelligent software agents are used to impersonate *users*, *service broker* and *ISPs* in the next-generation Internet domain in order to enable automated interaction and business transactions.

Figure 2. A model of an intelligent software agent.

An intelligent software agent is a program which autonomously acts on behalf of its human (or organizational) principal, while carrying out complex information and communication tasks which have been delegated to it. From the owner's point of view, agents improve their efficiency by reducing the time required to execute personal and/or business tasks. Figure 2 presents the relations between the main features of intelligent software agents:

- ***Intelligence*****:** An agent must posses some intelligence grounded on its *knowledge base*, *reasoning mechanisms* and *learning capabilities*. The intelligence of an agent is a prerequisite for all its other characteristics. Depending on the assignment of a particular agent, different types of information will be maintained in its knowledge base. In general such information can be divided into two parts – the *owner's profile* and the agent's *knowledge about its environment*.
- ***Adaptivity*****:** It is very important to notice that the agent's knowledge base does not contain static information. Adversely, the agent continuously updates its owner's profile according to the latest needs of the owner. This allows the agent to efficiently represent its principal in the pervasive environment of the next-generation Internet, thus realizing the calm technology concept.

Additionally, the agent updates knowledge about its environment with the latest events from its ambience and with the current state of observed parameters intrinsic to its surroundings, thus realizing context-awareness. *Context-awareness* describes the ability of an agent to provide results depending on changing context information.

- ***Autonomy***: An agent executes tasks autonomously without any interventions from its principal, what makes it an invisible servant, just as Weiser envisioned (Weiser & Brown, 1997). Autonomous execution presumes that an agent has the ability to control its actions and can ensure resources needed for execution of these actions.
- ***Reactivity***: An agent must have the capability to react to impacts from the environment in which it operates.
- ***Proactivity***: An agent does not just react to excitations from its environment, but also takes initiatives coherent to its tasks. A well-defined objective is an inevitable prerequisite for proactivity.
- ***Cooperativity***: An agent continually collaborates with other agents from its surroundings. On the basis of this cooperation, the agent takes actions which facilitate more efficient solutions for its delegated assignments.
- ***Mobility***: An agent is capable of migrating between heterogeneous communication-enabled devices interconnected through the ubiquitous next-generation Internet network. Conventional programming systems do not allow migration of programs. Consequently, additional system preconditions must be ensured on all network nodes that are potential hosts for mobile software agents.
- ***Temporal continuity***: An agent has a lifetime throughout which the persistency of its identity and its states should be retained.

Agent-enabled Internet service discovery

A description of the agent-mediated B2C e-market architecture shown in Figure 3 follows, along with a demonstration of how it operates.

Figure 3. An agent-mediated B2C e-market in the next-generation Internet

The Provider Agent

In the proposed B2C e-market, various types of Internet services $\mathcal{IS}$ are offered:

$$\mathcal{IS} = \{is_1, is_2, \ldots, is_{|\mathcal{IS}|}\}, \quad is \subset \mathcal{IS}, \quad is_i \subset \mathcal{IS}: |is_i|=1;$$

which are provided by different Internet service providers $\mathcal{ISP}$:

$$\mathcal{ISP} = \{isp_1, isp_2, \ldots, isp_{|\mathcal{ISP}|}\}, \quad isp \subset \mathcal{ISP}, \quad isp_i \subset \mathcal{ISP}: |isp_i|=1.$$

Internet service providers are represented in the e-market by Provider Agents $\mathcal{A_P}$:

$$\mathcal{A_P} = \{a_{p_1}, a_{p_2}, \ldots, a_{p_{|\mathcal{ISP}|}}\}, \quad a_p \subset \mathcal{A_P}, \quad a_{p_i} \subset \mathcal{A_P}: |a_{p_i}|=1.$$

An a_{p_i} represents an $\mathcal{ISP}$ which offers a certain service is_i. An a_{p_i} advertises its service (advertised is_i is denoted as is_{adv}) with a service broker (i.e., the Broker Agent) (interaction **1** in Figure 3).

The User Agent

$$\mathcal{U} = \{u_1, u_2, \ldots, u_{|\mathcal{U}|}\}, \quad u \subset \mathcal{U}, \quad u_i \subset \mathcal{U}: |u_i|=1;$$

are represented on the B2C e-market by User Agents $\mathcal{A_U}$:

$\mathcal{A}_{\mathcal{U}} = \{a_{u_1}, a_{u_2}, \ldots, a_{u_{|C|}}\}, \ \ a_{\mathcal{U}} \subset \mathcal{A}_{\mathcal{U}}, \ \ a_{u_i} \subset \mathcal{A}_{\mathcal{U}}: |a_{u_i}|=1.$

An a_{u_i} acts on behalf of its human owner (i.e., user) in the discovery process of a suitable service is_i. An $a_{u_{req}}$ wishes to get the best advertised Internet service from the set of all advertised Internet services ($\bigcup is_{adv}$) which can successfully fulfill its needs (the requestedis_i is denoted as is_{req}) (interaction **2** in Figure 3).

