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Applying semantics to Parlay-based services for telecommunication and Internet networks

Research Article

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Abstract: Ubiquitous convergent telecommunication and Internet networks need to deliver services and content to users in a way that is tailored to the users' context information and preferences. Thus, there is a new challenge in the areas of accurate service description, linking dynamic service discovery and invocation, which involves the services of telecom networks and the Internet. Semantic annotation can provide advantages for precise service description, discovery and composition. However, open service interface specifications of telecommunication networks are currently still in the syntactic level. By applying semantics to Parlay-based services for telecommunication networks and the Internet, we present an OWL-S-based semantic description approach for telecommunication network services, enabled by the telecommunication service domain ontologies to address the semantic interoperability that exists. Using this approach, we have implemented the semantic telecommunication services gateway and proposed the unified service integration architecture of telecommunication and Internet networks within the semantic-web service environment. Proof-of-concept prototype and case studies demonstrate the practical feasibility of the suggested solution.

Keywords: semantic telecommunication network services • telecommunications service domain ontology • semantic Parlay/Parlay X • service-oriented architecture • ontology • semantic web service

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1. Introduction

The *future ubiquitous convergent network* [22] is a user-centric communication infrastructure integrating various heterogeneous networks (such as mobile and fixed network, Internet and emerging networks) and new 4G technologies [24, 28]. The goal of a ubiquitous convergent network is to provide pervasive, personalized, user-centric services. Such an infrastructure can enable information exchange between humans, entities and humans/entities (e.g., mobile devices), at any time, any place and in any way. When the *Virtual Network Operator* (VNO) [25] becomes a reality, *service delivery platforms* (SDP) [21] of VNO will be able to freely utilize the fundamental network services provided by the different network carriers. When users move among different service domains, Service Delivery Platforms (SDP) might be necessary to dynamically change the service resources to provide the best user experience based on the context information or user preferences, e.g. by switching from one network operator to another or by switching between similar service components provided by the different service providers. For example, it could be possible to substitute one service for another, if they can be proven to be similar enough [10]. Therefore, an SDP needs to accurately discover, automatically compose and invoke the services provided by telecommunication networks or the Internet depending on the service context in the service-oriented architecture [3, 17].

Semantic annotation will facilitate accurate service description, discovery and composition of telecommunication network services. However, the open interface specifications of telecommunication networks are currently still in the syntactic level. Currently, NGN (Next Generation Network)[1] and 3G network all adopt the open API (Application Programming Interface) technologies in the service layer, such as Parlay/OSA and Parlay X [14]. Telecommunication network services, such as call control, conference management, SMS sending/receiving and location-based services (LBS), are available to the service developers in the form of APIs. With the development of distributed computing technologies such as *CORBA* (Common Object Request Broker Architecture) and web services, different open interfaces are defined to facilitate value-added service development. With the growing popularity of web 2.0 technologies, the past several years have seen dramatic changes in the web services landscape. After the traditional XML-RPC web service, a new *representational state transfer* (REST) API style has been applied to web services. Such APIs are more suitable for integration with web APIs [1] however, as these current telecommunication network service interfaces lack rich semantic annotation information, keyword-based service matching cannot enable an accurate service discovery. Thus, current applications often directly invoke telecom network services resulting in the tight-coupling of application logics with service resources which restricts the dynamic adaptation capability of applications. The current telecommunication network services interfaces have only a limited provisioning of advanced intelligent services in the user-centric service era [15].

From the evolution of telecom network service interfaces (Fig. 1), it can be seen that interface descriptions should meet the requirements of Internet applications. As a consequence of semantic web-technology development [8], we can see that this has already been gradually applied to real Internet applications. For example, *Twitter* allows tweets to be tagged with information that will not appear in the message but can be read by computers[2]. So, in the future semantic web era, the opening of telecom network services and semantic interoperability across networks will be a natural consequence. Presently, the semantic web service (as an established research paradigm), is defined as an augmentation of web services and semantic annotation that facilitates the higher automation of service discovery, composition, invocation and monitoring in an open environment. In particular, W3C (World Wide Web Consortium) submissions, OWL-S (OWL for Services)[3] and WSMO (Web Service Modeling Ontology)[4] are prominent ontology description frameworks for semantic web services. Yet, as neither of them provide a general semantic web service description framework, neither defines domain-specific properties to describe important features of telecommunication network services such as charging, media type, and network or terminal characteristics. Nevertheless, OWL-S is meant to provide a basis for their construction that is flexible enough to accommodate many different contexts, domains and methods of use.

In this article, we apply semantic web services and ontology technologies to telecommunications services and present an infrastructure to enable the semantic interoperability of the telecom and Internet networks in the service layer. The proposed approach improves the accuracy of telecommunication network services description, discovery and matching

[1] *ITU-T, Next Generation Networks Global Standards Initiative, http://www.itu.int/en/ITU-T/gsi/ngn/Pages/default.aspx*

[2] *Semantics, tagging and Twitter, http://ml.sun.ac.za/2010/04/23/semantics-tagging-and-twitter*

[3] *W3C, OWL-S: Semantic Markup for Web Services, http://www.w3.org/Submission/OWL-S*

[4] *ESSI WSMO working group, Web Service Modeling Ontology (WSMO), http://www.wsmo.org/index.html.*

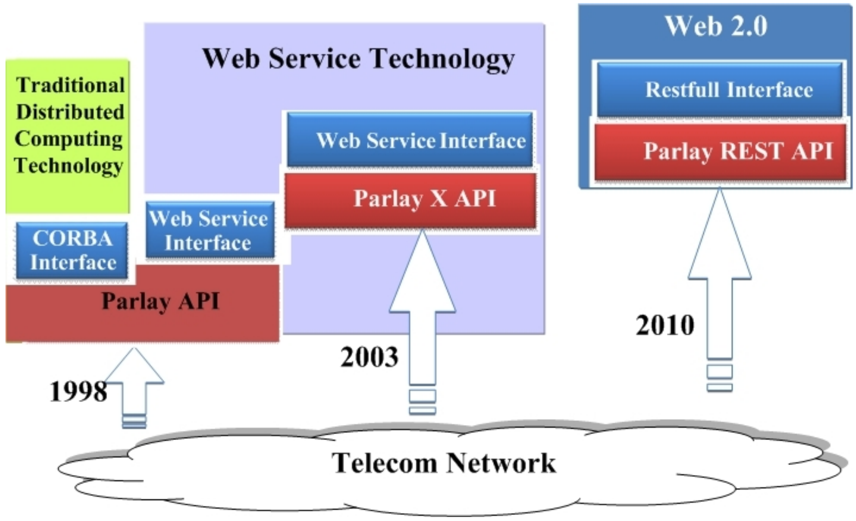

Figure 1. Open telecom network service interfaces.

and unifies the semantic representations of telecommunication and Internet services. Our main contributions are the development of the following items:

- A semantic description approach (TelecomOWL-S) to telecommunication network services via an extension of OWL-S. This enables the accurate description and matching of telecom network services with the annotated semantic information in an open and integrated network.
- A telecommunication service domain ontology (TSDO) which models the concepts, relationships and knowledge of telecom service domains and supports functional/non-functional property descriptions. This lays the foundation for semantic interoperability and knowledge sharing.
- An open capability gateway which provides telecommunication network services at the semantic level. We implemented a prototype to verify the semantic-based service integration architecture of the telecommunication network and Internet, and various use cases are demonstrated.

This paper is structured as follows. In section 2, we provide background information as well as challenges and assumptions of the presented work. In section 3, we introduce relevant prior work. In section 4, we present the semantic description approach of telecommunication services. Section 5 proposes the framework of the semantic telecommunication services gateway and discusses the semantic service integration architecture of telecommunication networks and the Internet. Section 6 introduces the experimental environment, and section 7 details the demo services and the evaluations of the approach. Finally, section 8 details the conclusions that we have drawn.

2. Background and motivation

In this section, we first define the telecommunication network and Internet services, explain the differences between them and then outline the challenges faced by each service.
Definition 1: TNS (Telecommunication Network Services) are fundamental network capability services provided by telecom network, such as call control services, SMS/MMS services, presence services and location services.
Definition 2: Internet services are web services provided by some service providers on the Internet, such as ticket selling services, searching services and traffic information services. Such services are distinct from Internet access services.
Compared to Internet services, TNS have certain distinct domain-related characteristics, especially those provided by mobile networks.

(1) For terminals, the services provided by different networks have different requirements. The provision of telecommunication network services is greatly dependent upon the capabilities of terminals and upon permanently evolving communication network technologies.

(2) From the network perspective, various communication networks currently exist which all offer different degrees of service quality e.g. GSM, CDMA, fixed network and WLAN.

(3) A significant difference between telecommunication network services and Internet services is the charging pattern used. Internet services are often free however, telecommunication network services utilise various charging models e.g. event-based, session-based, time and volume charging models.

From the points above, we can see that the provision of TNS is greatly constrained by the network's condition, terminal capability and other non-functional features. In order to describe TNS at the semantic level and not the syntactic level, two issues need to be addressed: (1) ***a tailored ontology for TNS*** (see subsection 4.1): TNS, especially when provided by mobile networks, have certain special non-functional features, such as network characteristics, billing policy, terminal capability requirements, and quality of service; (2) ***an ontology-based, formal description of TNS-related domain concepts and knowledge*** (see subsections 4.2.2 and 4.2.3): When semantically describing a TNS, its input/output parameters and certain important features such as network type and terminal requirements involve many domain-specific concepts and knowledge items.

