Semantic Interoperability for Reliable Information Interchange

Status and Challenges

by

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Acknowledgement

This report has been written by me and has not received any previous academic credit at this or any other institution.

I would like to thank Mr. R. Parker for providing guidance on the objective of the project, and Dr. D. Maxwell for his useful suggestions on the issues.

(signature)

Tom Servaes

Endorsement

I have read the report by Mr. Servaes and agree that it truthfully represents the work performed at Canada Health Infoway's offices in Bedford, NS in the period of June 14th, 2004 to September 3rd, 2004.

This report respects the agreements that Mr. Servaes has engaged in with Infoway for the purposes of the work-term, in particular maintaining the confidentiality of sensitive information.

All persons involved in academic evaluation at the Health Informatics program at Dalhousie University can be given access to the information in this report for the purposes of evaluating this student's academic credit.

(signature)

Ron Parker

Executive Summary

This report is an account of the author's work performed at Canada Health Infoway (Infoway) during the work term from June 14th to September 3rd, 2004.

Infoway is an independent but publicly funded organisation responsible for building Canada's interoperable electronic health record (EHR). The organisation is set up as an independent, private company to enable collaboration with private as well as public partners. Infoway strives to leverage its investment in interoperable EHR initiatives in Canada in three ways:

- By co-sponsoring EHR-related initiatives at less than 100%
- By introducing results-based reimbursement of eligible costs
- By replicating working solutions in other domains and geographies

The author performed his responsibilities in the Solution Architecture department, which holds responsibility for the business and technical architecture of the pan-Canadian interoperable EHR. The author has performed the following activities for Infoway:

- Compared e-prescribing message standards proposals from Canada and the Netherlands.
- Managed the definition phase of an investment initiative up to the final budget proposal to the operational management committee.
- Analysed the problem of semantic interoperability for the EHR architecture and provided recommendations.

The members of the Solution Architecture department have expressed their satisfaction with the reports and project artefacts resulting from these activities.

As a result of the wide variety of activities, the author has been able to apply a variety of topics from the Health Informatics curriculum, from "Health Informatics Systems and Issues" to "Research Methods." The work-term requirement in the health informatics curriculum is also a valuable component that adds to the education of future health informatics professionals.

The detailed problem of semantic interoperability was analyzed during the work term. Though information standards may help avoid semantic misinterpretation it is likely to be an impractical solution to change the systems and system users in a massive approach. The architecture used in Infoway's EHR blueprint also favours a composite standard where current systems can be integrated through add-on modules.

Future work-term engagements should be discussed early on with the prospective organisation, preferably during the end-of-year budget cycle. What worked well was the fact that the author was seen as health informatics professionals "in training" rather than a student, which allowed Infoway to realize maximum value from the engagement. A practical change the organisation should consider is have the work term participant engage with many stakeholders in the organisation during the first few weeks of the work term and establish efficient working relations.

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1. Introduction

This report is an account of the author's work performed at Canada Health Infoway during the work term from June 14th to September 3rd, 2004. The report will describe the nature of the organisation, the department in which the author resided, and the activities that were executed. It also describes how this work enabled the author to apply his training in health informatics to gain a deeper understanding for the practical issues. The second part of report will describe in detail the challenges of semantic information interchange. This problem exists when distributing health information collected from various sources such that the receiver of the information, who may work in a different context, can usefully interpret it.

2. Description of the Organization

Canada Health Infoway (Infoway) is an independent but publicly funded organisation responsible for building Canada's interoperable electronic health record (EHR). The stakeholders in the company are the deputy ministers of health of the federal, provincial and territorial governments of Canada. Infoway's corporate departments are:

- **Investment Strategy and Planning** – develop the business plan
- **Partnerships and Alliances** – manage relationships with external stakeholders
- **Solution Architecture** – develop EHR architecture and ensure its implementation
- **Investment Programs Management** – lead and monitor investment projects
- **Corporate Affairs** – manage communication, marketing, and knowledge
- **Resource Management and Administration** – manage the internal resources

The organisation is run as an independent, private company to enable collaboration with private as well as public partners.

