Integrating Mobile Devices into Semantic Services Environments

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***Abstract*—This paper addresses mobile service provisioning in a semantic service environment. The challenges of service provisioning in mobile environments are the dynamically changing context, the unreliable radio and the limitation of the mobile phone. This paper suggests implementing a virtual mobile in the semantic service repository, allowing the mobile services to become part of a semantic service composition. Mobile and proximity services are then executed either in the virtual mobile or on the device itself. The papers provides the functional architecture and suggests protocols to enable the virtual mobile.**

***Index Terms*—Service Oriented Architecture, Web Services, Mobile Services, Semantic Web, Context Aware, Access Control.**

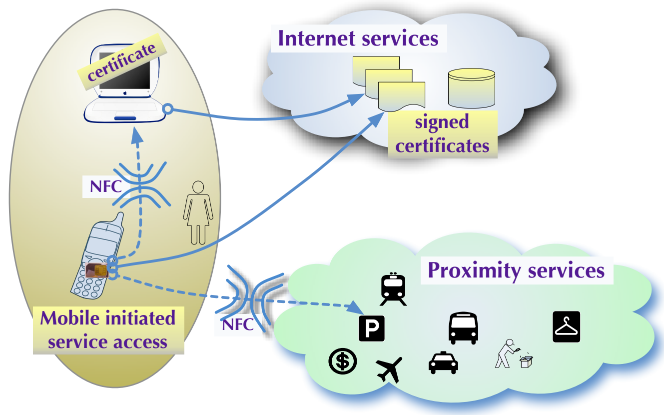

Fig. 1. The Mobile Service World connects mobile, Internet and proximity services.

I. Introduction

TECHNOLOGIES advancement not only enhances the mobile devices capabilities but also enables mobile phones to play a vital role in our daily life due to its always online functionality. The IT industry predicts that the technology development will continue at the same speed as today until at least 2025 [1]. The increase in service offering through the Internet and wireless/mobile network will make the mobile device a key tool for service access in digital environment. A Service Oriented Architecture (SOA) combined with Semantic Web technologies is assumed to provide interoperability between services, devices and networks. Noll et. al. performed a business analysis for semantic service provisioning in the mobile networks of Orange and Telenor, using location services as an example [2].

Currently the mobile service world can be categorized as addressing mobile services, Internet services and proximity services from a mobile device. Mobile services are typically native services in a mobile device, examples of which are phone and SMS services. Internet services are usually e-commerce and m-commerce services and proximity services are the services in the vicinity of the user such as payment, access and admittance. Today's mobile world is illustrated in figure 1.

The main challenge with today's mobile world is the segregation of the both mobile/proximity and Internet services. A mobile device is typically in a dynamically changing service environment, which makes the integration of mobile/proximity and Internet services difficult. The additional challenge is to combine these dynamically changing service worlds with user preferences, which will enable the user to control and use the available services. In this paper we propose the concept of a virtual mobile that together with the real device can work as the integrator of these service worlds and open service composition including context and user preferences. A new mobile web services architecture is proposed, consisting of a semantic service repository, handling both Internet and mobile/proximity services.

The paper is structured as follows. Section II provides some of related work detail. Section III provides details about the existing mobile web services development platforms. Section IV outlines the virtual mobile concept. Section V suggests the semantic mobile web services architecture and discusses the advantages of the selected solution. Section VI provides the evaluation of existing device and user profiles and delves into the service profile. Section VII provides the details of rule-base service execution Section VIII concludes the paper and gives some direction for future work.

