Cooperative Mobile Agents for Automation of Service Provisioning: A Telecom Innovation

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Abstract

This paper presents the application of cooperative mobile agents in service provisioning processes characteristic for Next-Generation Network (NGN). The advent of the NGN transforms traditional end-to-end approach to service provisioning towards a consumer-centric model. In a highly competitive market, telecom companies have to envision customers' future needs and rapidly develop and provide value-added services. Authors propose a semantically enhanced solution of the service provisioning process, where designed model automates complete service provisioning lifecycle in the NGN. Proof-of-concept prototype is deployed into 3G network and enables network operators to enhance their provisioning process with features of proactivity, semantic-awareness and consumer context-awareness.

1. Introduction

Traditional practice in the telecom industry is end-to-end service delivery, resulting in direct control of entire value chain by a single service provider. The advent of the Next-Generation Network (NGN) [3] transforms the telecom industry value chain and therefore requires novel approaches for service provisioning.

The emergence of NGN creates heterogeneous and semantic-aware environments populated with diverse types of communication-enabled devices. Great proliferation of the Internet enables numerous service providers to concurrently offer remarkable selection of ubiquitous resources (e.g. software or content). In this competitive market service providers have to automate their business processes and expand their business environment by broadening current Business-to-Business (B2B) [16] relationships (i.e. relationships with other service providers and/or network operators).

Service execution environment consists of different types of consumer terminals, wireless access technologies and network-supportive nodes. If we add increasing consumers' expectation on the level of the service fulfillment (they want to use it anywhere and anytime, and on different terminals), the result is very complex service provisioning process. Usually, the network operator will offer services to its consumers, establishing a Business-to-Consumer (B2C) [16] electronic market (e-market). On the other hand, since very often the network operator does not possess the software or content needed to completely deliver the service, it has also to establish B2B e-market with the software/content provider to buy needed software and content. Processes characteristic for service provisioning lifecycle are *discovery*, *fulfillment* and *charging*. A key challenge for the efficiency of service provisioning process is to keep the technical feasibility and the customer demand (i.e. commercial suitability) within reasonable limits. Additionally, Business processes between involved parties should be automated by utilizing every available technology.

Telecom companies need to transform themselves into more consumer-centric and highly innovative companies, and should envision customer's future lifestyle, predict potential needs and provide value-added services [15]. This idea was our main motivation in creating a multi-agent system of cooperative mobile agents for automation of service provisioning in NGN presented in this paper. The proof-of-concept prototype is integrated into 3G mobile network architecture. Cooperative software agents are used both by consumers and providers to achieve economic, time and resource efficiency. The resources needed for the service fulfillment are acquired on the e-market, through semantically-enhanced concept of Web Services.

This paper is organized as follows. Section 2 presents the technological fundaments for Next Generation Network. The solution for semantic-aware service provisioning in agent-supported NGN is proposed in Section 3. Section 4 explains directions for future work and concludes the paper.

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2. Technological Fundaments for Next Generation Network

Emergence of the NGN is result of fusion of existing WWW (*World Wide Web*) infrastructure and emerging 3G (*Third Generation*) mobile networks, enabled by wide-accepted technologies such as Web Services [3].

3GPP and 3GPP2 have introduced Multimedia Broadcast and Multicast Service (MBMS) [13], and Broadcast and Multicast Service (BCMCS) [14] specifications. They enables the network operators to provide multimedia services using just one stream per channel to the Broadcast-Multicast Service Center (BM-SC) entity, which is responsible for providing and delivering mobile broadcast services [12].

The fact that our model is based on predicting which users will be interested for the specific services, thus it is obvious that we have to acquire information about consumers' behavior. Therefore, we use both the network operator's information regarding the consumers' profiles as well as the information from Home Location Register (HLR) entity for determining consumer present location.

Dynamic and distributed content and software in 3G mobile network require computer programs to not only respond to the requests for resources, but to intelligently adapt to the changing environment. A cooperative work between the agents will help to overcome the heterogeneous and volatile environment in 3G mobile networks. Cooperative mobile agents, supported by AI (*Artificial Intelligence*) mechanisms, successfully enable automated interaction and coordination of the tasks in the service provisioning process.

