Transformation between HL7 and Continuity of Care Record to Facilitate Web-Based Personal Health Record Systems

by

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ABSTRACT

To establish interoperability between Health/Hospital Information System (HIS), there exist standards or protocols designed by capable organizations to help different HISs communicate better with each other. Reliable and accurate communication is nowadays a prerequisite to delivering fully integrated health care to patients. In practice, there are two main leading standards adopted by various HISs, Health Level 7 (HL7) and Continuity of Care Record (CCR).

The HL7 v2.x set of healthcare messaging standards are the predominant ones used by healthcare institutions in much of the world. They have been designed for managing healthcare and so provide a complete set of information and messages necessary for the provision of healthcare. Also, the scope of HL7 has expanded to include standards for the interchange of clinical data in all settings, a reference information model, data types, decision support and clinical guidelines, clinical documents and clinical templates, clinical context objects, terminology, security, XML, and the electronic health record.

More recently the Continuity of Care Record (CCR) standard was proposed as a digital form of referrals; it describes the condition of a person – a snapshot – at the time of the referral. It offers a light-weight, easy implemented approach, and its focus is on the exchange of health summaries. Personal Health Record (PHR) systems such as Google Health and Microsoft Health Vault use the CCR format for input (and output), which is correct, as such systems collect snapshots of health (rather than or in addition to healthcare) information.

While both were initially made for different purposes, the need to collaborate with each other was soon deemed necessary, resulting in the release by HL7 of the Continuity of Care Document (CCD). This is a patient summary clinical document that is derived from the HL7 CDA (Clinical Document Architecture) Reference Information Model (RIM), but provides health summary information parallel to that of the CCR. This result is a standard that is much more complex than the CCR, so it still does not solve the integration issue between HISs which favour the HL7 (version 2.x or CCD) and those (especially PHRs) which prefer the CCR due to its simplicity.

For healthcare institutions, which use HL7, to effectively communicate with PHR systems which use the CCR, there must be a translation between these two standard formats. We present such a translation; it is in the public domain, so is open for improvements from knowledgeable institutions and individuals.
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DECLARATION

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged.

Signature: ...... .... Date: 30 November 2011
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1 INTRODUCTION

1.1 Problem Statement

Computerization of health care started decades ago, but for developing countries such as Indonesia where ICT is not yet well developed and which has a small health budget of 2.2% of GDP (WHO recommended 5%) (http://www.depkes.go.id/downloads/SKN+.PDF), actual progress is relatively slow. Due to this, affordable alternatives have been demanded that could help to cut the costs, and especially those that move in the direction of integrated health care.

Web-based Personal Health Record (PHR) systems, have recently gained popularity as major players in ICT such as Google and Microsoft began taking part of delivering health care service to public. Their concept of high availability and accessibility as well as patient control can be seen as a possible solution for cheaper Health/Hospital Information Systems (HIS) particularly for developing countries. There is, however, a missing link between said PHRs with currently available HISs - that is the standards used by the two different types of health care systems.

The HL7 v2.x set of healthcare messaging standards are the predominant ones used by healthcare institutions in much of the world. They have been designed for managing healthcare institutions and so provide a complete set of information and messages necessary for the provision of healthcare. Also, the scope of HL7 has expanded to include standards for the interchange of clinical data in all settings, a reference information model (in version 3.0), data types, decision support and clinical guidelines, clinical documents and clinical templates, clinical context objects, terminology, security, XML, and the electronic health record (Hammond, 2003). Hospital systems use HL7 v2.x messages to communicate real time health and health management information.

More recently the Continuity of Care Record (CCR) standard was proposed as a digital form of referrals; it describes the condition of a person – a snapshot – at the time of the referral. It offers a light-weight, easily implemented approach, and its focus is on exchange of health summaries (Ferranti et al., 2006). Personal Health Record (PHR) systems such as Google Health and Microsoft Health Vault use the CCR format for input (and output), which is suitable in their context, as such systems collect snapshots of health (rather than or in addition to healthcare or health management) information.

Therefore, for healthcare institutions which use HL7 to effectively communicate with PHR systems which use the CCR, there must be a translation between these two standard formats. We present such a translation that sits in message gateway framework to enable the use of PHR on a bigger scale.
1.2 General Overview of Health Care and HIS related to Indonesia

Health Information System (HIS) refers to the use of Information Technology to help enhance the quality of services offered by health providers. There have been many practices and studies all around the globe that show how HIS can significantly improve productivity of each provider, but at the same time show many failures of implementations or unsatisfactory achievement of HIS (Armitage et al., 2009). In general there are two main types of HIS in the view of this paper, Clinical HIS and Personal Health Record (PHR) Systems. Clinical HISs are used in health institutions such as clinics, hospitals and laboratories whereas PHRs are personally owned by patient and usually stored in easily accessible (via the World Wide Web – WWW) databanks.