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II. Related Work

Intensive research and innovation is going on in the field of mobile services. In particularly, location based and context aware e-services became a popular idea for m-commerce. The mobile world incorporates semantic technologies such as RDF[1] and OWL[2] for adopted and personalized service provisioning. The main problem with semantic technologies is that they are targeted for the desktop computing environment and not for mobile environments and devices. Noll. et. al. presented the overview of semantic aware mobile services, business consideration and challenges related to semantic mobile services in [3]. In order to cope with the resource limitation of mobile devices several middleware based solution exist. CASS is a server based middleware intended to support context aware application on hand held devices [4] but context is not model in terms of an ontology and architecture is not based on SOA. Recently Gu et. al. proposed a mobile framework to support ontology processing and reasoning for mobile context aware applications that run on java based mobile devices [5]. The main restriction with this framework is that it's only supports a subset of semantic technologies. The reasoning engine supports only forward chain rule base inference and does not support backward chain rule base inference. Query language support is also limited. By employing SOA, our approach enables semantic service composition of both mobile and Internet services.

III. Web Services on Mobile Devices

Web services, the most important realization of a Services Oriented Architecture (SOA), have changed the way enterprise applications co-operate. They have also a profound impact on mobile services. Web services are a family of XML based standards, with figure 2 depicting the underpinning architecture of web services. Fundamental of web services are XML, SOAP, WSDL and UDDI. Information about the components and the second generation standards (i.e. WS - *) are provided in [6].

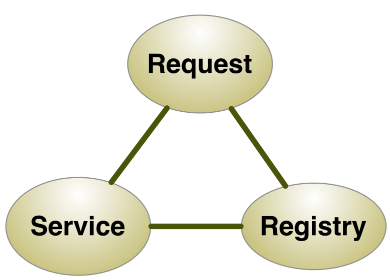

Fig. 2. Main components of a Web Service Architecture

Realizing web services on mobile devices is supported by all major mobile application development platforms such as Nokia Web services framework, S60, UiQ, Java ME, and .Net compact framework. A sketch of a Web Services enabled mobile phone is shown in figure 3, indicating both service registry, request and execution implemented on the device. In this section we will briefly describe some of widely used web services toolkits for mobile devices in order to support our postulation for a virtual mobile service repository.

[1]Resource Description Framework (RDF); http://www.w3.org/RDF/

[2]OWL Web Ontology Language; http://www.w3.org/TR/owl-features/

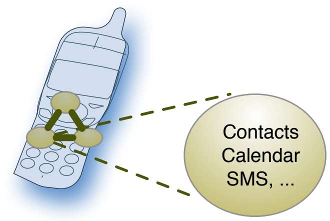

Fig. 3. Web Service Enabled Mobile Phone

A. Web Services for Symbian and Linux Mobile Devices

Symbian OS is a full featured mobile operating system that resides in the majority of the today's mobile devices [7]. Symbian based mobile devices provide a great opportunity for application developer to develop web services both in C/C++ and Java environment.

1) C/C++ Web Services Platform: gSOAP is a self contained platform independent development environment for C/C++ web services. It provides robust and easy to use means of realizing web services on mobile devices. gSOAP provides a C/C++ transparent SOAP API through the use of compiler technology that hides irrelevant SOAP-specific details from the user. The gSOAP stub and skeleton compiler automatically maps native and user-defined C and C++ data types to semantically equivalent XML data types and vice-versa [8]. The core of the gSOAP platform is the wsdl2h parser tool and soapcpp2 complier. The wsdl2h imports WSDL and XML schema to generate header file and the soapcpp2 complier takes the header file and generate .h and .cpp files of the data types, the client side stub and server side skeleton. The soapcpp2 also allow contract last web services development approach. gSOAP can be used with S60, UiQ and Linux for web service development.

2) Java ME Web Services Platform: Java ME previously known as J2ME consists of several components known as configurations, profiles and optional packages. The most import configurations are Connected Device Configuration (CDC) and Connected Limited Device Configuration (CLDC) and the most successful profile is Mobile Information Device Profile (MIDP) which is now established as the ubiquitous java platform in mobile phones. Widely used web services platforms on MIDP based are kSOAP and JSR-172. kSOAP[3] is a tiny open source library for web services. The core of the kSOAP library is the kXML parser. The limitation of kSOAP is that it does not support the entire SOAP specification and does not allow automatically client stub generation. JSR 172[4], the Java ME web service specification, defines a standard set of API for XML processing (a subset of JAXP) and SOAP Web services (a subset of JAX-RPC). JSR 172 provides a stub compiler that generates all code required for consuming web services.

