

Topic Maps, Web Services, and the Semantic Web Semantic Network Services (SNS) – a case study

SchlumbergerSema GmbH, Köln

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1 Introduction

In the recent months, Web Services have been discussed in the context of the Semantic Web quite frequently. In most cases the discussion was about using Web Services to process the Semantic Web, as by Tim Berners-Lee ("A story of program and data as old as computing"¹), or using the Semantic Web for an approved Web Service description, as in Semantic Web Enabled Web Services (SWWS)².

Here we focus on *using Web Services to access ontology* in the Semantic Web.

An example has been implemented by Semantic Network Service (SNS)³, a German R&D project. The project has been run in the years 2001 and 2002, and there has been an early decision to use Topic Maps to model the ontology. From today's perspective one would consider to use the Ontology Web Language (OWL)⁴ instead, but this had not been available at that time.

While there is a – sometimes controversial - discussion about Topic Maps and the Semantic Web⁵, I recommend considering Topic Maps as a pattern to be applied to Web Ontology which may include using OWL to serialize Topic Maps⁶. This would not change the architecture of SNS, it would only replace one Topic Map interchange format by another.

2 SNS, Topic Maps, and Web Services

SNS has implemented a Topic Map in the scope of environmental protection in the German government, in 2001 and 2002. The Topic Map content is based on the legacy of the German Environmental Information Network (*gein*®)⁷ project, which includes a classical thesaurus, a gazetteer, and a chronology – all in all 87,900 professional terms, place names, and events to become 87,900 topics, integrated and semantically networked in a single Topic Map⁸.

SNS was intended to become a centralized common terminology service for the German environmental authorities, with *gein*® as a first client. This has been implemented in early 2003, using the W3C Web Service Architecture⁹ for the integration mechanism. That's why SNS had to provide a Web Service interface to a Topic Map and related methods.

We found standardization quite developed in both the fields (Web Services and Topic Maps), but there was a gap about how to embed Topic Maps into a Web Service scenario.

SNS had to close this gap to provide a working example, at state-of-the-art.

Firstly, there was no standard ready to use¹⁰ about how to access a Topic Map at all. This might be seen as a question up to the application, which can publish its choice of interface using a formal Web Service Description.

Secondly, the formal Web Service Description has to be provided in any case, and it requires an XML Schema for the Topic Map itself – which was missing.

Section 3, Structure of the XML Definitions, will demonstrate how we closed this gap, while section 4, Definition of SNS Topic Classes (SNS-CLASSES.XTM), gives comments on the Published Subject Identifiers¹¹ provided for the Topic classes of the SNS ontology.

3 Structure of the XML Definitions

The implementation requires a nested structure of XML definitions.

SNS.WSDL – general definitions of services, bindings, and types (includes SNS.XSD)

SNS.XSD – definitions of specific request and response formats (includes XTM.XSD)

XTM.XSD – XML Topic Map interchange format (conforming ISO 13250).

From the view of a client, the Web Service Description (SNS.WSDL) will be the first contact. It should contain all the necessary information necessary to reference and access the supplied services by formalized requests and to process the resulting responses. Among other, WSDL provides the Web addresses and all the XML formats ready to be processed by several tools that can automatically generate interfacing source code in Java and many other languages.

The Web Service Description document embeds the SNS-specific XML type definitions given in a separate XML Schema (SNS.XSD). These definitions in turn include the definition of the XML interchange formats for Topic Maps as provided in an annex of ISO 13250.

3.1 SNS Web Service Description (SNS.WSDL)

See <http://www.semantic-network.de/service/xtm/sns.wsdl>.

This document conforms to the Web Services Description Language (WSDL) Version 1.2¹². It provides definitions of *messages*, *interfaces*, *bindings*, *services*, and *types*. It is intended to be processed by the client to enable an automated access to the provided services.

From a practical point of view, the client can read the Web addresses (URL) of the provided services as well as the binding of each service to a communication protocol. Most commonly, the Web Service protocol is the Simple Object Access Protocol (SOAP)¹³. What is of interest here is that SNS supports the HTTP GET protocol in addition.

We support HTTP GET to be able to provide single Web addresses (URL¹⁴) referencing each single Topic, as it has been recommend by the Topic Map community to support a set of "Published Subject Identifiers" (PSI)¹⁵.

