The Use of HL7 CDA in the National Health Information System (NHIS) of Turkey

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Abstract*- Turkey's National Health Information System (NHIS) aims to provide a nation-wide infrastructure for sharing the Electronic Health Records (EHRs). The current implementation supports the transfer of EHRs, called the "Transmission Schema" instances from the Family Medicine Information Systems (FMIS) and the Hospital Information Systems (HIS) to the NHIS servers at the Ministry of Health (MoH). During the localization of the "Transmission Schemas", the rules which are set in the "HL7 Refinement, Constraint and Localization" are applied. In other words, the CDA RMIM is edited and then converted to HMD and XSD, respectively. Hence, the "Transmission Schemas" are HL7 CDA compliant and are based on the national Minimum Health Data Sets (MHDS). The MHDSs use the data elements from the National Health Data Dictionary (NHDD). The data elements are coded with coding systems which are available from the Health Coding Reference Server (HCRS). "Doctor Data Bank (DDB)" provides healthcare professional identity and specialization. HL7 Web service Profile is used for the transportation of "Transmission Schema" instances. In this paper, we explain the differences between the "Transmission Schemas" and the HL7 CDA R2 conformant EHRs and describe the "Adaptor" that is being developed to convert the "Transmission Schema" instances to the HL7 CDA R2 conformant EHRs. It turns out that this process is straight forward in one direction, which is, converting the "Transmission Schema" instances to the HL7 CDA R2 conformant EHRs. The transformation in the reverse direction requires keeping various mapping tables giving the correspondences between elements.

I. INTRODUCTION

In the current use of the National Health Information System (NHIS) [1], Turkey, the Family Medicine Information Systems (FMIS) [2] and the Hospital Information Systems (HIS) send "Transmission Schema" instances to the NHIS servers at the Ministry of Health (MoH). The following mechanisms are used to serialize "Transmission Schemas" into HL7 CDA R2 compliant EHRs [3, 4]:

1) HL7 CDA sections are comprised of Minimum Health Data Sets (MHDSs) [5]. The Minimum Health Data Sets are formed from the data elements specified in the National Health Data Dictionary (NHDD) [6]. The NHDD is developed to enable the parties to share the same meaning of data, and use them for the same purpose. NHDD data elements conform to ISO/IEC 11179-4 Standard [7]. Currently, there are 261 data elements and 46 Minimum Health Data Sets. Some example data elements are: Address, Name, Main Diagnosis, Vaccination, Treatment Method, Diastolic Blood Pressure, Healthcare Institution and Marital Status. Some example MHDS are: Citizen/Foreigner Registration MHDS, Medical Examination MHDS, Prescription MHDS, Pregnant Monitoring MHDS, Cancer MHDS and Inpatient MHDS. As more data is collected from the field, the MHDS will be updated in certain periods to meet the new needs.

2) The data elements within the Minimum Health Data Sets are mostly coded with coding systems in use in Turkey and all these coding systems are available at the Health Coding Reference Server (HCRS) [8] as Web services to be directly used by the applications. If a data element is defined in the National Health Data Dictionary as coded or classified, then within the definition of the data element, the related coding/classification system is given in the "HCRS System Code" field. There are two possibilities for a coded element: either the value is gathered from a coding system such as ICD-10, or healthcare institutions' codes, or physicians' specialties or the value is of parametric kind such as "gender" or "marital status".

3) Ministry of Health is authorized to provide the work licenses to the physicians in Turkey. The diploma/specialty information of the medical professionals is recorded together with their Turkish citizenship numbers in the Doctor Data Bank (DDB) [8]. As of October 2007, there are 162,446 registered doctors in the data bank. This includes all the physicians who obtained a license since 1923.

The Doctor Data Bank, that is, the Healthcare Professional Registry serves two purposes: The first one is that most of the payment providers control the health service and the prescriptions according to the physicians' specialty. For example, when a rule indicates that only the physicians with a certain specialty can prescribe certain medicines, it becomes possible to check whether the doctor who has signed the prescription has the required specialty. The related institutions signed an official protocol and started their implementations based on DDB in the last quarter of 2006. The second use of the DDB will be for authorizing access to the EHRs of the patients according to patient consent.