3. Related work

Integration of *semantic web services* (SWS) technology and telecommunications systems is currently a subject of intense research. In this section, we provide an overview of related work, which, so far, has focused on applying ontological and semantic web service technologies to the mobile service domain.

Sungjune Hong [9] presents Parlay X with QoS/QoE extension for 4G networks. Songtao Lin [12] presents a semantic web enabled *virtual home environment* (VHE) for 3rd Generation Telecommunications. Tomas Vitvar [27] illustrates how semantic web service technology can facilitate dynamic, optimal integration of voice and data services with specific characteristics that conform to users' needs and preferences. Taking into account the compatibility and interoperability of mobile terminals and services, Eyhab Al-Masri [6] presents a mobile device-aware system for enhancing the discovery of mobile web services from mobile devices. In order to integrate trust into the process of selecting service providers, H. Cebrin [2] proposes a trust-based recommender for mobile devices in semantic environments. However, all these approaches have not explored the problem of telecommunication network service openess with semantic web services.

Based on the need for a standardized ontology that describes semantic models of the domains relevant for scalable NGN service delivery platforms, Villalonga, C. et al. [26] provides an overview of a mobile ontology which comprises a core ontology, several sub-ontologies, and examples of its application in the service delivery platform. This work, as part of the IST SPICE project, is a meaningful attempt to establish a standardized ontology for mobile service delivery in NGN. The presented construction approach for mobile ontologies is considered helpful for dealing with the issues of flexibility and extensibility however its main use is to address the issue of semantic sharing among the distributed components of a SPICE service platform. The proposed ontology is intended for mobile networks, issues related to the evaluation of results from ubiquitous convergent network environments, and further unresolved ontology extensions/management.

The core idea of the IST's *semantic interfaces for mobile services* (SIMS)[5] project is that semantic interfaces provide new means to specify and design service components and to guarantee compatibility in static and dynamic component compositions. Compared to the well known static interfaces currently in use, semantic interfaces also define the dynamic behavior and collaboration goals across an interface. This enables the effective checking of safety/vitality properties and support of service discovery/composition at runtime with compatibility guarantees. SIMS defines a domain-specific ontology whose main is to establish a common description of the SIMS-related concepts and their semantics. However, the main goal of the SIMS approach is oriented towards semantic service marketplaces and does not address the openness of basic telecom network services in the semantic level.

[5] *IST SIMS project, http://www.ist-sims.org*

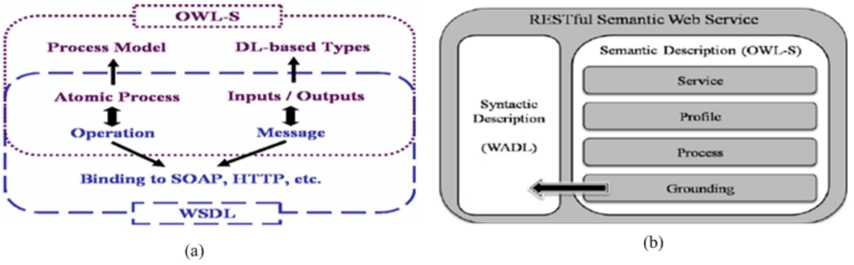

Figure 2. The ServiceGrounding mechanism of OWL-S.

Alistair Duke [4, 5] explores the use of semantic web services within the *operational support system* (OSS). OSS ensures the visibility of service delivery and assurance for end customers. To enable the BT Wholesale Gateway to integrate easily with its partner's system, BT discussed the dynamic B2B integration with semantic web service technologies. However, this approach only focuses upon telecommunication management-related aspects.

Currently, with the rapid development of Web2.0, the RESTful APIs [7] and more light-weight web services are becoming more and more popular in web-based mash-up applications. A *RESTful* web service (also called a RESTful web API) is a simple web service implemented using HTTP and the principles of REST (Representational State Transfer). In order to meet this technical trend, RESTful Parlay APIs have been released by the *Open Mobile Alliance* (OMA). In relation to the REST approaches, Parlay is a family of Open APIs for telecom network services. With the development of distributed computing technologies, the interface description specifications have several versions designed to meet different needs, such as CORBA IDL-based, WSDL-based and REST-based web service specifications. Different interfaces have different market demands respectively. For example, whilst the WSDL-based Parlay/Parlay X web services are more suitable for enterprise service systems such as SMS notification in logistics systems, REST-based interfaces are more appealing to web applications. Thus, besides WSDL-based web services, there are also a large number of RESTful APIs on telecom networks and the Internet. Various open APIs technologies will coexist in the future as they do now but the question of how to integrate these heterogeneous service interfaces on the semantic level needs to be considered. In response to this, we believe that our proposed approach can conveniently address this issue. It is well known that OWL-S is an abstract semantic service description model which binds the real implementation mechanism through a *ServiceGrounding* ontology. Currently, OWL-S has chosen the existing industry-standard WSDL to describe the implementation specification for ServiceGrounding as shown in Fig. 2a. So our proposed approach has the practical possibility to interoperate with RESTful based services. The grounding problem of OWL-S with RESTful services has already been addressed by defining a new OWL-S ServiceGrounding ontology for RESTful services as illustrated in Fig. 2b[6]. Thus our proposed approach can easily interoperate with RESTful-based OpenAPIs on the semantic level.

4. Semantic description for network services

Here, a technical modelling overview of the proposed infrastructure is provided, namely semantic solution choices and extensions for description of converged services and associated information[7].

4.1. TelecomOWL-S: an extension of OWL-S

Compared to plain, transaction-based Internet services, general telecommunication services are often event-driven and stateful. So the telecommunication services, especially certain complex value-added services, often involve complex internal service logic control descriptions. However, TNSs are often the basic network capability services in comparison

[6] *RESTfulGrounding, http://www.fullsemanticweb.com/blog/ontologies/restfulgrounding*
[7] *Source files of the developed ontologies online: http://int.bupt.edu.cn/jsp/centers/bupt506/intro.htm*

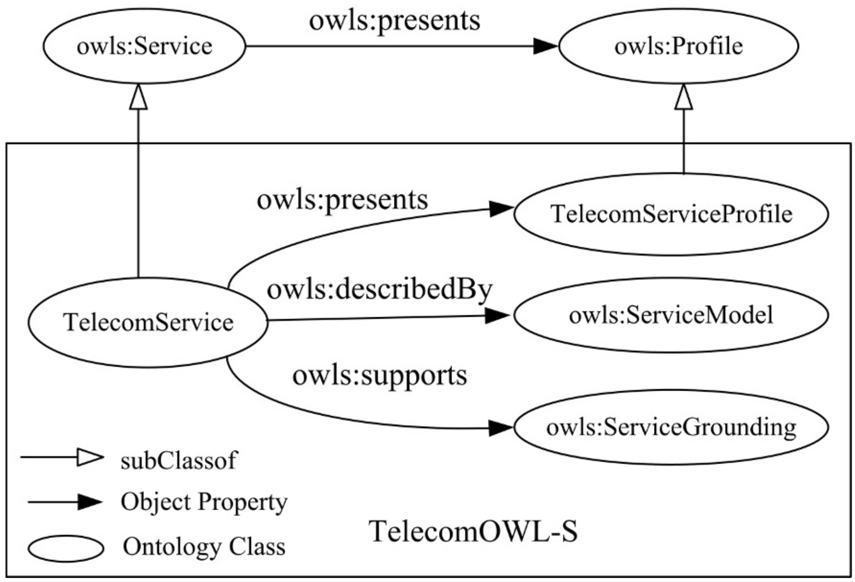

Figure 3. High-level ontology of TelecomOWL-S.

to the general value-added telecommunication services. They only need to provide the semantic specifications of a network capability service interface and do not involve complex service logic descriptions. The ServiceModel and ServiceGrounding of OWL-S are partially suitable for the semantic description of TNS. Specifically, the atomic process ontology of ServiceModel can be directly used to model the network operations such as MakeACall and CancelCall. The ServiceGrounding ontology can be used to map the atomic process of ServiceModel to the operation of WSDL-based open interface specifications like Parlay X. The ServiceProfile of OWL-S needs to be extended to describe the related important features of TNS. To accurately describe the important features of TNS, we present a tailored service ontology - TelecomOWL-S, which exemplifies an extension of the ServiceProfile ontology of OWL-S.

Similar to OWL-S, TelecomOWL-S also has three parts: TelecomServiceProfile, ServiceModel and ServiceGrounding. As the semantic description of TNS does not involve complex service logic control, TelecomOWL-S adopts the same ServiceModel and ServiceGrounding ontology as those of OWL-S. The difference is that TelecomOWL-S redefines a new TelecomServiceProfile by extending the ServiceProfile of OWL-S based on the characteristics of TNS. Fig. 3 depicts the high-level ontology overview of TelecomOWL-S. The TelecomServiceProfile is directly derived from the ServiceProfile of OWL-S. The extensions are of two types, one limits the range of an existent property, and the other defines a new special property. Specifically, the classes and properties of the TelecomServiceProfile ontology are shown in Fig. 4.

The TelecomServiceProfile consists of 4 parts: service functional description, service provider information, service feature description and telecom services-related non-functional feature. The former three parts are inherited from OWL-S so the general properties of the OWL-S profile ontology are inherited by the TelcomServiceProfile ontology. Only the value ranges of some properties like serviceClassification and contactInformation are constrained by the specific concepts defined in the TSDO. The last part in particular is used to describe the distinctive features of TNS (four new object properties):

(1) **needForTerminal**: This property can be used to depict the service requirements for a user's terminal capabilities and includes information regarding the users' terminal browser, terminal hardware and WAP. The concepts and terminology about terminal capability are taken from the Terminal Capability Ontology of TSDO.