[3]kSOAP; http://ksoap2.sourceforge.net

[4]JSR 172; http://jcp.org/en/jsr/detail?id=172

TABLE I
CHALLENGES IN MOBILE SOA PROVISIONING

	Fix SOA	Mobile SOA
SOAP Protocol	- always online - fixed internal delay $l < 50$ ms	- bad radio, packet loss, retransmission - round-trip-delay[5] up to 1 s [11] - cost of air-time
No. of Messages	- practically ”no limitations	-cost of air-time
Services Repository	- UDDI, always available	- context and location dependent services - no reliable services due to bad radio, packet loss and service termination
Services Support	Resources available	- limited CPU & battery power - specialized OS - device optimized for limited resource usage
Semantic Support	- increased computing resources	- services optimized for device OS, not for interoperability - limited support for semantic SOA

B. Web Services for Windows Mobile Devices

Microsoft approaches the cell phone OS market with the release of its new Windows Mobile OS, version 6.0. The mobile OS is based on Windows CE .Net OS. Microsoft Windows Mobile is a software platform that also contains the .Net Compact Framework (NCF), a set of tools and APIs for both managed and unmanaged (native) code development. For managed code application development the .Net Compact Framework is the only recommended framework on Windows Mobile devices. The .Net Compact Framework consists of Common Language Runtime (CLR) and .Net Compact Framework class libraries [9]. One of the primary features of this framework is web services support. Consuming Web Services in the .Net Compact framework is just a matter of adding the web reference into the application. Handling the web services is completely performed through the framework [10].

C. Challenges in Mobile SOA

There exist a number of issues and challenges for Mobile SOA service provision, mainly because wireless and mobile networks are based on an unreliable radio transmission[5] and costs for mobile usage are not easily predictable. The challenges of mobile SOA with respect to fixed SOA are summarized in table I, indicating that handling the service repository might be the dominating challenge. ”Cost of air-time” are related to business consideration, while service support and semantic support might be solved through more powerful devices in the upcoming years [1].

IV. THE VIRTUAL MOBILE

The discussion in the previous section has outlined that handling of the services registry in the mobile phone is the dominating challenge for mobile web service provision. The unreliable radio, round-trip-delay and cost of air-time make interworking with a mobile-based service registry impractical.

[5]Latency in Mobile Systems[11]: GPRS (~700ms), EDGE (350ms-600ms),WCDMA (200-300ms), HSDPA (~150ms) [11]

This paper suggests moving the service registry of mobile and proximity services into a Web based service registry. The following sections will outline the approach.

A. Virtual Mobile as Service Aggregator

Future mobile phones can enclose all the functionalities that users will need. But information and service overflow will restrict the usability of all the functionalities [12]. Telephony and SMS are the dominant services in GSM even 15 years after launch of the first GSM networks. Data traffic only accounts for a few per cent of the total traffic. The challenge of mobile service provision is to come up with just the services the user needs in a certain context. Our approach is to provide the user with a set of services such as calendar service and messaging service instead of a number of devices which the user has to handle. This service-based approach is flexible and adaptive which allows the user to add and remove services according to his needs in a certain context. Our envisaged future mobile is a set of services noted through the terminology virtual mobile (see figure 4). A virtual mobile integrates various user devices and both mobile/proximity and Internet services.

Our approach of defining a virtual mobile opens for the semantically enriched realisation of the often approached virtual terminal [12]. Services might be integrated into one device, e.g. a mobile phone, or might be distributed among different devices, e.g. music player for audio and glasses for video. Another case is the transfer of the video to a TV, while sound comes from the headset of the mobile phone. The virtual mobile is a platform that consists of a layer for web services, a semantic service layer and a service manager. The virtual mobile incorporates the information about user profile and preferences, context, mobile and Internet services, and device capabilities in a semantic way. The semantic integration enhances the interoperability between heterogeneous devices, networks and services.