In the current version of the NHIS, the Transmission Schema instances are regarded as HL7 v3 messages and localized according to the Turkey's HL7 Profile [9]. During the Localization Process, the rules which are set in the "HL7 Refinement, Constraint and Localization" [10] are applied. In other words, the CDA RMIM [11] is edited and then converted to HMD [12] and XSD, respectively. However certain modifications are applied to the original CDA XSD schemas as explained in Section II.B. Hence, this version of NHIS Transmission Schemas are not HL7 CDA conformant since a conformant CDA document should at a minimum validate against the CDA Level One Schema [13]. However, since the messages are derived from CDA RMIM, the current versions of NHIS EHRs are HL7 v3 CDA R2 compliant. These compliant versions have greatly facilitated the fast deployment of NHIS Web services because in this way, the XML schemas themselves contain the constraints rather than expressing the constraints as a set of rules. For the applications that need HL7 CDA R2 conformant EHRs, an XSLT Adaptor is being developed to convert the "Transmission Schemas" into HL7 CDA R2 conformant EHRs.

It should be noted that there is no specific HL7 v3 Domain for all of the Transmission Schemas. For example, there is no HL7 Domain that is suitable for "Pregnant Psychosocial Observation" or "Communicable Disease Possible Case Notification". Therefore, the CDA, which provides a generic mechanism to identify the contents of electronic healthcare documents, is selected as the wire format.

In this paper, we explain the differences between the "Transmission Schemas" and the HL7 CDA R2 compliant EHRs and describe the "Adaptor" that is being developed to convert the current "Transmission Schema" instances into the HL7 CDA R2 conformant EHRs.

A. *A Brief Introduction to HL7 CDA*

The HL7 Clinical Document Architecture (CDA) [3, 4] is a document markup standard that specifies the structure and semantics of "clinical documents" for the purpose of exchange. CDA documents derive their machine processable meaning from the HL7 Reference Information Model (RIM) and use the HL7 Version 3 Data Types. They are encoded in Extensible Markup Language (XML).

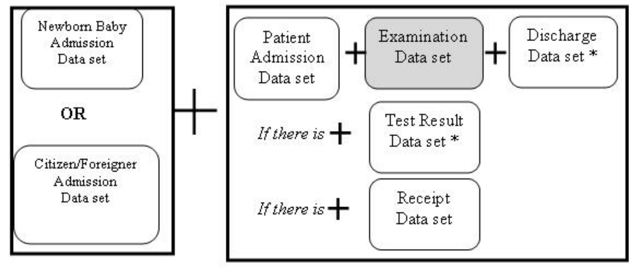
A CDA document is wrapped by the <ClinicalDocument> element, and is comprised of two parts, a header and a body. The header lies between the <ClinicalDocument> and the <structuredBody> elements, and identifies and classifies the document and provides information on authentication, the encounter, the patient, and the involved providers. The body, wrapped by the <structuredBody> element contains the clinical report, and can be a combination of structured text and/or structured markup.

Each section of a CDA document can be either in the form of just free text or can also be defined to have discrete data elements in addition to the free text representation. The discrete data elements, called CDA entries represent structured content provided for further computer processing.

The generic CDA specification can be constrained through the document-level, section-level and entry-level templates. The unconstrained CDA specification is called "CDA Level One". When section-level templates are applied to an unconstrained CDA document, it is called "CDA Level Two". "CDA Level Three" is the CDA specification with entry-level (and optionally section-level) templates applied.

II. GENERATION OF TRANSMISSION SCHEMAS

The Level One CDA Schema is too generic for the requirements of the NHIS. In the current version of the NHIS, the Transmission Schema instances are localized according to Turkey's HL7 Profile. During the Localization Process, the rules which are set in the "HL7 Refinement, Constraint and Localization" [14] are applied. However, the original HL7 CDA schemas are modified which breaks the CDA conformance of NHIS Transmission Schemas, since a conformant CDA document should at a minimum validate against the CDA Level One Schema [13]. Yet, since the messages are derived from CDA RMIM, the current version of NHIS is HL7 v3 CDA R2 compliant.



