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INTRODUCING ENUM TO THE SEMANTIC WEB

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ABSTRACT
This paper evaluates linking ENUM with the Semantic Web. ENUM is a protocol for mapping a telephone number to a Uniform Resource Identifier (URI) which can be used to contact a resource associated with that number. ENUM therefore gives access to a wide range of a person's (communication) identifiers by looking up a specific domain associated with that person's telephone number. After describing the basic functionality and structure of both ENUM and the Semantic Web, promising links between the two are highlighted and applications introduced. Finally the structure of ENUM is modeled as an RDF vocabulary named SEMNUM for usage in applications enriching standard ENUM or FOAF/RDF query results.

KEY WORDS
ENUM, ENUMservices, Semantic Web, FOAF, RDF, SEMNUM.

1. Introduction and Motivation

According to a definition by Berners-Lee, Hendler and Lassila [1], the **Semantic Web** is described to be an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation. Another definition defines the Semantic Web to be the representation of data on the World Wide Web and being based on the Resource Description Framework (RDF), which integrates a variety of applications using XML for syntax and URIs for naming.

ENUM is a protocol defining the translation of a Telephone Number to an Internet Domain Name, which can subsequently be used for retrieval of a wide range of (communication) identifiers of the associated telephone number's owner. Thus knowing someone's telephone number gives access to that person's other identifiers like e.g. e-mail address, SIP Address-of-Record (AoR), Web URL and informs on the services to be used with these identifiers. Typically this is done with "personal numbers" like mobile phone numbers or corporate extension lines.

While the Semantic Web can be seen as an evolutionary development of today's World Wide Web towards an increasingly machine-processable web, ENUM is a comparably evolutionary development for today's rather strictly separated worlds of Telephony and Internet towards a significantly converged environment. Both concepts focus on a highly automated inter-machine communication rather than a human-machine communication. To identify relevant aspects of both ENUM and the Semantic Web, basic introductions are given. This is followed by discussing issues connecting the Semantic Web and ENUM. Finally, ENUM is modeled by defining an RDF Vocabulary (SEMNUM) for a proposed use in combination with Semantic Web applications, e.g. Friend-of-a-Friend.

Introducing ENUM to the Semantic Web potentially brings advantages to both areas. A first application combining ENUM and the Semantic Web is enriching the result of a standard ENUM query. Instead of a couple of (communication) identifiers a query enriched with information from the Semantic Web gives valuable additional information on a contacted (queried) person in the course of e.g. setting up a Voice-over-IP (VoIP) call, i.e. giving details available on the Semantic Web (e.g. a depiction, a work item website, a private homepage or working groups involved in). Another application considered is modeling the internal structure of a company with departments, working groups, individuals and their relations and using this taxonomy with ENUM for automatically redirecting incoming connections. The degree of relationship between a company's employees defined in an ontology can be mapped onto the ENUM data with the Semantic Web's reasoning capabilities adding extra value by enabling the establishment of well-founded redirect options or rules. Computer Telephony Integration (CTI) Systems can take advantage of this type of application.

2. ENUM

ENUM is the acronym for Electronic Number Mapping and describes a protocol specified by the Internet Engineering Task Force (IETF) in [2], which defines the mapping of a Telephone Number in the international format, called E.164 telephone number in this paper, as specified by the International Telecommunications Union (ITU) in [3] to an Internet Domain Name, which can subsequently be used for supporting a wide range of (communication) services. The introduction of ENUM brings the opportunity to use an ordinary E.164 telephone number as a single, unique identifier for pointing to other (communication) identifiers related to the holder (owner) of the telephone number.
With ENUM implemented, knowing someone's telephone number opens access to a wide range of other identifiers, names and numbers this person (or organization) publishes in ENUM. A simple example is an ENUM-enabled E-Mail client translating the addressee's telephone number into a mailto: URI (i.e. an e-mail address).