The integration of business applications is traditionally achieved by utilizing costly customized solutions for each business. The data format and the used protocols are often an obstacle [4]. As a result, the degree of reusability in such integration solutions is remarkably low. Web Services [5] support interoperable machine-to-machine interaction over a network by providing a set of standards for the provision of functionality over the Web. The principles of the Semantic Web [6] can be applied to create Semantic Web Services [7], by applying the OWL-S (*Web Ontology Language for Services*). This allows the available Semantic Web Services to be easily accessed by intelligent software agents, who can interpret and exchange semantically enriched knowledge [8].

In the proposed multi-agent system, Semantic Web Service technology is used to unambiguously represent services in the heterogeneous and semantic-aware environment of the designed B2C and B2B e-markets.

3. The Service Provisioning

The introduction of new software components that enable advanced mobile services (video streaming or music) has rapidly increased service provisioning complexity both in discovery and fulfillment phases. In order to increase their revenue, reduce operating costs and satisfy new consumer demands, network providers have to tune their provisioning operations according to initial service deployment which take into account both the consumers' profiles and the B2B relationships in the telecom market.

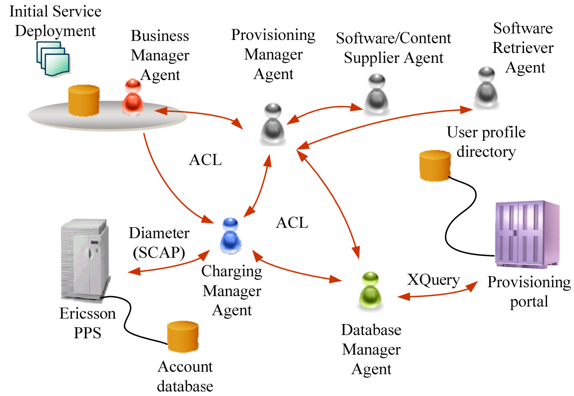

Figure 1. Cooperative agents in semantic-aware service provisioning model

Our agent-based solution for strategic service provisioning (Figure 1; more detailed illustrations can be found in [17]) enables the proactive triggering of provisioning operations. Agents employ cooperative strategies towards other agents and entities in the system in order to gain knowledge needed to successfully complete provisioning process. The predicted consumer needs for services are stored in the Jess rule engine [9], where they are combined with parameters that are handled by the network operator's BSS (Business Support System) entity. The BSS entity monitors parameters such as the type of consumers and their location, season period, and the type of content. Consequently, the proactive triggering of provisioning operations reflects the changes in the competitive environment (telecom market) in which the network provider is embedded. Furthermore, it allows sustainable competitive advantage in the future as it takes into account consumer behaviour and B2B relationships. Following subsections present main features of discovery, fulfillment and charging phase of the designed model.

3.1. Proactive Service Discovery

The key idea of proposed service discovery process is proactivity. In traditional service provisioning processes every consumer separately requests for specific service and afterwards the network operator reruns all operations needed for fulfillment of requested service, which generates of enormous quantities of unnecessary network traffic. Final result is network provider's inefficiency and increased OPEX (*Operational Expenses*). In the environments with lots of consumers with similar profiles and preferences much better approach is to predict the need of group of consumers for the identical service, and upon that prediction run most of the operations which are prerequisite for that service fulfillment just once.

Provider Agents (PAs) put up bids for advertising their resources (i.e. software or content) in the Semantic Pay-Per-Click Agent (SPPCA) auction (Interaction **1** in Figure 2). The SPPCA auction is a novel auction model developed for enabling businesses to dynamically and autonomously advertise descriptions of available resources in the semantic-aware environment of the NGN. The detailed specification of the SPPCA auction can be found in [19].

Presented semantic-aware discovery model combines an economic approach with AI concepts. Every network operator's consumer is assigned one software agent (the Consumer Agent – CA). The CA continuously updates information about its consumer by monitoring its behaviour and by querying the network operator's databases (i.e. HLR, terminal database and user profile database). Periodically (e.g. once a day) every CA generates OWL-S request with most likely service needs of its consumer (Interaction **2** in Figure 2). In such a manner CA uses two-level filtration of advertised descriptions of services to efficiently discover most adequate ones. First-level filtration is based on semantic matchmaking between description of service requested by CA and those available at network provider. Services which pass the first level of filtration are then considered in the second filtration step. Second-level filtration combines information regarding the actual performance of businesses that act as resource providers and the prices bid by PAs. The performance of a business (with respect to price and quality) is calculated from the CAs' utilized services feedback ratings. Following filtration, a final ranked set of eligible resources is chosen. This set is then used as an input for proactive service fulfilment process.