(2) **useChargingWay**: This property describes the various service-related billing policies and corresponding tariffs such as time-based, volume-based, event-based and flat fees. The concepts and terminology relating to charging is taken from the Charging Ontology of TSDO.

(3) **needForNetwork**: The characteristics of network service provision can be described by this property and includes information about network type and network bandwidth. The concepts and terminology about charging are taken from the Network Ontology of TSDO.

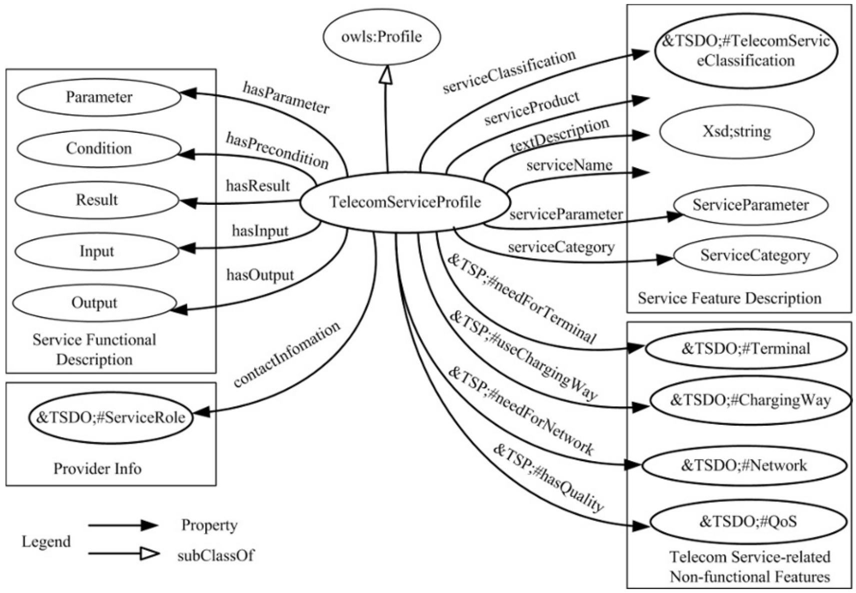

Figure 4. TelecomServiceProfile ontology.

(4) **hasQuality**: This property describes information relating to service quality such as response time, connectivity and delay. The relevant concepts and terminology are taken from the Service Quality Ontology of TSDO.

4.2. Ontology modeling of telecommunications service domain knowledge

4.2.1. Modeling method of telecommunications service domain knowledge

The telecommunication service field consists of a large number of concepts/terminologies and relations. Some concepts have a higher sharing degree and others are only related to concrete applications. Deciding how to abstract the sharing domain concepts and organize them reasonably is a big challenge. Reusability and extensibility are two important ontology modeling factors considered. So, an efficient ontology modeling approach is needed.

In practice, we adopted the layered ontology modeling method [18] to organize the domain concepts and improve the reusability and extensibility (see Fig. 5). Common ontologies, like time and space ontologies, can be shared in different domains such as telecom and medical domains. A concrete domain ontology can be shared by different domain-related application ontologies. For example, a telecommunications service domain ontology may be used to create a service context ontology, network management ontology, etc.

4.2.2. Telecommunications Service Domain Ontology (TSDO)

To support the semantic descriptions of TNS with telecommunications services domain knowledge, we have designed a Telecommunications Services Domain Ontology (TSDO) specifying the domain of telecommunication services.

Considering the scalability and flexibility of TSDO, we construct the domain ontology to comply with a graph-like, open structure. TSDO provides core domain concepts and based upon this, we construct specific, application-related ontologies such as the telecommunication service application ontology or service context ontology.

Fig. 6 gives an overview of telecommunication services domain ontologies. Based on a modular design principle, it comprises several sub-ontologies, such as the Terminal Capability Ontology, Network Ontology, Service Role Ontology, Charging Ontology, Service Quality Ontology, etc. In addition, the construction of the TSDO needs the support of commonsense ontologies and other specific domain ontologies such as time ontologies and location ontologies.

(1) Terminal Capability Ontology: defines main concepts about terminal software, terminal hardware, terminal browser and network characteristics supported by a terminal. Currently, CC/PP and UAProf, which are defined by Resource Description Framework (RDF) language, are used to describe terminal capability: they cannot be directly used to

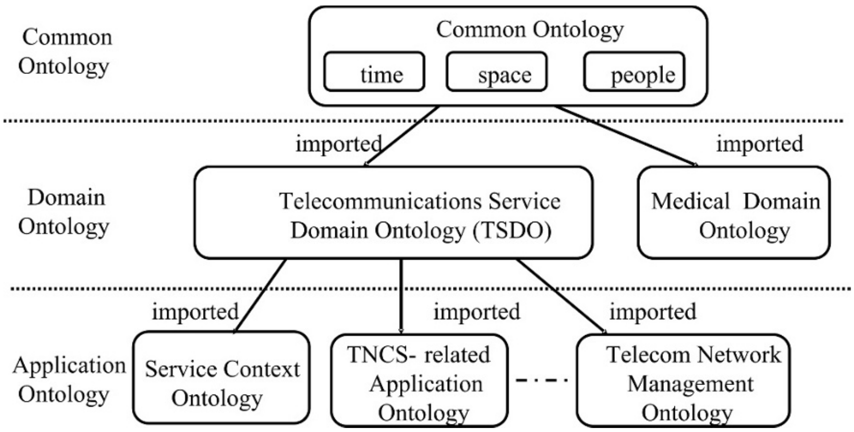

Figure 5. Layered ontology modeling method.

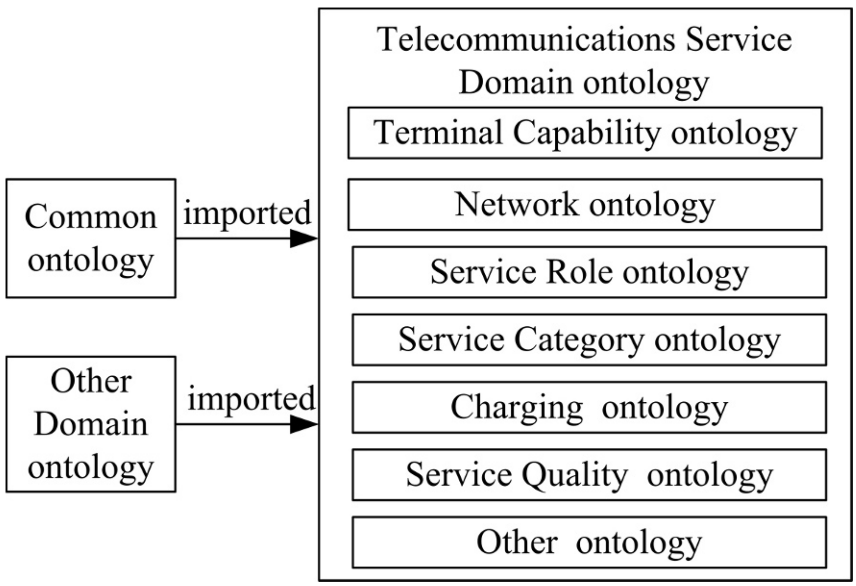

Figure 6. Telecommunications services domain ontology.

describe a semantic TNS. We have created the Terminal Capability Ontology by employing the OWL-based CC/PP and UAProf specifications.

(2) Network Ontology: specifies the network's concepts, category and features as well as the relationships between various networks such as mobile networks, fixed networks, GSM, CDMA, UMTS, WCDMA, WLAN and the Internet.

(3) Service Role Ontology: describes the stakeholders' concepts of the service supply chain e.g. service provider, content provider, network operator and service user.

(4) Service Category Ontology: describes the telecommunications service classification. As a proposed service category standard used by OWL-S, the United Nations Standard Products and Services Code (UNSPSC) provides an open, global multi-sector standard for efficient, accurate classification of products and services. It is often used in the e-commerce field however, whilst UNSPSC is not based on an ontology (so it is only suitable for the serviceCategory property of ServiceProfile, not the serviceClassification property of ServiceProfile), it has no concrete telecommunications service classification except at the Telecommunications Services (code: 81161700) level. Due to this, UNSPSC has no ability to enable an accurate telecommunications service query. We construct the Service Category ontology in TSDO to enable

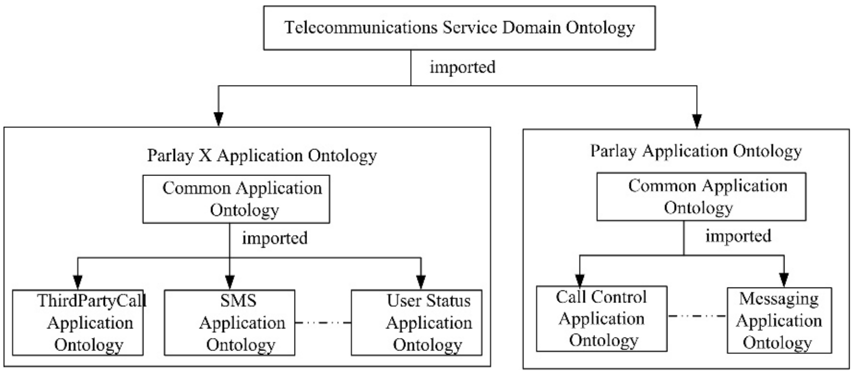

Figure 7. Application ontology overview of TNS.

an accurate description of TNS. The ontology defines the relationships between various telecommunications services like basic service, value-added service, voice service, data service, conference service, presence service, download service, browsing service and messaging service.