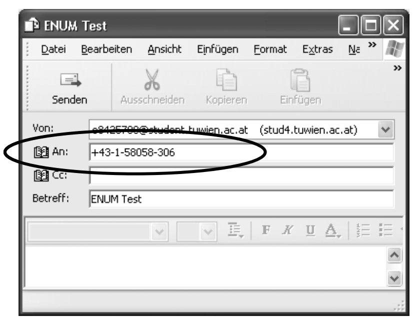

Fig. 1. ENUM-enabled E-mail client accepting E.164 telephone number as input parameter for sending mail

In order to make the E.164 telephone number accessible by clients on the Internet, it has to be mapped onto the Internet. This task is performed by ENUM, translating a fully qualified E.164 telephone number into a fully qualified Domain Name in the e164.arpa domain. As E.164 numbers have the most significant parts to the left (i.e. the +43 in +43-1-58058-306) while Domain Names have the most significant parts to the right (i.e. the .com in www.example.com), the order of the E.164 number is reversed, applied with dots between each digit and the sub-domain ending of e164.arpa, resulting in a structure known from domain names. In this string 6.0.3.0.8.5.0.8.5.1.3.4.e164.arpa every digit can be treated as a node in the DNS name hierarchy. Using this method as defined in [2], the E164 telephone number +43-1-58058-306 becomes 6.0.3.8.5.0.8.5.3.4.e164.arpa, for example.

Generally, the Domain Name System (DNS) allows a collection of URI resource records to be associated with a domain name and to be returned as answer to an appropriate DNS query. The URI resource records used by ENUM are the so-called Naming Authority Pointer (NAPTR) DNS resource records (RR) explained within the Dynamic Delegation Discovery System (DDDS) in a series of IETF Requests for Comment (RFC) [4], [5]. A resource record (RR) is a unit of data in the DNS, defining some attribute for a domain name such as an IP address, a string of text or a mail route. The NAPTR RR specified in [5] was originally created as a way to encode rule-sets in DNS. In the ENUM case scenario, the data stored in the NAPTR RRs are basically simple rewrite rules, with the ENUM domain name being the unique key to request this rules. Among other fields, a NAPTR RR contains an Order field to specify the order in which multiple NAPTR records must be processed, a Preference field to determine the processing order when multiple NAPTR records have the same order value and a Service field to specify the resolution protocol and service.

The range of URIs and related services, which can be made available via the NAPTR RR Service field is broad. The services currently proposed for ENUM implementations are explained in a draft technical specification by the European Telecommunications Standardization Institute (ETSI) [6] with some of them already agreed by the relevant Internet Authority IANA. These so-called "ENUMservices" are defined in groups describing services for interactive media-stream exchange (i.e. voice and video), discrete messages (i.e. email, fax, ifax, SMS, EMS, MMS), information source (i.e. web, file transfer), service resolution services (i.e. SIP, H.323, presence), session-oriented message-exchanges (i.e. instant messaging), instant information display and announcements, location information and public key information.

Each "ENUMservice" indicates how an associated URI should be interpreted by the application initiating the ENUM DNS query and therefore adds meaning to a URI. ETSI suggests that "ENUMservice" fields generally should be in the format type:subtype as defined in [6] (see above: services field). Table 1 shows the type:subtype relations for "ENUMservices for interactive media-stream exchange" as well as for "ENUMservices for information source", as an example.

Table 1. Two examples of ENUMservices proposed by ETSI

„ENUMservices" for interactive media-stream exchange		
voice:sip	voice:h323	voice:tel
video:sip	video:h323	video:tel
„ENUMservices" for information source		
web:http	web:https	ft:ftp

The group of „ENUMservices for interactive media-stream exchange" is indicating that the resource identified by the associated URI is capable of being contacted to provide a communication session during which interactive media streams carrying `voice` or `video` data can be exchanged (with a SIP AoR, a H.323 address or a E.164 telephone number as URI), while the group of „ENUMservices for information source“ is indicating that the associated resource can act as a source for information with the type field differentiating between `web` and `file transfer` (with the associated URIs being http:, https: and ftp).