The Broker Agent

Mediation between Internet service requesters (i.e., users) and providers (i.e., ISPs) is performed by service broker $\mathcal{SB}$. There is one $\mathcal{SB}$ located on every B2C e-market and it is represented by the Broker Agent $\mathcal{A}_{\mathcal{B}}$:

$\mathcal{A}_{\mathcal{B}}: |\mathcal{A}_{\mathcal{B}}|=1.$

The $\mathcal{A}_{\mathcal{B}}$ mediates between u (i.e., $a_{\mathcal{U}}$) and all isp (i.e., $a_{\mathcal{P}}$) which advertise their services on this e-market. An $\mathcal{A}_{\mathcal{B}}$ enables $\mathcal{A}_{\mathcal{P}}$ to advertise its service descriptions and proposes the most eligible service to $a_{\mathcal{U}}$ in response to its requests (the most eligible is_i is denoted as is_{win}) (interaction **3** in Figure 3). It is assumed that $\mathcal{A}_{\mathcal{B}}$ is a trusted party which fairly mediates between service requesters and service providers.

Figure 3 also depicts actions which enable service discovery in the proposed B2C e-market. Firstly (interaction **1**), $a_{\mathcal{P}}$ advertises its services (is_{adv}) with the Broker Agent $\mathcal{A}_{\mathcal{B}}$. Sometime after, user agent $a_{u_{req}}$ requests an Internet service most similar to the its needs (i.e., most similar to is_{req}) by sending CFP (*Call for Proposal*) to $\mathcal{A}_{\mathcal{B}}$ (interaction **2**). The $\mathcal{A}_{\mathcal{B}}$ then performs matchmaking (m_{disc}) between the requested service requested service is_{req} and all advertised services ($\bigcup is_{adv}$), where matchmaking is defined as:

$$m_{disc}\left(is_{req}, is_{adv}\right): \mathcal{ISP} \times \mathcal{ISP} \rightarrow [0,1], \forall\, is_{adv}.$$

Following matchmaking, the most eligible service is_{win} (is_{adv} with the highest $m_{disc}\left(is_{req}, is_{adv}\right)$ value) is chosen and proposed to the $a_{u_{req}}$ in response to its request (interaction **3**).

Service matchmaking

Semantic Web languages, such as *Resource Data Framework* (*RDF, http://www.w3.org/RDF/*), *RDF Schema* (*RDFS, http://www.w3.org/TR/rdf-schema/*) and the *Web Ontology Language* (*OWL, http://www.w3.org/TR/owl-features/*), can be used to describe Internet services (Internet service descriptions are hereafter referred to as *service profiles*). With the help of various query languages, based on *Structured Query Language (SQL)* syntax, it is possible to perform very efficient semantic matchmaking, providing the service profiles have been created according to a certain standard.

In computer and information sciences, an ontology is a formal representation of a set of concepts within a domain and the relationships therein. It is used to reason the properties of that domain, as well as to define it. For example, an ontology can contain knowledge regarding an Internet service. Part of such ontology is shown in Figure 4 (Frkovic, Podobnik, Trzec, & Jezic, 2008).

Figure 4. Part of an Internet service ontology

Common attributes used for describing objects can be classified as follows:

- *Interval*: An interval attribute is defined by a continuous linear scale divided into equal intervals (e.g., display resolution, available memory);

- *Ordinal* (or *rank*): An ordinal attribute has multiple states that can be ordered in a meaningful sequence. The distance between two states increases as they are further apart in the sequence. Furthermore, intervals between consecutive states can differ. As an example, *Quality of Service (QoS)* in Figure 4 could be qualified as an ordinal attribute with values *Bronze*, *Silver*, and *Gold*);
- *Nominal* (or *categorical*): A nominal attribute takes on multiple states, but these states are not ordered in any way. In the ontology shown in Figure 4, *preferred content type* is an example of a nominal attribute.
- *Binary*: A binary attribute is a nominal attribute that has only two possible states (e.g., *data transfer type* can be *streaming* or *nonstreaming*).

Apart from the basic parts mentioned above, attributes can also contain references to other objects within the ontology.