WSDL allows multiple bindings of each service to different protocols, and so we implemented an HTTP-GET binding for each of the services. This may be used by machines to simply reference a specific service application, but it also allows human users (especially developers) to inspect the XML response of a service request directly in an XML-capable Web browser.

In all, the specifics of the WSDL are to embed any given service in an interoperable global networking environment. As far as it has to give access to the specific formats of the described services as well, it imports the "native" XML Schema Definitions of these services (SNS.XSD).

3.2 SNS Schema Definition (SNS.XSD)

SNS has to provide schema definitions for each service request and for all the responses. This includes the structure of the request parameters and of the returned classes. As far as this includes an XML Schema for Topic Maps, the external XML Topic Maps Schema Definition (XTM.XSD) is imported.

What remains is the structure of the three services **findTopics**, **getTopic**, and **autoClassify**, and of their common response **topicMapFragment**.

- *findTopics* – search for the occurrence of a given character string in the Topic characteristics – supports various parameters;
- *getPSI* – returns all the characteristics of a referenced Topic, with options to include associations and associated topics – this can be used as a Published Subject Identifier when used in the HTTP-GET binding variant;
- *autoClassify* – returns an ordered list of Topics that are significant for the content classification of a given document or piece of text.

All the three requests return a subset (fragment) of the SNS Topic Map. This subset formally is a Topic map itself, which is formatted conforming to the XML Topic Maps Schema Definition (XTM.XSD) which is imported by SNS.XSD

- *topicMapFragment* – response of all the three requests – documents the Topic map filtering and contains a subset of the SNS Topic Map, selected according to the request parameters.

Additionally, there is a request named *getTypes* which returns the content of *sns-classes.xtm*, as described in chapter 4.

3.3 XML Topic Maps Schema Definition (XTM.XSD)

XTM is the recommended XML interchange format for Topic Maps. It is defined in an annex to ISO 13250. The structure is defined in a DTD¹⁶.

There is no normative XML Schema for XTM. Many of the modern XML applications (such as Web Services) require an XML Schema. This has been discussed¹⁷ in the public Topic Map mailing lists in February, 2003. In this context there has been a first draft¹⁸ by Max Voskob, which later has been “slightly modified” by Lars Marius Garshol¹⁹.

SNS uses this version, with one further modification: Lars Marius did not declare any explicit XML namespace (*xs:targetNamespace*) for XTM. This is required so that XML serializations of Topic Maps are able to reference the XTM namespace, as it can be seen in SNS.XSD.

4 Definition of SNS Topic Classes (SNS-CLASSES.XTM)

Beside the Web Service Description, SNS defines Topic, Association and Occurrence classes according to chapter “3.4 Classes and Instances”²⁰ of the XTM definition document: The basic classes defined in the XTM 1.0 Core Published Subject Indicators²¹ are extended by SNS specific classes in SNS-CLASSES.XTM.

4.1 Namespaces and Entities

The inclusion of XTM references together with SNS references in one document require multiple references to both of the definition URLs. As these references occur in attribute *values*, and not in XML element and attribute names only, XML namespaces cannot be used in all cases. As a workaround we used XML entities following the proposal contained in the Web Ontology Language (OWL) Guide Version²².

As an aid to writing down references to lengthy URLs it can often be useful to provide a set of entity definitions in a document type declaration (DOCTYPE) that precedes the ontology definitions. The names defined by the namespace declarations only have significance as parts of XML tags. Attribute values are not namespace sensitive. But in OWL we frequently reference ontology identifiers using attribute values. They can be written down in their fully expanded form, for example “<http://www.example.org/owl/wine#merlot>”. Alternatively, abbreviations can be defined using an ENTITY definition, for example:

```
<!DOCTYPE owl [
  <!ENTITY vin "http://www.example.org/wine#" >
  <!ENTITY food "http://www.example.org/food#" > ]>
```

After this pair of ENTITY declarations, we could write the value “&vin;merlot” and it would expand to “<http://www.example.org/wine#merlot>”.

Following this practice, we write “&xtn;” for “<http://www.topicmaps.org/xtm/1.0/core.xtm> - [topic](#)”, and “&sns;” for the path of the SNS definitions (to be published).