ENUM implementations are still in their early stages and related work is mainly focusing on VoIP issues. The current list of "ENUMservices" therefore is open for enlargement if demand arises. The procedures and requirements for registering a new ENUMservice are well defined by IETF and IANA [6].

3. The Semantic Web

The Semantic Web envisioned by Tim Berners-Lee is now in a process of being further defined and developed. The Semantic Web represents a concept in which machine-processable content builds the base for a whole set of new applications on the Internet. For these new applications to work and communicate with each other it is necessary to create a system of structured semantic knowledge. In order to bring such as system to life, languages for ontologies and rule-systems are needed. Moreover, the communities need to agree on shared ontology vocabularies.

While today's Web is all about content, the Semantic Web is all about content's relations. Today's Web is heavily focused on document presentation, typically programmed in HTML. The evolvement of metadata languages such as XML, RDF and others allow a web-wide realization of ontologies, rules, proofs and logic. Extensible Markup Language (XML) and Resource Description Framework (RDF) form the basis for representing such content [7]. While XML is dealing with document structure, RDF expresses the meaning encoded in sets of triples, with each triple being comparable to subject, verb and object of an elementary sentence and opens the possibility to make statements that are machine-processable. Of course a computer still does not "understand" what someone actually said, but it knows how to deal with it.

Another basic component of the Semantic Web comprises collections of information called ontologies that formally describe the relations among terms. Such descriptions (again implemented in RDF) enable computer systems to use terms more easily and to convert between them. Examples for such Web ontologies are DAML+OIL and OWL. This enables agents to search the Web on a semantic basis, draw conclusions and present the results in a personalised way [8], [9], [10].

Moving up the "Layer Cake" Logic and Proof are next. Although the introduction of schemas and ontologies already is an important step towards a machine-processable web, it is even better if logical principles can be stated. Such logical statements allow an agent to make inferences and deductions. With this system of logic getting implemented, it will become increasingly possibly to use it to prove things. So different people can write logic statements and a machine can be used to follow these "Semantic Links" and try to begin to prove facts.

As "anybody can say anything about anything" on the Web, it becomes a crucial question which information to trust, and which not. One piece of the puzzle are Digital Signatures, which generally provide proof that a certain person created (or agrees with) a document or statement. This makes it possible to explicitly tell an agent which sources are classified trustworthy and which are not. With millions of authors and billions of documents on the Web, this is no promising solution. That is where the "Web of Trust" [11] steps in, a network of trust measures taking into account how many people a person knows (and trusts), trust other people (this person does not know). In this way the person can use the trust levels other people set for each other.

4. Connecting the Semantic Web and ENUM

The similarities start at the very basement with URIs building an integral part of both the Semantic Web and ENUM. While URIs are mainly used for naming objects on the Semantic Web, they are used in the form of URI RRs (NAPTR RRs) enabling the implementation of DNS redirect rules in ENUM with the final result being a URI, again. As these URIs are accessible and retrievable on the Web, they can be used in all sorts of applications, generating space for interoperability between the Semantic Web and ENUM.

Looking at RDF vocabularies and ontologies, this is an issue rather related to the Semantic Web than to ENUM. At first glance, ENUM does not provide or use ontologies, as the information stored in NAPTR RRs only describes redirect rules for a single E.164 telephone number. However, as an ontology is defined as a way to describe the meaning and relationships of terms on the Semantic Web, the "ENUMservices" definition (see chapter 2) can be interpreted as describing the meaning of a specific URI, e.g. whether a http: URI is to be interpreted as identifier giving access to a website, to an announcement, to location information or to public key information. Additionally ENUM holds information on the sequence URIs found have to be processed in an ENUM resolving process. Accordingly, ENUM information can be ontologically modeled to be used in combination with other ontologies (see chapter 5).

