Evaluation of Semantic Web Services: Before and After Applying in Telecommunication

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Abstract— **Semantic web services (SWS) have emerged as a new paradigm for meaningful data retrieval in a distributed environment. Literature review reveals that SWS have automated the information processing which was missing in current state-of-the-art technologies. This paper investigates that as an application moves from single tenant to multi-tenancy, it substantially increases the volume of homogenous as well as heterogeneous services, thereby making service discovery much more complicated. It is for these reasons this research work intends to overcome the drawbacks of services discovery with the integration of semantic technologies. We present a goal based service discovery framework offers semi-automated service discovery of homogenous as well as heterogeneous services from huge volume of services. Based on the proposed framework novel application and domain ontologies are created. A prototype system was also developed, which validated the proposed framework by integrating Web Service Execution Environment (WSMX) and Internet Reasoning Service (IRS-III). Finally, it presented preliminary results of experiential evaluation based on services discovery and mediation scenarios. Results demonstrate that by considering proposed approach required time in service discovery, and human efforts can be reduce.**

Index Terms— **Semantic web services, SWS, evaluation of SWS, telecommunication ontology, semantic application, services discovery, goal based services discovery.**

I. Introduction

Enterprises wanted to move to a more “plug and-play” business IT infrastructures. Software as a Services (SaaS) separates the software ownership from the operator, the supplier who hosts the system and lets the operator execute it on-demand through some form of client-side architecture via the internet or an intranet. SaaS as a new services based model delivers software as utility services and charges on a per-use basis, similar to the way a utility company charges for electricity [2]. As, web service allows the building of large, complex systems by linking together any number of modules that each performs one or more tasks; ease inter-enterprise computing as required in Business-to-Business (B2B) e-business environments, and finally it permits flexible business network through which aggregations of products and services can flow freely which is not possible in the past. However, web services enable us to access relevant applications but still need to be supported by human interaction; this is the point where Semantic Web comes to act, combining the strength of web services and the added value of Semantic Web will result in a concrete base for enterprise applications [3].

Semantically- enable Service Oriented Architecture (SOA) is a recent buzz word for industry but it’s been under research for nine to ten years. Semantic web vision is more decentralized; retrieves data form distributed data sources using arbitrary vocabulary. Semantic web defines common formats to interchange data between applications. Semantic web vision, on the contrarily is more decentralized; retrieves data form distributed data sources using arbitrary vocabulary. Semantic web defines common formats to interchange data between applications [1]. Cardoso in [4] express that Enterprise businesses required their heterogeneous systems and applications to communicate in a transactional manner; The Extensible Markup Language (XML) was one of most successful solutions developed to provide B2B integration. Unfortunately, XML-based solutions for integration were not sufficient since the data exchanged lacked an explicit description of its meaning as depicted in figure 1. Semantic integration and interoperability is concerned with the use of explicit semantic descriptions to facilitate integration.

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	Static	Dynamic	Syntax	Semantic
Encoding	HTML	+ RDBMS	+ XML	+ RDF/OWL
Creation	Manually	Generated by server-side applications	Generated by applications based on schema	Generated by applications based on models
Users	Humans	Humans	Humans and applications	Humans and applications
Paradigm	Browse	Create/Query/ Update	Integrate	Interoperate
Applications	Browsers	Browsers	Process Integration, EAI, BPMS, Workflows	Intelligent agents, Semantic engines

1995 2000 2005

Figure 1. Evolution of the Technology adapted from [4].

Semantic offers great opportunities for businesses by providing understanding of data and information. Information on a right time and in a required context with less human effort in filtering the search results greatly reduces the cost and time involvement in comparison with current technologies. A semantics technology not only helps to extract and manipulate data from structure data but is equally helpful for unstructured data that would previously have been very problematic. In this study we have discussed that Semantic technologies can be combined with SaaS based application to strengthen the Industry. We stated that the Web service allows the building of large, complex systems by linking together any number of modules that each performs one or more tasks; ease inter-enterprise computing as required in Business-to-Business (B2B) e-business environments. However services are discovered manually by browsing and searching within service registry. The need of such integrated framework for semantic web services is targeted to support rapid and frequent changes in businesses which is greatly required and suitable for industrial application. However multi-tenancy support also empower supplier to address large market or support distributed network of same operator. Multi-tenancy architecture also brings complex technical challenges of tenant provisioning, database sharing, scalability, hardware usage, and tenant-specific Quality of Service (QoS) but the good news is that various reliable solutions and technical guidance are is available from industry’s big players like IBM [5] Oracle [7], Sun [8] and Microsoft [6] are presented to overcome these challenges.

Despite these existing SaaS based solutions, it still lacks the power of dynamic service discovery and service provisioning offered by semantic web services. The aim of this work is to provide a solution to the problem of automated services discovery in a distributed environment. Various models have been presented for automated services discovery however the main demerit was its inability to support for heterogeneous and homogenous services features in one single model. This article has accomplished the following research contributions:

- The gathering of literature on Semantic web services specifically in terms of its service discovery enhancement.
- Identifying a strong area of Semantic web service research with s the integration with Software as a Services environment for enhancement in service discovery.
- Development of domain and application ontologies for telecommunication
- Present and implement the proposed for enhancement in semantic web service discovery.

This paper is organized as follows: In this section, we have introduced the motivation for our research. This is followed by background to identify and give an introduction to the various limitations and challenges in current state-of- the-art web services and to discuss the provided appropriate solutions by semantic web services. In the next section, we review some related works and compare our proposed framework to these works. Then we further elaborate the proposed framework of enhanced semantic web service discovery. Then also discusses the implementation and methodology details of ontology development and prototype system for proposed framework. After that, evaluated results are disused and compared with the existing of industrial technologies. Finally, we

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summarize the results conclusions and discuss about viable future research.

II. Background

In this section, first we review limitation in current state-of-the-art service followed by what semantic web service offer to overcome these limitations. Weske in [12] authors have Identified the following limitations in service oriented systems. Services are discovered manually by browsing and searching within service registry; these Services are hard wired to the application so that when the service fails, the application will also fail, unless additional measures are taken. Static service-binding restricts service-based applications to a fixed service landscape. Due to this adaptation, existing applications use new services that require changing the application code and brings significant overhead. Static service composition characterizes the composition of existing services as a manual task. Service based application needs to define non- functional parameters such as time or cost of using the services for externally invoked services. Currently available platforms do not have these required capabilities. No established interoperable language specification for defining, agreeing on, and monitoring SLAs between service-client and provider. In the same context, Kuropka et al., [9] has attempted to identify the following drawbacks in State-of-the-art Service provisioning. No automatic notification for newly available services, therefore services-provision platform client needs to explicitly invoke the specific new service. To implement new or adapted business processes, clients need to be changed because Service invocation order is hard-coded in the clients. In case when invocation of a specific service fails may be due to network problem on services provider side, service platform do not provide any fall-back solutions might there be another service available with an equivalent functionality. In slightly new dimension authors in [12] highlighted the limitation of missing explicit semantics in current web services technology. Presence of XML, WSDL, SOAP, WS-BPEL, ebXML and other state-of-the-art technologies, web services still require human effort to interpret services descriptions as they provide only limited support for automated discovery. Information is not readable by machines to perform reasoning to deduce new information due to missing of explicit semantics.