Figure 2 also shows the architecture of a discovery mediator entity. Note that the IA serves as a network operator's agent whose task is to predict most likely service needs of the network operator's consumers. The SPPCA Auction Agent (SAA), the Matching Agent (MA) and the Discovery Agent (DA) enable the necessary functionalities of the service prediction entity to be realized. The SAA is in charge of conducting the SPPCA auction. Interaction **1.1** is used for registering/deregistering software/content providers in the auction, while the SAA uses interaction **1.2** to announce a new auction round. The MA facilitates semantic matchmaking which corresponds to the first level of filtration in the service prediction process. It receives OWL-S descriptions of requested services through interaction **2.1** and forwards a list of semantically suitable ones through interaction **2.2** to the DA which carries out second-level filtration and recommends top-ranked advertised services (interaction **2.3**). Sometime later, the DA receives feedback information from the CA (through the IA) regarding the performance of the utilized services (interaction **2.4**).

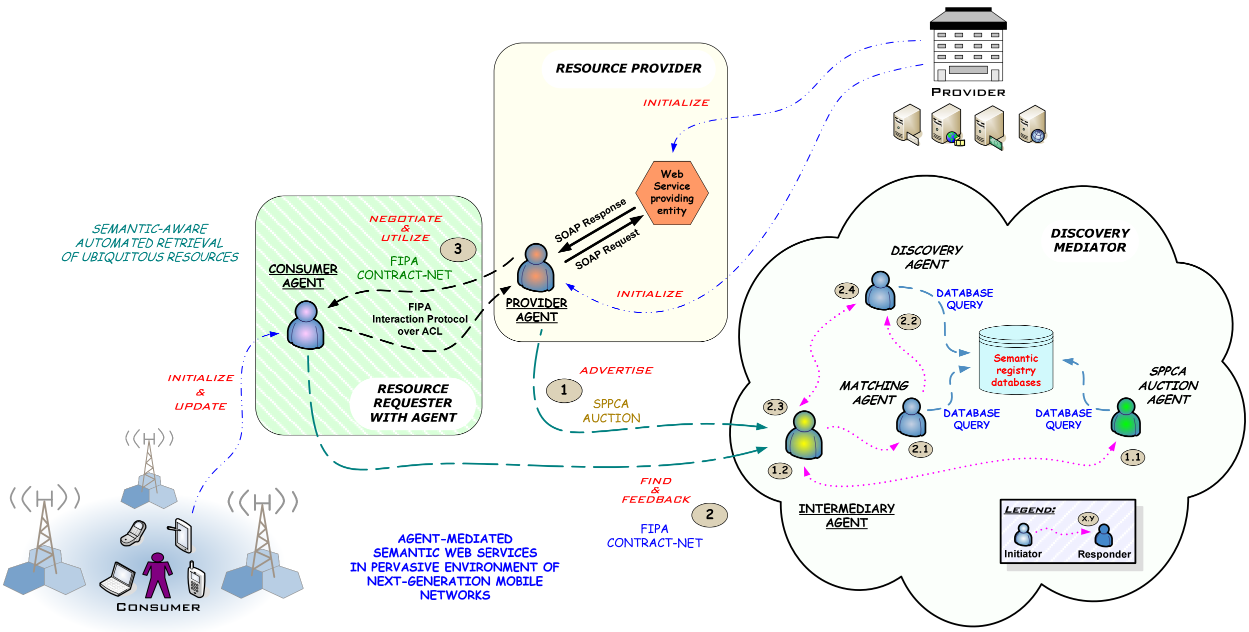

Figure 2. Architecture for proactive service discovery

3.2. Proactive Service Fulfillment

In the NGN, the process of service fulfilment is influenced with user's preferences. Typically, users posses more than one terminal equipment (e.g. mobile phone, PDA and laptop computer), and they would like to have the same service available on all of the terminals. Evidently, not all of the users have similar habits in consuming the available services. As the result, the network operators have to take those facts into the account while developing their business models for service provisioning in the NGN.

In order to capture user demands, we have adopted ”Take Five” user segmentation model [10]. The segmentation model defines five groups of consumers with similar profiles that are drawn from people's basic values, their attitude to technology and telecommunications as well as from the mobile applications market. The defined groups are: *pioneers*, *materialists*, *sociables*, *achievers*, and *traditionalists*. The suggested model offers the proactive service provisioning on the mobile terminals taking into account user's demands and B2B relationships of the network provider in the telecom market. The network operator purchases content from the content providers and resells it to its consumers. Furthermore, the network operator interacts with the terminal suppliers that offer software components for their mobile terminals. The matching between the user terminal type and the software is done by a multi-agent system.

