Testing the Conformance and Interoperability of NHIS to Turkey's HL7 Profile

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***Abstract*- Turkey's National Health Information System (NHIS) aims to provide a nation-wide infrastructure for sharing Electronic Health Records (EHRs). In order to guarantee the interoperability, the Ministry of Health (MoH), Turkey developed an Implementation/Integration/Interoperability Profile based on HL7 standards. The current implementation supports the transfer of Minimum Health Data Sets, called the "Transmission Schemas", from the Family Medicine Information Systems (FMIS) and the Hospital Information Systems (HIS) to the NHIS servers at the MoH premises. The "Transmission Schemas" are HL7 CDA R2 compliant EHRs.**

In this paper, we describe how the conformance and interoperability tests of NHIS are performed. For this purpose we use a generic testing tool, namely, TestBATN, and configure it to test the conformance of applications to Turkey's HL7 CDA R2 Profile and their interoperability.

I. INTRODUCTION

The current version of the NHIS, Turkey provides 23 Web Services, each of which is specialized to a specific Minimum Health Data Set Transmission as described in [1]. In order to guarantee the interoperability, the MoH, Turkey published an Implementation/Integration/Interoperability Profile [2] for vendors of Family Medicine Information System (FMISs) and Hospital Information Systems (HISs). This profile is based on the following national and international standards and specifications:

- For transport protocol, HL7 Web Services Profile [3] is used. For security, WS-Security [4] Username Token over SSL is required for conformance.
- The "Transmission Schemas" are HL7 CDA R2 [5] compliant EHRs and each HL7 CDA section is a Minimum Health Data Set (MHDS) [6] which is formed from the data elements specified in the National Health Data Dictionary (NHDD) [7].
- The Transmission Schemas are regarded as HL7 v3 messages and localized according to the national requirements. Localizations are represented as XML schemas for each Transmission Schema.
- Health Coding Reference Server (HCRS) [8] serves all coding systems in use in Turkey which is used in the data elements within the Minimum Health Data Sets. For some specific data elements, some other coding systems, like ICD-10 coding system [9], are specified for use.
- For each Transmission Schema and Minumum Health Data Set, several semantic Business Rules are defined to provide consistency among the values used in the data elements.
- In Turkey, every citizen has a unique identifier and these identifiers are maintained in a system called MERNIS (Central Demographics Management System) [10]. The patient id numbers in the messages are required to exist and be consistent with this system.
- In Turkey, every physician is registered to a system called Doctor Data Bank [8]. The id numbers of the doctors in the messages should exist in this system.

The Integration Profile and its reference specifications present all the restrictions and the requirements for vendors to update or to develop their FMISs and HISs for a successful integration. However, without an extensive and effective testing process this may become difficult for vendors. Furthermore, only through testing, correct information exchange among these eHealth applications can be guaranteed and products can be certified.

By analyzing the requirements given in the integration profile and the eHealth market in Turkey in terms of the FMIS and HIS products, the following testing requirements are identified:

a) Basic Conformance Testing: The first step in the testing process is to test the ability of the HIS or FMIS systems to send valid "Transmission Schemas" in terms of syntactic and structural constraints. These tests include:

i. Checking the ability of the systems to send HL7 Web Services Profile conformant SOAP (Web Service) messages,

ii. Checking the ability of the systems to send WS-Security Username-Token Profile conformant SOAP (Web Service) messages,

iii. Checking the ability of the systems to use the username and the password assigned to it correctly, as specified in the WS-Security Username-Token Profile in the corresponding SOAP header,