Indonesia is one of the major developing countries in South-East Asia with huge population (being 4th most populated country on the earth) and geographically divergent across many islands (17,508 islands). The challenges of having a mass population geographically divided amongst the islands and having a small health budget, while seen as huge obstacle to creating integrated health care across the nation, at the same time indicate the prospect of using a Web-based PHR as a better alternative than computerizing hospitals.

1.2.1 History of health care in Indonesia

According to the Ministry of Health official website (http://www.depkes.go.id), granting easy access to healthcare and further escalating the use of a surveillance system for monitoring health and health information is one of the major missions any health provider in Indonesia should prioritize. Therefore, the Ministry of Health has already envisioned a single information system that connects all health providers in Indonesia into a single complex entity. This gave birth to SIKNAS (Sistem Informasi Kesehatan Nasional), or also referred as SKN (Sistem Kesehatan Nasional) systemized long term healthcare plan designed by the Ministry of Health for the nation.

There are 6 main aims of SIKNAS as mentioned in the Ministry of Health’s SIKNAS official letter in 2004, with the last point being ‘Sub-system of Health Management’. In that particular chapter it was stressed that the ‘National health information system as the collection of regional health information systems other related information systems’.

SIKNAS was already founded in 1969; it favours a centralized government system which includes health care. This however was not realized before the monetary crisis struck Indonesia; a further push for decentralized policy in 2001 led to complete hibernation of SIKNAS. Until 2007, a new SIKNAS called SIKNAS ONLINE is a web-based national health information system that is still undergoing many improvements to help connect all the hospitals in Indonesia regardless of the geographical conditions.
Poor IT penetration in Indonesia becomes a major issue in HIS implementation. The Internet is available in most provincial areas, but mostly not to the regions below provincial level such as suburbs and villages. Furthermore, most people are not familiar with computers. While the penetration rate of IT drastically increasing over the years (http://www.internetworldstats.com/asia/id.htm), HIS in Indonesia does not follow the same speed.

From the following figure, the SIKNAS framework already focused on how to manage fragmented health information across cities to better help government to visualize the state of health care of the country. There are 6 steps to the strategic plan of SIKNAS framework as can be seen from the figure:

1. Integration and simplification of existing reporting system
2. Implementation of the new reporting system
3. Facilitating the development of HIS across nation
4. Development of technology and relevant resources
5. Improving health data and information management
6. Improving health data and information service for public

Figure 1-1: SIKNAS Strategic Development Plan (Ministry of Health of Indonesia, 2007)
From the next figure, it is explicitly shown how the Minister envisioned integrated health care service to share their information using ‘intranet and internet cloud’. Hospitals, clinics, information centres and even the public are seamlessly connected and health information is shared commonly at single point.

![Diagram showing the use of ICT for health information communication](image)

Figure 1-2: The use of ICT for health information communication (Ministry of Health of Indonesia, 2007)

1.2.2 Different levels of players in the chain of health care

In the chain of health care, those who are involved can be categorized into several groups of players. Depending on the role, the stakeholders are categorized as following:

1.2.2.1 Patient level

A patient in general could be described as a person who is in need of health or medical assistance and usually seeks such help from a clinic or hospital. Due to the goals of health care, this level can be categorized as the most important level in the entire flow of health care system because the aim of health care itself is to improve the health of the patients. Thus, the measurements of a successful health care system can be quickly identified from the patients.

In conjunction with this, the Institute of Medicine delineated 6 ‘aims of improvements’ in which 1 of the aims stated ‘Patient-centred’ approach must be escalated (Leavitt 2001). Apart from the 6 aims, another 10 ‘redesign rules’ were also proposed in the same paper, in which a few of them state that the patient
should become the source of protocols, and customization should be based on patient needs and values.

While patient generally refers to one person, it is important that those who are close to the patient such as relatives and perhaps friends can also be included because information about one person’s health condition does not just come from the individual – rather, it can be collected as a whole from other persons as well.

**1.2.2.2 Clinical level – primary care, general practice**

A clinic is a level where a patient can obtain primary care and which usually operates on lower scale than a hospital. Hence, a clinic usually manages less complex health information records in terms of the size and the type of data. In Indonesia most clinics are private and therefore are not financially supported by Government. A clinic is also a replacement for a hospital in places far away from hospitals. A clinic can be considered as one of the lowest health provider organizations available.