The advent of Semantic web services brings several advantages over traditional web services. As per Fensel et al. [30] goal of Semantic Web Services is to provide a conceptual framework and languages to describe Semantic Web Services. According to Duke et al. [10], Kuropka et al. [9] and Mocan et al. [32] Semantic web services overcome the limitation and drawback of current state-of-the- art web services which we have identified above, and provides several advantages. In particular services discovery, composition and mediation [10] has attempted to identify the explicit relationship between services and ontologies as a key element of semantic web service (SWS) technologies. Semantic offers search on ontological concepts rather than by keyword. This would allow not only users but also machines to find the most appropriate services more quickly and then narrow down their search via more expressive queries if required. Semantic web services allow to express and achieve high level goals in terms of an ontology to a service or set of services. It should be possible to carry out decomposition into components parts and then match these components with appropriate services. Mediation relies upon the mappings of messages and data elements to ontology. In the case when two or more services interact with same semantic communication requirements but syntactically different, it should be possible to automatically construct a translation between message data elements that allows the services to communicate.

One year later, [32] suggested that Enterprise information system design has been re-tailored to fit these paradigms in smaller compose-able units of functionality known as services. Service Oriented Architecture (SOA) offers the advantages of loose coupled components, well defined interfaces, peer-to-peer interactions but does not solve the problems of semantic interoperability. Semantic Web Services (SWS) containing machine-understandable information, research explores how Web Service technology can be enhanced from a static structural to machine-understandable descriptions of services' data and processes. Combining semantic annotations of data and behavior and SOA offers more flexibility and speed in handling changes of circumstances for the dynamic Web. In recent times, Kuropka et al. [9] describe the Semantic web services provide the opportunity of dynamic service compositions. If a service fails, the platform is able to identify semantically equivalent services or service compositions and use these instead. New service is published in the platform, it is considered as a candidate to be used in a service composition. Logic is not hard coded but it is composed at runtime and therefore it is capable of dealing with changes in the service landscape.

Weske in [12] identified, that currently we have static service discovery, fixed service landscape, static

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service composition and poor Service Level Agreements (SLAs) specification. In the same year researchers in [9] highlighted, in the current state-of-the-art service that we have no automatic notification for newly available services, hard-coded service invocation order, and no fall-back solution in case of service failure. Lastly [10] accentuates on the fact that explicit semantics is missing in current state-of-the-art service. In search to overcome these limitations (Duke et al. [10] emphasizes the use of semantic web service to improve service discovery, semi-automatic service composition, and mediation between data and process requirements of component services. To maximize the advantage, Mocan et al. [32] concentrate on combining semantic web services and Service Oriented Architecture (SOA) for adding more flexibility and speed in handling changes. According to Kuropka et al. [9] semantic web service provides better Service provisioning in comparison with current state-of-the-art service. This conclude that Web Services with all the advantages of Interoperability between application and network based on open protocols, Reusability, Support of business processes, Cost efficiency and Risk reduction still have various problems and challenges. Advent of semantic web service in industry promises to overcome these challenges and limitations by offering dynamic service discovery, invocation, execution monitoring and better service provisioning.

III. RELATED WORKS

In this section discuss the contributions made in the field of semantic web service discovery and establish its link with proposed framework. This work is focused on three aspects (i) make service discovery automated (ii) conclude service requester's aim to discover identical services (iii) Service discovery for homogenous as well as heterogeneous functionalities.

Preist in [21] presented developed an abstract level architecture of semantic web services lifecycle for broad-based use. Authors projected both macro and micro-architecture service solicitor and service supplier agent. Projected framework maintains service choreography, orchestration, and mediator if required. It supports the communication and source organization, supervising and data parsering. In our paradigm Web Service Modeling Ontology (WSMO) supports basic Web, semantic web and distributed service oriented design principles. One year later in [15] the author's approach for semantic web services is bit akin to our framework with regard to selection among different service provider. In the same context [20] developed discovery algorithm focusing on semantic heterogeneity in terms of multitude of ontologies.

In 2006, [16] presented offered semantic web service discovery along with OWL-S service matchmaker that harmonizes logic based reasoning with estimated matching based on syntactic Information Retrieval (IR). In [18] authors suggested a framework for semantic web service discovery entailing annotations of both functional and non-functional qualities in the context of SAP's Guided Procedures. The planned approach not only supports functional and non-functional characteristics but also proposes upgrading. For another way to service discovery [22] suggested, Peer-to-Peer (P2P) indexing system for supporting multiple service queries. Authors developed layered model that assists semantic service discovery by issuing advertisement of semantic Web services.

In 2007 [17] suggested SNet, a Skip Graph based semantic web services discovery. SNet support finding the extensive services in Skip Graph, compare the given key with the local keys at the current peer node to look up its neighbours, forward the query message and matches exact services in matching engine until the given key is found or it reaches the lowest level neighbours and fails; this process continues. In [13] authors propose a Business-to-Business (B2B) integration architecture using semantic Web services. Their approach based on WSMX to provide strong partner de-coupling and facilitate a conversation between heterogeneous services that support both the RosettaNet standard and proprietary information models.

In recent times, [19] projected "BiOnMap", a reasoning-based approach for resource discovery and composition. BiOnMap service is composed of catalogue which uses domain ontologies to annotate resources semantically and express domain rules that capture path equivalences at the level of the ontology graph and a reasoning engine. In compression, [14] planned a Conceptual Situation Spaces (CSS) that gives descriptive characteristics of situation characteristics in geometrical vector spaces. Authors also aligned CSS and SWS with established semantic web service standards. Their proposed architecture supports runtime reasoning on CSS through a SEE by implementing IRS-III. Our work is similar to the former work. However, our work entails: dynamic service discovery; communication keeping the data

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format same, ontological segregation of web service and service user to figure out heterogeneous as well as homogenous services. Analogous to our framework, pervious work explained semantic web services with respect to OWL-S, OWLS-MX, and BiOnMap for execution of services discovery. However, primarily focus on WSMO in order to remove interoperation differences on structural, semantic, or theoretical level. The proposed framework is bit different from previous work as it is based on pairing between WSMX and IRS-III that can be a potential solution to diminish the weakness of each one.