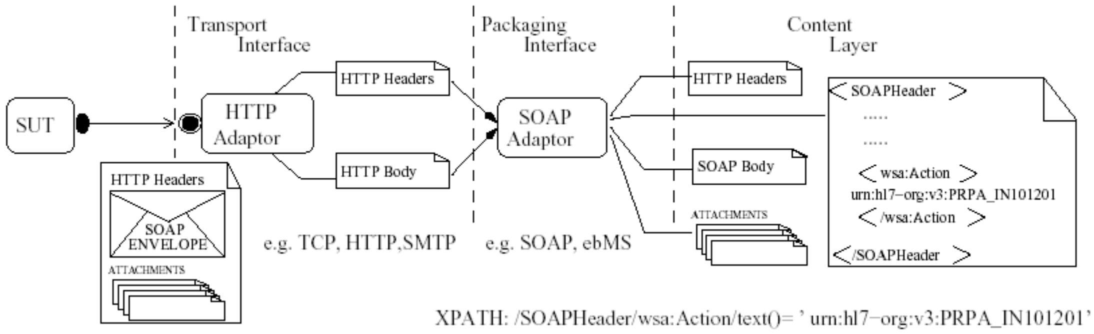

Figure 1 The Overview of TestBATN Messaging Interface [12]

iv. Syntactic validations of "Transmission Schemas" sent by the systems against their corresponding XML schemas,

v. Checking if the code systems and the codes used in the "Transmission Schemas" are valid, that is, checking whether the code system is one of the code systems specified in the integration profile and whether the code value is valid,

vi. Validation of the "Transmission Schemas" according to the corresponding business rules.

b) Functionality/Semantic Testing: Basic Conformance Testing guarantees the conformance of the "Transmission Schemas" sent by a system to the specified standards and specifications and hence it partially guarantees the MoH NHIS servers to accept the transmission and store its content to their database. However, it does not ensure that the information in the transmissions accurately represents the intentional semantics of the FMIS or HIS users (e.g. doctors, family practitioners). For example, a data element in the "Medical Examination MHDS" is called "Incident Type" which should contain values such as "Normal", "Emergency", or "Industrial Accident". For this data element, the following tests should be performed in order to guarantee the semantically valid transmissions:

i. Testing whether the system provides all possible code values to its user for selection,

ii. Checking whether the system accurately packs the value selected by the user into the transmission,

iii. Testing whether the system (HIS or FMS) has the ability to render this value to its users.

These testing requirements necessitate scenario based testing where vendors are given with a set of test scenarios and are requested to use their products' user interfaces to construct a transmission which is conformant with the given scenarios.

c) Interoperability Testing: Testing the conformance of applications systems to produce and consume the correct "Transmission Schemas" is necessary but not sufficient in deciding whether a FMIS or a HIS can properly be integrated into Turkey's NHIS. It is necessary to ensure that the selected options, bindings, and deployment settings of the implementations are compatible across partners [11].

In this paper, we describe how a general purpose testing framework, called TestBATN [12] is configured to test the conformance of FMISs and HISs to Turkey's HL7 CDA R2 Profile and their interoperability.

