DELIVERABLE

Project Acronym:	**ANTILOPE**
Grant Agreement number:	**325077**
Project Title:	**ANTILOPE - Adoption and take up of standards and profiles for eHealth Interoperability"**

D3.1:

Testing tools overview: Testing tools gap analysis with description of required new tools

Version: 1.1

Work Package:	WP3
Version & Date:	1.1/ 4 Feb 2015
Deliverable type:	Report
Dissemination level	Public
Authors:	Milan Zoric, ETSI
	Eric Poiseau, IHE

Alexander Berler, IHE

Barry Reinhold, Continua Health Aliance

Karima Bourquard, IHE

Project co-funded by the European Commission within the ICT Policy Support Programme Dissemination level		
P	Public	

REVISION HISTORY AND STATEMENT OF ORIGINALITY

Revision History

Revision	Date	Author	Description
V0.90	28.11.2013	WP3 team	Version for publication on the ANTILOPE web pages
V1.00	16.12.2014	WP3 team	Final version
V1.1	04.02.2015	WP3 team	Final version with two minor corrections in cross-references and links

Statement of originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

Table of Contents

Table of tables

Glossary: Definitions and Abbreviations

Abbreviation	Explanation
CEN	European Committee for Standardization
CHA	Continua Health Alliance
HRN	Continua Health Alliance Health Record Network Interface
LAN	Continua Health Alliance Local Area Network Interface
PAN	Continua Health Alliance Personal Area Network Interface
WAN	Continua Health Alliance Wide Area Network Interface
eEIF	eHealth European Interoperability Framework
ETSI	European Telecommunications Standards Institute
HL7	Health Level Seven
IHE	Integrating the Healthcare Enterprise
ISO	International Standards Organisation
HITCH	Healthcare Interoperability Testing and Conformance Harmonisation
NIST	National Institute of Standards and Technology (U.S.A.)

Executive Summary

The requirement that eHealth solutions can interoperate seamlessly between products from different vendors and across organisations is today very common and implied even when not spelled out. Unfortunately, many solutions are not able to share data as expected. As a result, end users get reduced quality of service and additional costs are created since many failures occur when systems are already in use. This is in general not acceptable but for eHealth the situation is further aggravated by the fact that the treatment of patients may be adversely affected.

This deliverable deals with testing tools required to continuously improve the interoperability of eHealth solutions. It specifically addresses testing tools that would be sufficient for testing the selection of recognised profiles used to implement eHealth Interoperability Framework and further elaborated in Antilope Work Package 1 deliverable D1.1.

The realisations scenarios for selected Use Cases specify the associated profiles. For these Use Cases and their associated profiles the information on available testing tools was collected and analysed. The source of information was HITCH testing tool analysis, publicly available information from all identified testing tools, information on IHE web pages, information received from Continua Alliance and other public sources.

For each of the existing testing tools that have been identified and analysed the most important information is provided. The basic tool information such as relevant profile, tool name, tool developed by, tool location and tool info pages is supplemented with information on the tool use (web or local), access to source code and last but surely not least a tool category.

Testing tool categories considered relevant for this work are defined in the methodology section as test management tools, conformance testers, interoperability validators, simulators/stubs, software libraries, test data generators, reference implementations, and support tools. The information on tool category has a particular importance in the gap analysis.

The information on existing tools is split across several tables dealing with IHE profiles, Continua Alliance profiles, and generic HL7 testing tools that are not profile specific. In the end, an additional small set of testing tools is identified and analysed but recommended not to be used.

The results of the gap analysis indicate that for all relevant profiles numerous testing tools are available. The finding collected in this deliverable should be used to promote their wider use.

Further analysis on the summary of available testing tool categories for each profile focused on the required future testing tools improvements. The proposed improvements are profile specific but are independent of the Use Case where the profile is used. Clearly conformance testers and interoperability validators provide a more powerful testing solution. If they are not currently available, the proposal is to develop them. Otherwise, other less powerful but rather specific and useful improvements were proposed. The required testing tools improvements per profile are listed in section 5.2 of this document.

These improvements would positively affect testing of all Use Cases where a profile is used.

Testing tools improvements that are profile independent but that would improve the testing precision, testing efficiency or both are described in section 7.

The ongoing analysis is examining specific testing requirements coming from Use Case groups or individual Use Cases that would go beyond just profile testing.

A short summary of findings coming out of the work on testing tools is as follows:

- Gap analysis shows that testing tools for eEIF Use Cases do exist
- The use of existing testing tools will improve interoperability of systems implementing eEIF Use Cases
- In addition to immediate use of existing tools, improved testing tools should be developed to increase testing precision and productivity
- Improvements needed at this point in time have been identified and the call to develop new or improved testing tools has been issued
- As the eEIF evolves, there should be a continuous process of review, development and deployment of improved testing tools

This deliverable formed the basis for ANTILOPE deliverable D3.2 [9]that is asking for the development of new or improved testing tools that would further improve the interoperability of eHealth solutions across Europe.

1 Introduction

1.1 The project

Antilope is a thematic network of European organisations supporting the adoption and testing of existing eHealth standards and specifications that define an eHealth European Interoperability Framework (eEIF). Based on the results and recommendations in the HITCH project, the network will promote and drive adoption of testing guidelines as well as testing tools on a European and national levels. The network will arrange a number of events and workshops across EU Member States. The outcome will be a common approach for testing and certification of eHealth solutions and services in Europe.

1.2 Purpose of the document

The purpose of this document is to identify the required new or improved testing tools that would, together with existing test tools, be sufficient for testing the selection of recognised profiles described in the eEIF framework and further elaborated in Antilope Work Package 1 deliverable D1.1 [6] Areas of desired improvements are identified and described.

1.3 Document structure

Section 2 describes the way the gap analysis has been done. It defines the information that is collected and presented for existing testing tools. Very important element in it is the definition of the testing tools categories. These categories are key to the analysis of existing tools but also in identification of the needs for improvements or new development.

Section 3 discusses some important conditions for achieving interoperability, in particular when it comes to cross border interoperability. The text highlights the fact that interoperability can be achieved if there is a common basis coming from international standards and profiles specialized for national use in an organised way.

Section 4 contains the tables listing the existing testing tools, each with information that was collected or derived according to the definitions provided in section 2.

Section 2.6 provides the list of relevant profiles and summary on available test tool categories. From that, the information on possible improvements was derived and included in the table. Improvements could be achieved as evolution of existing tools or complete new development. At this level the improvements are profile specific and are independent of the Use Cases where they may be used.

Section 6 contains the analysis that is specific for Use Cases and or a group of related Use Cases.

While section 5 identify the required new or improved testing tools functionalities, section 7 provides a more detailed description of required testing tools improvements.

Section 8 offers the conclusions of this work.

Appendix A contains some tools that are not recommended for use. The reasons may be that the tools are out of date, are not relevant for any of the profiles or the information that is available was insufficient for recommending the tool.

2 Methodology of testing tools gap analysis

In order to identify which tools exist and which are the new or improved tools that are required, the steps that have been performed are described here below.

The basic information required for starting the gap analysis were the Use Cases that are part of the eEIF and that have been further elaborated in the WP1 of this project [6]. The realisation scenarios for each Use Case are described in section 3 of ANTILOPE deliverable D1.1 [6] where for each Use Case the associated profiles are listed. The list of profiles that are used in realisations of Use Cases was then used to collect information on testing tools that may be available for each of those profiles. The first source of information on testing tools was HITCH Deliverable 2.1 [1]. However, the HITCH information had to be double checked and updated to reflect changes in their status. Publicly available information from all identified testing tools was consulted and used. In addition, information on IHE web pages [4], information received from Continua Alliance and other sources on the web were used. With this the raw information on available testing tools was collected. The raw information was structured in a number of tables listing the testing tools that have been identified and analysed. For each tool the most important information is provided. From the tables listing available testing tools with all their characteristics it was possible to extract the summary testing tool status for each of the relevant profiles. The initial assumption was that a summary table would identify profiles for which one or more testing tool exists, profiles that require no testing tools and profiles for which testing tools would be required but do not exists at this point in time. However, the results are such that there is only one profile for which no testing tools are required but all other profiles are to some extent covered by corresponding testing tools. The results are summarised in a table where for each profile the existing test tool categories are highlighted. For each profile it was then possible to identify some areas of improvements that are independent of the Use Case in which a profile is used.