Attribute	**Type**	**Value (service A)**	**Value (service B)**	**Score**
ID	abstract	Mobile 1	Laptop 1	none
Class	class	MobilePhoneProfile	LaptopProfile	0,250
User preferences				
InformationType	instance	PlainText	Avi	0,250
InformationService	instance	CroatiaPoliticsInstance	MoviesInstance	0,142
Language	instance	English	Hrvatski	0,500
Genre	instance	RockMusic	ThrillerMovie	0,250
QoS	instance	Silver	Gold	0,500
DeliveryType	instance	NonStreaming	Streaming	0,500
Hardware				
AvailableMemory	integer	18000	1000000	0,018
HorizontalResolution	integer	180	1600	0,113
VerticalResolution	integer	230	1050	0,219
BitsPerPixel	integer	16	32	0,500
Software				
Os	instance	BasicOs	WindowsVista	0,500
Browser	instance	SonyEricssonBrowser	MozillaFirefox	0,500
JavaVersion	integer	15	16	0,940
			Profile similarity	**0,370**

Table 1. Profile comparison results.

Table 1 shows how service profile matchmaking is done. Each attribute in the service profile is asserted individually, while the end result is the arithmetic mean of the individual attribute scores. The details about the semantic matchmaking procedure follow:

- *Position within the class hierarchy*: Each service profile is an instance of a certain class from the ontology. Figure 5 shows how the class hierarchy position is transformed into a real number that reflects the similarity between two classes, or objects. A greater distance between two classes should result in a decreasing similarity between class instances. For example, we can see that the *MobilePhoneProfile* and *LaptopProfile* classes are separated by four steps in the hierarchy. The similarity score is calculated as the inverse of the number steps (in this case 4), giving a similarity score of 0,25;
- *Common attribute types*: When comparing binary and nominal attributes, the result is either *0* (if the values are not the same), or *1* (if the values are identical). When comparing ordinal

attributes, the result is a number between *0* and *1*, depending on the rank of each value. The result is calculated as the ratio between the smaller and the bigger number: e.g., when comparing the *Silver* and *Gold* levels of *QoS,* the similarity score is 0,5;

- *Attributes with object values*: Some attribute values contain references to other class instances. They can also be compared using the previously mentioned approach of class hierarchy positioning.

Figure 5. Class hierarchy

FUTURE RESEARCH DIRECTIONS

The future of provisioning emerging Internet services is directed towards creating an environment aware of user preferences, device capabilities, and communication context. In other words, it takes into account personalization, as well as collaboration issues, through dynamic user group formation defined by similar characteristics (user preferences, user device, context, etc.). Consequently, our research efforts will be aimed at extending the presented agent-mediated B2C e-market with group-oriented provisioning features. In particular, we will investigate different clustering techniques in order to identify groups of customers with homogeneous buying preferences, so-called market segments. Such an e-market will have large number of users that interact and form a complex trading (social) network. Consequently, we aim to implement broker agents capable of executing both scalable and computationally efficient graph clustering algorithms suitable for dealing with multidimensional data sets, such as service profiles.

In many respects, intelligent agents on the presented B2C e-market are likely to benefit from a closer interaction of both ontology-based knowledge representation and graph clustering techniques. Therefore, our future research will also be directed towards building agent architectures that enable synergistic usage of Semantic Web technologies with graph clustering techniques to provide sufficient incentives and motivation for users and providers to participate in B2C e-markets at large.

CONCLUSION

In this article, we presented an agent-based framework for the B2C e-market where interactions between User Agents, Broker Agents and Provider Agents enable Internet users to select the most suitable Internet service provider (ISP) in an automated manner. The main benefit of the proposed approach is seen in situations when many ISPs offer the same or similar Internet service. Namely, in such cases, the user cannot search for the content manually or exhaustively.

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KEY TERMS & DEFINITIONS

Next-generation Internet: An Internet which enables people and machines to connect, evolve, share, and use knowledge on an unprecedented scale.

Internet service: Any service provided to the user through the Internet infrastructure.

Intelligent software agent: A program which autonomously acts on behalf of its human (or organizational) principal while carrying out complex information and communication tasks which have been delegated to it.

Electronic market: An ICT-based system that creates value by bringing together stakeholders in the market to enable transactional immediacy and supply liquidity, by supporting the exchange of demand and supply information, and reducing transaction time and cost.

Semantic Web: An extension of the current Web in which information is given well-defined meaning, enabling people and machines to connect, evolve, share, and use knowledge in a better way.

Ontology: A description of concepts and relationships between these concepts in an area of interest. Therefore, an ontology is the terminology used for a given domain of interest.

Service discovery: The process of searching for possible matches between requested and available services.