The provisioning process related to the proactive deployment of the software components to targeted users in the 3G mobile network consist of four processes:

- Initial service deployment conformation: the order in which the initial service deployments will be executed.
- Selection of target users: in this process, target mobile users are determined according to their preferences (defined in profiles) and the current location.
- Delivery of software/content components to the Broadcast/Multicast Service Centre (BM-SC) nodes: this process involves the delivery of the software components to the appropriate BM-SC node which enables multicast of software components to selected mobile terminals.
- Deployment of software/content components on the mobile terminal: In this process, a multicast request for the deployment of new versions of software components is sent to targeted group of users. If it is accepted, the appropriate software component is installed on a mobile terminal.

Agent technology can be successfully applied in automation of managing operations in large complex telecom systems. We have shown this in the development of the Multi-Agent Remote Management Shell (MA-RMS) system [1]. Furthermore, the agent technology can be utilized to make provisioning operations sensitive to Customer Relationship Management (CRM) issues and B2B relationships.

MA-RMS system represents a protected environment for software verification without suspending or influencing regular operation. It includes the following remote operations that support software maintenance: delivering software to a remote system, remote installation, uninstallation, software starting, stopping, maintaining several versions of software, selective or parallel execution of two versions and version replacement [2]. In addition to the MA-RMS agents we have added several new agents, each assigned with the special task within our suggested model.

3.2.1. Initial Service Deployment Conformation. In the process of initial service deployment creation [18] the following agents are involved: Business Manager Agent (BMA), Provisioning Manager Agent (PMA), Database Manager Agent (DMA), Software/Content Supplier Agents (SSAs/CSAs) and Software Retriever Agents (SRAs). Their relationships are already shown in Figure 1.

When a software supplier releases a new version of software component, it sends a notification with the software component's metadata to the network provider's BMA. The announced software component will not be retrieved from a software supplier's download server until an initial service deployment requiring this software is ready for execution. The decision about the initial service deployment conformation is a responsibility of the BMA.

The BMA informs the PMA about the region where to deploy the service and the important software data like the software IDs and the final state of the software. Once the BMA ordered the execution of the initial service deployment from the PMA, the selection of target users and the migration of the required new software components from the software supplier's download server to the appropriate BM-SC node(s) should be performed.

Once the group of targeted users is established the PMA starts the software retrieval process by asking the DMA if the necessary software is already downloaded. If the software is not downloaded the DMA sends the list of SSAs or CSAs to the PMA. The PMA creates a plan for the software retrieval, creates and starts the SRAs and waits for them to execute their tasks. Each software supplier has its own SSA that gives the requested software to the corresponding SRA. After the software is downloaded the PMA informs the DMA to update the database with the list of latest downloaded software. The process is based on a genetic algorithm and assures a minimum operational costs regarding provisioning of new services to consumers.

3.2.2. Selection of target users. The software component required for the execution of a multimedia mobile service should be deployed on the mobile terminals of the users that are denoted by the triggered rule in the initial service deployment. Since the rule only specifies the type (segment) of users according to ”Take Five” user segmentation model, the PMA has to find concrete mobile users (i.e. their IMSI numbers) on whose mobile terminals the software component will be deployed. This is achieved by the usage of Provisioning Portal that has access to several databases which contain information required for the identification of target users. The data extracted from these sources enables the operator to employ principles of knowledge management.

In particular, the Provisioning Portal has access to:

- User Profile Directory: In this database are stored users' profiles. Among other preferences, the user profile contains information whether the user is subscribed to the software upgrades on mobile terminals or not.
- Terminal Database: This database contains a list of IMEI numbers that uniquely identify the type of mobile terminals that are used by users.
- Terminal Profile Knowledge Base: This knowledge base contains information about the characteristics of mobile terminals from different vendors.
- Home Location Register (HLR): This database, which is used for mobility management in the mobile network, contains the information about the user's current location.