III. Proposed Framework

The previously proposed framework [22], [15], [20], and [18] for semantic web service discovery had a number of advantages for instance, decentralized service discovery, context-specific ontology mapping, support for semantic heterogeneity and semantic annotations of both functional and non-functional attributes. During the last few years, a lot of work has been done on semantic web services enhancement such as WSMO [29]. Instead all of these advantages, the major limitation of the work was the deficiency not only to support these features but also consolidate new enhancement in one single framework. On the one hand Haselwanter at al. [23], provides a framework for the discovery, selection, mediation and invocation of Semantic Web services, so on the other [24], supports one-click publishing and standard web services can also be published. Before moving forward towards the framework itself, it is important to emphasize the necessity of proposed framework that why exactly do we need to have framework for the integrated Service discovery? To answer this important question we begin the explanation that It is evident from the literature review that none of the proposed work in the past had been targeted towards the integration between semantic and SaaS (in telecommunication domain) to maximize the advantage of both. The goal of our proposed framework is to support service discovery without knowing specific service provider, which does not require any change in data format or order of the messages to communicate, and does not bound to any one service provider, along with ease of use and allow ontological separation of user and web service contexts. The proposed framework achieves its objective as it integrates WSMX with IRS-III and uses both of them together in single particular scenario. We have proposed goal based service discovery framework for combination of semantics and SaaS to support multi-tenancy for telecommunication services operators and providers. It can be generic solution for any sort of applications like CRM (Customer Relation Management), HR (Human Resource), Mediation and Billing. Billing Application is one of the key applications for SaaS while most of the other applications are usually available in the market and enterprise prefers to purchase the one that fulfills its maximum needs among Commercial off-the-shelf (COTS). Moreover we have specifically chosen Billing Application vis-a-vis other applications because it is more complex in terms of high volume of services involved.

We elaborate the distinct components of our proposed framework for the dynamic service discovery in telecommunication domain. Semantic middleware allow billing service providers to store their service descriptions and WSMO goal based ontologies, along with mapping rules with domain and other existing ontologies in middleware repositories. Figure 2 depicts the proposed framework, which not only integrates WXMS with IRS-III but also enforce integrated enhancement in their performance and, provides

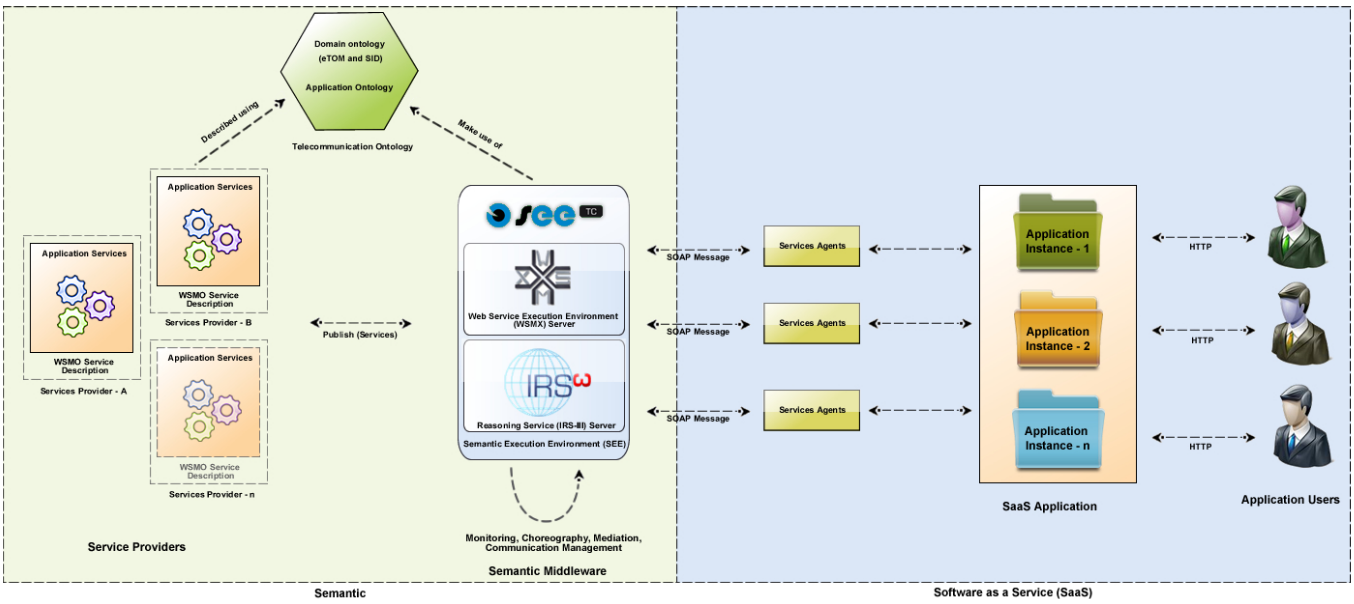

Figure 2. Proposed framework for service discovery.

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monitoring and communication management throughout service lifecycle

Service Providers: Services providers are telecommunication service providers or mobile phone operator that publishes services related to billing application. In our scenario service provider exposes both homogenous and heterogeneous services through a public interface based on WSMO description. This later can be invoked by requestors of the service. Service provider can also publish service through Java, Java WS or Lisp publishing environments.

Ontology: Ontology is the back bone of the semantic web services. Proposed framework can identify services by using application and domain ontology. Application ontology entails customer billing, interrelated settlement and data mediation while domain ontology explains the generic vocabulary of telecommunication.

Semantic Middleware: Semantic middleware permits billing service providers to lay up their service descriptions and WSMO goal oriented ontologies. Semantic Execution Environment (SEE) adds flexibility and scalability for upgrading or replacing the implementation of middleware services by separating descriptions and their interfaces from the implementation [11]. The projected framework not only incorporates WXMS with IRS-III but also provides supervision and messages management by Semantic Execution Environment (SEE). On the other hand IRS-III supports one-click publishing of standard program code by generating a set of wrappers which turn standalone program into a web service [24]. The proposed framework achieves its objective through WSMO which is the similar conceptual framework for both IRS-III and WSMX. WSML messages exchange between IRS-III and WSMX to provide design-time integration. WSML compliant parser code handed over to same open-source software (WSMO4j) to validates and represent messages description internally [37]. This enables our framework to support Peer-to-Peer (P2P) technologies. We have adapted hybrid P2P topology for connecting together similar as adapted by Sapkota and fellow researchers in [38] to dynamically be discovering distributed Web service. IRS and WSMX integration makes our framework more flexible and scalable, maximizes search recall; enable dynamic and distributed Web service discovery and matchmaking by also minimizing the maintenance cost [38]. In the same order several IRS or WSMX environments can attach consecutively to form a distributed or Peer-to-Peer (P2P) network. The best available service in the network can be discovered using semantic description. The framework we have devised is based on distributed, loosely coupled components with no hard-wired bindings.