(5) Charging Ontology: defines the charging-related concepts and rules of telecommunications services including payment methods such as pre/post-paid methods, charging types such as time, volume, event and content-based charging, billing rates and account balances.

(6) Service Quality Ontology: A telecommunication network must provide services that have end-to-end QoS guarantees. Depending on the technical characteristics, the QoS provided by different networks varies. The Service Quality ontology primarily defines the QoS-related concepts of telecommunication services such as access network QoS, core network QoS and user's QoS. These concepts take into account call delay, message size, call through rate, positioning accuracy, network bandwidth, etc.

4.2.3. Application ontologies for TNS

A TNS typically has different interface parameters *i.e.* input/output. To semantically describe a TNS these interface parameters must be formatted in an ontological manner. Therefore, a related application ontology needs to be created such as Parlay X Application Ontology or Parlay Application Ontology (see Fig. 7).

Concrete application ontology modeling refers to the existing XML-based parameter type definitions of Parlay or Parlay X specifications. The main advantage of this is that ontology-based input/output can enable both reasoning and accurate matching.

5. Architecture of semantic network services

In this section, the architecture *i.e.* the service layer, network layer and message exchange mechanisms of the semantic infrastructure unifying telecommunications and Internet services is explained.

5.1. Semantic telecommunication network services gateway

Using TelecomOWL-S in conjunction with a TSDO such as Semantic Parlay X Gateway or Semantic Parlay Web Service Gateway, the semantic telecommunication network services gateway is developed. Fig. 8 presents an overview of the architecture of a semantic telecommunication network services gateway (STNSG).

The ontology repository provides shared ontology concepts and domain knowledge. It consists of a Telecommunications Services Domain Ontology (TSDO) and a Telecommunication Network Services Application Ontology (TNSAO). The TSDO is used to describe the non-functional features of telecommunication network services such as service classification, terminal requirements etc. and the TNSAO is used to describe the functional features of telecommunication network services such as input/output parameters, preconditions and effects.

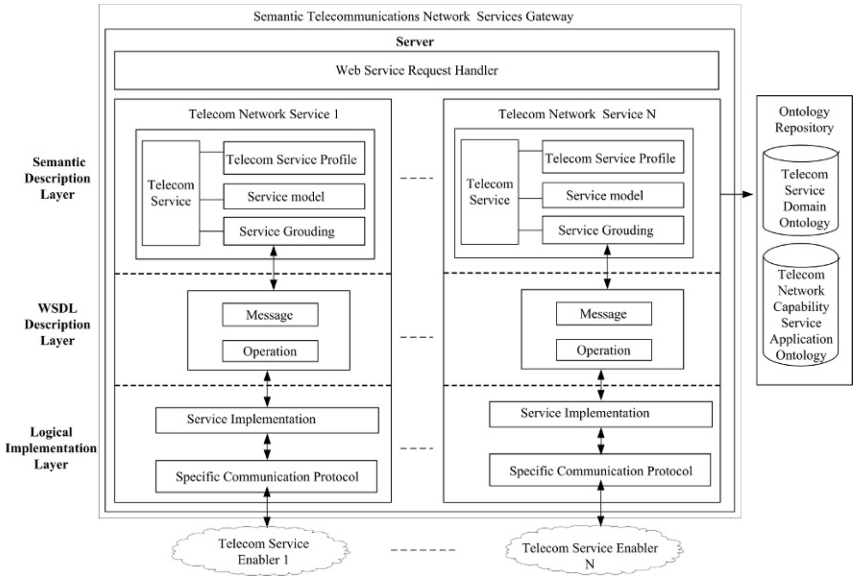

Figure 8. Architecture of STNSG.

The semantic description layer provides the ontology-based semantic descriptions for telecommunication network services. Every semantic description for a concrete network service is an instantiation of TelecomOWL-S. The telecommunications services profile describes the functional and non-functional features of telecommunication services and provides a description of "what the service does". The service model uses atomic process to describe network capability e.g. MakeACall, EndCall, SendSMS. Service grounding is responsible for the description of the binding relation between the semantic description layer and WSDL description layer. Namely, it specifies the mapping details between the atomic processes and input/output parameters of semantic descriptions, communication protocols, message formats, port numbers and other WSDL description information. The ontologies classes and properties can be mapped to an abstract type definition of WSDL using XSLT transformation technology. In fact, the semantics are processed by the client and WSDL still conveys the general data type. The WSDL description layer specifies the WSDL-based service descriptions for telecommunication network services. It mainly describes the communication details in the service-oriented computing architecture e.g. endpoints, port, transport protocol, operation, message, etc. For telecommunication network services, the standard WSDL-based service description specifications such as Parlay X and Parlay Web Service have been published. The logical implementation layer is used to implement the web services provided by the WSDL description layer through a defined programming language and service execution environment. The service implementation module utilizes specific communication protocols, e.g. CAMEL and SIP, to interact with various service enablers of telecommunication networks such as SMS servers, location servers and call control servers.

All semantic telecommunication network services are deployed on the server. The service requester uses a simple object access protocol (SOAP) request message which is based on the semantic description file of the service and then sends an HTTP "POST" message, which includes the SOAP request message, to the server. Then, the server forwards this request to the web service request handler. The web service request handler is responsible for analyzing the received SOAP request and invoking the corresponding web service. The web service request handler is also in charge of the creation of the SOAP response message: when the server receives the returned SOAP response message, it returns this message to the service requester via the HTTP response message.

5.2. A Semantic service integration architecture for a ubiquitous convergent network

The Semantic Telecommunication Network Services Gateway (STNSG) functions by providing semantic telecommunication network services. The semantic service description information can be published on the semantic web service registry. The semantic web services on the Internet can also be registered to the service registry. This will facilitate

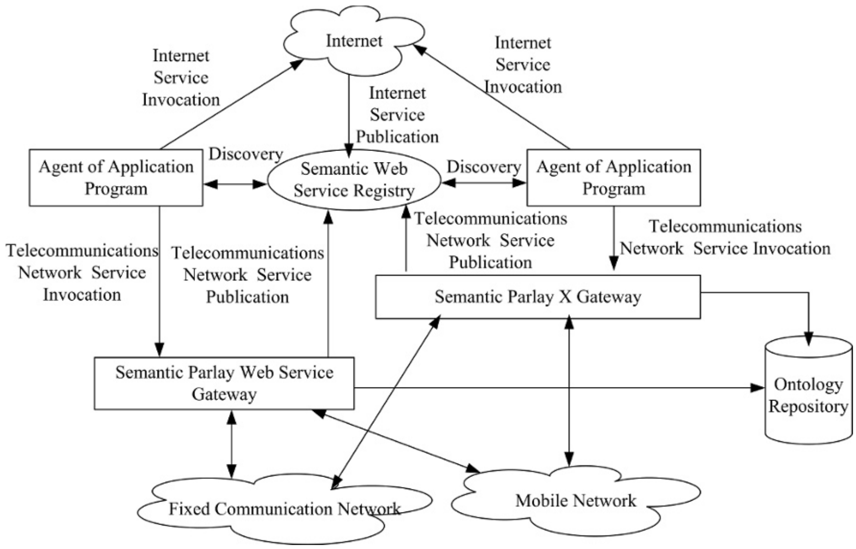

Figure 9. Semantic-based service integration architecture.

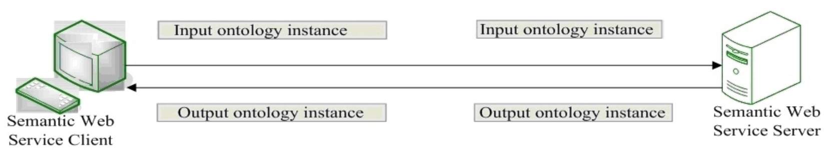

Figure 10. The semantic-enabled message exchange pattern.

the semantic integration of telecommunication networks and the Internet at the service layer. Depending upon the current service context, intelligent service agents can accurately discover, automatically compose, and invoke the services provided by telecommunication networks and the Internet.

The semantic-based service architecture of telecommunications networks and the Internet is shown in Fig. 9. Both Semantic Parlay Web Service Gateway and Semantic Parlay X Gateway provide ontology-based telecommunication network services. However, the abstraction level service of the former is lower than that of the latter. The ontology repository is used to provide and manage the shared ontology-based service concepts and domain knowledge.

5.3. Message exchange mechanism of STNSG

In the real semantic web service environment, the ontology-based input/output instance should be directly exchanged between the client and the server (see Fig. 10). However, in order to support this approach, the existing WSDL specification along with a transport protocol such as SOAP and an industrial web server software such as Axis/Apache needs to be upgraded. As implementing upgrades increases costs, this transition needs to occur gradually.

Currently, the input/output parameter types defined in the WSDL-based Parlay web service or Parlay X specifications are based on XML schema definitions (XSDs). In addition, the existing industrial web service servers and transport mechanisms cannot directly support an ontology-based message exchange. In order to reuse the extensive work already implemented by WSDL, SOAP etc. and to provide software support for message exchanges based on these declarations, as defined to date for various protocols and transport mechanisms, extensible stylesheet language transformations (XSLT) script can be used in the ServiceGrounding part to map the ontology class to XSD-based parameter type. The semantic web service client uses the OWL-S API to invoke the service, and OWL-S API is responsible for executing the XSLT script. In this way, semantic web services can also be provided using the existing web service architecture (see Fig. 10).