Other considerations need to be mentioned here. The issues considered are only indirectly related to testing tools as they are impacting the testing and therefore the required testing tools.

For each of the Use Cases it is be beneficial to have a corresponding test specification. A test specification is a document that elaborates in details how interoperability of a given Use Case is to be checked. The requirements to be tested are derived from the definition of the Use Case itself as well as from the relevant standards and profiles on which the realisation of a given Use Case is based. It is important to note that at this point in time the test specification documents are not provided and the needed information on what precisely needs to be tested is not sufficiently explicit. The tests are implemented in the testing tools and elements of test specifications can at times be reverse engineered from the testing tools.

Clear identification of the requirements that could be tested would allow a more detailed analysis of the coverage with which existing testing tools are able to test those requirements. Different testing tools are capable of testing a Use Case with a different level of depth and precision. While testing with less depth and precision, covering only part of the requirements, contributes to interoperability, more thorough testing would provide increased evidence that interoperability can be reached. This analysis is needed to identify the areas of improvement for existing testing tools. This information is also helpful in selecting a testing tool that provides better test coverage than other tools. While it is not realistic or economically viable that the coverage is hundred percent, the coverage level should

be chosen as an engineering compromise that yields good confidence in the results of the testing activity.

2.1 Testing tool categories

A number of different categories of tools are needed to cover the wide spectrum of testing functionality required in order to support eHealth interoperability testing of eEIF profiles.

Initial set of testing tool categories was taken from HITCH Deliverable D2.1 [1]. HITCH defined 5 testing tool categories:

- validators
- simulators
- test management tools
- sniffers and
- libraries

For the purposes of the ANTILOPE project it was felt necessary to expand and modify the testing tool categories with respect to those defined by HITCH project. Table 1 below presents the testing tool categories with their descriptions. This categorisation of testing tools is an important element in the gap analysis.

Table 1. ANTILOPE list of testing tool categories

Test tool category	**Description**
Test management tools	A **Test Management Tool** needs to facilitate the execution of tests but may include additional functionalities that would be useful in performing the tests and collecting the results. This document will focus on two distinct groups within the wide range of Test Management tools: a) Tools that help organize and run large interoperability events involving large number of participants and a large number of tests. The tools in this group will typically manage test scenarios for peer-to-peer tests and may also support test planning and setup for large test events. They may also support the configuration process for all participating communication partners (e. g. IP addresses, ports, codes to be used, message types, other tools like simulators and validators). In order to trigger actual test runs, the software ideally selects the communication partners from the pool of existing systems based on a number of criteria, including their communication capabilities and test instances required to reach the system's certification goals for the event (e. g. to run each test case with a certain number of distinct test partners). Such tools may also support other functionalities such as authoring of test cases and reporting of interim and final test results to the test managers and test partners. b) Execution frameworks that facilitate the selection of individual tests, collection of test results including evidence of tests performed such as pass/fail verdicts with corresponding traces.
Conformance testers	A **conformance tester** is an automated tool that is capable of checking the behaviour of the system under test. The tester takes the role of the communication partner, provides stimuli to the system under test, collects the responses and evaluates whether the order, timing and/or content of messages sent by the system under test conform to the requirements of a given standard and profile. Advanced testers may take the roles of all entities that are communicating with the system under test. In some situations a conformance tester is used to validate the structure and/or content of a document used in eHealth systems. Conformance tester tools vary in the extent to which they test the requirements in the profile. The simplest testers may only check some requirements, for example message or document syntax. Advanced conformance testing tool would check most or all important requirements. Depending on the level of precision in reporting problems discovered, conformance tester tools can provide valuable aid in rapid discovery and resolution of interoperability problems.

Test tool category	**Description**
Interoperability validators	An **interoperability validator** is an automated tool that is checking the behaviour of two systems that are interoperating. It collects the messages exchanged between the two interacting systems and evaluates the order and/or content of messages exchanged against the requirements set by the profile. Just like conformance testers, the Interoperability validator tools vary considerably in their checking capabilities. In addition, the level of automation in triggering testing activities and in collecting the test traces can be quite different.
Simulators/stubs	A **simulator or a stub** is a tool acting as a connection partner to the system that needs to be tested. In most cases, a simulator stimulates the system under test (SUT) in order to trigger certain behaviour. The kind of stimulation depends on the type of partner to be tested. For a system on a network, the stimulation would be done by sending network messages. For other systems, this could be feeding data into specific directories, simulating user input or any other input. A simulator itself does not asses the behaviour of the tested entity. However, a simulator may have integrated capability to collect the trace of the exchange that could then be evaluated manually or using other means. Simulator tools are useful for pre-testing before interoperability events or as replacement for needed communication partners that are not available in an event. For eHealth interoperability testing general purpose tools may not be sufficient and specific sophisticated simulators may be required.
Software libraries	**Software libraries** may be used to build both eHealth systems as well as eHealth testing tools. An example is a library that supports encoding and decoding of HL7 messages. Such a library can be and is used to build a system that follows an IHE profile but it can also be used to build testing tools that can be used for testing the same profile. While strictly speaking such libraries are not testing tools as such, the ability to share code development efforts may contribute significantly to improvement of interoperability of eHealth systems.
Test data generators	A **test data generator** accelerates test data preparation by providing valid, input data to be used in testing. The best results are achieved if a data generator can be used such that it efficiently generates data that respects the constraints set by a profile being tested.

Test tool category	Description
Reference implementations	A reference implementation is, in general, an implementation of a specification (standard or profile) to be used as a definitive interpretation for that specification. Other testing tool categories (libraries, conformance testers, and others) may also represent reference implementations.
Support tools	During testing and debugging various support tools may be useful. While they do not test anything themselves, they may provide means of collecting the information that is needed to progress with testing. The examples are viewers that present the information in an understandable format, proxies that facilitate reliable and uniform collection of traces and many others.
Network sniffers	Sniffers are also known as network analysers or protocol analysers. A sniffer is capable to decode and analyse communication protocol messages inside the data packages. This can be done transparently to the ongoing communication, as required by non-destructive protocol testing. Network sniffers must be able to decode all relevant communication protocols (TCP/IP, HL7, DICOM, etc.) in order to prepare message validation or other tasks. Sniffers are used not only in eHealth but are applicable to any domain that uses network messaging to exchange information.

2.2 Testing tool use

Testing tools can either be used over the web or installed and run locally. This information is made visible for each testing tool.

2.3 Testing tool source code

The conditions under which the source code of a testing tool is developed and maintained are an important aspect of testing tool usefulness. Open source code has been proven to accelerate innovation and time to market for new technologies. An open source platform can bring together many stakeholders such as solutions providers, testing tools developers and users alike to define a new type of reference platform for the industry, integrating existing open source building blocks with new components and testing that accelerates development and deployment. Open source development should in particular increase confidence that such testing tools may be easier to maintain, correct detected problems and facilitate evolution of the tools. However, with all these qualities, it should not be understood that free open source does not mean that overall cost of development and use are by any means negligible. In any case, free open source benefits should outweigh the costs.

There are numerous examples of successful open source software developments. One example from communication networks is OpenDaylight project [8]. In the eHealth domain notable examples are

the HL7 library HAPI listed among eHealth testing tools and, last but not least, Gazelle test management tool.

It is also interesting to note the ETSI Special Report on the relation of standardization and open source software [10]. The report clearly indicates that open source and standards could and should go together and that with time this will gain in importance.

Table 2. classifies the testing tools according to the availability of their source code.

Table 2. Testing tool source code

Testing tool source code	**Description**
Open source	The source code of a testing tool is freely available.
Not open	The source code is not freely available.
Partly open	The source of the testing software is freely available but requires run time support that may not be free.

2.4 Testing tool access

The conditions under which the testing tool can be accessed and used are another important aspect of test tool usefulness. Table 3 shows the access right mechanisms that ANTILOPE distinguishes and for each testing tool the access conditions are highlighted.