Infoway strives to leverage its investment in interoperable EHR initiatives in Canada in three ways. Firstly by co-sponsoring EHR-related initiatives from the jurisdictions only a percentage of the funds will come from Infoway, ensuring the initiative fulfills a real need. Secondly, the reimbursement of the funds committed to the initiative will happen through the principle of "no cure, no pay." The success of the initiative (i.e., the "cure") is defined by the business objectives agreed upon at the outset. These objectives are measured through acceptance criteria for the project deliverables as well as actual use of the solutions. The third way Infoway aims to leverage its investment is by replicating the working solutions in other domains of the healthcare sector or other geographies.

The author performed his responsibilities in the Solution Architecture department. This department is responsible for "the development of the business and technical architecture for [the] EHR, and conducts technical due diligence on opportunities and projects."[1] The department is headed by Infoway's chief technology officer and supported by various

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[1] From the Infoway corporate website: http://www.infoway.ca/aboutinfoway/structure.php?lang=en
Accessed September 26th, 2004.

directors of architecture. Each director is responsible for one aspect of ensuring the interoperable EHR architecture is fulfilled (e.g., data requirements, vocabulary standards, messaging standards, privacy and security) or for guiding an investment project that is affected by the need for interoperability. Directors work with the project manager, project sponsor, project team, and other involved parties (e.g., vendors) to ensure that the final work products are compatible with earlier work elsewhere or from other initiatives.

The Solution Architecture department is a central part of the aforementioned investment leveraging strategy through its ability to influence the repeatability and integration of the individual projects. An EHR blueprint has been developed to support the work of the Solution Architecture department. It describes the overall architecture of the pan-Canadian EHR and provides a framework for the practical approach of implementing this in the real world.

3. Description of the Work Performed

The objective at the outset was to assist Mr. Ron Parker from the Solutions Architecture Department in the following activities:

- **Consolidating Clinical Messaging Standards**: Comparing and consolidating international business requirements for clinical messaging standards in HL7 v.3 in pharmaceutical applications (e.g., e-Prescribing)

- **Constructing Project Charters for Investment Initiatives**: Contributing significantly to the Phase 1 project charters for Infoway initiatives such as:
  - Health Informatics Profiling based on ISO standards
  - Composite Clinical Data Dictionary (C2D2)
  - Policy Harmonisation through peer-to-peer knowledge exchange

As a result of his engagement with the Solution Architecture department, the author has performed the following activities for Infoway:

1. Created a report on the comparison of e-prescribing message standards under development by the Rx5 project at Infoway with a similar initiative in the Netherlands at "Nationaal ICT Instituut in de Zorg" (NICTIZ)

2. Managed the definition phase of an investment initiative up to the final budget proposal to the operational management committee. The project aimed to create a project support tool for the cataloguing, storage, and retrieval of health informatics artefacts (e.g., standards descriptions, conceptual solutions, vendor solutions.) This is typically an Investment Programs Management role but due to the subject matter needed to be driven by the Solution Architecture department.

3. Created a report on the problem of semantic interoperability as needed in the EHR architecture for meaningful exchange of health information and provided recommendations.

Clearly only a subset of the planned activities has been performed. This was due in part to getting to know the operational aspects of the organisation involved in project start-up. Unfortunately this was confounded by the internal reorganization resulting from a recent strategic reorientation. The timing of holiday schedules of internal and external stakeholders created some delays.

Feedback on the e-prescribing messaging report from the Director for Messaging Standards[2] was positive and the report was valuable to the project team. Similarly the report on semantic interoperability received positive feedback from Mr. Ron Parker, supervisor of the author. Mr. Parker has said he will be able to use the semantic interoperability report as a starting point for the new Task Force in the ISO/TC215 working group 3, which he will lead.