Figure 11. The semantic-enabled message exchange pattern in the existing web service environment.

```
<grounding:wsdlInput>
    <grounding:WsdlInputMessageMap rdf:ID="WsdlInputMessageMap_17">
        <grounding:owlsParameter rdf:resource="#callee"/>
         <grounding:wsdlMessagePart rdf:datatype="http://www.w3.org/2001/XMLSchema#anyURI"
         >http://59.64.156.212:8888/axis2/services/ThirdPartyCall?wsdl#callee</grounding:wsdlMessagePart>
             <grounding:xsltTransformationString>
                 <![CDATA[
                     <xsl:stylesheet version="1.0"
                        xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
                        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
                        xmlns:common="http://www.bupt.edu.cn/ParlayX_1_0/common.owl#">
                     <xsl:template match="/ ">
                         <xsl:value-of select="rdf:RDF/common:EndUserIdentifier/common:value"/>
                     </xsl:template>
                   </xsl:stylesheet>
                 ]]>
            </grounding:xsltTransformationString>
    </grounding:WsdlInputMessageMap>
</grounding:wsdlInput>
```

Figure 12. The example of XSLT transformation script.

This will greatly facilitate the evolution from WSDL-based Parlay web service to semantic Parlay web service.
Figure 12 gives an example of how to transform the ontology input from an "EndUserIdentifier" to a "callee" input parameter in WSDL file using an XSLT script.
In the existing web service environment, semantic TNS can be expediently provided through adding semantic descriptions to the Parlay web service gateway or Parlay X gateway. The STNSG can publish the concrete TelecomServiceProfile on the semantic web service registry and then the intelligent service agent can discover the needed service and invoke it. Fig. 13 describes the message exchange flow in detail.

6. Experimental environment

We implemented an experimental environment to validate the proposed approach. The framework of this environment is shown in Fig. 14 and its major components are as follows:
(1) Semantic Parlay X Service Provider: In the experimental environment, we use three different approaches to provide the semantic Parlay X services.

- **Parlay X services provided by our own integrated service platform**: The service delivery platform, which can support the voice and data value-added service, is extended. We have developed the ThirdPartyCall, SMS and conference services of the Parlay X specification in this platform and then deployed these services as WSDL-based web service. Finally, the semantic Parlay X description part has been added and bundled with the corresponding WSDL description file.

- **Parlay X services provided by Aepona-GBox**: Aepona-GBox[8] is designed to facilitate the creation of advanced

[8] *Aepona, Aepona-GBox for TAS 4.X-Empowering Telecom Development, http://downloads.aepona.com/gboxweb/gboxdownload.php*

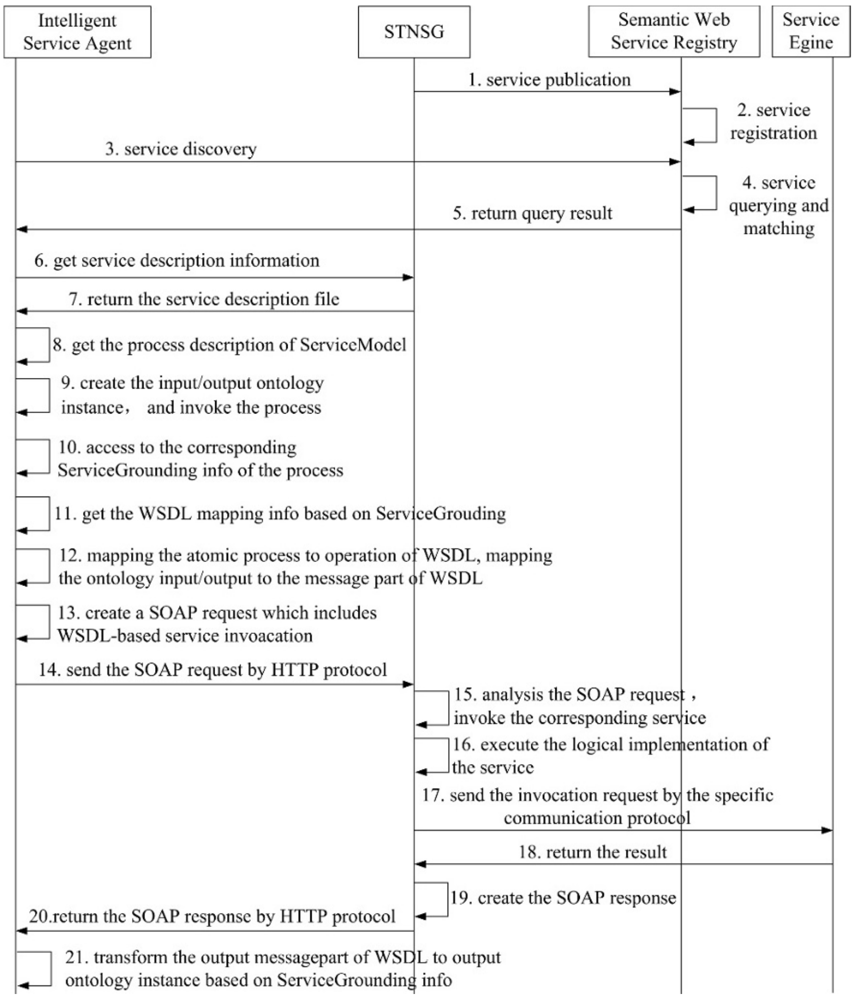

Figure 13. The execution mechanism of the semantic TNS.

telecom services and IT services using web service technologies. As Gbox can directly provide the Parlay X service we only need to add the semantic descriptions based on the Parlay X web services to implement a semantic Parlay X gateway prototype.

- **Parlay X services provided by China Telecom Operator**: China Telecom is one of the three telecom operators in China. Individuals and small/medium enterprises (SMEs) can invoke these basic services to create advanced telecom and IT services. We also added semantic annotation information to these network capabilities and published this information to the semantic web service registry.

(2) Semantic Web Service Registry: To enable the publication of semantic Parlay X services, a semantic web service registry prototype has been developed which consists of the service publication interface, the service matching engine, the service repository, the service discovery interface, and the service management. The *service publication interface* is responsible for receiving semantic service description information from service providers and then registering the service profile into the service repository. The *service discovery interface* responds to the service enquiry from the intelligent service agent by transmitting the service request description to the service matching engine and returning the list of satisfactory services. The *service matching engine* matches a service request to a service advertisement and is based on matching all functional properties (input and output parameters, preconditions, effects) and nonfunctional properties (such as price, quality). The matching degree depends on the correlation of the telecommunication service domain

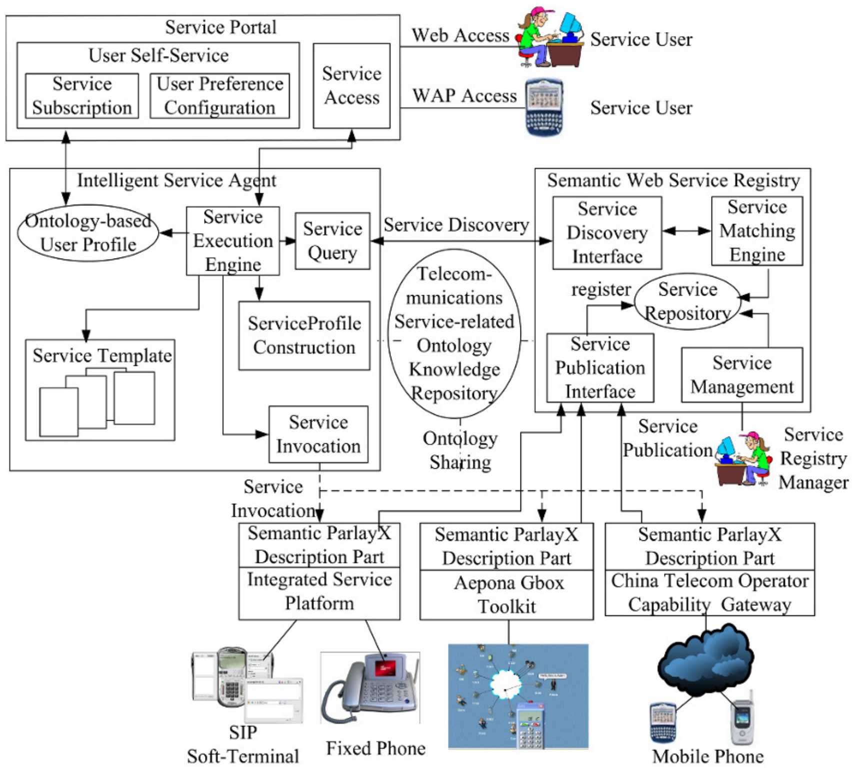

Figure 14. Experimental environment.

ontology (TSDO) concepts associated with these properties. The *service repository* holds the all-registered semantic web service description information. In addition, the manager of the semantic web service registry can administer the registered services information through the *service management module*.

The semantic web service registry can enable the registering and matching of semantic web services not the general WSDL-based web services. Compared to the existing universal description discovery and integration (UDDI), the semantic web service registry can support ontology-based reasoning, but not keyword-based matching. It is a pure semantic web service registry akin to the existing OWL-S/UDDI, in other words, it only supports semantic web service registration. It uses a service repository to store the registered service profiles so it does not involve the tModel. The registered service profile instances must conform to the TelecomOWL-S and OWL-S profiles ontology.