Table 3. Access rights to testing tools

Access to testing tool	**Description**
Free	Free use of a testing tool, either over the network or free download and installation.
Commercial	A testing tool can be accessed under commercial conditions set by the entity that developed or owns the tool.
Member restricted access	The testing tool can be accessed under condition of membership in an organization that owns/controls the tool.
Combined access	There are examples of testing software that is free to use but requires run time

	environment that is proprietary and subject to commercial conditions.

2.5 Testing tools considered out of scope

Some types of testing tools have not been considered in this evaluation. In particular, ANTILOPE is focusing on testing the interoperability of eHealth systems and the corresponding testing tools. For example, testing the robustness of systems against malicious attacks is not considered to be relevant for interoperability. In contrast, testing tools checking the interoperability of privacy, authentication, and safety related functions are clearly in scope.

The following (incomplete list of) types of test tools are explicitly considered out of the scope for the evaluation:

- Performance benchmarking,
- Load testing
- Security attacks: exploit, denial of service (DOS)

2.6 The list of profiles used to realise Use cases

Table 4 lists all the profiles that are used to realise one or more eEIF Use Cases.

Table 4. eEIF relevant profiles

Profile acronym	**Profile**	**Link**
ATNA	Audit Trail and Node Authentication	http://wiki.ihe.net/index.php?title=ATNA_Profile_FAQ
CHA: HRN	Health Record Network Interface Design Guidelines	http://www.continuaalliance.org/products/design-guidelines
CHA: LAN	Sensor-Local Area Network Interface Design Guidelines	http://www.continuaalliance.org/products/design-guidelines
CHA: PAN	Personal Area Network Interface Design Guidelines	http://www.continuaalliance.org/products/design-guidelines

Profile acronym	**Profile**	**Link**
CHA: WAN	Wide Area Network Interface Design Guidelines	http://www.continuaalliance.org/products/design-guidelines
BPPC	Basic Patient Privacy Consents	http://wiki.ihe.net/index.php?title=Basic_Patient_Privacy_Consents
DIS	Pharmacy Dispense Document	http://wiki.ihe.net/index.php?title=Pharmacy_Dispense_Document
PAM	Patient Administration Management	http://wiki.ihe.net/index.php?title=PAM
PDQ	Patient Demographics Query	http://wiki.ihe.net/index.php?title=Patient_Demographics_Query_Implementation
PIX	Patient Identifier Cross-Referencing	http://wiki.ihe.net/index.php?title=Patient_Identifier_Cross-Referencing
PRE	Pharmacy Prescription Document	http://wiki.ihe.net/index.php?title=Pharmacy_Prescription_Document
RTM	Rosetta Terminology Mapping	http://wiki.ihe.net/index.php?title=RTM
SVS	Sharing Value Sets	http://wiki.ihe.net/index.php?title=Sharing_Value_Sets
SWF	Scheduled Workflow	http://wiki.ihe.net/index.php?title=Scheduled_Workflow
XCA	Cross-Community Access	http://wiki.ihe.net/index.php?title=Cross-Community_Access
XD-LAB	Sharing Laboratory Reports	http://wiki.ihe.net/index.php?title=Sharing_Laboratory_Reports

Profile acronym	**Profile**	**Link**
XDM	Cross-enterprise Document Media Interchange	http://wiki.ihe.net/index.php?title=Cross-enterprise_Document_Media_Interchange
XDS	Cross-Enterprise Document Sharing	http://wiki.ihe.net/index.php?title=Cross-Enterprise_Document_Sharing
XDS-MS	Cross-Enterprise Sharing of Medical Summaries	http://wiki.ihe.net/index.php?title=PCC_TF-1/XDS-MS#Cross-Enterprise_Sharing_of_Medical_Summaries_.28XDS-MS.29_Integration_Profile
XPHR	Exchange of Personal Health Record Content	http://wiki.ihe.net/index.php?title=Exchange_of_Personal_Health_Record_Content_Profile
XCPD	Cross-Community Patient Discovery	http://wiki.ihe.net/index.php?title=Cross-Community_Patient_Discovery
CT	Consistent Time	http://wiki.ihe.net/index.php?title=Consistent_Time
PCD	Patient Care Devices profiles	http://wiki.ihe.net/index.php?title=Patient_Care_Devices

3 Conditions for achieving interoperability

Achieving interoperability on national or regional levels is the primary goal with high impact on the level of service and cost of the health system.

The first and most important step in achieving interoperability is deciding on the specifications for an interoperable system. If the specifications are not using standards and profiles, interoperability will not be possible, no matter how much effort is invested later on. Testing and testing tools will only improve interoperability if the specifications of a system or service are based on standards and profiles that define the requirements for interoperable products and services. This applies to all levels of interoperability, i.e. legal and regulatory, organisational, semantic and technical. Testing and testing tools can address semantic and technical levels of interoperability. Legal and regulatory as well as organisational interoperability have to be ensured by other means, testing is of limited use when it comes to legal and organisational interoperability.

Provided that national or regional specifications are built as specializations of international standards, several important benefits can be obtained. First and foremost, the stable common parts of international standards and related methodology, knowledge, vocabulary and other aspect are simply reused. Building national specifications as specializations of the international specification does not invalidate the inherent general principles of the standards that are specialised, it simply adds requirements that are only applicable on a national or regional level.

Testing tools for national specifications can also be specializations of the testing tools built for testing international standards. This would reduce the cost of building testing tools for national/regional use and increase the stability of testing solutions on all levels.

To support above claims we highlight the approach used in Switzerland [7]. IHE Switzerland defined the way HL7 specification of CDA documents can be specialised to suite specific needs of their Use Cases. Using standardized document content for the initial forms, numerous reusable templates and related Schematron rules can be defined. The Schematron rules permit the automated validation of CDA document content. New rules specific for a specialized template are simply added to rules coming from the original HL7 specification. Using such CDA documents, key processes such as the exchange of medication and emergency case data or accident insurance forms can be significantly improved in terms of interoperability. The normative specification is based on proven international standards and norms such as HL7 V3, Clinical Document Architecture, IHE Patient Care Coordination and Schematron (rule-based XML validation).

Solutions built in this way in one country can to a large extent be reused in other countries. This is valid for both eHealth applications and corresponding testing tools.

For Europe the approach described above has a fundamental positive effect that it is cross-border compatible. Interoperability across national or regional borders is facilitated and testing tools can be shared as well.

4 Existing testing tools

The existing tools that were identified during the gap analysis are grouped in a number of tables. Table 5 lists the existing testing tools that could be used for testing IHE profiles relevant for the eEIF Use Cases. The initial input for this list is taken from [4] where the information is regularly updated. Table 6 lists the existing testing tools that could be used for testing the Continua Health Alliance profiles relevant for the eEIF Use Cases. Table 7 lists the tools that may be quite useful for testing the HL7 protocol but are not specific to any of the profiles. In the end, Table 10 lists testing tools that have been identified during the analysis but that could not be recommended for use. The reasons may be that the tools are out of date, are not relevant for any of the profiles or the information that is available was insufficient for recommending the tool.

Each row in the table presents a collection of most relevant information for a given tool. The rows are sorted by profiles. Each testing tool is characterized with following information:

- The profile
- Tool name
- Developed by
- Use (web or local)
- Access to the tool
- Source code
- Tool location
- Info pages
- Tool category

During the gap analysis other information available through tool info pages was also used. However, the decision was made to include in the tables only the above listed most relevant information.