* *In case of multiple tests applied to the patient*

Figure 1. Examination Transmission Schema

Generally, the "Transmission Schemas" contain a main data set (from which the transmission schema is named after) and a set of auxiliary data sets that helps the interpretation of the main data set. An example transmission schema for "Examination" is shown in Figure 1 where the "Examination" data set is sent together with the "Newborn Baby Admission" or "Citizen/Foreigner Admission" data sets. Furthermore, "Patient Admission" and "Discharge" data sets are also required. If there are any "Test Result" data sets or "Receipt" data sets, they are also sent along with the "Examination" data set.

The transmission schemas are generated as follows: First, three new code systems are created in which there is a unique code for each of the artifacts:

1) NHIS Document Type Code System (DocumentType-CS) gives the codes for the "Transmission Schemas".

2) NHIS Data Set Code System (DataSet-CS) contains the codes for data sets in MHDS (Minimum Health Data Sets) [5].

3) NHIS Data Element Code System (DataElement-CS) specifies the codes for data elements in NHDD (National Health Data Dictionary) [6].

```
<examination classCode="DOCCLIN" moodCode="EVN">
    <code code="MUAYENE" codeSystem="2.16.840.1.113883.3.129.2.2.1"
codeSystemName="Dokuman Tipi" codeSystemVersion="1.0"
displayName="Muayene MSVS (Vatandas/Yabanci)" />
```

Figure 2. A Part of the Examination Transmission Schema

Each “Transmission Schema” is wrapped with a root element named after the main data set in the transmission. For example, as shown in Figure 2, the root tag of the “Examination Transmission Schema” is <examination>. In this example, the document type (“Dokuman Tipi” in Turkish) is “Examination” (“MUAYENE” in Turkish) and this code is obtained from the DocumentType-CS Code System whose object id (OID) is “2.16.840.1.113883.3.129.2.2.1”.

The “Data Sets” in the “Transmission Schemas” correspond to the “Sections” in the CDA Documents. The name of the opening tag of the “Data Set” is obtained by concatenating the name of the dataset with the “Dataset” keyword. The “code” of a “Data Set” is retrieved from the DataSet-CS Code System. For instance, in the example given in Figure 3, the opening tag is <examinationDataset> and the code is specified as “Examination” (“MUAYENE”). This code is obtained from the DataSet-CS (“Veriseti”) Code System whose object id (OID) is “2.16.840.1.113883.3.129.2.2.2”.

```
<examinationDataset classCode="DOCSECT" moodCode="EVN">
  <id root="2.16.840.1.113883.3.129.2.1.4" extension="4e7e0004-8e9e-
44d2-9a9e-099d071e646a" />
  <code code="MUAYENE" codeSystem="2.16.840.1.113883.3.129.2.2.2"
codeSystemName="Veriseti" codeSystemVersion="1.0"
displayName="Muayene Veriseti" />
```

Figure 3. An Example Section for the Examination Transmission Schema

Finally, the data elements are represented by nesting new “section” elements in the data set’s “section” elements. The opening tag of a data element is obtained by concatenating the data element’s name with the “section” keyword. For example, the diagnosis (“TANI” in Turkish) data element is introduced to the examination data set with the <diagnosisSection> element as shown in Figure 4.

```
<examinationDataset classCode="DOCSECT" moodCode="EVN">
  <id root="2.16.840.1.113883.3.129.2.1.4" extension="4e7e0004-8e9e-
44d2-9a9e-099d071e646a" />
  <code code="MUAYENE" codeSystem="2.16.840.1.113883.3.129.2.2.2"
codeSystemName="Veriseti" codeSystemVersion="1.0"
displayName="Muayene Veriseti" />
…
  <diagnosisSection classCode="DOCSECT" moodCode="EVN">
    <id root="2.16.840.1.113883.3.129.2.1.5" extension="6c4b1e87-c4f4-
42b0-aaeb-05e23a77ed5a" />
     <code code="TANI" codeSystem="2.16.840.1.113883.3.129.2.2.3"
codeSystemName="Veri Kismi" codeSystemVersion="1.0"
displayName="Tani Versinin Oldugu Bolum" />
  <text mediaType="text/x-hl7-text+xml">
    Hastada vaskuler bagirsak bozuklugu teshis edilmistir.
  </text>
```

```
      <component typeCode="COMP" contextConductionInd="true">
        <diagnosis moodCode="EVN" classCode="OBS">
        …
        <value code="K55" codeSystem="2.16.840.1.113883.6.3"
codeSystemName="ICD-10" codeSystemVersion="1.0"
displayName="BARSAGIN VASKULER BOZUKLUKLARI" />
          </diagnosis>
      </component>
    </diagnosisSection>
…
```