Services Agents: In traditional systems it is difficult to determine what is data means? and what foster duplicates the application. Data across the organization is often inconsistent and potentially inaccurate. In proposed framework service agents maintain the integration between back-end systems to the semantic middleware through semantic descriptions. The data communication adapters overcome data representation mismatches and transform the format of a received message into Web Service Modeling Language (WSML) compliant format based on defined mapping rules.

SaaS based Billing application: The proposed Billing System as a Service (BSaaS) model support highly customizable multi instance/tenant (client) application, provide platform scalability, data security, performance management and billing related reporting by using web services for integrations purpose. BSaaS architecture is based on general SaaS application architecture. For the sake of simplicity we are only explaining some specific component to the BSaaS application architecture, an overview of the billing application architecture is described in Figure 3. We elaborate the five distinct layers of the proposed architecture which are 1) Presentation layer, 2) Facade layer, 3) Business layer 4) Data Access layer and 5) Metadata/Personalization layer. Each layer along with its components is discussed in separate sections of this chapter. To begin with, we start with the presentation layer.

Presentation Layer: The top layer may call the presentation layer provides the browser-based interaction to application's user. Browser-based interaction provides independence of application usage without installation on client side. Any authorized user from tenant side can request to BSaaS using Hypertext Transfer Protocol Secure (HTTPS). HTTPs are a combination of the Hypertext Transfer Protocol and a network security protocol.

Facade Layer: In Facade layer we are exposing the core functionality of BSaaS. It’s a simplified interface of high level services beneath it; every single method on this layer is a service. Usage Processing, Bill Processing and Settlement are some of the core methods under its layer:

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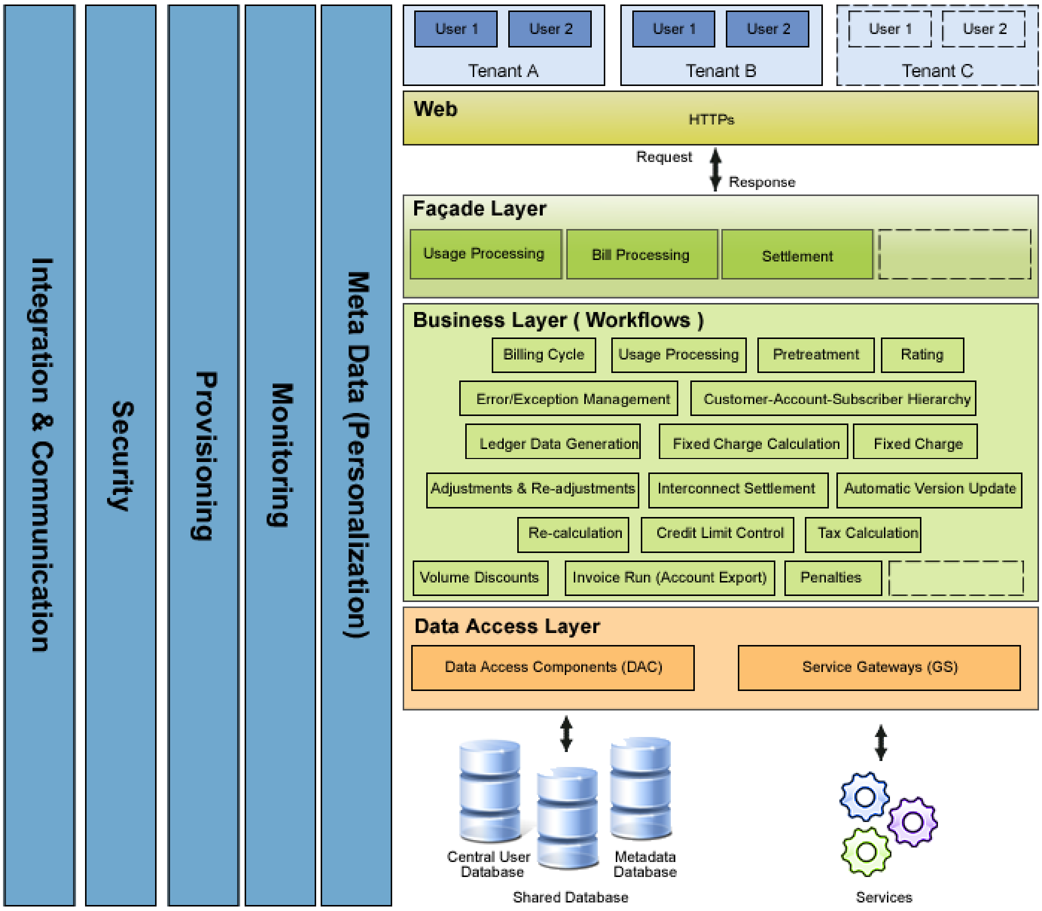

Figure 3. SaaS based Billing Application Architecture.

- **Usage Processing:** This includes Call Detail Record (CDR)/ Event Detail Record (EDR) collection (for events/data captured through mediation or any other sources for example Senior Revenue Officer (SRO), Banks, Meter readings and others) , validation, guiding to associate usage events with customer service instance, Error/Exception Management and Rating by a variety of rating methods, e.g. flat-rated, corridor plans, time-of-day, day-of-week, special dates etc. using a standard or configurable customer-specific rating structure as a pre-requisite for the bill run.

- **Bill Processing:** This includes Data Management (creation, modification and deletion functions of all associated services and billing structures through standard graphical user interface (GUI)), Billing and Invoice Creation (with flexible billing cycles as per customer preferences covering recurring and non-recurring charges, taxation calculation, discounts, penalties and unit-credits). All this information will be stored in a database. All the billing related data will need to be kept available online for at least six months, and will be flexible to cater for changes in policy from time to time without degradation of performance. However, any hardware for enhancing the online storage capacity will be procured additionally. The system will support adjustment and re-adjustment of bill data after the bill data is transferred from Billing System to Receivable System in case some mistake happen to bill data.

- **Settlement:** Production and accounting of periodic settlements for foreign operators (international), national third-party network/ telecom services operators (such as Pre-Paid Calling Cards, Pay Cards, and Mobile Operators), multi-operator, and Inter-carriers billing. Produce

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monthly revenue and re-conciliation reports (such as apportionment of revenue or calls made).

Business Layer: In this layer we replace the business processes with sequential workflows. Workflow is the series of steps, decisions, and rules needed to complete a specific task while sequential workflows completes one activity and moves to the next, executing a sequence of consecutive steps [39]. This approach enables supplier to address any change in business requirement with ease. All they need is just change or replace the business workflows. This layers includes the Business components, entities and all the domain specific services (functionality) of BSaaS.