As a result of the internal strategic reorientation of the organisation the operations management committee did not approve the budget proposal for a cataloguing and project support tool. Through this work the author became familiar with the organisation, its relationship with external stakeholders, and the complexity of the decision making process in the Canadian healthcare field. Unfortunately it took up the majority of the time and did not return any other value to the organisation.

4. Application of the Health Informatics Curriculum

4.1 Patient Medication History and E-Prescribing

The main reason for the report was evaluating the potential for a common standard among the countries that are developing e-prescribing solutions.

The author's understanding of the importance for such an international standard was the result of the "Health Informatics Systems and Issues" course, which clearly described the reasons for standardization as well as presenting the steps of a standardization process.

The work context allowed further understanding of Infoway's strategic decision to use a standards-based approach. From the academic course the author has learned about the importance of standards in the healthcare field to enable integration of the diverse information systems in a healthcare institution. The added benefit to the investment initiatives of Infoway is the ability to spread the implementation in time and geography while maintaining the interoperability requirements. This is necessary due to the limited budgets that co-sponsoring organizations can dedicate to such initiatives. Therefore the investments have to be synchronized with the availability of funds at any one time in any jurisdiction be it federal, provincial, or territorial.

4.2 Health Informatics Profiling Framework Internet Tool

The work involved the construction of a project charter and a statement of work. Through the course on "IT Project Management" the author was able to understand the role of the

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[2] Personal telephone conversation initiated by Mrs. Sharon Moore, Director of Architecture for Messaging Standards at Canada Health Infoway.

different artefacts and their importance in managing the project and measuring its progress.

The Health Informatics Profiling Framework upon which the tool was to be based became easy to understand for the author as a result of the "Knowledge Management for Health Informatics" course. Understanding the purpose and workings of the tool was helpful in creating the project charter and help the project team create a realistic work breakdown structure.

The framework is a way to structure the collected information on health informatics initiatives such that a crystallization of knowledge about the Health Informatics field can be done. That knowledge should then be disseminated through the tool via search capabilities. A topic map of the health informatics terminology would be constructed to aid with the classification and retrieval of relevant artefacts. The construction of the topic map would start with a term frequency table as in the course "Special Topics: Information Retrieval."

4.3 Semantic Interoperability

The problem of semantic meaning of information became clear in the courses of "Health Information Systems and Issues" as well as "Research Methods." In order for health information to be useful it is necessary that is as unambiguous as possible or can be interpreted in a meaningful way.

There are very few standards for health information and there was historically very little opportunity to exchange information beyond local communities. As a result de-facto standards came into being which are now hindering the universal exchange of the information.

More detail will be given in the next section.

5. Semantic Interoperability

5.1 What is Semantic Interoperability?

Individual and aggregate health information is required for managing patient health status (primary purpose), healthcare service planning, health policy, research, etc. (secondary purposes). When that data is retrieved from different sources within a healthcare organisation, or potentially even from other organisations, errors in interpretation can occur when insufficient context is given. Not all data has the same meaning or is collected for the same reason.

There are various reasons why the information may have a different meaning. The following examples illustrate some possible origins of the opportunity for misinterpretation [1]:
- Laboratory tests and methods
    - Test methods may vary from one hospital to another and give different results. E.g., A substance in the blood called Troponin indicates heart