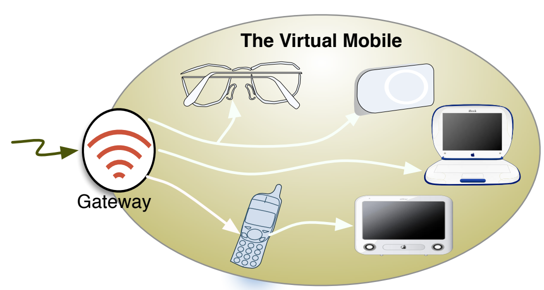

Fig. 4. Communication with the Virtual Mobile

From the outside world, communication can be seen as communication to the Personal Area Networking (PAN) gateway, where the gateway is the web services entry point to mobile, proximity and Internet services.

B. Virtual Mobile Capabilities

The introduction of the virtual mobile brings a number of advantages:

- *Security will be increased*, as the devices and services of the user are not visible to the outside world. Only services capabilities might be announced in the service repository of the virtual mobile.
- *Handling of communication according to the user preferences:* The user might define that after working hour calls from office colleague are transferred directly to the answering machine.
- *Integration of the context into dynamic service delivery*. As the virtual mobile can cache context information (location, presence, and identity), this information can easily be integrated into the service composition process.

Our approach is based on semantic technologies, and details about ontology storage, ontology process, and reasoningare discussed in section VI.

V. Mobile Web Services Architecture

The usage of SOA in mobile environment is hindered due to the variation of radio quality, cost of air-time, context and location dependent services, device to device communication over WS protocols, processing capabilities and security protocols. Advances in device capabilities will allow a semantic description of device and service capabilities, and enable an easier integration. Currently resource limitation is a big hinder for a full fledge support of second generation standards for web services, i.e. WS-* in mobile environments. The Nokia Web Service framework[6] supports WS-Security, but lacks support for other WS second generation standards such as WS-SecurityPolicy, and WS-SecureConversation. In order to cope with the idiosyncratic behaviour of mobile networks Microsoft provides a Disconnect Service Agent in the Microsoft Mobile Client Service Factory. This agent in the mobile device can queue web services request and dispatched them automatically when the network is available. Thus a mobile phone without a network connection would only see the services inside the mobile phone or the services in the proximity as indicated in figure 5, but not the Internet services world.

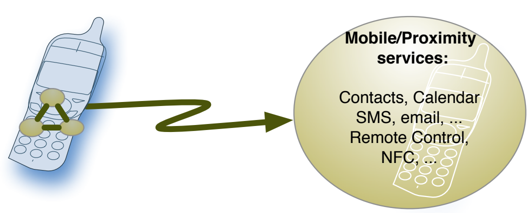

Fig. 5. Mobile Phone with Mobile/Proximity Services

In the off-line mode service requests from the Internet would not be able to see and handle services of the mobile phone, thus service composition is limited to the case where the mobile phone is on-line.

A. Mobile Services Integration into WS Architecture

In contrast to a queue base mechanism our concept establishes the virtual mobile as a virtual representation of the mobile phone in the network. Thus service capabilities are always available and allow for a service composition based on mobile and Internet services. Service execution might happen through the virtual mobile or the real mobile, the latter one enabled through a proxy interface or a full semantic web service stack on the mobile phone.

The proposed mobile web services architecture will thus be extended by a new intelligent service registry, consisting of both the Internet services and the mobile/proximity services, indicated in figure 6. In addition to the mobile phone representation, the virtual mobile has a semantic layer to handle semantically enabled mobile services. The availability of web service interfaces of mobile/proximity services into the Internet service world opens for a new dimension of service composition.

However, mobile services should not automatically be included in a service composition as mobile service usage might be restricted or costly. Policy-based access control can be enrolled to tackle the issue of authorised use of services. Examples of such policies are SMS/Phone services which are restricted to the user of the mobile phone, while the calendar service is available for people specified in the user's profile. Other services regulated by policies might be the collection of sensor data, and health care information for relatives or the health care system. The implementation of policy-based access control is discussed in section VII.