Figure 4. An Example Data Element “Diagnosis (‘TANI’ in Turkish)”

As shown in Figure 4, the “code” of this “diagnosisSection” is ‘TANI’ which is obtained from the DataElement-CS Code System whose OID is “2.16.840.1.113883.3.129.2.2.3”. The value of this data element is set in the “diagnosis” element under the “component” element. The “diagnosis” element is derived from RIM Observation (OBS) Class, and its value is retrieved from ICD-10 code system. In other words, the values for the data elements are given with elements whose classCode attributes are Act or Act’s subclasses, such as Observation or Procedure and they are associated to the related “section” element through the “component” element.

Figure 5 summarizes the relationships between the artifacts of NHIS, the “Transmission Schemas” and the HL7 CDA R2. Once this mapping is defined, the constraints implied through these mappings are reflected to the schemas by modifying the CDA Level One schema.

A. Validation of Transmission Schemas

A two phase validation technique is applied for the validation of the incoming messages to the NHIS. In the first phase, which is called syntax validation phase, an incoming instance document is validated against the “Transmission Schemas”. If successful, the message is conveyed to the second phase which is called the semantic validation phase.

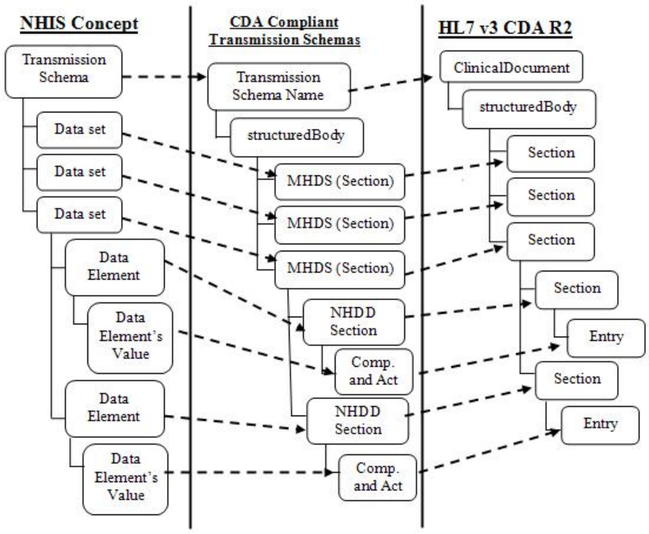


Figure 5. Mapping NHIS Concepts to CDA R2

The semantic validation phase checks the values in the data elements and the relationships between them. The semantic constraints are categorized into four classes:

1) Coded elements: The coded elements should have values from Health Coding Reference Server (HCRS) [8].

2) Business rules: There are some rules among the message elements such as the examination end date should be later than the examination begin date.

3) MERNIS Central Demographics Management System: In Turkey, every citizen has a unique identifier and these identifiers are maintained in a system called MERNIS (Central Demographics Management System) [15]. The patient id numbers in the messages should be validated against this system.

4) Doctor Data Bank (DDB): In Turkey, every doctor is registered to a system called Doctor Data Bank. The id numbers of the doctors in the messages should be validated against this system.

The semantic validation is realized in four steps: (1) The validation of the coded elements using HCRS, (2) Checking business rules using Schematron rules [16], (3) Patient id control by connecting to the MERNIS and (4) Doctor id control by connecting to the DDB. All these steps except for (2) are validated by using Web services provided by the HCRS, MERNIS and DDB systems.