Logic and Proof layer are meant to introduce logical principles to the Semantic Web allowing agents to make inferences and deductions. With this system of logic, it will become increasingly possibly to prove things. So different people can write logic statements and a machine can be used to follow these "Semantic Links" and try to begin to prove facts. On the one hand Semantic Web technologies can help to improve search results on ENUM, and on the other hand existing Semantic Web standards can be spiced up with additional information gained with ENUM. Depending on the respective logic and proof levels, the combination of ENUM and the Semantic Web has the potential to add extra quality.

Considering the influence of combined Semantic Web and ENUM applications on Trust issues, ENUM enables agents to perform a cross-check on data found on the Semantic Web by querying the logically and architecturally separated ENUM database.

Enriching RDF Query Results

ENUM can be used to provide the user (human or machine) with an enriched output of a standard FOAF/RDF query. The Friend of a Friend (FOAF) application [12] allows the expression of personal information and relationships, and is a useful building block for creating information systems that support online communities. After an initial FOAF/RDF query looking for a foaf.rdf file on a Web Server, the results retrieved are analyzed for the occurrence of an E.164 telephone number, which subsequently can be used as input for an ENUM query. If the ENUM query results in a set of (communication) identifiers, these can be used to describe the queried person in more detail or to find relations between persons or resources, when combining the results with those of other queries or with already known information from other sources. Information retrieved by means of an ENUM query can be annotated using the SEMNUM vocabulary (see chapter 5) enabling the ENUM data to be directly integrated in other RDF documents. Secondly, ENUM query results can be used for cross-checking data retrieved from FOAF/RDF. As ENUM currently is mainly used for enabling VoIP, data within the NAPTR RRs has a high probability of being correct and up-to-date, which is not necessarily the case with rather static information within the FOAF/RDF file on a user's web page.

If a FOAF/RDF query result contains more than one E.164 telephone number, all of these can be used to search for further (communication) identifiers with ENUM.
Figure 2 shows the process running queries from an RDF+ENUM enabled client with an enriched (RDF) Information File as final output. Alternatively, it is an option to create a server-sided Web Service performing all these tasks, providing an agent accessing this particular Web Service with the final result, at once. As a consequence, the client would not need to have RDF and ENUM query capabilities implemented anymore, as this would be performed by the Web Service on the client's demand.

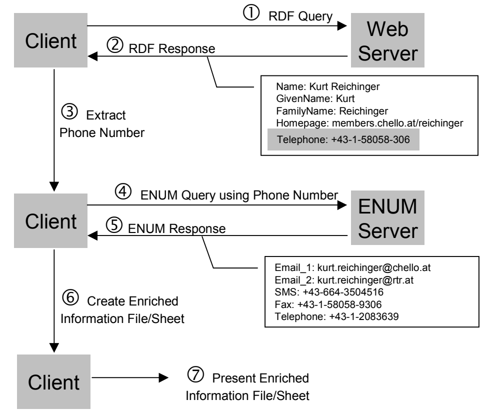

Fig. 2. Enriched RDF Query Results

This kind of application can be used for enriching and cross-checking results gained by means of a FOAF/RDF query. Future research will show if the introduction of ENUM can increase the trust level for FOAF query results significantly.

Enriching ENUM Query Results

An Enriched ENUM Query provides the user (human or machine) with additional information about a person or a resource, in general. Starting with a known E.164 telephone number, a standard ENUM DNS query is used to retrieve the available information about a users other (communication) identifiers from the ENUM DNS name server. Today's ENUM applications mainly do this for translating an E.164 telephone number into a SIP AoR for setting up a VoIP call. After this initial ENUM query the results are analyzed for the occurrence of a URL, where a FOAF/RDF file may be available. If a URL is to be found in the ENUM response, a subsequent RDF query using this URL is performed to gain additional information about the person associated with the E.164 telephone number checked first.