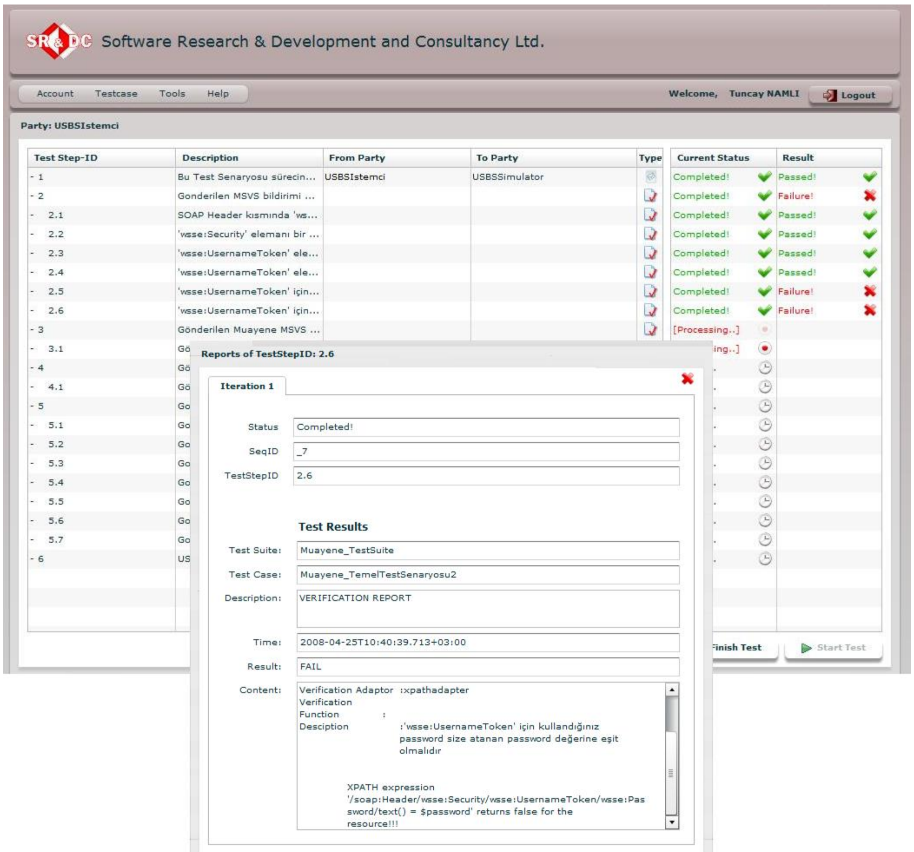

Figure 2 Test Management GUI

II. A BRIEF INRODUCTION TO THE TESTBATN FRAMEWORK

As described in [12], the TestBATN (Testing Business Process, Application, Transport and Network Layers) framework with its computer interpretable test description language provides the necessary functionalities for the set-up and execution of test cases. By offering a choice of messaging adaptors to be plugged into a test case, as shown in Figure 1, the TestBATN framework gives the flexibility to tailor test scenarios that meet the varying transport and network layer needs of different systems. Its messaging framework enables the underlying intra-system communication to be intercepted without interference, hence making interoperability testing possible.

In the interoperability testing, the actual behavior of system components in each business transaction are observed by the framework and validated. Apart from the messaging capabilities, the TestBATN language provides constructs for test writers to build sequences of syntactic and semantic validation steps from its pool of validation adaptors. Consequently, tests involving the functionality such as schema validation, business rule validation, conformance to profiles can easily be assembled. Furthermore, the framework's user-interaction capability prior to and during the scenario execution enables the underlying application semantics to be tested, too. In the end, test results are conveyed to the SUT (System Under Test) administrators through a combination of holistic as well as stepwise reports.

Interaction with the users and report rendering is handled by the framework's Test Management Graphical User Interface (Test Management GUI) as shown in Figure 2. The TestBATN Test Management GUI is an interactive, multi user, event-driven, Web-based monitoring and management environment for test executions. It provides a medium for the SUT administrators to monitor the test execution while controlling their own systems based on the instructions received from the Test Engine. These instructions are performed in an event-driven way during the configuration management, as well as during the initialization and handling of the test data. Furthermore, users are able to observe the overall scenario flow and the status for each scenario step through customized reports [12]. The TestBATN framework is designed to support multiple languages. Currently, Turkish and English are supported.

III. HOW GENERIC IS THE TESTBATN FRAMEWORK ?

The TestBATN Framework has an XML based Test Description Language [12] for Test Designers which allows a very wide variety of scenarios from different domains to be defined. The Test Engine in fact executes this language.

TestBATN services are available for public use and further support is available to develop custom scenarios from [14].

IV. TEST SCENARIOS OF THE TESTBATN FRAMEWORK FOR NHIS

A. *Basic Conformance Testcases*

For each "Transmission Schema", a basic conformance test case is written to test the conformance of FMISs and HISs to the requirements defined in the Integration Profile for the corresponding transmission. The following test steps describe these scenarios and the corresponding TestBATN framework functionalities used to execute them:

a) SOAP Message Conformance: The first step is the messaging step where the SUTs (FMISs and HISs) are requested to send a transmission to the specified TestBATN Engine ports. By using the TestBATN messaging capability and choosing the "SOAP Message Adaptor" for this messaging step, the scenario is configured to accept only valid SOAP messages. Furthermore, by using the ability of TestBATN framework to define further configurations on Messaging Adaptors, the "SOAP Message Adaptor" is configured to test the further conformance criteria (HL7 Web Service Profile) defined for the transmission web services.