The business rules, on the other hand, are described using Schematron rules [15]. An example Schematron rule is shown in Figure 6, which is used to check that “the examination end time should be prior to the discharge time”.

```
<sch:pattern name="rule 2 validation">
 <sch:rule
context="hl7:examinationSection//hl7:encounter/hl7:effectiveTime">
  <sch:assert test="
   ( number(substring(string(hl7:high/@value),1,4))
   &lt; (number(substring(string(root()//hl7:dischargeSection//hl7:discharge/
hl7:effectiveTime/@value),1,4)))) or (
   (number(substring(string(hl7:high/@value),1,4)) =
number(substring(string(root()//hl7:dischargeSection//hl7:discharge/
hl7:effectiveTime/@value),1,4)))
   and (number(substring(string(hl7:high/@value),5,2)) &lt;
number(substring(string(root()//hl7:dischargeSection//hl7:discharge/
hl7:effectiveTime/@value),5,2))))
   or ( (number(substring(
string(hl7:high/@value),1,4)) = number(substring(string(root()//
hl7:dischargeSection//hl7:discharge/
hl7:effectiveTime/@value),1,4)))
   and
   (number(substring(string(hl7:high/@value),5,2)) =
number(substring(string(root()//hl7:dischargeSection//hl7:discharge
/hl7:effectiveTime/@value),5,2)))
   and
   (number(substring(string(hl7:high/@value),7,2)) &lt;=
number(substring(string(root()//hl7:dischargeSection//hl7:discharge/
hl7:effectiveTime/@value),7,2)))
   ) ">Rule 2 is not valid
  </sch:assert>
 </sch:rule>
</sch:pattern>
```

Figure 6 An Example Semantic Schematron Rule

B. The Differences between The “NHIS HL7 CDA R2 Conformant CDA” and the “NHIS HL7 CDA Compliant Transmission Schemas”

In the current version of the implementation of the “Transmission Schemas”, there are six main deviations from the HL7 CDA Level One Schema:

1) In an HL7 CDA R2 compliant EHR, the “ClinicalDocument” should be the root element of the document as shown in Figure 7. However, in the “Transmission Schemas” the root of the document is the name of the transmission schema as shown in Figure 2 (i.e. it is not “ClinicalDocument”).

```
<ClinicalDocument xmlns="urn:hl7-org:v3" xmlns:voc="urn:hl7-
org:v3/voc" xmlns:xsi="http://www.w3.org/2001/ XMLSchema-instance"
xsi:schemaLocation="urn:hl7-org:v3 CDA.xsd">
    <typeId root="2.16.840.1.113883.1.3" extension="POCD_HD000040"/>
    <id root="2.16.840.1.113883.3.129.2.1.3" extension="6048d1e4-3af5-
49b7-b9d7-60e685b2a150" />
    <code code="MUAYENE" codeSystem="2.16.840.1.113883.3.129.2.2.1"
codeSystemName="Dokuman Tipi" codeSystemVersion="1.0"
displayName="Muayene MSVS (Vatandas/Yabanci)" />
```

Figure 7 The CDA root element for an example EHR

2) In HL7 CDA conformant EHRs, the datasets sections should start with “<section>” tag as shown in Figure 8. In the “Transmission Schemas”, the name of the opening tag of a section is the name of the dataset concatenated with “Dataset” keyword, e.g., “<examinationDataset>” tag as shown in Figure 3.

3) In the “Transmission Schemas”, the NHDD data elements’ sections do not start with “<section>” tag. The name of the tag is the name of the data element concatenated with “Section” keyword. For example, as shown in Figure 4, the diagnosis data element in the examination dataset is wrapped with “<diagnosisSection>” tag.

```
<section classCode="DOCSECT" moodCode="EVN">
    <id root="2.16.840.1.113883.3.129.2.1.4" extension="4e7e0004-8e9e-
44d2-9a9e-099d071e646a" />
   <code code="MUAYENE" codeSystem="2.16.840.1.113883.3.129.2.2.2"
codeSystemName="Veriseti" codeSystemVersion="1.0"
displayName="Muayene Veriseti" />
```

Figure 8. An Example CDA Section for the Examination Transmission Schema

4) In the Level One CDA Schema, the body is composed of “<section>” elements combined with “<component>” elements. In other words, a “<component>” relates a “<section>” element with its subsections. In the NHIS implementation, the components are numbered sequentially, i.e., the component element names are “<component1>”, “<component2>”, …, “<componentN>”. Figure 9, shows the components of Examination Transmission Schema. Each of the components contains a data set section element.

```
<examination classCode="DOCCLIN" moodCode="EVN">
  [CDA Header]
  <component typeCode="COMP" contextConductionInd="true">
```

```
  <structuredBody classCode="DOCBODY" moodCode="EVN">
    <component1 typeCode="COMP" contextConductionInd="true">
        ...
    </component1>
    <component2 typeCode="COMP" contextConductionInd="true">
        ...
    </component2>
    <component3 typeCode="COMP" contextConductionInd="true">
        ...
    </component3>
    <component4 typeCode="COMP" contextConductionInd="true">
        ...
    </component4>
    <component5 typeCode="COMP" contextConductionInd="true">
    </component5>
  </structuredBody>
 </component>
</examination>
```