Figure 3 shows the process running queries from an ENUM+RDF enabled client. Annotation in SEMNUM and integration in other RDF documents again is possible. As before, Enriching ENUM Query Results can be incorporated into a Web Service, finally providing the user with an enriched set of information on the holder of the E.164 telephone number initially used.

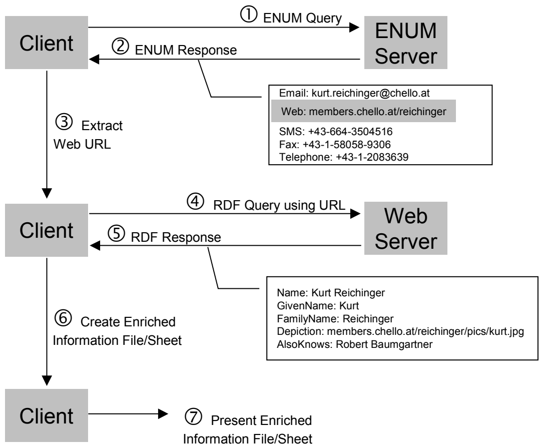

Fig. 3. Enriched ENUM Query

This kind of application is perfectly qualified to be used during the set-up of a VoIP call using ENUM. Assumed that the VoIP call is initiated from a terminal with capability to present information on a screen, e.g. a PC, Laptop, mobile phone or PDA, Enriched RDF Query Results can be presented to the calling party. On the one hand this enables businesses as well as individuals to present specific information to the calling party on call set-up. On the other hand – and even more important – a basis for drawing semantic conclusions is provided to the calling user.

In order to ease the discovery of a foaf.rdf file, the authors consider to initiate an enlargement of the set of "ENUMservices" by defining an additional „ENUMservice for information source" (in addition to web:http, web:https and ft:ftp already defined) and requesting approval by IANA. A new ENUMservice of type foaf and subtype http: (foaf:http) would immediately indicate that the associated resource acts as a source for a FOAF/RDF document, i.e. that a foaf.rdf file is to be found at the given http: URI.

5. SEMNUM ENUM RDF Vocabulary

SEMNUM is a new RDF vocabulary describing all terms contained in ENUM and being compatible with other RDF formats such as FOAF. It contains properties and classes structuring the information to be found through an ENUM query and enables users (or agents) to further process the data found and to create new documents based on RDF. The vocabulary is called SEMNUM (for "Semantic Numbers").

SEMNUM is meant to contribute a further important vocabulary to the Semantic Web. The specification of this vocabulary uses the conventions of the W3C's Resource Description Framework (RDF). As such, SEMNUM adopts a syntax (using XML), a data model (RDF graphs) and a mathematically grounded definition for the rules that underpin the SEMNUM design. SEMNUM is an application of the Resource Description Framework, because the complexity of the subject described – people and their various connections – is best addressed by a combination of different RDF vocabularies. SEMNUM by definition only deals with information defined in ENUM (see chapter 2), but with RDF being used, SEMNUM is well prepared to be extended by several other RDF vocabularies dealing with the description of people, communication services and their relations. Due to the RDF nature of SEMNUM its classes and properties (see Table 2) can also be incorporated in other RDF documents.

Table 2. SEMNUM classes and properties

Classes			
Service	Email	Voice	Fax
Ifax	Video	Sms	Ems
Mms	Announcement	Location	Web
Key	Instantmessaging		
Properties			
mbox	securehomepage	homepage	file
database	securesipphone	infotext	phone
sipphone	h323phone		

Due to lack of space in this paper the full specification of the proposed SEMNUM vocabulary is to be found in a separate technical report [13].