b) WS-Security Username-Token Profile Conformance: The "SOAP Message Adaptor" partitions the message into three fragments; HTTP Headers, the SOAP Header, and the SOAP Body and TestBATN framework allows the test designer to use these fragments independently in the test steps that follow. WS-Security Username-Token Profile and further restrictions defined in the Integration Profile regulate the usage of "UsernameToken" header in SOAP Header. In order to test these restrictions, semantic validation steps of the TestBATN framework are used. Each semantic validation step is actually the evaluation of an XPATH expression (corresponding to a single restriction) over TestBATN built-in "XPATH Validation Adaptor". For example, an XPATH expression is written to test whether the message includes a single "Username" element in "UsernameToken" header element. Figure 3 illustrates a validation step with XPATH expressions to check the existence of wsse:Password element in wsse:UsernameToken security header.

```
- <VerifyContent verificationAdapter="xpathadapter"
    description="'wsse:UsernameToken' elemanı bir tane wsse:Password
    elemanı içermelidir, ve bu elemanın 'Type' alanı 'http://docs.oasis-
    open.org/wss/2004/01/oasis-200401-wss-username-token-
    profile-1.0#PasswordText' olmalıdır.">
    <Expression>$soapHeader</Expression>
    <Expression namespaceBindings="{soap =
      http://schemas.xmlsoap.org/soap/envelope/, wsse =
      http://docs.oasis-open.org/wss/2004/01/oasis-200401-wss-
      wssecurity-secext-1.0.xsd, wsu = http://docs.oasis-
      open.org/wss/2004/01/oasis-200401-wss-wssecurity-utility-
      1.0.xsd}">count
      (/soap:Header/wsse:Security/wsse:UsernameToken/wsse:Password
      [@Type = 'http://docs.oasis-open.org/wss/2004/01/oasis-
      200401-wss-username-token-profile-1.0#PasswordText']) =
      1</Expression>
  </VerifyContent>
```

Figure 3 Some Validation Steps for Username-Token Profile Conformance

c) Username and Password Validation: The TestBATN user-interaction ability enables the test designer to obtain some preliminary information from the SUT user before test execution. By using this ability and its corresponding TestBATN construct "PreliminaryData" in the testcase definition, the username and the password that is assigned to the SUT are obtained before test begins. Then by exploiting two semantic validation steps with XPATH Validation, the username and password provided in preliminary steps are compared with the values given in the "UsernameToken" header of the message. This test is used for checking the ability of the SUT to use the correct login and password.

d) Syntactic Validation of "Transmission Schemas": This step is configured to use another built-in validation adaptor "XSD Validation Adaptor" and the input entries for the adaptor are the XML Schema of the corresponding transmission and the "Transmission Schema" received from the SUT (FMIS or HIS) in the SOAP Body.

e) Validation of Coding Schemes and Codes: As mentioned previously, Health Coding Reference Server (HCRS) maintains all coding systems and codes in use in Turkey. This information is available through Web services from HCRS. In order to validate the codes and code systems used in a transmission, a new validation adaptor, SKRS Valisdator, is developed and plugged into the TestBATN framework. The SKRS Validator extracts all data elements with coded value type from the transmission and calls the HCRS services to validate these code values and the corresponding code systems.

f) Validation Against Business Rules: Schematron definitions are used in specifying the business rules defined for the local constraints. For each transmission and for each MHDS in the transmission, the schematron rules corresponding to business rules for that transmission or MHDS are defined. In order to use these schematrons in the test execution, a validation step employing the built-in "Schematron Validation Adaptor" is used in the test case definition. Figure 4 illustrates a schematron rule, a part of the schematron for Patient Admission data set in Medical Examination transmission schema, which tests the business rule: "If the admission type is not 'Other'; a value for the referrer clinic must be specified."

```
<sch:pattern name="rule 5 validation">
  <sch:rule context="hl7:registration/hl7:code">
    <sch:assert test="number(@code)=3 or (0 < count(root
      ()//hl7:referral/hl7:referrer/hl7:referralFromClinic))">
      Kural 5 gecerli degil: kabul tipi:
      <value-of select="@code" />
      , geldigi poliklinik degeri olmali:
      <value-of select="count(root
        ()//hl7:referral/hl7:referrer/hl7:referralFromClinic)" />
    </sch:assert>
  </sch:rule>
</sch:pattern>
```