Table 5. List of existing IHE testing tools

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
ITI: ATNA	ATNA: Digital Certificate Generator	IHE-Europe	web-based	Free	Open source	Digital Certificate Generator for European Testing events (epSOS, Connectathon): http://gazelle-gold.wustl.edu/certificate/	Documentation page: http://gazelle.ihe.net/content/public-key-infrastructure	Data generator
ITI: ATNA	ATNA: Digital Certificate Generator	MIR	web-based	Free	Info not available	For NA2014 Connectathon: Digital Certificate Generator: http://gazelle-gold.wustl.edu/certificate/ For Europe Connectathon : IHE Europe Public Key Infrastructure: http://gazelle.ihe.net/pki	For North America: http://ihewiki.wustl.edu/wiki/index.php/Test_Certificate_Generator_Viewer For Europe: http://gazelle.ihe.net/content/public-key-infrastructure	Data generator

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
ITI: ATNA	ATNA: Syslog Collector	MIR	web-based	Free	Open source	access via Syslog Collector info page: http://ihewiki.wustl.edu/wiki/index.php/Syslog_Collector	Syslog Collector info page: http://ihewiki.wustl.edu/wiki/index.php/Syslog_Collector	Interoperability validator (Role of audit record repository)
ITI: ATNA	ATNA: Syslog Message Browser	MIR	web-based	Free	Open source	NA connectathon Syslog msg browser: http://gazelle.ihe.net/cas/login?service=http%3A%2F%2Fgazelle-gold.wustl.edu%2FSyslogBrowser-eu%2F EU connectathon Syslog msg browser: http://gazelle-gold.wustl.edu/SyslogBrowser-eu/	Syslog Msg Browser info page: http://ihewiki.wustl.edu/wiki/index.php/Syslog_Message_Browser	Support tool (Viewing)

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
ITI: ATNA	ATNA: Syslog Sender	MIR	web-based	Free	Open source	Syslog test message sender: http://gazelle-gold.wustl.edu/SyslogSender/Sender.jsf Syslog Sender info page: http://ihewiki.wustl.edu/wiki/index.php/Syslog_Sender	Authentication test description: http://gazelle.ihe.net/content/pre-connectathon-tests/atna/11109	Simulator/stub (Sending the audit message)

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
ITI: ATNA	ATNA: TLS simulator tools	IHE-Europe at Kereval	web-based	Free	Open source	for NA2014: http://gazelle.ihe.net/tls-na/home.seam Note: may not be available at all times for EU2013: http://gazelle.ihe.net/tls/home.seam	TLS simulator user guide: http://gazelle.ihe.net/content/tls-simulator-tools for NA2014 ATNA resources page: http://na2014.wustl.edu/TechnicalPrep/ATNA.html for EU connectathons: How to generate certificates for the EU connectathon: http://gazelle.ihe.net/content/public-key-infrastructure	Data generator (Generation of certificates) Interoperability validator (secure note as server or as client)

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
ITI: XUA	XD* Client	IHE-Europe at Kereval	web-based	Free	Open source	Gazelle XD* Client Application http://gazelle.ihe.net/XDStarClient/home.seam	Introduction to XDStarClient: http://gazelle.ihe.net/content/xdstarclient	Data generator (Generation of SAML assertions) Interoperability validator (XUA+XCA Initiating Gateway)
BPCC: XDS-MS (all CDA-based profiles except APE, TRS, ETS, ITS)	CDA Validation tool	NIST	web-based or download	Free	Not available	CDA Validation Tool: http://hit-testing.nist.gov/cda-validation/validation.html	CDA Tool home page: http://hit-testing.nist.gov/cda-validation/index.html	Interoperability validator (no behaviour) (Checking the content of a document)

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
BPCC: XDS-MS PHARM: DIS, PRE, PADV	CDA Validation tool in EVS Client	IHE Europe at Kereval	web-based	Free	Open source	External Validation Service Front-End, IHE-->CDA: http://gazelle.ihe.net/EVSClient/cda/validator.seam	CDA Doc validation user guide: http://gazelle.ihe.net/content/cda-document-validation	Interoperability validator (no behaviour) Same thing as above in Gazelle
c'thon testing	Gazelle Demographic Data Server (DDS)	IHE-Europe at Kereval	web-based	Free	Open source	Demographic Data Server: http://gazelle.ihe.net/DDS/home.seam, or on your connectathon's gazelle under menu Connectathon / Patient Generation & Sharing	DDS info page: http://gazelle.ihe.net/content/dds-demographic-data-server also, Patient Generation & Sharing training slides: http://gazelle.ihe.net/files/PatientGenerationAndSharing.pdf	Data generator

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
LAB: LCSD, LDA PCC: XBeR, XTHM PHARM: DIS, PRE, PADV	Gazelle External Validation Services (EVS) aka "EVS client"	IHE-Europe at Kereval	web-based	Free	Open source	External Validation Service Front-End: http://gazelle.ihe.net/EVSClient/home.seam	IHE EVS info page: http://gazelle.ihe.net/content/evs-ihe-external-validation-services	Support tool (Web services tool component supporting validators)
LAB: LCSD	Gazelle LCSD Simulator	IHE-Europe at Kereval	web-based	Free	Open source	LCSD Simulator: http://gazelle.ihe.net/LCSDSimulator/home.seam	LCSD simulator info page: http://gazelle.ihe.net/content/lcsd-simulator	Simulator/stub Ref implementation Gazelle EVS could be invoked

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
RAD: SWF (HL7-based transactions, RAD-5) LAB: LTW	Gazelle Order Manager	IHE-Europe at Kereval	web-based	Free	Open source	Order Manager application: http://gazelle.ihe.net/OrderManager/home.seam	Order Manager info page: http://gazelle.ihe.net/content/order-manager	Simulator/stub, Data generator Gazelle EVS could be invoked
ITI: PAM, PDQ, PIX RAD: ADT for SWF	Gazelle PAM Simulator	IHE-Europe at Kereval	web-based	Free	Open source	Patient Manager application: http://gazelle.ihe.net/PatientManager/home.seam	Patient Manager user manual: http://gazelle.ihe.net/content/patient-manager-user-manual	Interoperability validator Gazelle EVS could be invoked Simulator/stub, Data generator

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
c'thon testing	Gazelle Proxy	IHE-Europe at Kereval	web-based	Free	Open source	Gazelle proxy: http://gazelle.ihe.net/proxy/channels.seam	Proxy info page: http://gazelle.ihe.net/content/proxy	Support tool
ITI: SVS	Gazelle SVS Simulator	IHE-Europe at Kereval	web-based	Free	Open source	Gazelle Sharing Value Set Simulator: http://gazelle.ihe.net/SVSSimulator/home.seam	SVS Simulator info page: http://gazelle.ihe.net/content/svs-simulator Value sets provided by the SVS Simulator: http://gazelle.ihe.net/content/gazelle-value-sets	Interoperability validator Simulator/stub, Data generator
c'thon testing	Gazelle Demographic Data Server (DDS)	IHE-Europe at Kereval	web-based	Free	Open source	Demographic Data Server: http://gazelle.ihe.net/DDS/home.seam	DDS info page: http://gazelle.ihe.net/content/dds-demographic-data-server	Support tool (Demonstrations) Data generator

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
SWF	MESA Tools	MIR	install/run locally	Free	Open source	MESA Release page: http://ihedoc.wustl.edu/mesasoftware/index.htm	Actor test plans: http://ihewiki.wustl.edu/wiki/index.php/Pre-Connectathon/MESA_Software	Interoperability validator (No development, some maintenance)
PCD: all profiles	PCD Isolated testing	NIST	web-based	Free	Not available	IHE-PCD Pre-Connectathon Test Tool: http://hit-testing.nist.gov:13100/PCD-HL7WebPreCon/	IHE-PCD Pre-Connectathon documentation: http://hit-testing.nist.gov:13100/PCD-HL7WebPreCon/#documentation.htm	Interoperability validator
PCD: all profiles	PCD Instance testing	NIST	web-based	Free	Not available	IHE-PCD Connectathon Test Tool: http://ihe-pcd-con.nist.gov/PCD-HL7WebCon/#home.htm	http://ihe-pcd-con.nist.gov/PCD-HL7WebCon/#documentation.htm	Interoperability validator (The same as above)

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
ITI: PDQ, PDQv3, PIX, PIXv3	PIX / PDQ tool	NIST	web-based	Free	Not available	IHE PIX and PDQ Pre-Connectathon Test Tool: http://pixpdqtests.nist.gov/pixpdqtool/	PIX / PDQ Tool documentation: http://pixpdqtests.nist.gov:8080/#documentation.htm	Interoperability validator
ITI: XDS.b clients	XDS Public Registry Server	NIST	web-based	Free	Open source	access via NIST IHE Doc Sharing Public Registry Test Facility: http://ihexds.nist.gov/	XDS implementors google group http://groups.google.com/group/ihe-xds-implementors	Reference implementation, simulator
RAD: REM	REM DoseUtility tool	PixelMed	web-based or install locally	Free	Open source	access via External Validation Service Front-End, IHE-->DICOM: http://gazelle.ihe.net/EVSClient/home.seam	how to use DoseUtility: http://www.dclunie.com/pixelmed/software/webstart/DoseUtilityUsage.html	Interoperability validator