Data Access Layer: Data access layer includes data access components and service gateway. Data access components expose the stored data (in databases) to the business layer. Service gateway encapsulates complex functionality in provider applications and exposes that functionality as a single simple interface to consumer applications. As MSDN library (Service Gateway) explain that data access layer hides the complexities of accessing a service from the application and provides an ideal location for providing common features such as asynchronous invocation, caching, and error handling

Metadata (Personalization): BSaaS model support both options, different operators can use a single version of the application or separate customized versions for each. Metadata is responsible for tailoring the application according to the operator requirements. Metadata stored in Extensible Markup Language (XML) file format allows for the extension of system objects via custom fields.

Services Requestors: Services requestors are the sender of Simple Object Access Protocol (SOAP) based message to invoke particular web services based on its respective goal. All SOAP messages are sent via Hypertext Transfer Protocol (HTTP). Services requestors can be telecommunication services operator, service agents, or it may be a back-end application.

VI. IMPLEMENTATION

This section explains implementation details of the proposed model for service discovery enhancement. The proposed model implementation starts with the development of application ontology. The first step of the implementation is the billing ontology development. To serve the purpose of step 1, we require application ontology for Billing System and in order to maximize the advantage of semantic in Billing System we also require domain ontologies (in our case for telecommunication domain) to interact with other application, automate services discovery based on shared concept with in telecommunication domain. In order to develop ontology there is a need to have awareness about the different methodologies like [31], [32], [33], [34], [35]. In most of the above discussed/mentioned methodologies required documentation/procedure has not been available, so author decides to go for the interviewing method. However we have adopted Toronto Virtual Enterprise Method (TOVE) methodology [33] for application of ontology development. TOVE provides the motivational scenarios in order to fulfill the need of specification of ontology on the basis of these scenarios. Competency questions are developed to keep focus towards the ontology based on these scenarios. Following are some examples of the competency questions:

- What activities have to be made to achieve the goal of landline to mobile phone services discovery?
- How specific batch of services was used by one or more services requester over a given period of time?
- Under what condition(s) settlement collection are traceable for illegal usage record?
- What are the best tariff policies for rated usage record?
- What are the tax policies and bill data to run for invoice?
- What happens when Duplicate CDR files are aggregated?
- What are the different collection points during pay cycle?
- What are the characteristics to keep the log and status during different stages of processing?

This process has been covered out in an iterating manner from different companies, as this is also validating the method as well as discussed in [31]. We have used Protégé ontology editing tool by Stanford Center for Biomedical Informatics Research available at [69], for Billing System's application ontology development as depicted in Figure 4.

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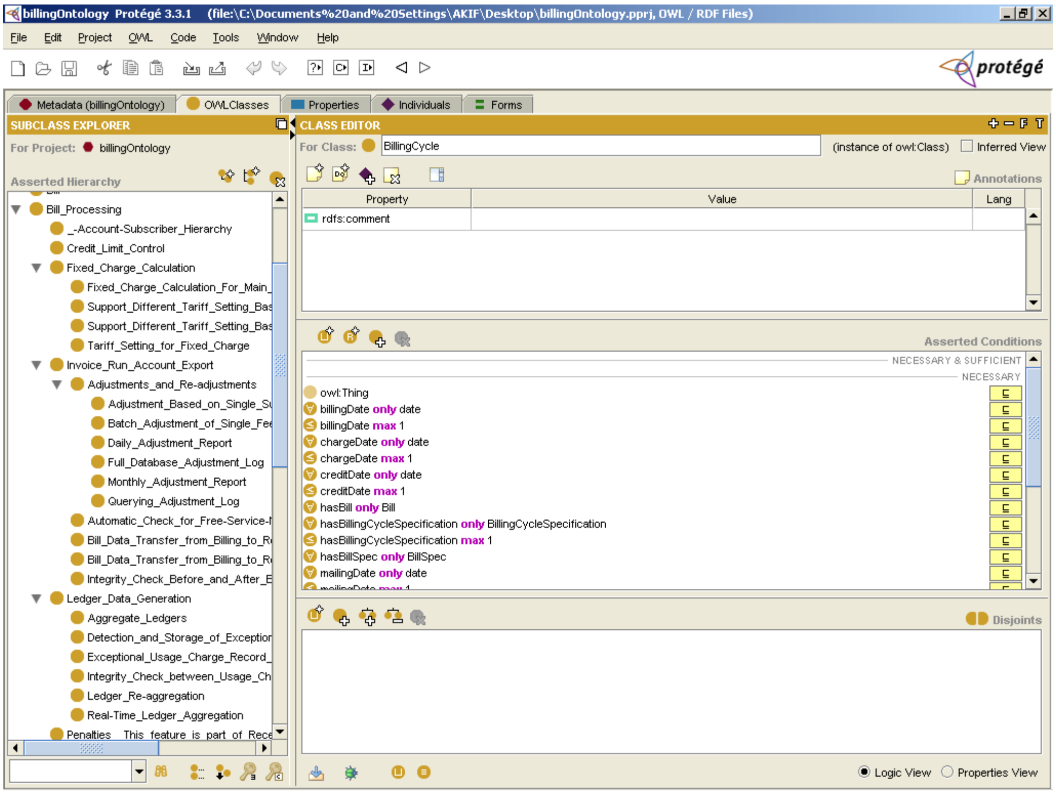

Figure 4. Billing System Application Ontology using Protégé ontology editor

Step 2, Domain Ontology: In this step, we have developed domain ontology for telecommunication. In search of domain ontology there are several standards and worldwide standardization bodies that exist to cover the telecommunication domain such as 3GPP (3rd Generation Partnership Project), WiMAX Forum, NGN (Next Generation Networks), IEEE (Institute of Electrical and Electronics Engineers) and The TeleManagement Forum (TMForum). New Generation Operations Systems and Software (NGOSS) is one such industry-wide standard (Solution Frameworks) developed by TM Forum [25]. enhanced Telecom Operations Map (eTOM) and Shared information/data model (SID) are two key components of the NGOSS solution frameworks which provides the shared understanding for a telecommunication domain. Systems integrators and their partners, capture the past best practices (Global knowledge to local focused solution), Intelligent problem solving, Provide direction to the industry, more over already in industrial use, which help us to integrate other application based on NGOSS. We have considered eTOM and SID for the domain ontologies due to following reasons. There combination address the need of all stakeholders (Service Providers, The focus of eTOM are the business processes, aiming to develop linkages among processes; the identification of interfaces; and the use of customer, service, resource, supplier/partner and other information by multiple processes since it provides a reference framework for categorizing all business activities at all levels of the enterprise [26]. On the other hand SID provides a common information model (common vocabulary) to identify and describe the data with pertinent business processes as well as a standardized meaning for the relationships that exist among logical entities. For example, a common definition of what is "customer" and how it relates to other elements, such as mailing address, purchase order, billing records, trouble tickets, and so on [27]. eTOM and SID both frameworks are under ongoing development by TM Forum. The current models are published in set of different format (XSD, XMI, UML, and HTML browsable document) but in order to make use for Billing System as a domain ontology we need to express these framework in formal ontology language. Web Ontology Language (OWL) is a semantic markup language to describe, publish and share the ontologies on the World Wide Web, and make it understandable for both human and machines [28]. eTOM is organized into different hierarchal levels. Level-1 is the highest level of business process framework. It is then further elaborated into different conceptual levels. We have transformed these processes into OWL class by using

Protégé ontology editor. SID is much complex than eTOM and time consuming to transform manually for this purpose we have used TopBraid Composer available at [40] to convert XSD (XML Schema Definition) format to OWL classes as display in figure 5. Later these ontologies (application and domain) imported into WSMO Studio available at [41], to convert form (Web Ontology Language) OWL to WSML format. Once the ontologies are ready to work with the next phase is semantic web service and Goals creation. Furthermore, alignment of these ontologies together with functional, non-functional, and interface description of services and publish them to the semantic middleware repositories.