muscle damage, but can be measured in different ways, using completely different methodologies. Each method will give results that are both different in scale and significance.
- o Laboratories may qualify results as high, low, critical, etc. without accounting for the circumstances of the patient such as age, current medication, etc. resulting in misleading messages.
- o Laboratories maintain their own 'normal' values based on values measured in the local populations for which they perform tests and these also evolve with time.
- Diagnoses, vocabulary, and coding
  - o The coding system used may be different for each purpose. E.g., in Nova Scotia trained health records personnel encode in-patient diagnoses using ICD-10, while secretaries encode outpatient data in ICD-9 for billing purposes.
  - o Many encoding systems (ICD, LOINC, SNOMED, etc.) have no unique mapping or translation tables to other systems. Even the WHO ICD-9 and ICD-10 are significantly different such that any translation happens by re-encoding the original diagnoses.
  - o The descriptions of visits and clinical findings may also happen using different vocabulary. E.g., Respirology terminology has evolved in the past 10 years, and different physicians may be using old or new terminology. Unfortunately the same term will have different meaning depending on which version is used.
  - o A host of "poetic" terminology is used for clinical conditions that is usually not included in the encoding systems or controlled vocabularies.
- Pharmaceutical products and preparations
  - o Brand names and chemical names can be and are used interchangeably. Some even have multiple chemical names (e.g., paracetamol and acetaminophen.)
  - o Differences in the description of dosage (e.g., "aspirin 2 tablets", "ASA 650mg.", "ASA 325 mg. X 2", "ASA tab ii", etc.)
  - o Frequency of administration may be specified as exact time of day (e.g., 8am & 5pm), frequency (e.g., 2x daily, every 6 hours), relative to external conditions (e.g., before meals, at bedtime, when temperature exceeds 39°C), or combinations. The choice of description by the physician may or may not have been significant.
- Radiology
  - o Views may vary from one hospital to another. Series may include more or less pictures and include different angles.
  - o Radiologist interpretations have different structures depending on the radiologist.
  - o No consistent indications for "normal", "abnormal", or other quantifications are used and may depend on experience.

Semantic interoperability is then the ability to communicate the health information outside the original context or timeframe without loosing meaning, nor changing it. It

necessitates exchanging the patient information together with the context. When a patient's laboratory test results in the example above are stored, they should be combined with the laboratory's explanation of what list of criteria was standard procedure at the time. This is necessary to allow the same interpretation to be given to the results, whether it is across organisational boundaries, or within the same organisation at a later time. In most cases some contextual information is already included to make the information readable to local physicians, but many times known organisational assumptions are not repeated.

5.2 Semantic Issues

When the current situation is allowed to persist and information is shared across organisational boundaries the information will be useful to the receiving physician only if they use the same terminology and coding. If not, then the physician will know that some diagnosis or codification has occurred but nothing else. Mostly this will result in delays because of extra communication around the information. In the worst case, an undetected misinterpretation can have fatal effects on the patient's health status.

The semantic issues can appear in many different types of information for various reasons. We already discussed some real-world examples in the previous section. Below is an initial list composed of general issues:

- Textual descriptions
    - Concepts and vocabulary are usually listed in medical textbooks and other guides as terminology or controlled vocabulary. These may or may not be shared and known by all users of the information.
    - Language and translation issues may arise as not all communities share the same natural language (English, French, Inuktitut, etc.) and their understanding of the other language terms is limited or imprecise.

- Coding systems and shorthand
    - Encoding of textual information or data is used in most IT systems and for various purposes (discharge abstracts, billing, resource planning, mortality statistics, etc.). With each coding system comes a set of assumptions and usually a different rationale for classification of the codes. While most coding systems describe the human conditions in one way or another, there are currently very few ways of uniquely cross-referencing among the codes. [2]
    - One of the most pervasively used coding systems, WHO ICD, has the same problem between its two most recent versions. ICD-9 and ICD-10 are not uniquely translatable and there is no straightforward way of cross-referencing among the encoding tables.
    - The additional problem associated with ICD is the extent of detail with which it distinguishes among conditions. Some areas are overly specified and overlap with others. Expert encoders will use the codes they are most familiar with or are within their area of speciality (e.g., respiratory disease, etc.)

- o Shorthand is used in many situations where the person recording the information assumes that the use of the information will be limited in time or for a limited audience that is familiar with the non-standardized coding. Examples are prescriptions, physician orders, etc. These assumptions are unfounded with any form of electronic records or electronic information exchange. Many times the initial purposes for the electronic format of storing and exchanging information will be expanded as new uses for the information or communication medium are found.