4.2 SNS Topic class hierarchy

SNS uses the superclass-subclass concepts defined in XTM 1.0²³ to build class hierarchies.

The class identified by “<a href=<#>#” is the root element of the SNS Topic class hierarchy. On the second level, there are three classes of Topics:

- Thesaurus (“<a href=<#>#”)
- Event (“<a href=<#>#”)
- Location (“<a href=<#>#”).

These are defined as instances of “<a href=<#>#”, without having an explicit superclass-subclass association with “<a href=<#>#”.

5 Each of these classes has a number of subclasses as listed in Conclusions

The project has proved the interoperability between Web Services and XTM. With the help of an (unofficial) XML Schema, XTM can be embedded in a Web Service Description scenario and is processed by Web Services tools such as Apache Axis or Microsoft DOT.NET. Both tools have proved to publish and to consume the given description. Especially, they are able to auto-generate client stubs that can be directly integrated into ontology-aware applications.

The project further on has generally proved the usability of Web Service access to Ontology. The 2003 version of *gein*® (to be released to the public in September 2003) includes heavy terminology access which is completely executed via the SNS Web Services. More clients in the environmental domain are expected in 2004 and later on.

Besides this, SNS has shown a way to provide Published Subject Identifiers for large Topic Maps that are not likely to be maintained in HTML or XML files, but in databases with a service that uses the HTTP GET binding, and so can address a single Topic by a unique URL.

Annex A: SNS Topic Types Overview. These subclasses are defined as instances of “<a href=<#>#”, having an explicit superclass-subclass association with their respective superclasses.

SNS supports **extensions of characteristics** along the class hierarchy: Events have a temporal extent, while locations may have a “bounding box”. Any Topic may appear with a ranking value in a ranked list. The only way to model such extensions in XTM is by defining additional Occurrence classes. SNS decided to use these Occurrence classes with inline values (“resourceData”).

5.1 SNS Association Templates

While the described interface has been implemented, the “The Topic Map Constraint Language”²⁴ working group has continued to discuss the requirements for such a language. There has also been some discussion about the applicability of the Ontology Web Language for this purposes, but SNS could not wait for the results.

So we used Published Subject Identifiers to define Association classes. Further on, SNS tries to define Association templates, including the definition of Member roles, and Associations that tie an Association class to its dedicated Member roles.

In detail, there are three steps to complete an Association template.

1. Define a Topic that represents the Association class.
2. Define Topics for each of the Member roles and tie them to valid Topic classes

3. Tie the Association class to its Member roles.

5.1.1 Association classes

Example: The Association class “narrowerTermAssoc” shall establish relations between wider and narrower terms in a thesaurus structure. First we define a Topic that represents the Association class:

```
<topic id="narrowerTermAssoc">
  <instanceOf>
    <topicRef xlink:href="#xtn;core.xtn#association"/>
  </instanceOf>
```

...

Note that this Topic is an instance of the XTM core Topic “association”

5.1.2 Member roles

Now we need two Member roles: wider term and narrower term.

```
<topic id="narrowerTermMember">
  <instanceOf>
    <subjectIndicatorRef xlink:href="#xtn;#roleSpec"/>
  </instanceOf>
```

...

Note that this Topic is an instance of the XTM core subject “roleSpec” (not defined in core.xtn, but in the HTML standards text).

Now we want to express that a narrower term must be a descriptor. To make this possible, SNS defines a Topic that represents type constraints. The definition of the narrowerTermMember role continues:

```
...
<occurrence>
  <instanceOf>
    <topicRef xlink:href="#sns;typeConstraint"/>
  </instanceOf>
  <resourceRef xlink:href="#sns;descriptorType"/>
</occurrence>
```

....

Now we do the same for the wider term Member role.

5.1.3 Associations between Association classes and Member roles

So far, we have an Association class (narrowerTermAssoc) and two Member roles (narrowerTermMember and widerTermMember). Now we want to express that the specific Association class is supposed to have Members of these two roles.