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
ITI: XCA, XDM, XDR, XDS.b	XDS toolkit	NIST	web-based, or download	Free	Open source	access via NIST IHE Doc Sharing / Public Registry Test Facility: http://ihexds.nist.gov/	XDS implementers google group: http://groups.google.com/group/ihe-xds-implementors	Interoperability validator
ITI: XCA, XDM, XDR, XDS.b	XD* Client	IHE-Europe at Kereval	web-based	Free	Open source	Access via http://gazelle.ihe.net/XDStarClient/home.seam	http://gazelle.ihe.net/content/xdstarclient	Interoperability validator (simulate the client side)
ITI: XCPD	Gazelle SVS Simulator	IHE-Europe at Kereval	web-based	Free	Open source	http://gazelle.ihe.net/XCPDRESPSimulator/home.seam		Simulator/stub

Table 6. List of Existing Continua Health Alliance Testing Tools

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
CHA: HRN	HRN Test Tool	Continua Health Alliance	install/run locally	CHA members restricted	Not open	Test Management Lite from Continua Health Alliance	HRN Test Tool DG2011 Usage Document.pdf	Conformance tester
CHA: LAN	PAN-LAN, LP-PAN & USBHost Test Tool	Continua Health Alliance	install/run locally	CHA members restricted	Not open	Test Management Lite from Continua Health Alliance	PAN-LAN, LP-PAN & USBHost Test Tool Test Tool DG2012 Usage Document v1.5.pdf	Conformance tester
CHA: PAN	PAN-LAN, LP-PAN & USBHost Test Tool	Continua Health Alliance	install/run locally	CHA members restricted	Not open	Test Management Lite from Continua Health Alliance	PAN-LAN, LP-PAN & USB Host Test Tool Test Tool DG2012 Usage Document v 1.5.pdf	Conformance tester
CHA: PAN	PTS	Bluetooth SIG	install/run locally	Bluetooth SIG members restricted	Not open	https://www.bluetooth.org/en-us/login-required?returnurl=/pts/download/index.cfm		Conformance tester

Profile	Tool	Developed by	Use	Access	Source code	Tool Location / Installation	Info page / User Instructions	Tool category
CHA: PAN	USB20CV	USB-IF	web-based, or download install/run locally	Free	Not open	http://www.usb.org/developers/tools/usb20_tools/USB20CV_Releasex86_1.4.13.0.msi		Conformance tester
CHA: WAN	WAN Test Tool	Continua Health Alliance	install/run locally	CHA Members restricted	Not open	Test Management Lite from Continua Health Alliance	WAN Test Tool DG2012 Usage Document v1.3.pdf	Conformance tester

Table 7. Existing tools that are useful for HP7 protocol testing not specific to IHE profiles

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
HL7 and International and Australian Standards:	AHML Message Testing Service	AHML: Australian Healthcare Messaging Laboratory	Web based	Free	Open source	http://www.ahml.com.au/	http://www.ahml.com.au/	Conformance Tester
DICOM Implementation in JAVA	dcm4che	Gunter Zeilinger Damien Evans.	Local	Free	Open source	http://sourceforge.net/projects/dcm4che/files/	http://www.dcm4che.org/	Libraries
DICOM	DCMTK - DICOM Toolkit	OFFIS computer science institute	Local	Free	Open source	http://dicom.offis.de/dcmtk.php.en	http://dicom.offis.de/	Libraries
DICOM creates DICOM files and workflows	Dicom3tools Software	David A. Clunie	Local	Free	Open source	http://www.dclunie.com/dicom3tools.html	http://www.dclunie.com/dicom3tools.html	Libraries

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
HL7, DICOM, IHE-RO profile Open source project for testing, validating and diagnosing communication protocols and scenario's in medical environments.	DVTk	DVTk	local	Free	Open source	http://ihe.dvtk.org/modules/wiwimod/index.php?page=Download+IHE-RO+Test+Tools+2009&cmenu=downloads	http://www.dvtk.org/modules/wiwimod/index.php?page=DVTk&cmenu=home	Simulator/stub Conformance Tester
All HL7 based profiles HL7 parser for Java, HL7 programming API, message editor, transmitter and receiver.	HAPI	University Health Network Toronto, Canada	web	Free	Open source	http://hl7api.sourceforge.net/hapi-testpanel/install.html	http://hl7api.sourceforge.net/	Simulator/stub Conformance Tester Interoperability validator
HL7 based profiles	Mirth Connect	MirthCorp	local	Free (community Edition only)	Open source (community Edition only)	http://www.mirthcorp.com/community/downloads	http://www.mirthcorp.com/products/mirth-connect	Test management Simulator/stub, Libraries Interoperability validator

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
HL7 v2 based profiles The Messaging Workbench is under consideration for rewriting at NIST	HL7 MWB	HL7	local	Free	Open source	http://gforge.hl7.org/gf/project/mwb/	http://www.hl7.org/Special/committees/ictc/docs.cfm	Simulator/stub Libraries Conformance tester
HL7 based profiles	Nule.org	Michael Litherland michael.litherland@gmail.com	local	Free	Open source	http://nule.org/	http://nule.org/	Simulator/stub Support tools Libraries
HL7 based profiles and CDA List of 35 projects Model-Driven Health Tools (MDHT), IHE XDR implementation> OHT provides client side implementations of several key IHE profiles (ATNA, MPQ, PAM, PDQ, SVS, XCA, XDR, XDS, XUA).	Open health tools	Open Health Tools, Inc Skip McGaughey Emeritus CEO	local	Free	Open source	http://www.openhealthtools.org/storage/architecture-council-documents/OHTStandardsVisionV2.pdf https://www.projects.openhealthtools.org/sf/sfmain/do/home	http://www.openhealthtools.org	Support tools

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
Security and Identity Management projects OpenCA Labs hosting the projects	OpenCA Labs	Massimiliano Pala	local	Free	Open source	http://sourceforge.net/projects/openca/?source=directory	http://sourceforge.net/projects/openca/?source=directory	Libraries
DICOM This is a stand-alone DICOM toolkit that implements code for reading and creating DICOM data, DICOM network and file support, a database of DICOM objects, support for display of directories, images, reports and spectra, and DICOM object validation. PixelMed Java DICOM Toolkit CT and MR Multi-frame Test Tool PixelMed Java UCUM Toolkit	PixelMed	PixelMed Publishing, LLC	Local	Free	Open source	http://www.pixelmed.com/	http://www.pixelmed.com/	Support tools

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
Generic testing tool OS. Dealing with questions answer questions such as: - For which requirements new or update test cases are still required - Which tests should be run for a given software version - How much progress was achieved on testing a release - Which test cases are failing, and what the errors are - On which version was this group of test cases last run, and is it time to run them again? - Is a version of the product fit for release	TestLink	Francisco Mancardi Toshiyuki Kawanishi	local	Free	Open source	http://sourceforge.net/projects/testlink/files/latest/download?source=files	http://testlink.org/	Test management tools

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
The EuroRec UseTools™ suite enables the licensee to prepare and to manage certification, documentation and procurement of Health IT products in general, actually mostly focused on Electronic Health Record systems.	Eurorec Use tools	Eurorec	web	Registered access only	Not open	http://www.eurorec.org/tools/index.cfm	http://www.eurorec.org	Test management tool Simulator/stub Conformance tester Support tools
SoapUI. A cross-platform Functional Testing solution. Graphical user interface, allows creation and execution of automated functional, regression, compliance and load tests.	SoapUI	SmartBear	web	Free	Open source	http://www.soapui.org/About-SoapUI/what-is-soapui.html http://sourceforge.net/projects/soapui/files/	http://www.soapui.org	Simulator/stub Interoperability validator Support tools

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
General test management A flexible test case management, test execution & results tracking, combined with QA project planning.	TestRail	Gurock Software	web	Commercial	Not open	http://www.gurock.com/testrail/tour/1/	http://www.gurock.com/testrail/qa-tools.l.html?utm_source=adwords&utm_medium=cpc&utm_campaign=testrail.search.lc&utm_content=software%20testing%20tools&gclid=CNbe_savirkCFUSV3goda0MAkg	Simulators/stubs Support tools
HL7 Test Level 7 (TL7) is a messaging test sandbox that allows e-Health application developers to check their HL7 messages.	TL7	intelliware	web	Commercial	Not open	http://tl7.intelliware.ca/public/downloadWhitepaper	http://tl7.intelliware.ca/index.faces	Simulators/ stubs Interoperability validators Support tools