Figure 4 A Schematron Rule to test a Business Rule

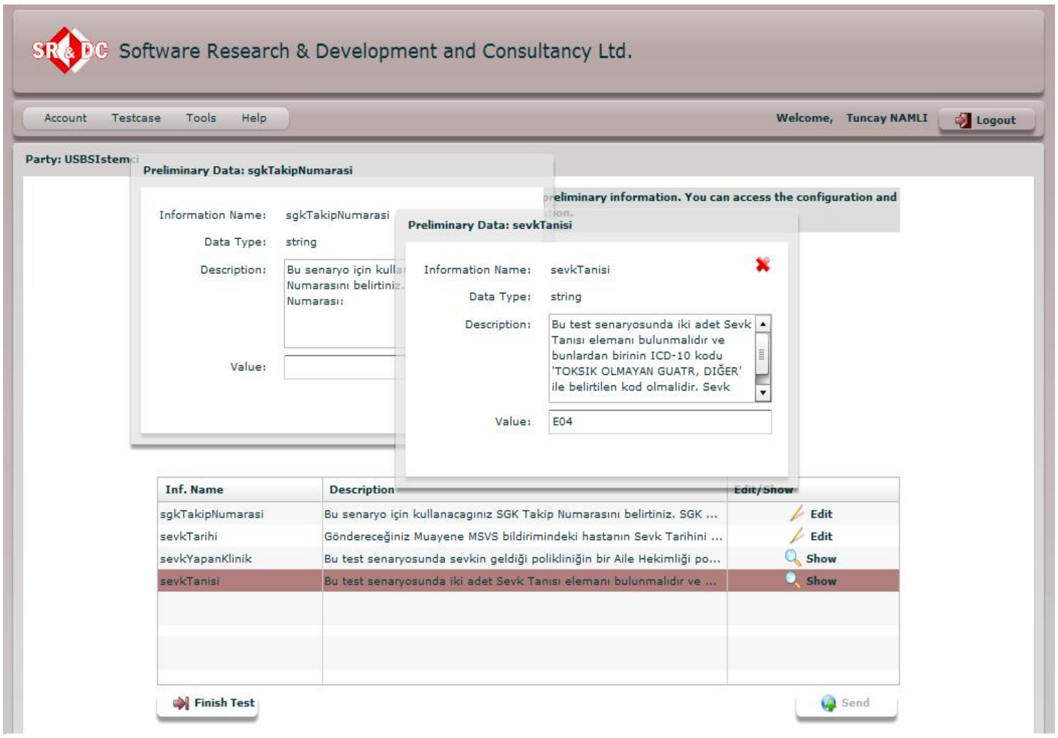

Figure 5 GUIs for the Run-time Customization of the Test Data

B. *Interoperability Testcases*

The TestBATN framework realizes the interoperability testing of Turkey's NHIS for compliance with the Integration Profile defined by the MoH, Turkey, and the interoperability of the involved applications as follows:

- First, it functions as a proxy between the SUTs (FMISs and HISs) and the MoH NHIS Server. The "Transmission Schemas" produced by the sender application are forwarded directly to the MoH Server by the TestBATN framework. Similary, the transmission responses produced by the MoH Server are intercepted and then forwarded to the SUTs.
- The framework internally stores all intercepted messages for further testing. Communication, Document and Business Process layer syntactic and semantic validations are performed as described in Section IV.A.
- The TestBATN framework generates its own transmission response based on the profile constraints described in the MHDS. Its description language is equipped with the constructs (variable declarations, expressions and placeholders; flow constructs and corresponding messaging handlers [12]) necessary for the Test Execution Engine to emulate the desired application behavior.
- As the final step, the transmission responses of the MoH Server are validated against the ones generated internally by the TestBATN framework. At this stage, any inconsistency is an indication of the MoH server's noncompliance with the profiles and in such a case, applicable test reports are generated.