(3) Intelligent Service Agent: The *service execution engine* controls the whole service execution process. The *service profile construction* module creates a personalized service request profile based on the user's preferences or profile and then the *service execution engine* sends the request profile to the semantic web service registry by the *service query* module. After receiving the returned service list, the *service invocation* module is responsible for calling the semantic web services that are based on the OWL-S API using a service URI. Currently, this service agent can only enable the template-based composite service and cannot support the automatic service composition function.

The *service template* is described through an XML document. It mainly consists of two parts: (i) **Service Data Part**: Used to define the shared variables in the service template. The parameters declared in the service data part can be used as the input or output of the following atomic service. (ii) **Service Logic Part**: We use an activity-like diagram to describe the service logic. A service template only has an initial node tagged with "start" and may have several end nodes tagged with "end". A composite service template is made up of several atomic services which have an input and output. To represent the service execution sequence, we use the "next" tag in the atomic service to point to the following atomic service according to the specific transition condition, *i.e.* "linkCondition". Fig. 15 depicts the processing approach of template-based composite service in the service agent.

(4) Ontology-based Profiling: User profiling is an important enabling technology for the personalized service provision as

```
Receive a request for a composed service X from service portal;
Load X's template;
Define cs represents current service in the template, ns represents the next service after cs in the template;
cs = initial service in X's template;
While (cs != final service) {
    Create cs's profile using input type, output type, classification and user preference of cs;
    Send profile to semantic web service registry and get the satisfied service instance address;
    Invoke the satisfied service instance by its address and get result;
    Find ns by checking cs's result matches which transition condition of cs in the template;
    cs = ns;
}
```

Figure 15. The processing approach of template-based composite service.

Figure 16. Web-based service portal.

user preferences can be used to customize the service to satisfy the user's personalized wishes and expectations. However, as already mentioned, the existing user profile specifications, such as *vCard* and *Friend of A Friend* (FOAF), are typically limited to their specific application scenarios. Here, we apply an integrated user profile based on the existing profile specifications. Our user profile consists of three parts: the user's personal information (name, phone, address, career, and birthday), mobile terminal capability (terminal hardware, software, and browser) and service preferences (charging method, QoS). Users can fill out forms in the service portal and then a service agent transforms this information into an OWL-based file. User mobile terminal capability information can be automatically obtained by service agents through interactions with mobile terminals and then the service agent transforms the UAP compliant RDF file to an OWL-based file. When subscribing to a service provided in the service portal, the user needs to configure the preference information related to this service. When the user initiates a service, the service agent will use the user's profile information to set the corresponding property values of the requesting TelecomServiceProfile instance on behalf of the current user. The semantic web service registry will then return the matching services to the service agent. The separation of service logics from user's profile information and dynamic service discovery can contribute to the provision of a personalized service.

(5) Service Portal: To facilitate service access and user self-servicing we developed a Web-based service portal (Fig. 16). This portal provides a bridge between the service users and the intelligent service agents. Users can login to the service portal, initiate the service invocation and maintain their own personalized preferences data. The user profiles are stored in the user profile repository of the intelligent service in the OWL format.

(6) Telecommunications Service-related Knowledge Repository: To enable sharing of telecommunications services-related knowledge among the service requester, semantic web service registry and service provider, we constructed an ontology-based knowledge repository consisting of the telecommunications service domain ontology and the Parlay X application ontology. All these ontologies are stored in the OWL file format and have a unified namespace. Currently, there are around 430 telecommunications services-related ontology concepts and terminologies in this repository.

(7) Service Matching Engine: The semantic web service registry enables the matching of input and output parameters, as well as the ontology-based matching of non-functional properties by extending the OWL-S API toolkit which uses the Jena2 reasoning engine. Service discovery calculates the semantic similarity of service properties between the advertising service profiles and the requesting service profile. The classic matching degree is divided into four categories: "exact", "plugIn", "subsumes" and "fail" [19]. The assignment rules for matching degree are as follows: Concept_R corresponds to a concept of request service profile and Concept_A corresponds to a concept of advertising service profile:

```
degreeOfMatch(Concept_R, Concept_A){
        if Concept_A equivalent Concept_R then return exact
        if Concept_R subclassOf Concept_A then return exact
        if Concept_A subsumes Concept_R then return plugIn
        if Concept_R subsumes Concept_A then return subsumes
        otherwise fail}
```

Some basic ontology reasoning operations can be supported by the OWL-S API toolkit including "equivalence", "subclassOf", "transitive", "reflexive" and "symmetric". In fact, sometimes there are no two exact logical matching services however, similar services are also meaningful for the service requestor. In addition, precision and efficiency are two very important factors of service discovery; if all advertising services in the semantic web service registry need to be matched with the requesting service profile efficiency becomes a salient problem. Thus, improving efficiency whilst ensuring accuracy should be considered, especially for telecommunication services. In the experiment, we use the matching subspace and heuristic functions to exclude the unqualified services, reduce the redundant computing for service matching and thus improve efficiency.

Formally, a ***Matching Space*** (MS) is a set which consists of services published by their providers in the semantic web service registry. $MS = (AS_1, AS_2, \cdots, AS_n)$, where AS_i is the advertising service i. Further, AS_i is defined as $AS_i = (SCS_i, FAS_i, NFAS_i)^T$, where SCS_i is the service category attribute of AS_i; FAS_i is the functional attributes of AS_i; $NFAS_i$ is the nonfunctional attributes of AS_i, so,

$$MS = \begin{pmatrix} SCS_1 & SCS_2 & \cdots & SCS_n \\ FAS_1 & FAS_2 & \cdots & FAS_n \\ NFAS_1 & NFAS_2 & \cdots & NFAS_n \end{pmatrix} = \begin{pmatrix} SCS \\ FAS \\ NFAS \end{pmatrix}$$

From the above analysis, a matching space can be divided into three subspaces: SCS, FAS and NFAS. The algorithm proposed by this paper is based on these subspaces.

A heuristic Function is an iteration function used to select the qualified service which will be matched in the next matching subspace:

$$f_{AS_i}(t) = \frac{\mathrm{sgn}[\prod_{k=0}^{2} \mathrm{match}_{(k)}(RS, AS_i) - t] + 1}{2}$$

Where: $k = 0, 1, 2$ respectively corresponds to three subspaces: SCS, FAS and NFAS. $\mathrm{match}_{(k)}(RS, AS_i)$ is defined as the matching degree between the requesting service and advertising service i, $t \in [0, 1]$ is called the matching threshold. The above heuristic function shows that we consider not only the matching value of the current subspace but also the matching result of the former subspace. By importing the heuristic function $f_{AS_i}(t)$, we can get the matching degree matrix with heuristic information which is used to select the candidate service matching in the next subspace. The advertisement service AS_i corresponding to a nonzero element in the matching degree matrix is the candidate service to be matched in the next subspace.

The algorithm proposed by this paper runs on the service matching engine of semantic web service registry. To import the heuristic information into the discovery process, we divided the matching space into three subspaces in a specified order: service category subspace, functional attribute subspace and non-functional attribute subspace. These three subspaces comprise the basic features of a semantic telecommunications service. Before matching service in the next subspace, candidate services are selected to match in the next subspace according to heuristic information which can reduce unnecessary computation for discovery and improve efficiency in matching. The service matching algorithm encrypted in pseudo code is as follows:

```
Service Matching Algorithm

Inputvar Request Service Profile
Outputvar ServiceList
For all services in service registry Do
      Computing the Service Classification (SC) similarity between Advertisement Service (AS) and Request Service (RS);
      Next service;
End For
Using the heuristic function to filter the Service Classification (SC) similarity;
Selecting the services whose value is nonzero as the qualified candidate services and adding it to a new Matching
Space labeled as MS' to enter the next matching step.

For all services in MS' Do
      Computing the Functional Attribute similarity between Advertisement Service and Request Service.
      Next service;
End For
Using the heuristic function to filter the Functional Attribute similarity;
Selecting the services whose value is nonzero as the qualified candidate services and adding it to a new Matching Space
labeled as MS" to enter the next matching step.

For all services in MS" Do
      Computing the Non-functional Attribute similarity between Advertisement Service and Request Service. The
      nonfunctional attributes include network type, terminal capability, charging way and Quality of Service.
      Next service;
End For
Using the heuristic function to filter the Non-functional Attribute similarity;
Selecting the services whose value is nonzero as the final qualified candidate services and adding it to ServiceList;

return ServiceList;
```

7. Demonstrators and evaluation

In this section, we describe a specific service test set-up with possible extensions and provide an evaluation outcome on the basis of our experimental environment.

7.1. User preferred click-to-call service

Currently, telecom operators have a positive attitude towards opening up their network capability services for application developers in the IT field. Since 2004, *Orange* has initiated a partner program committed to enabling a more open world and diverse service eco-system. *Telefonica* began to promote mashup applications in Spain and the UK from 2009 and there are more than 1,800 development communities located in Spain [13]. In China, two large telecom carriers have also enabled the open programming of network capability services. Now *China Telecom* has created an application development factory oriented to the mobile Internet[9]. Some main telecom network capability services have been published through web service and RESTful technologies such as *Interactive Voice Response* (IVR), SMS, multi-party call, and click-to-call. *China mobile*, the largest telecom operator in China, is also actively planning to establish the open mobile Internet platform program. In addition, some Internet giants, such as *Google* or *Skype*, can also provide some communication services. Therefore, there may be multiple communications services with the same or similar functions in the network. *Virtual Network Operator* (VNO) has an opportunity to select appropriate communication services on behalf of users based on their preferences to provide better user experiences and to reduce costs. In fact, websites that can compare prices in online shops already exist on the Internet (see services *Google Product Search* and *Yahoo! Shopping*) and such facilities are also feasible for the future telecommunications world.