Figure 9 Examination Transmission Schema Components

5) In the NHIS implementations, the values for the data elements are given with elements whose classCode attributes are Act or Act's subclasses, such as Observation or Procedure. Furthermore, they are bound to the data element's "<section>" element with "<component>" element as shown in Figure 4, whereas in CDA Level One Schema it is the "<entry>" element that realizes this relation as shown in Figure 10.

```
<section classCode="DOCSECT" moodCode="EVN">
   <id root="2.16.840.1.113883.3.129.2.1.4" extension="4e7e0004-8e9e-44d2-9a9e-099d071e646a" />
   <code code="MUAYENE" codeSystem="2.16.840.1.113883.3.129.2.2.2" codeSystemName="Veriseti" codeSystemVersion="1.0" displayName="Muayene Veriseti" />
…
<section classCode="DOCSECT" moodCode="EVN">
  <id root="2.16.840.1.113883.3.129.2.1.5" extension="6c4b1e87-c4f4-42b0-aaeb-05e23a77ed5a" />
  <code code="ANATANI" codeSystem="2.16.840.1.113883.3.129.2.2.3" codeSystemName="Veri Kismi" codeSystemVersion="1.0" displayName="Tani Verisinin Oldugu Bolum" />
  <text mediaType="text/x-hl7-text+xml">
    Hastada vaskuler bagirsak bozuklugu teshis edilmistir.
  </text>
  <entry>
            <observation moodCode="EVN" classCode="OBS">
               <code/>
               <value xsi:type="CD" code="K55" codeSystem="2.16.840.1.113883.6.3" codeSystemName="ICD-10" codeSystemVersion="1.0" displayName="BARSAGIN VASKULER BOZUKLUKLARI" />
            </observation>
   </entry>
</section>
…
```

Figure 10 An Example CDA Data Element "Diagnosis"

6) The main difference between "Transmission Schemas" and the HL7 CDA conformant EHRs is their syntax validation. With the modifications mentioned above, in NHIS, it is enough to validate an incoming message against the corresponding "Transmission Schema". However, for the syntax validation of an HL7 CDA R2 conformant EHR, an incoming EHR document is first validated against CDA Level One XSD and then against the structural Schematron rules which check the constraints on the entries and the sections. For example, Figure 11 gives some Schematron rules for validating section and entry level constraints in the "Examination" EHR. The first rule states that the "code" of the "ClinicalDocument" should be "Examination". The second rule is a section level rule and states that "Examination" ("MUAYENE") and "Admission" ("KABUL') sections should exist in the CDA Body. The third rule is an entry level rule and states that "Diagnosis" entry must exist in the "Examination" section and this element should obtain values from ICD-10.

```
<sch:pattern name="rule 2a validation">
 <sch:rule context="hl7:ClinicalDocument/hl7:code">
  <sch:assert test="compare(string(@code), 'MUAYENE')=0 and compare(string(@codeSystem), '2.16.840.1.113883.3.129.2.2.1')=0"/>
 </sch:rule>
</sch:pattern>
<sch:pattern name="rule 2b validation">
 <sch:rule
context="hl7:ClinicalDocument/hl7:component/hl7:structuredBody/hl7:component/hl7:section/hl7:code">
  <sch:assert test=" (compare(string(@code), 'MUAYENE')=0 and compare(string(@codeSystem), '2.16.840.1.113883.3.129.2.2.2')=0) or
   (compare(string(@code), 'KABUL')=0 and compare(string(@codeSystem), '2.16.840.1.113883.3.129.2.2.3')=0)"/>
 </sch:rule>
</sch:pattern>
<sch:pattern name="rule 3 validation">
 <sch:rule context="hl7:component/hl7:section//hl7:observation">
  <sch:assert test=" not(compare(string(hl7:code/@code), 'ANATANI')=0) or (compare(string(hl7:value/@codeSystem), '2.16.840.1.113883.6.3')=0 and compare(string(hl7:value/@codeSystemName), 'ICD-10')=0)"/>
 </sch:rule>
</sch:pattern>
```