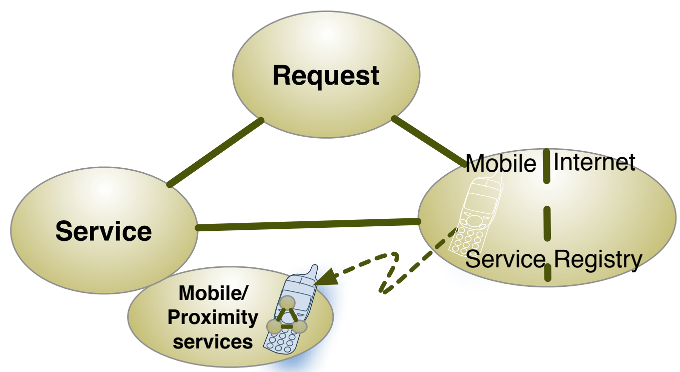

Fig. 6. Mobile WS Architecture with Virtual Mobile in Repository

The main advantages of placing the virtual mobile in the network are managing personal area networks, discovery of networks and services, managing user profile and preferences, role base access control and assuring privacy and security. A virtual mobile in the network will reduce the amount of data exchanged between the physical mobile and the services providers since a lot of information about the user, device capabilities and mobile services is available in the virtual phone. All mobile web services domains, e.g. personalised services, device inter-working, and community services, can be represented by the virtual mobile.

B. Extension to Semantic Service Execution

Semantic web is still evolving and composed of different standards. The heart of the semantic web is an ontology which is an explicit and formal specification of conceptualisation of a

[6]Nokia WSF; http://www.forum.nokia.com/main/resources/technologies/web_services/index.html

domain of interest. An ontology consists of concepts, relations, instances and axioms. There exist a number of ontology languages but OWL is the essence of ontology languages. OWL has an expressive power and is capable of creating all four components of an ontology. OWL is available in three flavours (i) OWL Lite (ii) OWL DL and (iii) OWL Full.

Rules are important paradigms which have complementary expressiveness. One of the most recent work of combining OWL and RuleML is the Semantic Web Rule Language (SWRL[7]). SWRL adds the expressive power of rules to OWL DL. SWRL is proficient to solve obvious reasoning problems at the cost of decidability.

Semantic technologies are not targeted for mobile devices and the currently available RDF parser, inference engines and rule engines are too heavy for mobile phones. Even though future mobile phone will be more powerful in terms of processing capabilities, they will still suffer from limited CPU, battery and radio resources. These limited resources are the biggest barrier when enabling mobile semantic web services for mobile terminals [5].

A virtual mobile in the network has no such limitations and can thus play the role of a semantic web execution environment. The virtual mobile can handle ontology storage, ontology processing, querying and reasoning. In a context aware service world systems consist of sensing, thinking and acting sub systems. The real mobile device is just acting as a context watcher/collector and thinking and acting will be performed on the virtual mobile. Thus performance issues are solved. With the help of a virtual mobile context aware service delivery is established and might incorporate highly personalised service delivery. Having introduced the virtual mobile and transferred the service repository to the Web will open for the novel approach of *the device as a service*.

In SOA each service is decomposed into components, which freely can interwork with each other. A mobile phone aims at a similar structure, where applications such as SMS can call other applications such as Contacts to retrieve connectivity information. Interworking between mobile applications is limited and defined through the available APIs in the operating system. Our approach is to present each mobile application as a set of web services, and to add semantics for enabling service interaction. This approach will allow to see the mobile as a service collector and to enable exchange of information between all services on the mobile device. It will further allow mirroring the services in the network, thus providing a virtual device. Access control to the services will be realised through policies and rules.

The following section will discuss profiles used in the mobile world to describe the mobile devices and the services on the device. It will then suggest semantic extension to realize the concept of a virtual mobile.