- Measurement [3]
  - o Measurement units are often the cause of interpretation problems
    - Omission of the units in the information repository, just the values are stored and no other indication is given.
    - Ambiguity exists with regards to the notation and abbreviation used.
    - Algebraic combination of units and meaningful redundancy. E.g., "*" in computer languages vs. "." in ISO2955; mass concentration ratio relative to body weight "mg/kg"
    - Symbols not readily translatable in standard character sets supported by computer records.
    - Exact transformation between metric and imperial units may be too precise for "indicative" values. E.g., a "10cm incision" should not be taken literally to mean "3.937 in" but "4 in."
  - o Ranges and thresholds used for indicator values as well as measurement conditions should be explicitly stated, especially to enable assessment of longitudinal data.
  - o Accuracy and certainty of the measurement should be included for the same reasons. The agreed format, precision, and granularity of the measurement are not the same for each institution or laboratory.
  - o Groups of measurements on the same biological elements should not be confused with aggregate values that give overall indicators.

- General interpretation
  - o The parameter being measured may be nested. Depending on the conditions of the measurement or the specified group of tests it may have subparts that in turn depend on parts of tests. All should be preserved to provide the ability to accurately translate the data.
  - o The value of parameter may be useless without knowledge of explicit or implicit null values used.
  - o The time of observation may vary from an instant, to intervals, or a period. The values may indicate snapshots of fuzzy data with a probability and confidence interval. As practice and preference differs for certain observations it may be necessary to record this context.
  - o There may be different possible circumstances of observation for different reasons (E.g., blood pressure while lying, sitting, standing, active, etc.)

- o Imprecise modifiers may deliberately indicate caution needs to be used when interpreting data:
    - Context (BP while "fasting")
    - Certainty ("likely", "possible" vs. "definite")
    - Degree ("mild")
    - Location ("RLL")
    - Specimen ("Plasma")
    - Status ("called", "preliminary", "critical")

5.3 Common vs. Composite Approach

Traditionally this problem is addressed by enforcing a standard terminology, coding, and syntax. Many examples have been published where this has been done successfully:

- INPC Indianapolis: common clinical data dictionary [4], [5]
- New-Zealand Centralized clinical data repository [6]
- US DoD Composite Health Care System [7]

It is important to note that successful initiatives involve one or a few organisations that already share other objectives. Few reports can be found on unsuccessful standardisation attempts. The absence of reports on unsuccessful standardization attempts is uncanny, but certainly does not mean these are non-existent.

The most general trade-off is whether or not to use a common, standardized approach among all stakeholders (providers, researchers, administration, policy makers, etc.) to each of the individual issues outlined above. Before a decision can be made, the following questions need to be answered:

- What standards exist and are in use today to address the issues listed above?
- What will be the cost of adapting or developing standards where none are currently adequate?
- What will be the cost of re-training healthcare staff (clinical, nursing, technicians, clerks, administrators, etc.) in the identified standards where they are not yet used?
- What will be the cost of purchasing, adapting, or developing IT systems that adhere to the identified standards?
- What will be the cost of translating or transforming historical health information to the new standards from electronic archives (and where necessary paper records)?

An alternative may be to acquire or develop the capability to transform the health information in a way that is sufficient to eliminate or avoid misinterpretation. Here the following questions need to be answered:

- Who is responsible for the correctness of the transformation?
- How much of the information can be successfully and uniquely transformed to be understandable by the receiver?
- What information is potentially useful to transform?