Figure 11 Structural Schematron Rule Examples for the Examination CDA

III. Generating the HL7 CDA Conformant EHRs from the Transmission Schemas

For the applications that need HL7 v3 CDA R2 conformant EHRs, an XSLT based Adaptor is being implemented. The Adaptor converts the "Transmission Schema" instances to conformant CDA documents and vice versa. It is detached from the NHIS and acts as a mediator. The NHIS system forwards a CDA compliant message to the XSLT Adaptor which produces the HL7 CDA conformant version.

The Adaptor uses the XSLT rules which are designed to reconcile the differences described in Section II.B. Basically, the following conversion rule types are implemented in the XSLT Adaptor:

1) Document name translator: This rule is for the difference shown in Figure 2 and converts the root tag of the document to "<ClinicalDocument>". For example, the rule shown in Figure 12 converts the "<examination>" tag to "<ClinicalDocument>" tag.

2) MHDS section name translator: This rule converts the names of the MHDS sections to "<section>" in order to reconcile the difference shown in Figures 3 and 8.

3) NHDD section and entry creator: A set of rules are developed first to transform the names of the NHDD data elements in the “Transmission Schema” instances to CDA “<section>” tags. Then, to reconcile the structural differences as shown in Figures 4 and 10, further rules are provided to create the necessary CDA “entry” elements.

4) “ComponentX” renamer: This rule converts all of the “<componentX>” tags to “<component>” and it is designed for the difference depicted in Figure 9.

```
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0">
<xsl:template match="@* | node()">
 <xsl:copy>
  <xsl:apply-templates select="@* | node()"/>
 </xsl:copy>
</xsl:template>
<xsl:template
match="MCCI_IN000001TR01/controlActEvent/subject/examination">
 <xsl:element name="ClinicalDocument">
  <xsl:apply-templates select="@* | node()"/>
</xsl:element>
</xsl:template>
</xsl:stylesheet>
```

Figure 12 XSLT Rules for Document Name Translator

Converting the “Transmission Schemas” to HL7 CDA R2 EHRS by using these rules is quite straight forward. But for reverse transformation, various mapping tables are maintained giving the correspondences between elements in XPath expressions such as:

```
/ClinicalDocument/component/structuredBody/component
/section/code[@code='MUAYENE']
==> /examination/component/structuredBody/component3
```

This entry states that a HL7 v3 CDA R2 "section" whose code is 'MUAYENE' (“Examination” in English) corresponds to "component3" in the related “Transmission Schema” instance.

Note that when the HL7 CDA R2 conformant EHRs are generated from the “Transmission Schema” instances, there is no need to perform syntax validation against Schematron rules since this is already performed while the instances are validated against the “Transmission Schemas”.

Apart from the renaming modifications that are described in this paper, there are further restrictions on the original CDA XSD such as removing the "time" element under the "author" of a section, which is in fact mandatory. In order to be able to effectively back-transform these modifications, we have decided that the Extensible Stylesheet Language Transformations (XSLT) is the best option for our adapter. XSL transformations provide configurable and human readable transformation definitions in contrast to hard-code based alternatives such as deserialization of XML to object model and then serialization of the edited object model back to XML.

IV. TRANSPORTING THE MESSAGES

A “Transmission Schema” instance constitutes a message’s payload. In other words, “Transmission Schema” instances should be encapsulated in messages. For this purpose, “HL7 Transmission and Control Act Wrapper” is used. The transmission wrapper provides information on the id, creation time, sender, receiver of the message. The sender and receiver block contains the logical id of the sender and the receiver. When the transport software transmits the message, they are converted to the real physical addresses. In other words, this information is used by the application level software to convey the sender/receiver information to the transport software.