Step 3, Semantic Web Services: In the previous step, ontologies have been ready to work with. The next phase is semantic web service and Goals creation. Furthermore, alignment of these ontologies together with functional, non-functional, and interface description of services and publish them to the semantic middleware repositories. We have implemented the similar approach used in [11] for service creation as depicted in figure 6. Our models supports both design-time and run-time approaches for service execution but we have implemented Bottom-up approach in our case, Billing service provided already have web service with WSDL description. Specifically IRS-III provides one-click service publishing by automatically creating semantic wrapper over programming code. WSMX also provide runtime binding (late binding) of service requesters and service providers for dynamic discovery (the service that best fits the requester's goal) provide mediation (if required) and service invocation of semantic web

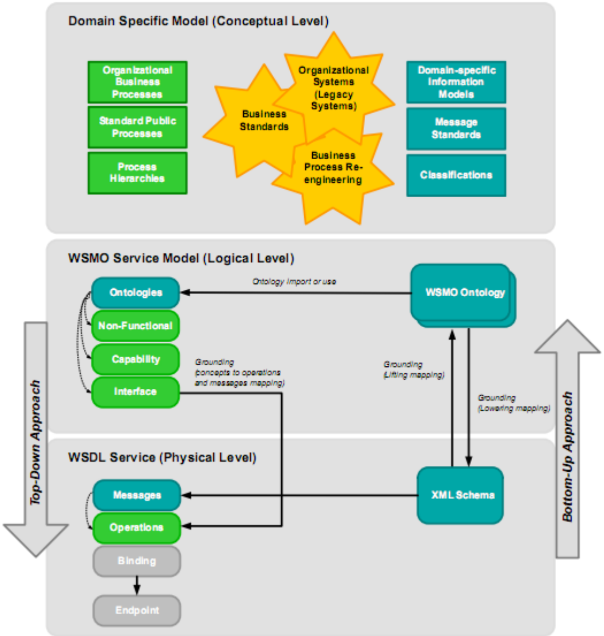

Figure 6. Semantic Service Modeling Levels, (adapted from [11]).

services. Semantic service creation phase involves enabling semantic annotation in existing WSDL services and Web Service Modeling Ontology (WSMO) service creation. According to [29], WSMO provides a rich conceptual model and a formal language (WSML) to semantically describe all relevant aspects of Web services. WSMO facilitates dynamic discovery, mediation, inter-operation, combining and invoking electronic services over the Web. WSMO

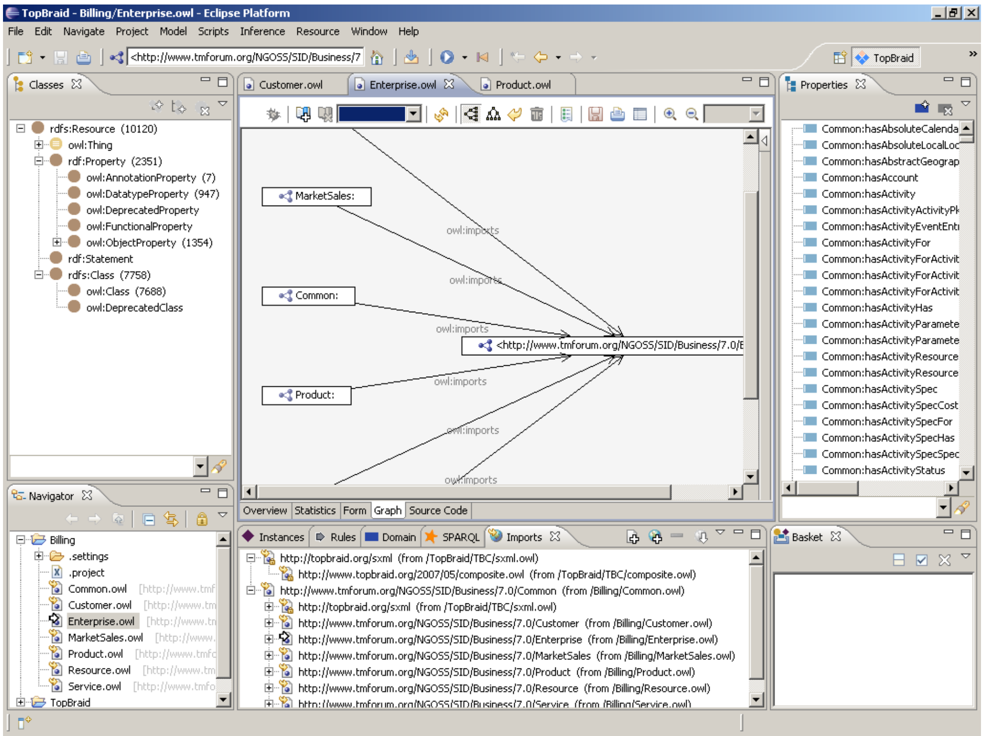

Figure 5. SID Ontology using TopBraid Composer

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inherits these four top elements; ontologies, goals, web service and mediators.

Ontologies: Represents the key element in WSMO; provide agreed common terminology used by other WSMO elements; also capture the semantic properties of relations, concepts and set of axioms, which are expressions in some logical language.
Web Service: Exchange data and combine data in new ways also describe the functional, non-functional and behavioral aspects, provides the semantic description of web services; capability (functional) and interfaces (usage).
Goals: Represent the objectives of the client that wants to achieve by using web services to satisfy the client desires.
Mediators: Overcome the semantic, structural or conceptual mismatch between different components that build up a WSMO description for handling heterogeneities. Mediators aim at automatically handling interoperability problems.
Semantic Web Services and Goals are described according to WSMO service and WSMO Goal definitions, WSMO Goal and WSMO service have the same structural definition but differ in what they represent [11].