VI. Semantically Enhanced Profiles

A. Device and User Profiles

With the rapid increase in mobile/proximity and Internet services, next generation services need to adopt to user preferences, context and device capabilities. As device independence is concerned two approaches have emerged as solution. CC/PP[8] is a W3C recommendation for description of device capabilities and user profile. CC/PP is based on RDF. The CC/PP profile is a 2-level hierarchy that consists of set of components, where each component has at least one or more attribute.

UAProf[9] is a variant of the CC/PP profile. UAProf consists of the following components: Hardware platform, Software Platform, BrowserUA, Network Characteristics and WAP Characteristics. UAProf is concerned with capturing classes of device preferences information for content formatting purpose. The main issue with CC/PP is less expressive power that restricts reasoning possibilities. Particularly in context aware services CC/PP is inadequate. Indulska et. al. used CC/PP in context aware systems and concluded that even though it is possible to imply CC/PP in context aware the profile is unsuitable for this purpose [13]. Is is difficult to capture complex relationship through CC/PP and constraints in the profile makes it unsuitable for context aware services.

The Wireless Universal Resource File (WURFL)[10] is another effort to overcome practical issues related to device profiles. CC/PP and UAProf are not always accurately presented, and new capabilities require new vocabularies outside of CC/PP and UAProf. WURFL is an XML file that containes information on every known device in the WURFL community. The main attraction of this approach is that devices are arranged in an inheritance hierarchy that helps in inferring sensible defaults. But WURFL lacks information about the network, the software and the user preferences.

3GPP GUP[11] is an ongoing effort to define a generic user profile. GUP is composed of a number of user profile components i.e. user, services, and user devices. Its main objective is to provide a way to enable harmonised usage of user related information located in different entities. The GUP Data Description Framework (DDF)[12] does not specify the different components of a user profile. It rather describes a set of common rules for different profile components based on XML schema.

Our analysis and studies by Indulska et. al. have pointed out the needs of semantically enhanced profiles for user and device profiles [13]. In case of CC/PP we only require minor modifications to adopt CC/PP to become semantically more expressive. In case of WURFL and GUP more effort is required. Both are based on XML and XML schema which cannot provide any intended meaning to associated data and only constrain the structure of XML documents.

[7] Semantic Web Rule Language; http://www.w3.org/Submission/SWRL/

[8] CC/PP; http://www.w3.org/Mobile/CCPP/

[9] UAProf, http://www.openmobilealliance.org/tech/affiliates/wap/wap-248-uaprof-20011020-a.pdf

[10] WURFL; http://wurfl.sourceforge.net/

[11] 3GPP GUP; http://www.3gpp.org/specs/WorkItem-info/WI--31008.htm

[12] 3GPP TS 23.241 V0.3.1; http://www.3gpp.org/ftp/tsg_t/WG2_Capability/SWG2/SWG2_Joint_Meetings/0208_SWG2_SA5_Tampere/S5-023004T2C-020035T2-020683TS23.241GUPDDF(v0.3.1)(T2C-020003).doc

B. Service Profile

While SOA and business services have introduced semantic technologies for describing the services, mobile and proximity services are not described in a semantic way. Our *device as a service* is based on service profiles as semantic descriptions of mobile and proximity services. Bartolomeo et. al pointed out similar finding and emphasised the necessity of services profile but did not specify them [14]. This paper suggests the use of ontologies to describe all the types of services. The semantic description will enable mobile services to interoperate even though they are not designed to work together. Service profiles help the services to understand other services and reason about their functionalities. To illustrate the envisage service profile we use the OWL DL code snippet of service profiles. The code describes the capabilities of SMS as follows: SMS contains text only and the number of characters in an SMS limits to 160.

```
<rdf:RDF xmlns
    /* namespaces are here */
    ....
    <owl:DatatypeProperty rdf:ID="hasCharacter">
        <rdfs:domain rdf:resource="#Service"/>
        <rdfs:range rdf:resource="&xsd;int"/>
        <rdfs:comment rdf:datatype=
        "&xsd;string">160characters
        </rdfs:comment>
    </owl:DatatypeProperty>
    ....
    ....
    <owl:Class rdf:ID="Service"/>
    <Service rdf:ID="SMS">
        <hasSize rdf:datatype="&xsd;int">
        1120</hasSize>
        <hasCharacter rdf:datatype=
        "&xsd;int">160</hasCharacter>
        <contains rdf:resource="#Text"/>
    </Service>
    .....
</rdf:RDF>
```

Such a service description together with the device capabilities, a user profile and a context description will allow the provision of highly-adopted personalised services.