Used for	**Tool**	**Developed by**	**Use**	**Access**	**Source code**	**Tool Location / Installation**	**Info page / User Instructions**	**Category**
HL7 based profiles	HL7 Inspector	elomagic	local			http://sourceforge.net/projects/hl7inspector/	http://sourceforge.net/p/hl7inspector/wiki/Home/	Library Interoperability validator
CDA This free-to-use online application validates various flavours of CDA documents. A prototype for the NIST validator.	CDA validator	Lantana	web			https://www.lantanagroup.com/validator/	https://www.lantanagroup.com/resources/free-tools/	Interoperability validator
Recording information models used by health professionals. DECOR uses this model to generate various artifacts: documentation, XML- and test-tooling, etc.	ART-DECOR	Nictiz (National Healthcare Standards Institute) Netherlands	web	Free	open	http://art-decor.org/	http://art-decor.org/	Support tools

5 Profile testing tools with areas of improvement

This section takes the results of detailed analysis of existing testing tools from section 4 and first provides the summary of existing testing tool categories for a given profile. Following that areas of possible improvement are identified for each of the profiles.

5.1 Profiles where testing tools are not required

For this profile no specific testing tools are required.

Profile	Test tools
CT	No test software needed

5.2 Areas of improvement per profile

As already stated, for the profiles relevant for eEIF Use Cases testing tools do exist. Their categories vary and from there areas of possible improvements can be identified.

All categories of testing tool categories listed in the methodology section can represent a valuable aid in achieving interoperability. As a reminder the list of categories is: test management tools, conformance testers, interoperability validators, simulators/stubs, software libraries, test data generators, reference implementations, and support tools.

Test management tools represent a category apart from other categories. They usually have a dual role to manage the testing sessions and to invoke other testing tools such as interoperability validators or conformance testers. As improvements of the latter tools will be addressed, the improvements of test management tools will only address the pure test management and automation aspects.

Other testing tool categories provide different level of support in performing the testing. Clearly the highest categories of testing tools are conformance testers and interoperability validators. If they are available, they reduce (but do not exclude) the need for other tools such as data generator, sniffers and other support tools. Depending on the how the conformance testers and validators are built even simulators may no longer be required. However, the more complex tools such as conformance testers and interoperability validators are more difficult, time consuming and more expensive to develop. While ultimately it would best to have those most advanced testing tools, other categories of testing tools can represent a solid alternative in the absence of more advanced testing tools. These simple alternatives may serve their purpose for a given period until they are eventually replaced by more advanced testing tools. These simpler alternatives may also represent a stepping stone in the development of more advanced solutions. For example, a conformance testing tool would by its nature comprise elements of simulator and data generator. Once a simulator or a data generator is build, it can be used for testing. At the same time, this can be used for further development to build a complete conformance testing tool.

Above reasoning led to a conclusion that areas of improvements need to consider all possible testing tool categories, from the simples to the most complex and complete. The results are given in Table 8.

For each profile the existing testing tool categories are summarised. Following that areas of possible improvements are given.

The first row in Table 8 will be elaborated in more detail to illustrate the logic that was applied. ATNA profile has testing tools that fall into several categories, the highest of which is interoperability validator. First conclusion is that the category of conformance tester that is not currently available would represent an improvement if some organisation would decide to build it. Further to that other improvements could be identified. First of those possible improvements would be to build a Syslog message generator. This generator would facilitate data preparation to be used while testing with the existing interoperability validator. This would increase the testing productivity and ensure that data used for testing is sure to be accurate. Another aspect that was identified is that existing validator checks the conformance of the message content to the requirements. However, the extent to which the set of relevant requirements are actually covered by corresponding checks is not evident. Therefore the analysis of coverage achieved at this point in time may reveal that additional checks need to be added.

Table 8. Areas of improvements per profile

Profile	**Existing tool categories**	**Areas of improvement**
ATNA	Data generator Interoperability validator Support tool Simulator/stub	There is currently no conformance testing tool. Syslog message generator for testing the ARR actor would facilitate test data preparation. Current validator is checking message content. Analysis of coverage of profile requirements is likely to improve the testing.
CHA: HRN	Conformance tester Interoperability validator	Data generator: CESL to be added to HRN tools Simulator/stub: No CESL HRN tools PHMR document type to be added to interoperability validator Coverage of HRN testing could be improved as there are HRN sender tests but there are no HRN receiver tests.
CHA: LAN	Data generator (CESL Devices) Conformance Tester Simulator/stub (CESL Manager)	Checking and improving the coverage – LAN profile requires use of ZigBee's Health Care Profile. Data generation tools that exercise the partition cluster in the context of the 11073-20601 protocol are limited. The LAN testing infrastructure is split between Continua and ZigBee and is not well coordinated or covered from the perspective of integrated tooling.

Profile	Existing tool categories	Areas of improvement
CHA: PAN	Data generator (CESL Devices) Conformance Tester Simulator/stub (CESL Manager)	Support tool Checking and Improving the coverage: Missing some of the conformance items specified by 20601 Annex A Required ASN1 Structures. A number of these have been added piecemeal but there has been no comprehensive effort to address this issue.
CHA: WAN	Data generator (CESL wanbridge) Conformance tester	Interoperability validator: BXI WAN server has been closed, so generated data no longer sends from the wanbridge. The source code to enable a WAN server is still available. Checking and improving the coverage: Need to create set devices for WAN special condition/error message generation. The user is currently expected to generate these devices messages which creates a non-standard test experience and adds to the difficulty of running the test suite. Validation of Time from PAN through WAN is a critical area for clinical viability. There is limited system level testing for time.
BPPC	Interoperability validator	A generator of valid Consent document is required. A conformance tester would automate testing and ensure that requirements are well covered. In particular this would mean testing of Use Case workflow in addition to content checking.
DIS	Interoperability validator	Need a generator of Dispensation documents. Dispensation should be generated from a given Prescription. Useful to test the Dispensation workflow. Improved DIS testing tools should look to automate the testing while ensuring improved coverage of requirements. A conformance tester is not available and could be useful.
PAM	Interoperability validator Simulator/stub	Automation of workflow for PAM profile. The tools available nowadays allow the validation of the exchanged messages and the simulation of the missing partners. Automation of the exchange can be used to test the "server" actors in these profiles and thus provide means of more exhaustive testing, requiring less human interactions. The goal may be achieved as improved interoperability validator and/or as conformance tester.

Profile	Existing tool categories	Areas of improvement
PDQ	Interoperability validator Simulator/stub	Automation of workflow for PDQ profile. The tools available nowadays allow the validation of the exchanged messages and the simulation of the missing partners. Automation of the exchange can be used to test the "server" actors in these profiles and thus provide means of more exhaustive testing, requiring less human interactions. The goal may be achieved as improved interoperability validator and/or as conformance tester.
PIX	Interoperability validator Simulator/stub	Automation of workflow for PIX profile. The tools available nowadays allow the validation of the exchanged messages and the simulation of the missing partners. Automation of the exchange can be used to test the "server" actors in these profiles and thus provide means of more exhaustive testing, requiring less human interactions. The goal may be achieved as improved interoperability validator and/or as conformance tester.
PRE	Interoperability validator	There is currently no conformance testing tool. Current validator is checking message content. Analysis of coverage of profile requirements is likely to improve the testing and testing should be automated as much as possible.
PCD	Interoperability validator	There is currently no conformance testing tool. Current validator is checking message content. Analysis of coverage of profile requirements is likely to improve the testing and testing should be automated as much as possible.
RTM	Interoperability validator	Trial tests for PCD profiles that need to be conformant to RTM. To be stabilised first.
SVS	Interoperability validator Simulator/stub, Data generator	There is currently no conformance testing tool. Current validator is checking message content. Analysis of coverage of profile requirements is likely to improve the testing.
SWF	Simulator/stub, Data generator	There is currently neither conformance nor interoperability validator testing tool. Analysis of coverage of profile requirements is likely to improve the testing.