One characteristic of a clinic in Indonesia is that it usually operated by one doctor with several helpers, and does not yet have well established patient registration system.

**1.2.2.3 Hospital level**

A hospital provides patients with a huge range of functionalities and is involved with a large number of patients. In addition, patients from the clinical level are also referred to this level when the clinic does not have adequate resources to treat the patients. A hospital usually deals with a vast amount of data, with the types ranging across patient data, laboratory result data, MRI data, etc. Hospitals in Indonesia can be categorized into private and government hospitals based on the financial funding.

**1.2.2.4 How do they communicate with each other?**

A typical communication between different levels is usually initiated from the bottom; a patient went to a clinic with a problem regarding their health. When admitted at the clinic, a doctor would have to examine the patient to get general health information from the patient such as blood pressure, glucose level, etc. In many cases, the doctor would also want to know the health history record of the patient; if the patient were previously admitted to the same clinic then the doctor might be able to get such data.

The problem arises when the clinic does not have a previous record of the patient which could be important; e.g. allergic history.

In the case where a patient is being referred to a hospital, communication between the three levels becomes important; as patient moves from clinic to hospital, the health record of the patient needs to be transferred as well. With the record left in the clinic, a hospital will have to run the same examinations of the patient all over again. In order to distribute those data, typically a doctor can call
the referrer doctor for a patient’s information, or the referring doctor could write a letter, pass it to the patient and let the patient pass it to the doctor in charge.

1.2.3 Health Information System (HIS) in Health Care

HIS now supports critical activities in hospitals or clinics such as laboratory management, patient administrations, pharmacy, etc. Here we will take a look on how the computerizations in health care come to be as well the forms and consequences of the process.

1.2.3.1 Computerization of Health Care Management System

Health Care Management System (HCMS) refers to the use of information system to improve the quality, cost-effectiveness and efficiency of health care management.

1.2.3.1.1 Why do we computerize Health Care Management (HCM)?

One of the main drivers of computerization - and not exclusively for health care field - is the amazing growth of information technology and unprecedented benefits in terms of information management and sharing.

And as health care is an activity involving many levels of players and information shared between those players is huge, it is clear that health care can yield great profit from the use of IT, hence computerization of Health Care Management System.

Computerization also results from the fact that people over the world are now interacting with computers, mobile phones, laptops, PDAs and other similar devices more often than ever as they have proven to enhance information sharing and productivity.

1.2.3.1.2 What are the consequences?

With advanced information technology as it is, turning management of health care into a ‘computerized’ form is not hard, considering how easy it is to find resources and knowledge needed to build HCMS. But due to the nature of health care, a more sophisticated plan to build the foundation of the information structure should be regarded as the most important part.

Then again, many HISs have failed to do this. Though many HISs provide easier, more reliable and faster management functionality interoperability, standard structures are still pretty much the issue when systems have to interact with other, external systems. Furthermore, with many choices of HIS out there, each hospital in one region could have a different system, not to mention smaller health care organizations such as clinics, which would most probably have yet a different system running.
1.2.3.2 Transformation from paper record to electronic record

For more than a century the amount of patient data stored all around the world is bewilderingly large, complex and far flung (Coiera, 2003). Thus, many turn away from paper records to computer-based records in the hope that they will be able to fix the problem.

In 1991, the Institute of Medicine (IOM) in United States issued a report which provides a basic, broad and inclusive definition of the EMR (Dick and Steen, 1991). Stated there, Electronic Medical Record (EMR) is defined as ‘electronic patient record that resides in a system specifically designed to support users by providing accessibility to complete and accurate data, alerts, reminders, clinical decision support systems, links to medical knowledge, and other aids.’

Judging from the definition, it is critically important to point out that an electronic record is not a simple replacement of a paper record; rather, to also serve as a very powerful tool to actively participate in clinical care (Coiera, 2003).

According to Sujansky (1998), an effective representation for an electronic health record that conforms to certain specific design criteria is needed to define a “true” electronic health record.

1.2.3.2.1 Comparison between Paper Record and Electronic Record

Even though by general comparison, electronically stored data surpass those recorded on paper, one must be aware of the positive attributes a traditional paper record possesses that are often taken for granted.

Paper is portable and the access is self-contained. Apart from being a light-weight source, a paper record is useable in most places. It is also a medium to record information that had been developed and used since ancient times. The educational process to allow the user to be able to write and access information from it is pretty minimal, other than the knowledge of clinical terms for medical record.