VII. Rule Base Service Execution

With the introduction of semantic technology in user profiles, mobile and Internet services this paper has enabled service interaction. Service execution requires access control for privacy protection and restrictions of services. Semantically enhanced policy based access control is not only challenging but maintaining the security of user profiles is also critical. Chowdhury et. al. have introduced the concept of rule-based access control in organisational environments [15]. We suggest extending the rule base access control towards service consent and execution. For illustration purpose we implemented the following scenario using OWL DL and SWRL in Protégé.

A. Advanced communication scenario

Somebody sends an email to Josef. He is currently travelling abroad with his mobile phone switched on. His mobile subscribed to number of services including Short Messaging Services (SMS) and he prefers to receive SMS notification whenever someone sends email with high priority while travelling.

B. Resolving priorities and context

In the proposed system preferences and message forwarding activities are performed dynamically based on some predefined inputs and context information. To accomplish this an ontology is created which represents the virtual mobile of Josef. It contains Josef's user profiles, device profiles, service profiles and context information. The user profile will also includes preferences. A context watcher application on the mobile feeds the current context information (such as location, attached devices, status) to the ontology.

User preferences are set dynamically based on the user's context. To address this, we added a rule (Rule 1) using SWRL on the top of the ontology which dynamically creates preference entries. Josef's virtual mobile receives an email with high priority and rule 1 is applied in response to this service request that sets its service and device preference.

- Rule 1:
  $Person(Josef) \wedge$
  $currentlyLocated(Josef, ?X) \wedge$
  $hasPreference(?X, ?Y) \wedge$
  $attachedWithDevice(?X, ?Z)$
  $\longrightarrow Services(?Y) \wedge Devices(?Z)$
- Rule 2:
  $Services(?X) \wedge$
  $Devices(?Y) \wedge hasAction(?X, ?Z) \wedge$
  $\longrightarrow goesTo(?Z, ?Y) \wedge usingService(?Z, ?X)$

When running rule 1, it results in preference entries which represents the fact that Josef receives SMS notification on his mobile phone. When preferences are updated, Rule 2 provides the results of the message forwarding action. The result shows that a notification message goes to Josef's mobile using the SMS service.

Our approach has addresses the following challenges: processing capability, security in different domain, handling the complexity, mediation of ontologies, and opening of parts of an ontology. We see following advantages following this approach:

- Allowing services composition with information from the user.
- Enabling role base access to the mobile phone means that not all traffic has to go first to the mobile.
- Off-line service creation and exchange if mobile is connected through reasonable networks.
- Extending the mobile phone into a set of services (device as service.)

VIII. Conclusions

Semantically enriched mobile services will form the basis of next generation mobile services. However the integration of mobile phone services into a semantic service execution environment is hampered by a number of factors, specifically the unreliable radio network, round-trip delays and limited capabilities of the mobile phone. This paper addresses mobile service provisioning in a semantic service execution environment. It presents a new concept of a virtual mobile to mitigate the challenges of mobile service provision such the round trip delay of 700 ms and resource limitations. The virtual mobile is implemented into a Web based semantic service repository. This concept enables service integration of both mobile/proximity services and Internet services. In connection with this, we developed an ontology to represent the virtual mobile. Our implementation is based on OWL DL, enhanced by the Semantic Web Rule Language (SWRL) for restriction of service usage. Our implementation allows service interaction of mobile and Internet services. It further enables service adaptation based on user profile, service profile and user context. While the current paper demonstrated the use of ontologies for service interaction and SWRL for policy handling, future work will focus on advanced reasoning capabilities for decision making and implementation of additional elements of our approach.

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