Step 4, Semantic Middleware: The fourth step Semantic Execution Environment (SEE) acts as a semantic middleware to provide integration and interoperation for web services. We have implemented both WSMX and IRS-III based on the conceptual model provided by WSMO. This integrated approach facilitated the Telecom operator (services requester) to discover goal based service among the available service provider without any change in the order of the messages or data format. There are huge numbers of billing services available at different service provider and it has always been difficult to find out a particular service. Hence, goal based service discovery through our integrated approach play a vital role in finding heterogeneous and at the same time services with similar functionalities by different service provider.

Step 5, Services Discovery: In the previous section, Semantic Execution Environment (SEE) was introduced to serve the purpose of semantic middleware. This also helps Services requester to send a SOAP message to (achieve a goal) discover appropriate web services. Data/communication protocol adapters transform the received message into Web Service Modeling Language (WSML) compliant format and handle the data representation mismatches. Semantic middleware perform the rest of the communication management monitoring, and choreography of services. Steps may involve format translation (XML-WSML), validates, compiles, stores WSML description files, data and process mediator using set of mapping rules finally goal based invocation and discovery as displayed in Figure 7.

Step 6, BSaaS Prototype: At this point, we have implemented services discovery model for goal based dynamic services discovery for distributed

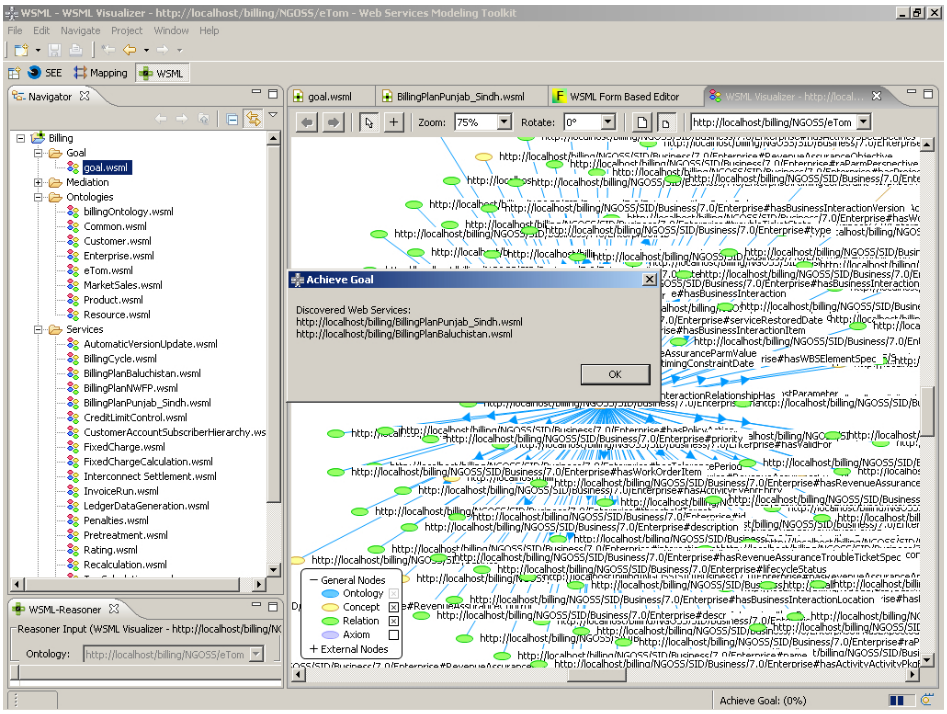

Figure 7. SID Ontology using TopBraid Composer

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environment. We developed a prototype for billing application to support multi-tenancy for telecommunication services operators as shown in figure 8. The prototype supports separate customized versions for each operator. Configuration file is responsible for tailoring the application according to the operator requirements. Metadata for each tenant store in eXtensible Markup Language (XML) file format. This allows for the extension of system objects via custom fields. The prototype has been developed using the Java programming language in Eclipse Software Development Environment (SDE) [42]. MySQL enterprise, and TOMCAT.

EVALUATION AND DISCUSSION

In order to implement SWS in industry great number of experiments and evaluation is required. In this section, we present the existing telecommunication industry scenarios to understand, evaluate and compare the current web services technology with our proposed framework for semantic web services. Furthermore, we have disused enhancement for two broader type of scenarios of service discovery and services mediation.

1) Interconnect Settlement Service Discovery

The purpose of settlement is to provide an automated and reliable sharing of revenue between service operators and other telecom service providers. This includes Data Management (creation, modification and deletion functions of all associated services and billing), Billing and Invoice Creation (with flexible billing cycles as per customer preferences covering recurring and non-recurring charges, taxation calculation, discounts, penalties and unit-credits); Accounting and production of periodic settlements for foreign operators (international), national third-party network/ telecom services operators (such as Pre-Paid Calling Cards, Pay Cards, Mobile Operators etc.) i.e., multi-operator, Inter-carriers billing and finally produce monthly revenue and re-conciliation reports (such as apportionment of revenue or calls made).

Revenue office firstly sends agreed rates to billing department, subsequently configuration team comprises of Manager, Manager and Data Entry Level in billing department, do all the required configuration which includes number series, trunks, and tariffs selection. Huge number of services having similar nature are available by different service providers hence service discovery is required on the contrary, existing web services technologies require tedious manual work, and greater time and human involvement in discovery. Billing team starts billing as soon as configurations are completed and updated. Service discovery based on our proposed framework allows configuration team to automate process using goal based discovery instead of keywords. This would lead to decrease the overall time required and human involvement at various stages.

2) Mediation System Scenario

The purpose of this feature is to bring the usage record data from Mediation System in real or near real time mode for processing of bills. This includes Call Detail Record (CRR)/ Event Detailed Record (EDR) collection for events/data captured through Mediation or any other sources for example Senior Revenue