Profile	**Existing tool categories**	**Areas of improvement**
XCA	Interoperability validator	There is currently no conformance testing tool. Analysis of coverage of profile requirements is likely to improve the testing.
XDM	Interoperability validator	There is currently no conformance testing tool. Analysis of coverage of profile requirements is likely to improve the testing.
XDS	Interoperability validator	There is currently no conformance testing tool. Analysis of coverage of profile requirements is likely to improve the testing.
XDS-MS	Interoperability validator	No conformance testing tool. Analysis of coverage of profile requirements is likely to improve the testing.
XPHR	Interoperability validator	No conformance testing tool. Analysis of coverage of profile requirements is likely to improve the testing.
XCPD	Simulator/stub	Automation of workflow for XCPD profile. The tools available nowadays allow the validation of the exchanged messages and the simulation of the missing partners. Automation of the exchange can be used to test the "server" actors in these profiles and thus provide means of more exhaustive testing, requiring less human interactions. The goal may be achieved as improved interoperability validator and/or as conformance tester.

6 Use Cases testing tools gap analysis

This section links the realisation scenarios of use cases given in ANTILOPE deliverable D1.1 [6] to the profiles required and testing tools for those profiles.

General conclusion of this analysis is that most profiles and therefore all relevant Uses Cases are already covered with testing tools. Having said that, it is clear as the tools can and should be improved as indicated in section 5.2 of this document.

6.1 Medication

For medication Use Cases all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

6.1.1 Use Case 1a: e-Prescription and e-Dispensing, cross-border

Profiles relevant for this use case are:

- Process flow: XCPD
- Information: PRE, DIS
- Infrastructure: XDS (Consumer), XDR (reference: epSOS D3.A.1_EED_II), ATNA, CT
  Access control: BPPC, XUA(++)

6.1.2 Use Case 1b: e-Prescription and e-Dispensing, national/regional

Profiles relevant for this use case are:

- Process flow: CMPD
- Information: PRE, DIS
- IT Infrastructure: XCA, ATNA, CT
  Access control: BPPC, XUA(++)

6.1.3 Use Case 1c: e-Prescription and e-Dispensing, intra-hospital

Profiles relevant for this use case are:

- Information: PRE, DIS
- Infrastructure: CT, ATNA, BPPC

6.2 Radiology

For radiology Use Cases all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

6.2.1 Use Case 2a: Request and results workflow for radiology

Profiles relevant for this use case are:

- Process flow: XDW, XbeR-WD, PAM, XCPD
- IT Infrastructure: XDS, XDS-i, XCA, XCA-i, ATNA, CT
- Access control: BPPC, XUA(++), PIX/PDQ

6.2.2 Use Case 2b: Request and results (imaging diagnostics tests) distribution workflow for radiology in intra-hospital setting

Profiles relevant for this use case are:

- Process flow: SWF (describes workflow within a radiology department), RWF (reporting workflow)
- Information: REM
- IT Infrastructure: XDS, XDS-i, ATNA, CT
- Access control: BPPC, XUA(++), PIX/PDQ

6.3 Laboratory

For laboratory Use Cases all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

6.3.1 Use Case 3a: Request and results workflow for laboratory

Profiles relevant for this use case are:

- Information: XD-LAB
- IT Infrastructure: PIX/PDQ, XDS, CT, ATNA, BPPC, XUA(++)
- IT Infrastructure, cross-regional: XCA, XCA-i , XCPD

6.3.2 Use Case 3b: Request and results (clinical laboratory tests) sharing workflow for laboratory in intra-hospital setting

Profiles relevant for this use case are:

- Workflow: LTW
- Information: XD-LAB, LSCD, SVS
- Infrastructure: CT, ATNA

6.4 Patient summary

For patient summary Use Cases all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

6.4.1 Use Case 4a: epSOS: patient summaries

Profiles relevant for this use case are:

- Process flow: XDS-SD, XCF (planned) (Ref: D3.A.1. EED 2)
- Infrastructure: XDR, ATNA, CT
- Infrastructure, cross-community : XCPD, XCA
- Security : XUA(++), BPPC

6.4.2 Use Case 4b: Access by patient to his/her patient summary.

Profiles relevant for this use case are:

- Information: XDS-MS (or other Patient Summary)
- IT Infrastructure: XDS, CT, ATNA, PIX/PDQ

- Cross-domain: XUA, XCPD
- Access control: BPPC

6.4.3 Use Case 4c: Patient Summary sharing on a patient-level scale

Profiles relevant for this use case are:

- Information: XPHR
- Infrastructure: XDS (Consumer), ATNA, CT, XCA
- Access control: BPPC, XUA(++)

6.5 Cross-enterprise Referral and Discharge Reporting

For cross-enterprise referral and discharge reporting Use Cases all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

6.5.1 Use Case 5a: Referral of patient from primary to secondary care

Profiles relevant for this use case are:

- Information: MS (also called XDS-MS)
- Infrastructure: XDR, CT, ATNA
- Access control: BPPC, XUA(++), PIX/PDQ

6.5.2 Use Case 5b: Discharge report from secondary care

Profiles relevant for this use case are:

- Information: MS (also called XDS-MS)
- Infrastructure: XDR, CT, ATNA
- Access control: BPPC, PIX/PDQ

6.6 Involvement of chronic patients in electronic documentation of healthcare information

For this Use Case all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

Profiles relevant for this use case are:

- Information: MS (also called XDS-MS)
- Infrastructure: PIX/PDQ, XDS/ XDR/ XDM, CT, ATNA

Infrastructure, Patient Care Device: HRN, WAN+, DEC*/RTM*, LAN+ or PAN+,(MHD, DEC)

- Access control: BPPC, XUA(++)

6.7 Remote monitoring and care of people at home or on the move using sensor devices

For this use case all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

Profiles relevant for this use case are:

- Infrastructure: Patient Care Device: PAN, LAN/WAN, (MHD, DEC)

6.8 Medical Board Review

For this Use Case all relevant profiles have some level of support with testing tools. Possible improvements for each of the relevant profiles are given is Table 8.

Profiles relevant for this use case are:

- Process flow: XDW, XTB-WD, PIX/PDQ
- Infrastructure: XDS/ XDR/ XDM, ATNA, CT
- Access control: BPPC, XUA(++)

6.9 Profile coverage of Use Cases

This section analyses which use cases get covered when a given profile is tested. The list of Use cases per profile is given in Table 9.

Table 9. List of use cases per profile

Profile	**Use Cases**
ATNA	1a, 1b, 1c, 2a, 2b, 3a, 3b, 4a 4b, 4c, 5a, 5b, 6, 8
BPPC	1a, 1b, 1c, 3b, 6, 7, 7, 8
CMPD	6
CT	2a, 2b, 3a, 4b, 5a, 5b, 6, 7, 8
DEC	1a, 1b
DEC*/RTM*	1c:
DIS	2b, 3b
HRN	2b
LAN/WAN	6
LAN+ or PAN+	2a
LSCD	3b:
LTW	3b:
MHD	6, 7
MS	5a, 5b, 6
PAM	2a,7

Profile	Use Cases
PIX/PDQ	2a,2b, 3a, 4b, 5a, 5b, 6, 8
PRE	1a, 1b, 1c
REM	2b
RWF	2b
SVS	3b
SWF	2b
WAN+	6
XbeR-WD	2a
XCA	1b, 2a, 3a, 4a, 4c
XCA-i	2a, 3a
XCF	4a
XCPD	2a, 3a, 4a,4b
XD-LAB	3a, 3b
XDM	6, 8
XDR	1a, 4a, 5a, 5b, 6, 8
XDS	1a, 2a, 2b, 3a, 4b, 4c, 6, 8
XDS-i	2a, 2b
XDS-MS	4b
XDS-SD	4a
XDW	2a, 8
XPHR	4c
XTB-WD	8
XUA	4b
XUA(++)	1a, 1b, 1c, 2a,2b, 3a,4a, 4c, 5a, 6, 8

7 Description of required testing tool improvements

7.1 Introduction

This section describes improvements that would improve the testing precision, testing efficiency or both.

7.1.1 Coverage (increase in coverage and make the coverage more visible)

An important improvement for all testing tools would be to increase the coverage of requirements set by standards and profiles as well as to make the coverage more visible.