Secondly, and independently, many factors will influence the ability to exchange meaningful information. Here are some of the major factors:

- Organisations' readiness to exchange information
  - Appropriate access mechanisms and authentication
  - Willingness to share certain types of information
  - Availability of resources for implementation and adoption
- Development of meaningful correspondence amongst commonly used semantic concepts:
  - Coding tables of nomenclature, interventions, and procedures
  - Measurement units
  - Natural language translations
- Rate of adoption and support for the principles of semantic information interchange in different communities:
  - Healthcare institutions
  - Community care and general practitioners
  - Healthcare IT support organisations
  - Medical equipment manufacturers
  - Packaged software vendors

5.4 Technologies

The technologies necessary for semantic information interchange are already in use for many other applications. The description above clearly demonstrates that the technology itself will not be sufficient to address the problem. Nevertheless it is necessary to explicitly state why some commonly used technologies in healthcare do not address the problem completely.

HL7 (currently version 3) is a commonly used protocol to exchange health related information. While it describes clearly what information is required to perform a certain type of transaction, it intentionally leaves room for custom description formats. E.g., HL7v3 provides the opportunity to communicate an "Observation" but does not specify how the content should relate to coding schemes or vocabularies.

XML and SGML are intentionally generic technologies and need to be adapted for every use. These technologies consist of the ability to create custom placeholders and define any format customized to the particular needs of the communication channel. The disadvantage is that no standard yet exists to address the aforementioned issues. Many commercial products use this technology to provide generic communication capabilities. Product names are: Tibco, BEA Systems, webMethods, IBM MQSeries, Microsoft BizTalk Server, OpenEAI Software Foundation, etc. While each of these can be used interchangeably as the foundational technology, they require additional effort to embed the solution to the healthcare specific interpretation issues outlined here.

Automatic codification of medical terminology through user-friendly tools such as Health Language's Language Engine [8] may provide standardization within one institution at the input of medical terminology into the system. However, it cannot be used in communicating across organisations that have implemented different coding standards.

5.5 Recommendations

Being able to exchange information while keeping the semantic meaning constant is intimately linked to the realization of a pan-Canadian electronic health record. If information is deliberately communicated outside the organisational boundaries semantic interoperability is required in order for the exchange to create any value whatsoever, including added value. On the other hand, without the need to share information across organisational boundaries, there is little value in a shared electronic health record.

Based on the discussion above, different solutions can be imagined:
- Single common standard for pan-Canadian health information capture and dissemination, eliminating the problem of ambiguous semantic interpretation
- An intermediary system that can convert to and from all health information formats from all current systems
- Conversion utilities that can be invoked to convert between the existing health information formats of the two native systems that wish to communicate
- Conversion utilities that can be invoked to convert between the existing health information format of the native system and an intermediary format

The first solution is not practical if the existing systems have to be reused as much as possible. The questions already mentioned in section 5.3 strongly suggest a composite approach because of the ability to spread the cost over all stakeholders as well as using different timelines for each stakeholder.

Infoway's blueprint architecture is based on a Health Information Abstraction Layer (HIAL) that will enable healthcare institutions to automatically locate patient information as well as retrieving the information from the respective sources. Given this architecture the best choice would be for an intermediary system that can handle the conversion of the native system information (see Figure 1a). While this solution has minimal impact on the existing systems, it has a number of disadvantages. Can the intermediate system be built at an acceptable balance between speed and cost? How will the construction of the intermediary systems be funded? Who will assume the collective responsibility for the correctness of the conversion?

An alternative solution includes the ability to convert native system formats into an intermediary standard format. This way the conversion can happen outside of the intermediary system (see Figure 1b) where the goal is to distribute the responsibility and cost of converting and communicating information. This approach also has the advantage that the conversion utilities can be created on an as-needed basis.