Using SEMNUM with FOAF

An example incorporating SEMNUM is an agent searching (crawling) the Web for ENUM and RDF/FOAF data (see Enriching ENUM Query Results). The data collected can be presented in a new "Enriched Personal Fact Sheet" based on RDF using vocabularies like FOAF, BIO [14], VISIT [15] or SEMNUM. The content of such a fact sheet is at least partially verified by querying two different data bases and can be stored on local machines building up an enriched private directory. On a large scale and on the basis of a verified fact sheet database grown large enough a (Web) could be created, offering this additional information for e.g. each VoIP call. Privacy concerns should not occur as all information collected is either freely available (to everybody) on the Web or restricted to usage in closed (or controlled) environments, e.g. company networks or online communities. Due to its specification based on RDF the SEMNUM data simply slots into standard FOAF documents as shown below.

The example document below states that it has to be interpreted as an RDF document and names XML namespaces of the languages and vocabularies used (RDF, RDFS, FOAF and SEMNUM). Regarding the information found on the Semantic Web by means of FOAF, it states that it is describing a person. Three FOAF details are explicitly mentioned: the person's name (literal), a phone number (resource) and a website giving information on the person’s work topic (resource). Regarding the information found by means of ENUM, two SEMNUM details are stated: an E-mail address (defined for receiving E-mail) and a phone number (defined for receiving SMS).

Example RDF document incorporating SEMNUM

```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:foaf="http://xmlns.com/foaf/0.1/"
  xmlns:semnum="http://semnum.org/vocab/semnum/0.1/">
<foaf:PersonalProfileDocument rdf:about="">
  <foaf:maker rdf:nodeID="me"/>
  <foaf:primaryTopic rdf:nodeID="me"/>
</foaf:PersonalProfileDocument>
<foaf:Person rdf:nodeID="me">
  <foaf:name>Kurt Reichinger</foaf:name>
  <foaf:phone rdf:resource="tel:+43-1-58058-306"/>
  <foaf:workInfoHomepage rdf:resource="www.rtr.at/enum/"/>
  <semnum:Service>
    <semnum:Email>
      <semnum:mbox
        rdf:resource="mailto:reiching@dbai.tuwien.ac.at"/>
    </semnum:Email>
    <semnum:Sms>
      <semnum:phone rdf:resource="tel:+43-664-3504516"/>
    </semnum:Sms>
  </semnum:Service>
</foaf:Person>
</rdf:RDF>
```

Figure 4 shows the example RDF document as a graph with solid lines indicating a FOAF relation whereas dashed lines indicate a SEMNUM relation.

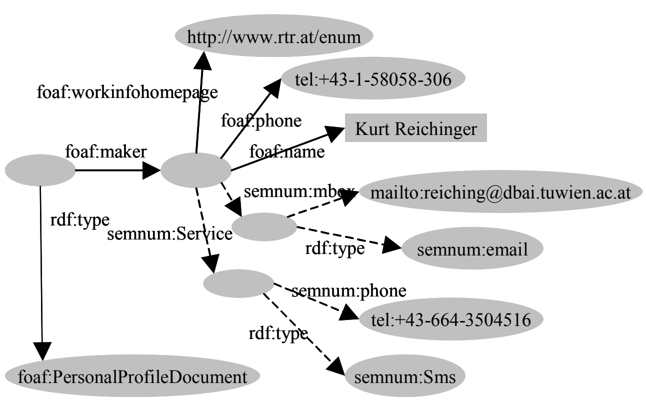

Fig. 4. FOAF/SEMNUM example document graph

6. Conclusions and Future Work

This paper highlights the positive impact of introducing ENUM to the Semantic Web. It illustrates approaches for combining the concepts of ENUM and the Semantic Web making their individual strengths available to each other. The applications proposed in this paper are closing the gap between the worlds of Telecommunications and Semantic Web, with the introduction of the SEMNUM vocabulary being an important step in this direction. As work progresses, an application example coded in JAVA will be used as a proof-of-concept and to study further synergies of the two areas. The issue of adding trust to Semantic Web data by means of ENUM data will get special attention in the future.

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