Testing tools currently in use cover the standard and profile requirements to some extent. As example, IHE technical frameworks set all the requirements for a given profile. The test are developed generally trying to cover those requirements to some extent.

In general the following could be said for coverage:

- Coverage level varies. It goes without saying that increased coverage improves the testing and improves interoperability. To achieve that investment is required and time to reach that and to carry out the tests increases. An economically viable compromise is clearly needed.
- Coverage level is not very visible. Tools should provide better means of tracking and evaluating the coverage.
- Linking of tests and requirements could be improved. This would help the test operators in determining what the actual requirements are, which requirements they may have missed or not fully respected and further help them to fix the problems they may have in their implementations. This would also help test developers to ensure that they cover what is required and they do not introduce in their tests the requirements that actually do not exist in the standard or profile. Not introducing requirements in a hidden way through the tests is extremely important and should never be underestimated.

Improvements related to requirements coverage would improve testing tools of all profiles. While some details may depend on the profile in question, the general approach would be common to all.

7.1.2 Increase of automation level

Running the test requires that test values are chosen and a number of steps are performed. This can be done manually or can be more or less automated. Increase of automation level of the tests brings numerous benefits such as increasing test coverage, productivity increase, repeatability etc. A few of those benefits are highlighted here below, where ordering of statements does not imply anything for the importance of the improvement:

- Automation reduces the influence of the human intervention in the testing, thus reducing the source of possible errors and the need to repeat the tests
- Automation speeds up test execution, giving more time for evaluating the problems found during testing or resulting in faster completion of automated tests. Overall productivity of the testing is as a rule considerably increased.

- Automation can facilitate achieving considerably higher coverage of the requirements. As example, the same test may need to be repeated with different combination of values used in testing, potentially leading to different expected results. An automated test could integrate all this into one comprehensive test.
- Automation does ensure repeatability of the test. A reliable test can be repeated any time and any number of times always yielding the same test result.
- Automation is of particular importance where whole workflow procedures need to be tested
- Automation may help in tying together values that need to be sent with values that were received in previous steps
- Automation may also help in selection of tests that need to be performed for a given actor, depending on many options, for example country where the tests are being run

7.1.3 Automate for query/retrieve combination testing

Many tools use a query/retrieve mechanism (Dicom query in the SWF, XCPD HL7v3 query, XCA search for a document…) New tools are needed that can automate the testing of the different query key combination and response. Today these are tests that are manually performed. Automation would allow testing more combination and improving the coverage of the query type transactions.

7.1.4 Building database of samples

For the content profiles that are CDA based (PRE, DIS, XPHR, XDS-MS), tools are needed to build a database of samples corresponding to different use cases. These samples could be used for testing the consumers of those documents, could be also be used as references to the developers of how to code a specific pattern. The database of samples can also be used by testing tools to automate the testing.

7.1.5 CDA Document generation tool

CDA documents are often required as inputs for the testing. As preparation of such CDA documents is not trivial, takes time and may lead to errors, automation of CDA document generation would improve the testing. As example a generator of Dispensation documents would be very beneficial. Dispensation CDA documents should be generated from a given Prescription document. This would be particularly useful to test the Dispensation workflow.

7.2 Requirements catalogue

A requirements catalogue is a tool or a database where all requirement could be stored in an organised way, facilitating later the extraction and manipulation of requirements coming from all relevant sources such as standards, profiles and Use Cases.

Strictly speaking a requirements catalogue is not a testing tool. However, such a catalogue could greatly impact the testing process and could be highly beneficial.

A brief description of the concepts behind a term requirements catalogue is as follows.

The requirements related to the given testing domain are almost never coming from a single source. For eEIF Use Cases the requirements could be coming from various versions of the HL7 standards and

from one or more IHE technical frameworks. The requirements are applicable to various actors, for example PIX source, PIX consumer or PIX manager. A requirement catalogue would collect all normative requirements from base standards and applicable profile specifications. Each requirement should be given a unique identifier and the following information should be included with each:

- the section number in the document from which the requirement has been extracted;
- the type of requirement (Mandatory, Optional, Recommended);
- the type of device to which the requirement applies (for example PIX manager);
- preferably the actual text from which the requirement was extracted or at least a precise link to it

Once such a catalogue is established it could be used for preparing the tests and in selecting the tests that need to be run. The existence of a requirement catalogue would greatly facilitate the evaluation of the test coverage and may also help in test automation.

In the context of eHealth testing it may be quite advantageous to supplement the above information with information on regional applicability. A requirement could be generic, i.e. globally applicable and should therefore always be tested. Another requirement could only be applicable in a specific country or region of a country. Some requirements could apply to different world regions such as Europe, US or Asia.

7.3 Development of test lab

A lot of progress has been made in terms of point to point testing involving two actors that need to communicate according to a given profile. However, many issues arise when one tries to integrate the systems together and the workflow is played from A to Z. Although all the one to one transaction may have been tested, the integration of the systems together still needs to be tested. One could gain in using a test lab equipped with a virtual platform for testing purpose only. Such a virtual platform would act as all the actors surrounding the system being tested. As example, the PIX/PDQ testing tool used in several Connectathons (ETSI/Fraunhofer Focus) was able to take the role of PIX source and PIX consumer and test a PIX manager, making sure that PIX manager communicated to the PIX consumer the updates initiated by a PIX source.

Similar needs exist in many profiles and improving such capabilities would facilitate testing the integration of several actors.

8 Conclusions

The gap analysis of the testing tools shows that testing tools for all eEIF Use Cases do exist and are already in widespread use. Spreading their use even further will on its own improve the interoperability of systems that realize the eEIF Use Cases and that are built according to relevant profiles.

The analysis done during this work shows that testing tools can be further developed, either as extensions of the existing tools or as complete new development. The areas of improvements are identified and described and should be used to orient future development of testing tools. The improvements that were identified should in the first place ensure that the coverage with which relevant requirements are tested is increased. Such improved testing would result with even higher levels interoperability of systems supporting eEIF Use Cases. At the same time the improved testing tools need also to increase the productivity of testing. Automation of testing needs to reduce the time needed for testing and make it economically more viable.

The improvements of testing tools that can be targeted at this point in time are identified and described in this document. This has been used as a basis of a call to develop new or improved testing tools [9]. As both eEIF and related testing tools evolve, there should be a continuous process of review, development and deployment of improved testing tools.

9 References

[1] FP7 Project HITCH Deliverable 2.1: Tool Selection

[2] FP7 Project HITCH Deliverable 2.2: Tools of the future

[3] FP7 Project ANTILOPE Deliverable 2.1: Quality Management System for Interoperability Testing

[4] IHE test tools index http://wiki.ihe.net/index.php?title=IHE_Test_Tool_Information

[5] European Commission – ISA Work Programme eHealth European Interoperability Framework (eHealth EIF): A population of the technical level of the eHealth EIF (4/4)

[6] FP7 Project ANTILOPE Deliverable 1.1: Refinement Definition document

[7] CDA-CH II: SPECIFICATION FOR CREATING TEMPLATES FOR THE HEALTH LEVEL 7 CLINICAL DOCUMENT ARCHITECTURE, Based on the HL7 Clinical Document Architecture (CDA), Release 2, Phase 2, Version 1.2a, 01 October 2011, HL7 User Group Switzerland

[8] OpenDaylight http://www.opendaylight.org/

[9] FP7 Project ANTILOPE Deliverable 3.2: Request for proposal

[10] ETSI SR 002 960 Working in ETSI within an OSS context: Guidance and recommendations

Appendix A: Existing tools not recommended for use

Table 10. List of testing tools that were identified but could not be recommended for use

Profile / Used for	Tool	Developed by	Type	Tool Location / Installation	Info page / User Instructions	Category
All HL7 based profiles	Message Maker	NIST	local	http://www.itl.nist.gov/div897/ctg/messagemaker/mm_download.html	http://www.itl.nist.gov/div897/ctg/messagemaker/	Conformance Tester
EJBCA is an enterprise class PKI Certificate Authority software, built using Java (JEE) technology	EJBCA Enterprise PKI CA	PrimeKey Solutions	web	http://ejbca.org/	http://ejbca.org/	Libraries