Infoway can contribute significantly to semantic information interchange by funding initiatives that develop or identify:
- Necessary and sufficient combination of terminology and contextual information to enable reliable interpretation for each domain (pharmacy, pathology, etc.)
- Conversion tables for international and local standards, measurement units, etc.
- Extract, transform, load (ETL) mechanisms for information interchange among commonly used software application packages for health information

- The ability to connect an organisation's existing health information sources to ETL mechanisms that enable communication with related organisations.
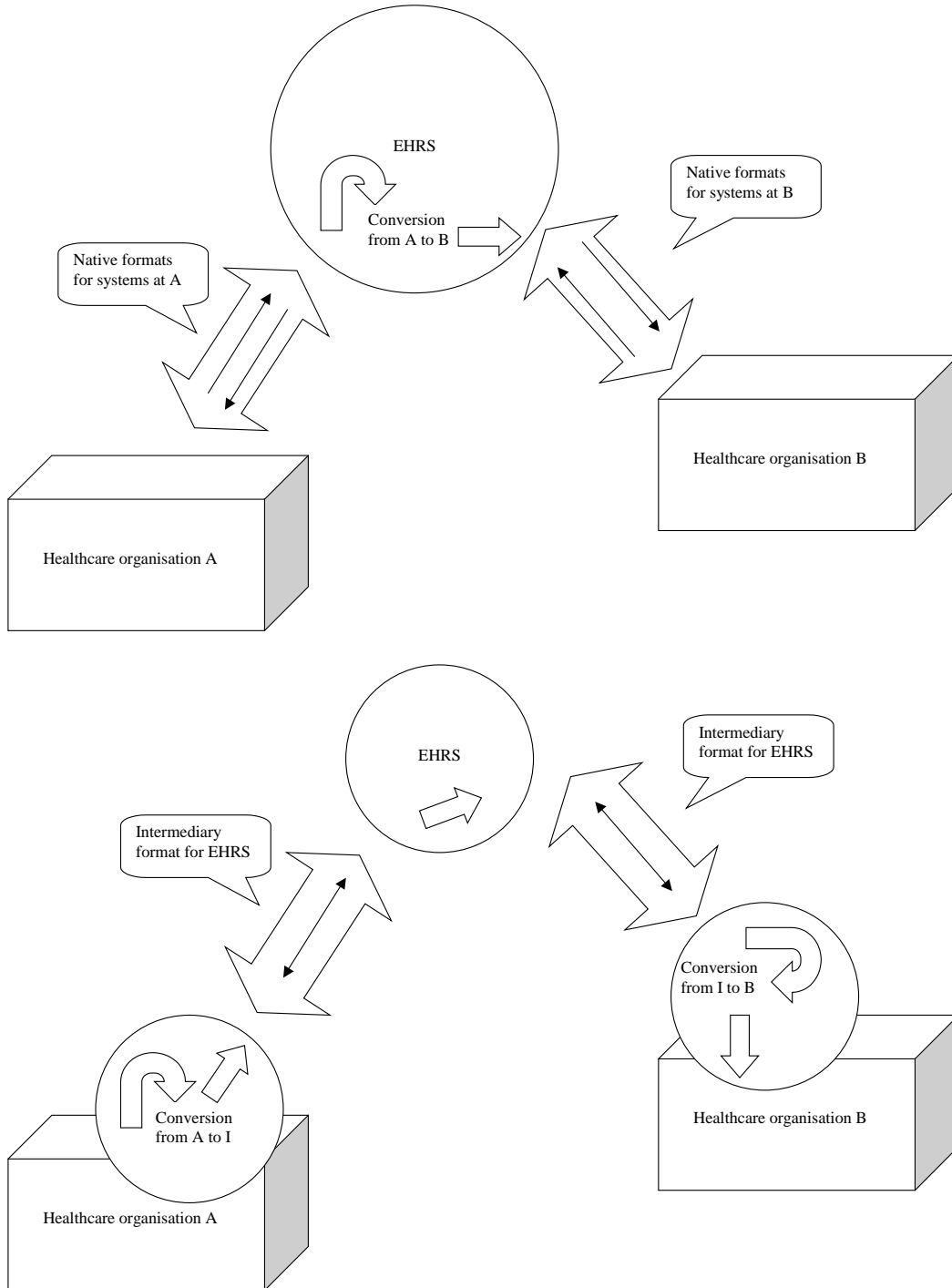
**Figure 1a - Native format conversion for information interchange
1b – Distributed conversion to an intermediate format**

6. Conclusions

The author has performed a wide variety of tasks while working at Canada Health Infoway. The activities included:

- Comparing existing proposals for e-prescribing HL7 message standards
- Managing a mixed internal and external team of experts responsible for the definition and budget proposal of a health informatics related investment initiative
- Preparing a report to initiate the activities related to semantic meaning in information interchange, a critical component in the interoperable EHR architecture.