“assoc-member-assoc” is a “meta”-Association that is used to tie Association classes to Member roles:

```
<association>
  <instanceOf>
    <topicRef xlink:href="#sns;assoc-member-assoc"/>
  </instanceOf>
  <member>
    <topicRef xlink:href="#sns;narrowerTermAssoc"/>
  </member>
```

```
<member>
  <topicRef xlink:href="#&sns;narrowerTermMember"/>
</member>
</association>
```

Note that there is no expression of cardinality here. This may be extended in a future version, but we would recommend leaving regulations like this to the future development of the Topic Map Constraint Language, or, possibly, to the expression of Topic Map patterns in OWL.

6 Conclusions

The project has proved the interoperability between Web Services and XTM. With the help of an (unofficial) XML Schema, XTM can be embedded in a Web Service Description scenario and is processed by Web Services tools such as Apache Axis or Microsoft DOT.NET. Both tools have proved to publish and to consume the given description. Especially, they are able to auto-generate client stubs that can be directly integrated into ontology-aware applications.

The project further on has generally proved the usability of Web Service access to Ontology. The 2003 version of *gein*® (to be released to the public in September 2003) includes heavy terminology access which is completely executed via the SNS Web Services. More clients in the environmental domain are expected in 2004 and later on.

Besides this, SNS has shown a way to provide Published Subject Identifiers for large Topic Maps that are not likely to be maintained in HTML or XML files, but in databases with a service that uses the HTTP GET binding, and so can address a single Topic by a unique URL.

Annex A: SNS Topic Types Overview

/event/

/event/conference/

/event/convention/

/event/disaster/

/event/guideline/

/event/historical/

/event/industrialAccident/

/event/initiative/

/event/institution/

/event/law/

/event/marineAccident/

/event/ofTheYear/

/event/publication/

/location/

/location/admin/

/location/admin/community/

/location/admin/district/

/location/admin/nation/

/location/admin/quarter/

/location/admin/state/

/location/land/

/location/land/catchmentArea/

/location/land/island/

/location/land/landscape/

/location/land/mountain/

/location/land/mountains/

/location/land/naturalLandscape/

/location/protected/

/location/protected/biosphere/

/location/protected/nationalPark/

/location/protected/naturalPark/

/location/protected/protectedArea/

/location/waters/

/location/waters/channel/

/location/waters/lake/

/location/waters/reservoir/

/location/waters/river/

/location/waters/see/

/thesa/

/thesa/component/

/thesa/descriptor/

/thesa/synonym/

Annex B: SNS TopicMapFragment sample

response in tmfrag.xml

```

<?xml version="1.0" encoding="UTF-8"?>
<topicMapFragment xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns="http://www.semantic-network.de/xmlns/XTM/2003/1.0"/>
  <listExcerpt totalSize="16" pageSize="20" offset="1"/>
    <requestParameters>passsword&eq;&amp;user=xxx&amp;queryTerm&eq;ozone&amp;searchType&eq;beginsWith&
&amp;lang&eq;en&amp;path&eq;&amp;fields&eq;captors</requestParameters>
    <topicMap xmlns="http://www.topicmaps.org/xtm/1.0"/>
      <topic id="uba_thes_51553">
        <instanceOf>
          <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/synonymType"/>
        </instanceOf>
        <baseName>
          <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
          </scope>
          <baseNameString>Atmosphärisches Ozon</baseNameString>
          <variant>
            <parameters>
              <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#sort"/>
            </parameters>
            <variantName>
              <resourceData>ATMOSPHAERISCHES OZON</resourceData>
            </variantName>
          </variant>
        </baseName>
        <baseName>
          <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
          </scope>
          <baseNameString>atmospheric ozone</baseNameString>
        </baseName>
      </topic>
      <topic id="calendarEvent_12">
        <instanceOf>
          <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/historicalType"/>
        </instanceOf>
        <baseName>
          <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
          </scope>
          <baseNameString>Zerstörung der Ozonschicht</baseNameString>
        </baseName>
        <baseName>
          <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
          </scope>
          <baseNameString>Depletion of the ozone layer</baseNameString>
        </baseName>
        <occurrence>
          <instanceOf>
            <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/descriptionOcc"/>
          </instanceOf>
          <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
          </scope>
          <resourceData>Erste Erkenntnisse zur Zerstörung der Ozonschicht.</resourceData>
        </occurrence>
        <occurrence>
          <instanceOf>
            <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/descriptionOcc"/>
          </instanceOf>
          <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
          </scope>
          <resourceData>First evidence of ozone depletion.</resourceData>
        </occurrence>
      </topic>
    </topicMap>
  </listExcerpt>