[9] *China Telecom, Application development factory of China Telecom, http://www.189works.com. (in Chinese)*

Table 1. Charging policies adopted by different operators

Service Name	Service Provider	Charging Rate			
	Operator 1	9:00 a.m.–17:00 p.m.	17:00 p.m.–22:00 p.m.	22:00 p.m.–9:00 a. m.	
		0.4 Yuan/Min	0.25 Yuan/Min	0.15 Yuan/Min	
ThirdParty	Operator 2	Any time			
Call		0.3 Yuan/Min			
	Operator 3	8:00 a.m.–11:00 a.m.	11:00 a.m.–14:00 p.m.	14:00 p.m.–20:00 p. m.	20:00 p.m.–8:00 a. m.
		0.35 Yuan/Min	0.2 Yuan/Min	0.35 Yuan/Min	0.002 Yuan/Sec
	Operator 4	7:00a.m.–19:00p.m.		19:00p.m. – 7:00a.m.	
		0.33 Yuan /Min		0.18 Yuan /Min	

Here we describe the scenario of our implemented use case based on user preferences, namely, the click-to-call service. In the past, online advertisements containing a company's phone number were static *i.e.* the numbers displayed were read-only; when customers need help or consultation, they often have to use telephones to dial these numbers by hand and consequently the user's experience is relatively poor. Currently, the click-to-call service is becoming increasingly popular on the Internet with the openness of telecom network services. When customers have an interest in specific product information on a web page they can easily click the telephone number to initiate a voice call by entering their own phone number. However, the existing click-to-call services are always statically bundled with the call service provided by a specific network operator. As different carriers have different pricing policies or quality of service, it is difficult for users to select the click-to-call services that will satisfy their preferences.

As different carriers use different network technologies, this nearly always results in the services prices or QoS being different. For example, an IP-based call is often cheaper than a circuit-switched call, especially due to the differences at traffic peaks: even the same operator may use different pricing strategies at different times and in different places. In addition, as a result of different business strategies, the rates of different ThirdPartyCall services provided by multiple carriers may also be different. For example, the costs of a call providing commercial *Color Ring Back Tone* (CRBT) ads are relatively cheap. In fact, through market competition, different carriers have already used different charging policies. As virtual network operators (*i.e.* VNO) can, some value-added service providers can use the fundamental network services provided by different carriers. So the value-added service providers have the possibility to automatically select appropriate network services on behalf of the user to put the user in charge of this selection.

Semantic web technology can be employed to resolve this problem and improve the user's experience. In the semantic web service environment, the network operators publish their ThirdPartyCall service of the semantic Parlay X with detailed charging and QoS information on the semantic web service registry. Once the user initiates the service request, the service agent is responsible for submitting the request service profile to the service registry on behalf of the user. The semantic web service registry will match the service request with the service information stored in the repository and return the corresponding results. The service agent then selects the appropriate service from the service list and dynamically invokes it.

7.2. User preferred click-to-call service

Compared with existing Parlay X services, the semantic Parlay X services has rich semantic description information, such as price policy, QoS and terminal capability requirement. The ontology-based description of service features can support ontology reasoning during service matching such as the subclass relation or subsumption relation, equivalent relation and even semantic similarity matching. For example, time units or currency units might be different between service rate descriptions. The ontology-reasoning technology can resolve such problems; however, keyword-based matching cannot deal with them. All these added features unambiguously state the characteristics of TNS and make the foundation for the provision of personalized services. In the experiment, we simulate four mobile operators to provide the semantic ThirdPartyCall services. Different charging policies are adopted during different time periods (see Table 1).

In the existing Parlay X service environment, the third-party valued-added services often directly invoke the telecom network services provided by the specific operator according to the signed agreement. This is due to the lack of a service

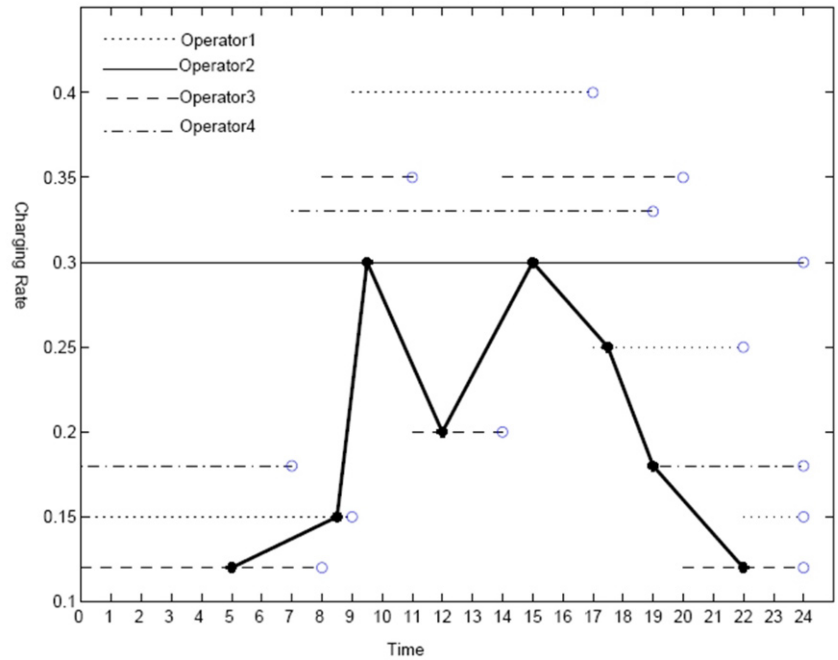

Figure 17. The service selection results based on the charging rate.

registry and semantic annotation information. Consequently, dynamic service discovery, precise service matching and invocation are missing. Users can only use the specific services provided by specific network operators and cannot use the services that best match their personalized requirements. In this experiment, we create the semantic ThirdPartyCall services and then publish them on the semantic web service registry. The service agent queries the cheapest services on the service registry and then dynamically invokes the satisfied services provided by the corresponding operator. We play the role of users to initiate the Click-to-Call service from the service portal at 5a.m., 8:30a.m., 9:30a.m., 12a.m., 15p.m., 17:30p.m., 19p.m., and 22p.m. In Fig. 17, we can see that the operator which has the lowest charging rates is selected. Compared with the static binding method, the experimental results show that by using the dynamically binding method the cost to the user is significantly reduced. Fig. 18 shows the cost comparison under the condition of a 3 minute voice conversation via a phone call.

7.3. Use case extension: adaptive telecommunication service provisioning for mobile roaming users

Making personalized services continuously available for roaming users is a big challenge for mobile Internet providers. To achieve this goal, 3GPP proposed the so-called *Virtual Home Environment* (VHE)[10]. VHE is a system concept that provides personalized service portability across network boundaries and between terminals. From 3GPP's perspective, VHE promises that users are consistently presented with the same personalized features, user interface customization and services no matter what the user's network, terminal (within the capabilities of the terminal and the network) or location may be. VHE will be created by a combination of capabilities provided by the service provider, network operator and terminal equipment.

Most of the current implementation mechanisms of VHE are based on the existing open interface specifications such

[10] *3GPP TS 23.127, Virtual Home Environment (VHE)/Open Service Access (OSA), http://www.3gpp.org/ftp/Specs/html-info/23127.htm*

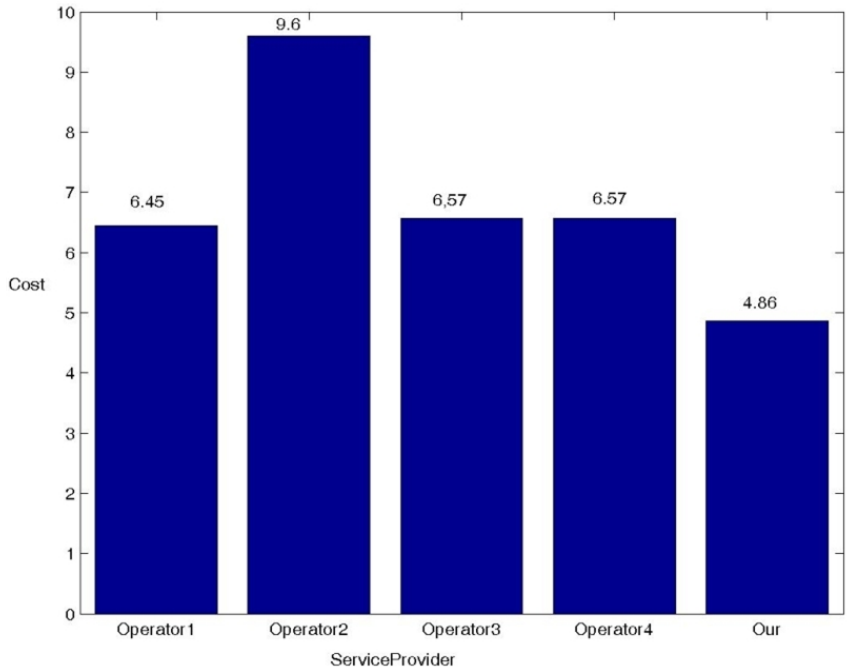

Figure 18. Cost comparison for a 3 minutes long phone call.