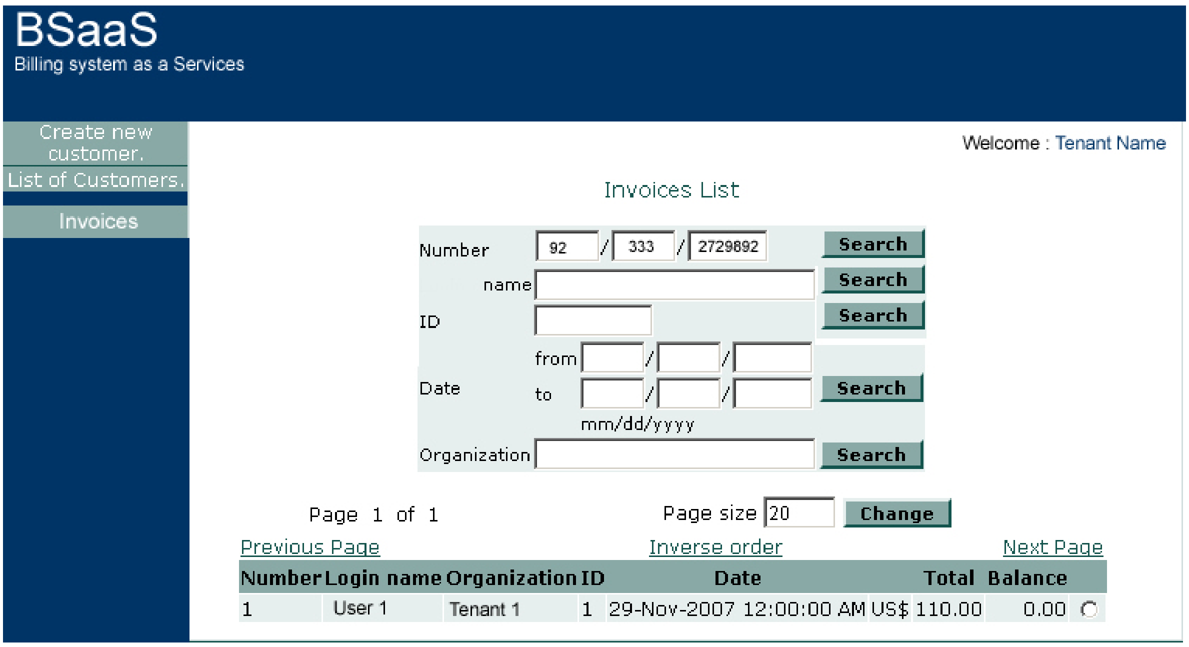

Figure 8. Billing prototype interface

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Office (SRO), Banks, Meter readings; validation, guiding to associate usage events with customer service assistance, Error/Exception Management and Rating by a variety of rating methods, for example flat-rated, corridor plans, time-of-day, day-of-week, special dates using a standard or configurable customer-specific rating structure as a pre-requisite for the bill run.

The problem of mediation can be solved by using existing technologies but semantic technologies as proposed in our approach provide ease in overall process; it saves time and involves less human efforts. Firstly the configurations team collects the information from online exchanges, in our case from ten different regional exchanges. When Billing System retrieves a Standard Usage Record file from Mediation System, one database log is recorded. Later the full database log is the basis of this balance check. Billing System receives the command and compares the summary of database log of both Billing System and Mediation System. This summary will contain total file number of Mediation System sent, total file number Billing System received, total usage record Mediation System sent, total usage record Billing System received. If the summary is not balanced, Billing System should list the details of unbalanced part. The system should contain three types of information: the records appear in Billing System but not in Mediation System, the records appear in Mediation System but not in Billing System, the records appear in both Billing System and Mediation System but the total usage record number is not same. Members from configurations team (Senior Manager, and Managers) configure, test these exchanges and run an automated system. Mediation based on our proposed framework provides better mediation facilities for handling structural, conceptual and semantic level mismatches. Semantic open environment for distributed sources supports heterogeneity among data sources, functionalities, and communication Processes.

We have compared time required using existing technology and our proposed approach specifically in service discovery through the presented interconnect settlement and mediation scenario. We have used total of 6761 records of Rules and Tariff for National Settlement and 518 records of Rules and Tariff for International Settlement to compose 5471 services grouped into six groups related to different billing tasks as shown in table 1. Each service take five inputs parameters including account type, zone mode, call type, effective date and expiry date while return billing rate as output. Table 1 also depicts compression between the time per task group ratio statistics for services discovery using existing system and after applying this data set to the proposed framework. The resultant small mean and standard deviation values shows that the time required after applying proposed framework is lesser than the by using existing technologies. This would lead to decrease the overall time required and human involvement at various stages. Moreover the mean-centered Coefficient of Variation (C.V) expresses the consistence of the results. In general C.V is the result of expressing the standard deviation as a percentage of the mean; the lesser value of C.V depicts the more consistencies in performance.

The final evaluated results presented as in table 1 are based on BSaaS prototype implementation, using sample data of a leading telecom operator in Pakistan, which has its Distributed Computer Centres in nine different cities of Pakistan name is not cited for privacy conditions. Experiments proves to be less effortless by decreasing the steps in processing, and by making it goal based research and easy to comprehend. Factors like one click services publishing, fault handling, better choreography, ease in mediation, service discovery for both heterogeneous and services with similar functionalities has introduced manifold gains in industry, and we believe that as system will mature progressively, it will rise above the existing challenges and unfold new horizons of opportunities.

VI. Conclusion and Future Work

In this work, we have stated the problems/limitations which our industry is facing in current state-of-the-art services and present appropriate solution provided by semantic web services. The research conducted in this study was motivated by the fundamental notion of shift of technology to the semantic web services to gain automated service discovery, mediation, and service provisioning. The proposed work presents an attempt to integrate framework based on WSMX and IRS-III to handle lager volume of telecommunication services and to maximize the advantages of dynamic service discovery in a distributed environment. Literature review reveals that semantic technologies give new life and hope to modern businesses for better integration between different applications no matter which platform or vender. Proposed framework is discussed along with its components, implemented semantic web service scenario develops WSMO based services, domain and application ontologies for billing system. Furthermore we have developed Software as a Service (SaaS) based billing application prototype to support goal base dynamic services discovery for a multi-

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TABLE I.
TYPE SIZES FOR CAMERA-READY PAPERS

				Using existing system			After applying proposed framework		
Billing Task	Group	Count	Percent	Mean	Std. Deviation	Coefficient of Variation Mean Centered	Mean	Std. Deviation	Coefficient of Variation Mean Centered
Basic level configuration	1-500	763	13.9%	33.644	21.130	62.8%	30.960	17.116	55.3%
Advanced level configuration	501-1000	1103	20.1%	33.413	18.428	55.2%	31.186	17.199	55.2%
Numbering Plan for Pakistani numbering series	1001-1500	85	1.6%	31.588	17.732	56.1%	29.482	16.550	56.1%
Trunks	1501-2000	376	6.9%	36.609	34.879	95.3%	30.594	16.980	55.5%
Tariffs	3000-3500	282	5.1%	37.270	30.677	82.3%	32.402	17.631	54.4%
Billing	3501-4000	2869	52.4%	33.200	20.469	61.7%	30.635	16.978	55.4%
Overall		**5478**	**100.0%**	**33.723**	**22.084**	**65.5%**	**30.862**	**17.068**	**55.3%**

tenancy distributed environment. The experimental details for the validation and evaluation of the proposed framework. We have used sample data of a leading telecom operator in Pakistan (name is not cited for privacy conditions). The experimental results showed that the integrated goal based services discovery not only lessens the required time and human involvement but also increase the overall usability. Our work can be continued in research areas, such as integration of WSMX and IRS-III, automatic services discovery, enhanced overall service lifecycle, implementation in software as a services. We will also focusing on to further strengthening and formalizing our ontologies with the help of telecommunication engineers, domain experts and involving rest of the other stakeholders for ease of integration and bidirectional information flow within distributed sources of information via a shared ontologies.

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