For transport protocol, HL7 Web Services Profile [17] is used. The Basic Profile and the Security Profile have been implemented. For security, WS-Security Username Token over SSL [18] is used. In the current version of the NHIS implementation there are 23 Web Services. These are: “15-49 Age Female Observation”, “Mouth and Teeth Examination”, “Vaccine Notification”, “Infant Feeding”, “Infant Observation”, “Infant Psychosocial Observation”, “Communicable Disease Definitely Case Notification”, “Communicable Disease Possible Case Notification”, “Diabetes”, “Birth Notification”, “Pregnant Observation”, “Result of Pregnant”, “Pregnant Psychosocial Observation”, “Patient Demographic Notification”, “Cancer”, “Puerperal Observation”, “Examination”, “Death Notification”, “Result of Test”, “Citizen/Foreigner Registration”, “Stateless Registration”, “Inpatient Admission” and “Newborn Registration”.

For each Web Service there are two operations. The clients send their “Transmission Schema” instances through the first Web Service operation. The first operation performs only syntax validation against the related schema and responds with an acknowledgement about the result of the validation. If the invocation of the first operation is successful, the client invokes the second operation to query the result by using the document’s UUID. If the processing of the document is successful an acknowledgement is received from the second operation; otherwise, the errors encountered in the semantic validation phase are reported to the user. The UML Interaction diagram in Figure 13 shows these interactions and the application roles used in Turkey.

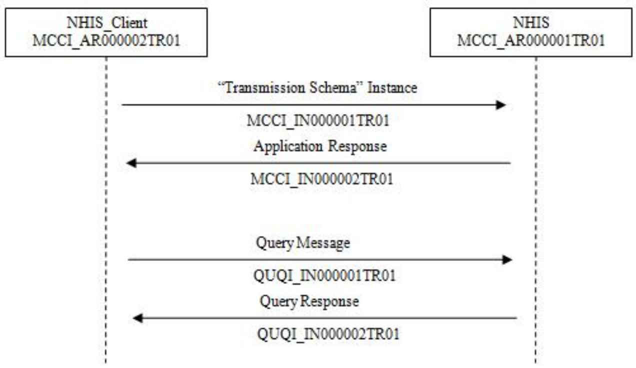


Figure 13 Application Roles and Interactions in NHIS

To protect the data collected at the MoH NHIS servers from unauthorized disclosures while ensuring its availability for authorized uses, a comprehensive set of security and privacy measures have been implemented. There are two types of administrators in the system: Security Administrator and the Database Administrator. Security Administrator is in charge of granting rights to the Database Administrators but they themselves have no right to access the database. Various "View" mechanisms are developed to hide the patient demographics data from the unauthorized users. Furthermore, currently, work is going on to pseudonymize the data. In Greek, a pseudonym means a false name and pseudonymization is the process of supplying an alternative identifier that permits a patient to be referred to by a key that suppresses his/her actual identification information.

The MoH has selected Oracle Identity Management System and "Layer7 SecureSpan" [19] application security gateway for identity management. Oracle Single Sign-on and Web Access Control Solution tools are used. The identity management services conform to the security rules required to support Public Key Infrastructure (PKI).

Access to NHIS data is audited by logging all the user events. Identity Management System provides group, role and rule based management and authorization options. Currently the work is going on for determining the legal ground about the access rights of various types of users.

VI. CONCLUSIONS

The NHIS Web services conveying "Transmission Schemas" from the Family Medicine Information Systems (FMIS) and the Hospital Information Systems (HIS) to the MoH NHIS servers are being tested with test data since February 2008. This testing will end by July 2008 and by January 2009, all of the healthcare organizations in Turkey are obliged by law to send patient data through NHIS.

The "Transmission Schemas" are HL7 CDA compliant rather than HL7 CDA conformant. An initial version of the system is described in [20]. These compliant versions have greatly facilitated the fast deployment of NHIS Web services because in this way the XML schemas themselves contain the constraints rather than expressing the constraints as a set of rules.

An adaptor is being developed based on XSLT to convert the "Transmission Schemas" to the HL7 CDA R2 conformant EHRs. It turns out that this process is straight forward in one direction, which is, converting the "Transmission Schema" instances to the HL7 CDA R2 conformant EHRs. The transformation in the reverse direction requires keeping various mapping tables giving the correspondences between element names. The HL7 CDA R2 conformant EHRs have the following advantages: The maintenance of the Web services and clients will be easier because the changes in the EHRs will not be reflected to the interface schemas but they will be expressed as rules. Additionally, considering the efforts in the EU for sharing EHRs across Member States [21], the conformant versions will facilitate this process.

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