Still, disadvantages of using paper mostly come from the physical form of paper and, as explained earlier, usually become apparent when patient data is getting larger and more complex.

Paper records consume large amounts of space especially when we are dealing with an enormous quantity of data. Furthermore, a hospital or clinic usually keeps patient information for a long time. Complex records can be difficult to search in paper records, thus slowing the process of information retrieval when needed. In case where a patient is suffering from chronic illness, the treatment history for a number of years can generate a large record for a single patient.

Paper records in most cases can only be used for one task at a time. According to Dick and Steen (1991), records are unavailable for up to 30% of the time in larger institutions.
There is also the necessity to record the same data many times (duplication) on different documents (Roman et al., 2006).

Perhaps one of the biggest disadvantages of using paper records for medical purposes is the difficulty of retrieving information from collections of paper records. Clinicians use a wide variety of information sources during decision-making, and patient-specific data stored in the record are a major component of that (Smith, 1996).

In one study, it was found that most clinical workers routinely fail to find pieces of information that they need during patient consultation from a paper medical record (Tang et al., 1994). At the time, it was discovered that out of 168 outpatient consultations, in as much as 81% cases the clinicians failed to retrieve required data even though the medical paper record was searched.

With such difficulties associated with the paper record, there has been growing drive to replace it with a computer-based one for most of the last half-century. By general comparison, EMR can resolve many of the problems suffered by traditional paper records, such as following.

Massive amount of data can be stored in a physically small storage device when we record health records in electronic form. Also in terms of cost, a storage device is very cheap and with current progression of technologies of optical storage will get even cheaper and hold even larger capacity.

Retrieval of information by querying a data repository is easy. A result of a complex search throughout patient data, particularly those with long history of chronic disease can be generated in relatively short amount of time.

Multiple simultaneous user access to a record is permitted and is not bound by geographical location of the users (i.e. can be accessed from anywhere using network).

Despite the powerful features that EMR can provide to practitioners, there are some factors that we need to consider, such as the cost of actually implementing health care system to fully support the use of EMR and acceptance from the users. (Loomis et al., 2002)

1.2.3.2.2 What are the consequences?

While on one hand EMR greatly improves effectiveness and efficiency compared to the traditional health record, on the other hand EMR has some undesirable attributes pertaining to the nature of electronic record - such as privacy issues. When a patient record is stored in electronic format, the record itself is easily shareable, and that could lead to privacy issues of the patient (Willison et al., 2009).

There is also no solid definition on how EMR should look like, though there are standards for them, the format of the record varies from one place to another. This in turn brings interoperability issues and makes the EMR less effective when we need to pass information across systems. In many cases EMR are
personal information they gave out to the hospital. This is mainly due to the fact that they don’t have control over the information itself once it is recorded. The record that they had given out is completely invisible to them, and that personal information can go everywhere without their knowledge.

Thus, a personal health record emerged. Personal health record is a record which is maintained by the user (patient), and the user chooses which party should have access to his/her record. This allows the user to always look at his or her own record and ultimately control who can see it.

A personal health record at the same time promotes portability and can solve some communication issues, such as allowing different hospitals or clinics to have the same understanding of patient health information by accessing the patient’s PHR with the consent of the patient.

Most PHR are more concerned about the wellness status of the user and keep track of lifelong health history of the patient. For users to enter their health information usually there are ways other than manually typing the information themselves, such as sensor devices and medical report imports.

There are however still some issues to be addressed PHR systems such as privacy and data integrity. The concern of how accurate the data can be, if patients themselves are the only one with full control over the record, mistaken modification on patient’s record becomes more likely. Privacy is also still an issue, when a patient link another HIS to his PHR, what are the information that is actually being shared, where will the information go afterwards – will the HIS replicate the same information in its data repository?

Some popular PHR have been working to solve this issue, such as Google Health and Microsoft Health Vault who claim to prioritize privacy control and protection in their PHR.
1.2.3.4 Indonesian Health Information System

As being mentioned earlier, HIS is one of the main focuses of the Ministry of Health of Indonesia. In practice however, this is far from realization, especially not for all islands in the country.

This might be due to the minimal structure to support information technology in most of the parts of the country; HISs are not established in many parts of the country, even in some places near to the capital city.

Based on interviews done with health providers in Indonesia, it is confirmed that HISs are used mainly for patient registration, and their sole purpose is to ‘write letters’ (see Result section). Patient data are kept in one hospital and used only to replace paper records. Patient data is stored locally in the hospital data repository and this data is mostly used when creating reports, forms or letters. When those patient data are needed by doctors and nurses, they will be printed out for use. This is therefore treating HIS as a replacement of paper storage room into electronic database.