C. *Functionality/Semantic Tests*

The TestBATN framework enables run-time customization of the scenario templates by means of its interaction capabilities with the SUT administrators (administrators of the FMISs, HISs and the MoH Servers) as shown in Figure 5. The TestBATN test description language supports user-interaction schemes to be defined either by its PreliminaryTestData or RequestTestData element constructs [12]. In this manner, three different user-interaction schemes have been developed and used in the NHIS tests:

a) Prior to scenario execution, the user is requested to fix the values for various test parameters: Some of the NHIS tests involve certain parameters to be fixed before the test execution by the SUT involved. The TestBATN framework uses the constructs called preliminary test variables for this purpose. For example, the healthcare institution and the author of the CDA document engaged in the "Transmission Schema" may need to be fixed in advance so that later on, the framework can use this information to perform various semantic tests such as i) the interface's ability to properly place this information in the related parts of the "Transmission Schema", ii) the FMIS's or HIS's compliance with the NHIS business rules. There is no limitation as to how preliminary test variables can be used within a test scenario, thanks to the capabilities of the TestBATN test description language [12].

b) Prior to scenario execution, the scenario designer fixes some parameter values to test SUTs ability to work in a certain mode of operation and with the given control parameters: In contrast to the approach followed in (a), this time, the test designer imposes certain restrictions on how the SUT user should control its application behavior. The main objective behind this user-interaction scheme is to verify that the developed FMIS or the HIS is able to run in different modes of operation and that the application fulfills the requirements specific to that mode of operation. As an example, consider the case where the doctor fills out a detailed report regarding the referral of a patient to another healthcare institute. In this case, checking that the application processes the user input and that it places the correct ICD-10 code [9] is one such test alternative.

c) During scenario execution, the user is requested to provide feedback on the observed application behavior: It may be desirable to obtain feedback from the user during scenario execution for the purpose of assessing the SUT's rendering capabilities. In one of the test scenarios for instance, the administrator of the FMIS/HIS is asked to provide the exact date/time of patient admittance. This information can be used in a validation step to ensure that the rendered date/time on the GUI of the FMIS/HIS is accurately used within the transmission.

D. Complex Scenarios

Some business rules defined for the NHIS impose semantic dependencies between different "Transmission Schema" instances. To be more specific, a business rule of the form: "No two different Vaccination Transmission Schema instances for the same patient may refer to the same Vaccination Code together with the same Vaccination Date/Time", is valid and needs to be tested accordingly. Such tests are adapted from the aforementioned approaches with some minor modifications on the previous scenarios:

- The first change involves extending the scenario with multiple ReceiveMessage constructs [12] so as to receive as many Vaccination Transmission Schema instances as required per test scenario.
- The TestBATN test description language enables list-type variables to be declared. Capacities of list-type variables are dynamic, that is, they expand as new items are inserted. The scenario is modified such that the received documents are stored consecutively in the list.
- By utilizing the flow constructs of the language, the content of each received message are compared with all other messages stored in the list to see if the business rule is satisfied.

V. On the Use of the Testing System

TestBATN system customized to NHIS, Turkey with 200 test scenarios categorized under 25 test suites is used in a workshop organized by MoH during June 30 - July 4, 2008 in Izmir. The aim was to bring together all the vendors in a physical location and test their products to speed up the integration process. During this workshop more than 5000 test scenarios have been executed through TestBATN by an average of 130 participants from 55 vendors on a 5-day period. Each vendor is supplied with a very detailed report on the test scenarios and steps performed.

The TestBATN services with the same test scenarios are publicly available from MoH, Turkey servers [13] with more than 60 active users daily.

VI. Conclusions

Turkey's National Health Information System (NHIS) aims to provide a nation-wide infrastructure for sharing Electronic Health Records (EHRs). In this paper, we describe a comprehensive test harness implemented using the TestBATN Framework in order to test the conformance of the Family Medicine Information System (FMISs) and Hospital Information Systems (HISs) to the Turkey's HL7 CDA R2 Profile, and their interoperability.

The TestBATN system itself has been tested both through continuous online users and during a testing workshop. The system proved to be robust supporting transactions from more than 130 simultaneously on a 5-day period. The online version has been working since June 2008 without any problems.

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