```

```

    <occurrence>
      <instanceOf>
        <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/temporalAtOcc"/>
      </instanceOf>
      <resourceData>1968</resourceData>
    </occurrence>
  </topic>
  <topic id="calendarEvent_13">
    <instanceOf>
      <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/historicalType"/>
    </instanceOf>
    <baseName>
      <scope>
        <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
      </scope>
      <baseNameString>Zerstörung der Ozonschicht</baseNameString>
    </baseName>
    <baseName>
      <scope>
        <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
      </scope>
      <baseNameString>Depletion of the ozone layer</baseNameString>
    </baseName>
    <occurrence>
      <instanceOf>
        <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/descriptionOcc"/>
      </instanceOf>
      <scope>
        <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
      </scope>
      <resourceData>Zusammenhänge zwischen der Zerstörung der Ozonschicht und der Freisetzung von
Treibgasen werden wissenschaftlich nachgewiesen.</resourceData>
    </occurrence>
    <occurrence>
      <instanceOf>
        <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/descriptionOcc"/>
      </instanceOf>
      <scope>
        <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
      </scope>
      <resourceData>Objective proof of the connection between the destruction of the ozone layer and the
release of aerosol propellants.</resourceData>
    </occurrence>
    <occurrence>
      <instanceOf>
        <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/temporalAtOcc"/>
      </instanceOf>
      <resourceData>1975</resourceData>
    </occurrence>
  </topic>
  <topic id="uba_thes_48273">
    <instanceOf>
      <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/synonymType"/>
    </instanceOf>
    <baseName>
      <scope>
        <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
      </scope>
      <baseNameString>Fotochemisches Ozonbildungspotenzial</baseNameString>
      <variant>
        <parameters>
          <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#sort"/>
        </parameters>
        <variantName>
          <resourceData>FOTOCHEMISCHES OZONBILDUNGSPOTENZIAL</resourceData>
        </variantName>
      </variant>
    </baseName>
    <baseName>
      <scope>

```

```

        <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
    </scope>
    <baseNameString>fotochemical ozone creation potenzial</baseNameString>
</baseName>
</topic>
<topic id="uba_thes_18829">
    <instanceOf>
        <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/descriptorType"/>
    </instanceOf>
    <baseName>
        <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
        </scope>
        <baseNameString>Ozon</baseNameString>
        <variant>
            <parameters>
                <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#sort"/>
            </parameters>
            <variantName>
                <resourceData>OZON</resourceData>
            </variantName>
        </variant>
    </baseName>
    <baseName>
        <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
        </scope>
        <baseNameString>ozone</baseNameString>
        <variant>
            <parameters>
                <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#variant"/>
            </parameters>
            <variantName>
                <resourceData>ozone</resourceData>
            </variantName>
        </variant>
    </baseName>
</topic>
<topic id="uba_thes_42261">
    <instanceOf>
        <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/synonymType"/>
    </instanceOf>
    <baseName>
        <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
        </scope>
        <baseNameString>Ozonzufuhr</baseNameString>
        <variant>
            <parameters>
                <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#sort"/>
            </parameters>
            <variantName>
                <resourceData>OZONZUFUHR</resourceData>
            </variantName>
        </variant>
    </baseName>
    <baseName>
        <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
        </scope>
        <baseNameString>ozone addition</baseNameString>
    </baseName>
</topic>
<topic id="uba_thes_18838">
    <instanceOf>
        <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/descriptorType"/>
    </instanceOf>
    <baseName>
        <scope>
            <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>