Working in a health informatics organization and in cooperation with experienced persons has given the author the opportunity to gain experience in the field. It also allowed the author to understand the complexity of decision-making processes in the healthcare field.

It was most gratifying to see the applicability of the material discussed in the academic courses. Many discussions around important topics and Infoway's challenges were very much related to course work and related student projects.

The work-term requirement in the health informatics curriculum is most certainly a valuable component that adds to the education of future health informatics professionals. It was certainly a great addition to the author's training, especially through the constructive and informative discussions with Mr. Ron Parker.

7. Recommendations

These recommendations will be useful for future engagements in work-terms with large organizations, and Infoway in particular. After consideration of the most positive experiences as well as some challenges, the health informatics program management should implement the following recommendations:

1. Engaging with the organization while budget calculations for the fiscal year are being prepared. At this time it will be easier to consider the use of student work-terms, even if the number of the students or their profile is unknown.
2. Ensuring that the student is involved in an undertaking that touches many aspects of the organization. This will both allow the student to show the broad coverage of the academic program and engage with multiple people in the organization.

The organization hiring the student can benefit greatly from the contributions of a mature graduate student if the following recommendations are implemented:

1. Welcoming the students as health informatics professionals "in training" and providing an early opportunity to meet with a wide variety of people in the organization to enable efficient and supportive working relations.
2. Making sure the graduate students are engaged in opportunities where their prior experience and academic expertise are leveraged, not just their time.

References

[1] "Advice on data exchange," personal email communication with Prof. Dr. David Maxwell on August 29th, 2004

[2] E.g., see also http://www.who.int/whosis/icd10/othercla.htm and http://www.ulb.ac.be/esp/emd/classifications.htm

[3] Units of Measure in Clinical Information Systems, Gunther Schadow, MD, Clement J. McDonald, MD, Jeffrey G. Suico, MD, Ulrich Föhring, MD, and Thomas Tolxdorff, PhD, J Am Med Inform Assoc. 1999 March; 6 (2): 151–161

[4] Design and implementation of the Indianapolis Network for Patient Care and Research, J M Overhage, W M Tierney, and C J McDonald, Bull Med Libr Assoc. 1995 January; 83 (1): 48–56

[5] A Successful Legal and Technical Infrastructure for Creating a True Communitywide Clinical Information System, J. Marc Overhage, MD, PhD, Jeffrey Suico, MD, Paul Dexter, MD, Michael Barnes, MD, Clement McDonald, MD, Telemedicine Initiative Symposium abstract http://collab.nlm.nih.gov/tutorialspublicationsandmaterials/telesymposiumcd/6B-1.pdf and video http://collab.nlm.nih.gov/webcastsandvideos/nlmtelemedicineconference

[6] From Present to Future: A draft national health information standards plan for New Zealand. Ministry of Health. June 2003. Wellington, New Zealand http://www.moh.govt.nz/moh.nsf/0/eae31d4872cb27a1cc256d5c0070897f?OpenDocument

[7] Military Computer-Based Patient Record: Design, Development, Deployment With Clinical Focus. Dr. Robert Wah, Dr. Bart Harmon, Dr. Dan Zinder. Presentation on February 12, 2003 http://www.himss.org/content/files/proceedings/2003/Sessions/session108_slides.pdf

[8] Health Language: "What Is LE", Health Language, Inc. website on August 16th, 2004 http://www.healthlanguage.com/whatle.html