In order to select target users that will receive the notification about the upgrade of software component(s), the PMA needs to determine users (i.e. their IMSI numbers) which are subscribed to the software upgrades and that belong to a user segment denoted by the initial service deployment. After the BMA informs the PMA about the initial service deployment it also sends a message to the Charging Manager Agent (CMA) informing it about the targeted user segment. The CMA requests the list of possible target users from the DA. Once the list is received the CMA contacts the Account database of the Charging server and removes the users that do not satisfy the necessary conditions (amount of money on the user account) from the list of possible target users.

The PMA also needs to identify the types of mobile terminals on which the new software components will be installed so it sends a message to the DA requesting the list of target users. As a result of this operation, the DA sends a list to the PMA that contains the IMEI numbers from the Terminal Database. These IMEI numbers identify users' terminals that will receive the notification about the software upgrade. If the initial service deployment contains the location information where a multimedia service will be multicast, then the PMA also checks the location of users and selects only those potential target users that are within the location area denoted by the initial service deployment. This list of possible users is then sent to the CMA which compares the two lists and returns the final list of target users to the PMA. Consequently, the target users selected by the PMA satisfy all constraints defined in the initial service deployment.

3.2.3. Delivery of software components to BM-SC nodes. The PMA starts the process of software deployment. It gets the list of deployment locations from the DA and creates the general deployment plan. In the next step it sends the list of remote systems, software and the final state of software to the Deployment Coordinator Agent (DCA). The migration of the required software components is coordinated by the DCA that controls RMS mobile agent(s).

When the PMA determines the target users who will receive the notification about the installation of new versions of software components on their mobile terminals, it sends a request through a Web Service to the DCA to initiate the delivery of the software components to the BM-SC nodes. The BM-SC node feature enables the mobile network operator to define broadcast and multicast mobile service (MBMS) for specific geographical areas at very fine granularity – essentially down to size of individual radio cells. Consequently, using the information about the location of target users, the DCA gives the assignment to the RMS mobile agents (i.e. coordinate them according to a coordination strategy [13]) whose task is to deliver required software components to the appropriate BM-SC nodes. More precisely, depending on the strategy, DCA creates one or more Multi-Operation Agents (MOA). The MOA migrates to the BM-SC node(s) and in collaboration with other RMS agents [11] (Cooperation Layer Agent, Installation Dock Agent, Application Handler Agent) performs the software migration, installation and starting of the software.

An MBMS can support either the streaming or download delivery method from one source to many receivers using a gateway GPRS support node (GGSN) and the serving GPRS nodes (SGSN) in the core network. Each core network node forwards MBMS data, which in our case represent the software component, to the downstream nodes that are serving registered users in the UMTS access network (UTRAN). The BM-SC node also provides the service announcements to the mobile terminals. These announcements contain all the necessary information (such as multicast service identifier, IP multicast addresses, and so on) that a terminal needs in order to join an MBMS service. In case that the MBMS service deals with the software deployment to targeted mobile terminals, the service announcement represents a notification to the mobile user about the installation of new versions of the software component.

3.2.4. Cooperative Deployment of Software Components. In order to transmit the notification, the BM-SC node must have a valid Packet Data Protocol (PDP) context address so that the announcement data may be transmitted to targeted users. The network-requested PDP context activation procedure, that requires knowledge of the targeted user's IMSI number, should be performed in order to activate a PDP context for the targeted users that are not SM-active. If the network-initiated PDP context activation is successful, the newly established PDP context is used to advertise the availability of the software upgrade (i.e. the installation of the software component on a mobile terminal).

The upgrade notification includes the relevant details of the download as well as the multicast address to be used for the download on the mobile terminal. For those target users that accept to install the advertised software components the download is multicast on their mobile terminals. After the software component has been installed, the user can start to use the newly available mobile multimedia service which required the installed software component.

3.3. Service Charging

Network operators have to find an efficient way to charge mobile users for the new, multimedia services they have offered. Our model suggests an introduction of a new mobile agent, called Charging Manager Agent (CMA). This section has not been implemented yet, and is part of our future work on this project. CMA will be responsible for the actual charging of the users accounts, stored in the Charging Server. CMA will also handle some communication with the BMA and PMA.

4. Conclusions and Future Work

This paper proposes cooperative software agents as a solution for the service provisioning problems in NGN. Described multi-agent system, which consists of mobile and semantic agents, provides automation of service provisioning processes for 3G mobile networks. It enables service providers to gain competitive advantage with its operations in service configuration and activation, and provisioning processes.

The future work includes the upgrade of a service charging part of our model, as well as testing the proposed model for scalability and time performance.

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