```

```

</scope>
<baseNameString>Ozongehalt</baseNameString>
<variant>
  <parameters>
    <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#sort"/>
  </parameters>
  <variantName>
    <resourceData>OZONGEHALT</resourceData>
  </variantName>
</variant>
</baseName>
<baseName>
  <scope>
    <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#en"/>
  </scope>
  <baseNameString>ozone content</baseNameString>
  <variant>
    <parameters>
      <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#variant"/>
    </parameters>
    <variantName>
      <resourceData>amount of ozone in the air</resourceData>
    </variantName>
  </variant>
  <variant>
    <parameters>
      <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#variant"/>
    </parameters>
    <variantName>
      <resourceData>percentage of ozone in the air</resourceData>
    </variantName>
  </variant>
</baseName>
</topic>
<topic id="uba_thes_48271">
  <instanceOf>
    <topicRef xlink:href="http://www.semantic-network.de/xmlns/XTM/2003/1.0/descriptorType"/>
  </instanceOf>
  <baseName>
    <scope>
      <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/language.xtm#de"/>
    </scope>
    <baseNameString>Ozonbildung</baseNameString>
    <variant>
      <parameters>
        <topicRef xlink:href="http://www.topicmaps.org/xtm/1.0/core.xtm#sort"/>
      </parameters>
      <variantName>
        <resourceData>OZONBILDUNG</resourceData>
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      <parameters>
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        </variant>
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  <baseName>
    <scope>
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    </scope>
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    </variant>
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    </scope>
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</baseName>
</topic>
</topicMap>
</topicMapFragment>

```

Endnotes

- ¹ Tim Berners-Lee: Web Services - Semantic Web.
<http://www.w3.org/2003/Talks/0521-www-keynote-tbl/>
- ² Semantic Web enabled Web Services. <http://swws.semanticweb.org/swws>
- ³ <http://www.semantic-network.de>
- ⁴ OWL Web Ontology Language Overview. W3C Working Draft 31 March 2003.
<http://www.w3.org/TR/owl-features/>
- ⁵ Some examples:
Le Grande: XML Topic Maps and Semantic Web Mining.
<http://www.idealliance.org/papers/xml2001/papers/html/04-04-05.html>
Decker: On the integration of Topic Map data and RDF data,
<http://www.semanticweb.org/SWWS/program/full/paper53.pdf>.
Garshol: Living with topic maps and RDF. <http://www.ontopia.net/topicmaps/materials/tmrd.html>
- ⁶ There is a first example showing how Published Subjects could be expressed in OWL, posted by Bernard Vatant. See <http://www.mondeca.com/owl/lang.rdf>
- ⁷ <http://www.gein.de>
- ⁸ http://www.idealliance.org/papers/xml02/dx_xml02/index/author/d0e32616.html
- ⁹ <http://www.w3.org/2002/ws/>
- ¹⁰ <http://www.isotopicmaps.org/sam/> The Standard Application Model for Topic Maps
- ¹¹ http://www.oasis-open.org/committees/documents.php?wg_abbrev=tm-pubsubj
- ¹² <http://www.w3.org/2002/ws/desc/>
- ¹³ <http://www.w3.org/2000/xp/Group/>
- ¹⁴ See the chapter "Identification and Resources" in: Architecture of the World Wide Web. W3C Working Draft 27 June 2003. <http://www.w3.org/TR/2003/WD-webarch-20030627/#identification> .
- ¹⁵ see footnote 11.
- ¹⁶ <http://www.topicmaps.org/xtm/1.0/xtm1.dtd>
- ¹⁷ Discussion about XML Schema for Topic Maps at:
<http://lists.oasis-open.org/archives/topicmaps-comment/200302/threads.html>
- ¹⁸ XML Schema Draft by Max Voskob:
<http://lists.oasis-open.org/archives/topicmaps-comment/200302/msg00000.html>
- ¹⁹ For some reasons, Lars Marius has posted this to
<http://www.infloom.com/pipermail/topicmapmail/2003q1/004395.html>, but not to topicmap-comments.
- ²⁰ (<http://www.topicmaps.org/xtm/1.0/#syn-classes>).
- ²¹ XTM 1.0 Core Published Subject Indicators <http://www.topicmaps.org/xtm/1.0/core.xtm>
- ²² Web Ontology Language (OWL) Guide Version 1.0. W3C Working Draft 4 November 2002.
<http://www.w3.org/TR/2002/WD-owl-guide-20021104/>
- ²³ <http://www.topicmaps.org/xtm/1.0/#desc-superclass-subclass>
- ²⁴ <http://www.isotopicmaps.org/tmcl/>