as Parlay/OSA and Parlay X. Service portability is implemented as the migration of service logics and user profiles from the home network to the visited network. As service logics are tightly coupled with pre-defined services, they cannot be dynamically discovered and invoked in the visited network upon a service request by the roaming user. The disadvantage of this implementation mechanism is, in particular, that the user's movements might sometimes result in the original service no longer being available. If one service part fails, the entire composite service would fail in the tightly-coupled mechanism. Here, it would be possible to substitute one service part of the home network with another one of the visited network if they can be proven to be similar enough. In addition, even if the home network service is still available on the visited network, the service quality may not satisfy the roaming user's requirements which may include cost or response time. However, the existing VHE resolutions have limitations such as being unable to precisely discover the qualified telecom network services provided by the visited network for roaming users. In such a case, the semantic web service technology can be employed to enhance the flexibility and efficiency of VHE. The service delivery platform can divide the service logic into two parts: abstract service logic (*i.e.* service template) and concrete network resources. The abstract service logic is coupled with concrete network service resources at runtime rather than design time. When the roaming user initiates the service request, the service delivery platform can dynamically discover and invoke the qualified service based on the user's preferences and the current context information such as location, terminal capability, etc. In this way, the semantic telecommunication network service will be an important enabling technology for the semantic-enabled VHE to provide an adaptive, personalized service for roaming users. This will promote the evolution of the VHE's implementation mechanisms from a static, tightly coupled pattern to a dynamic, flexible, and loosely coupled one.

In order to verify the semantic-enabled VHE mechanism, we further explored another service scenario for mobile roaming users. Besides service cost, the user location and terminal capability are also considered. In the experiment, we assume that there are two service domains: service domain 1 is the home environment of user *A* and service domain 2 is the virtual home environment. The concrete service scenario is as follows: when user *A* roams to a city which belongs to service domain 2, the change of user location triggers the migration of abstract service logic and preferences profile from the intelligent service agent of service domain 1 to that of service domain 2. In the meantime, user *A* was browsing recent movie information with his mobile phone when he suddenly found an interesting movie that was showing in this city. So he quickly clicked to dial the phone number on the web page and the system automatically made a call between the

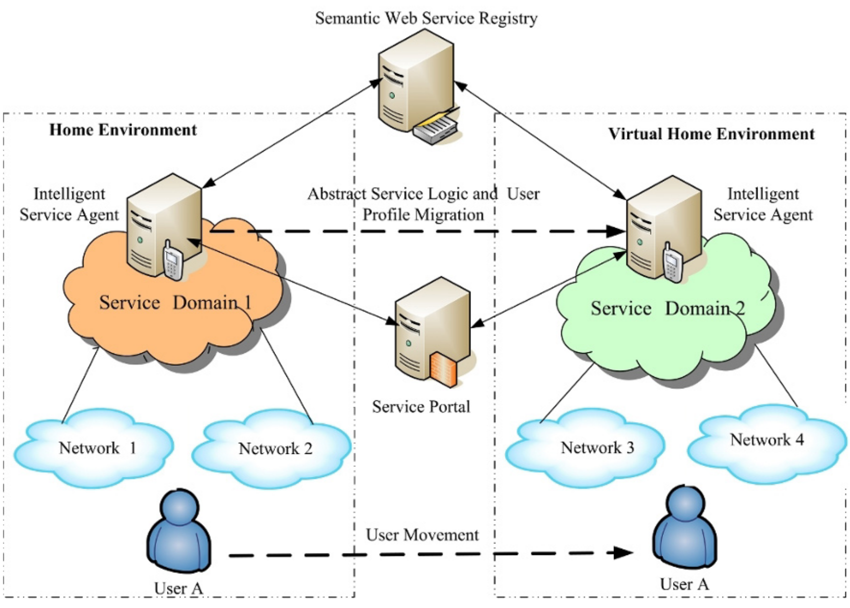

Figure 19. Semantics-enabled VHE experiment scenario.

user's phone number and this number. After the call was made, he consulted the related cinema personnel and ordered a movie ticket paid by his phone account. In conclusion, based on the user's location and his mobile phone capability (screen size, language, figure format), the system sent the digital ticket and routine of the nearest cinema to the user by Multimedia Messaging Service (MMS).

From the above descriptions, it can be seen that this is a typical integrated service which consists of a number of telecom network services (including call services, location space services, payment services and MMS) and information providing services on the Internet (such as map services, ticket booking services, etc.). In the virtual home environment, the system dynamically selected the suitable services according to the user's preferences (such as service cost, quality of service, location) and adaptively adjusted the content to fit the needs of mobile phone to be the same as in the home environment. The roaming user can enjoy the local services like a native subscriber of service domain 2 without roaming or long-distance communication fees.

In order to verify the feasibility of this approach, we further improved the experiment and reconfigured the system deployment structure as shown in Fig. 19. We deployed an intelligent service agent node as the service execution environment in service domains 1 and 2 respectively. The service portal is enhanced to support service re-direction based on the user's roaming information. When the service portal receives the service request from the user, it will first query the user profile to decide the forwarding destination of this request message and whether the user is roaming or not. The corresponding intelligent service agent will map the abstract service logic template into concrete service resources according to the user preferences and current context information. Fig. 20 describes the message exchange flow in detail.

8. Conclusions

The envisaged next-generation convergent semantic telecommunication and Internet networks services are still in a phase of early research. Dynamic extendibility of the telecommunications services domain ontology, including next generation semantic service composition, discovery and search approaches, are all technologically feasible and of value. Nevertheless, they still require further enhancement. The wide acceptance of standards and common practices of the semantic telecommunication network services and the telecommunications service domain ontologies are still far ahead. A definition of the telecommunications service domain ontology by standardization organizations would be in the foundation

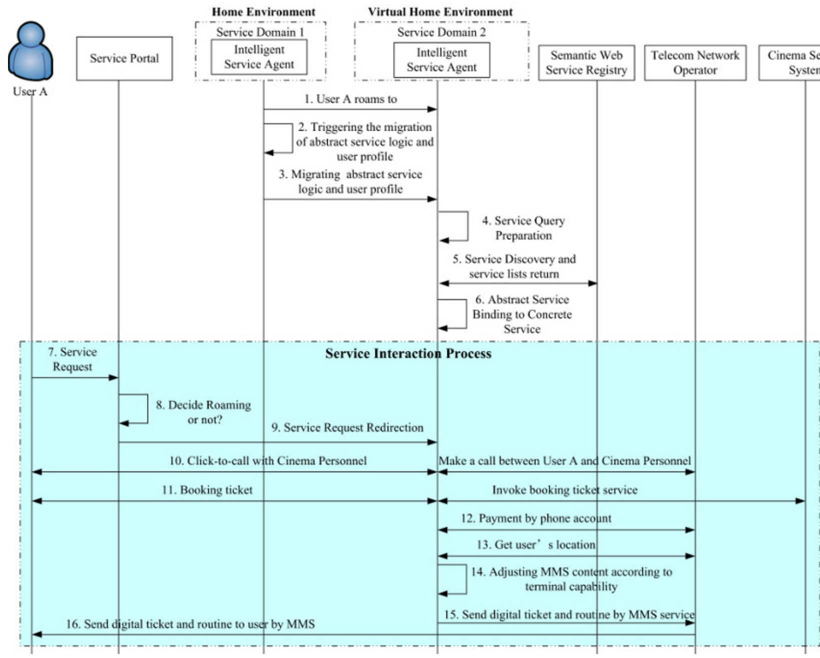

Figure 20. Action flowchart in the proposed semantics-enabled VHE use case.

for the semantic interoperability of heterogeneous communications equipments and the industrial practical convergent service integration. Moving in this direction, IEEE Standard Upper Ontology Working Group [23] has already been developing a standard that will specify an upper ontology to support computer applications such as data interoperability, information search and retrieval, automatic inference, and natural language processing.

In addition, compared to the existing Parlay X service, the semantic telecommunication network services have rich semantic information. This is a foundation of the service precise matching and dynamic discovery. The semantic telecommunication services are one of the key enabling technologies of the intelligent "user-centric" applications which have context-awareness and self-adaptive features. A scalable and robust semantic service discovery network for large-scale ubiquitous computing environment is needed. In fact, some researchers have already begun to explore this problem [11] [16, 20]. This will further facilitate the deployment of large-scale semantic web services in the real network environment.

We have presented the semantic description approach suitable for the telecommunication network services. Following this approach, the network operators can accurately describe service capabilities based on the network and operating conditions. This provides a foundation for the precise service discovery and dynamic service invocation. Alongside the existing Parlay X/Parlay gateway, the new semantic Parlay X/Parlay gateway can provide the semantic TNS. Moreover, the semantic Parlay X /Parlay gateway can further promote the formation of the unified service integration architecture of the telecommunication network and Internet in the semantic web service environment. This will substantially contribute to the convergence of the telecommunications networks and the Internet for the service layer of the future Internet. We have implemented a system, including the semantic Parlay X gateway, telecommunications services domain ontology repository, Parlay X application ontology, semantic web service registry, intelligent agent and context information processing platform. The Click-to-Call service meeting the user's preferences is developed to showcase the approach, and the feasibility of the suggested solution is demonstrated in the real system settings. The adaptive telecommunication service provisioning for roaming users scenarios show the solutions' applicability for future more intelligent mobile services.

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