Another proof that shows the slow progress of computerization can be seen from the following figure as given by Data and Information Centre of Indonesia (Pusdatin) about distribution and installation of IT systems on provincial and district level.

Figure 1-3: List of installed IT system to be installed on the branch office of Ministry of Health at provincial and district level
The above figure explains that even at the provincial level, in 2007 the government has just installed 5 PC workstations, a server, one printer, video conferencing and VoIP (Voice over Internet Protocol) devices, etc. and given internet access for main offices which did not have internet access before. On the district level, they are only supplied with one workstation with GSM Modem to receive Short Message Service (SMS) as the mean of communication from local hospitals or clinics.

1.3 Communication of Health Information in General

Communication plays a major part in health care be it from patient to practitioners, between practitioners, clinic to hospitals, and much more. A patient wants to know clearly their treatment plan, or a doctor needs to know the medical history of the patient.

Good communication between primary and secondary care providers is therefore essential for coordinating care for individual patients and providing continuity (Branger et al., 1992).

In some extreme cases communication breakdown can cost patients’ lives, e.g. with abnormal diagnosis tests. In other areas, communication is of the utmost importance, such as for physicians or psychiatrists. Psychiatrist and patients always seek for better communication to ensure both ways understanding and to improve the quality of care.

1.3.1 Current General Solutions for Communication

Here is listed the general medium of communications for conducting health care services, with discussion on the limitations of such method for communicating health information.

1.3.1.1 Basis of communication

The basis in which health information are transferred from one doctor to another ensure that the information is efficiently transmitted and correctly understood by other party.

1.3.1.1.1 English

Perhaps by far this is the most common and most accepted communication basis between practitioners across the globe. Though they may have different native languages, most (if not all) health practitioners learn and use English while delivering health care.

Even in the context of a widely used and well-validated case report form, natural language, particularly English, is often employed. While this generally improves readability by other human beings, it makes translation into machine-level semantics much more complicated (Hunscher et al., 2006).
1.3.1.2 Communication channels

The widely used channels for communicating patient’s health information generally are paper records and direct communication between doctors.

1.3.1.2.1 Paper records

Paper records can be a great communication tool between practitioners due to many factors. As long as a practitioner writes and states clearly information on the paper, information is pretty much preserved the way it was written on the paper to another practitioner.

According to the interviews done with Indonesia’s practitioners, paper records are still more favoured for understanding patient health information.

1.3.1.2.2 Direct communication between practitioners

Communication between health organizations regarding patient health information can be done by direct means between the parties involved. A doctor may call up the doctor who was referring a patient to his place and ask for patient information. A doctor may also read the record or letter written by the referring practitioner.

In Indonesia, communications by letters are the most common case when exchanging health information, especially when it comes to patient health data. This is supported by the interviews with Indonesia’s health provider (in Results section).

Calling the referral doctor does not guarantee the other doctor is available at the same time to provide information needed.

1.3.2 Problems with Current General Communication Solution

While the general communications are widely accepted and practiced in most health organizations, there are limitations arising from these types of communication, such as:

1.3.2.1 Easily lost

Also discussed earlier, though paper records easily preserve information and at the same time are easily understandable, their physical nature causes them to be easily lost. The loss of paper records or letters between doctors leads to loss of the only source of information. A doctor might easily forget about the referral letters he or she wrote yesterday about one particular patient, thus adding more problems.
1.3.2.2 Time consuming

In hospitals with large numbers of patients, writing letters or making phone calls to other doctors might be significantly time consuming. A doctor might not have time to write a patient record in a paper form to be passed to another doctor.

More than that, calling the referral doctor does not guarantee the other doctor is available at the same time to provide information needed. A doctor might have to wait for another doctor to be available before enquiring any information about one particular patient via telephone.

Having thousands of records of patients’ health information in paper format also causes inefficiency when there is the need to find one particular patient’s record.

1.3.2.3 Available one place at a time

This is more specifically applicable to paper records, where the record can only be in one place at a time, causing any practitioners have to ‘queue-up’ for one patient’s information. This could halt delivery of quality care, and proper communication should be able to be made so that this does not occur.

1.4 IT Systems in Health Care

As the problems with integration between various health care systems become apparent, many have taken initiatives to allow seamless communication between them. One of the obvious ways to allow communication between different systems that have different structures of information management is to establish a set of standards or protocol for the communication.

1.4.1 Types and Examples of Health Information Systems

By looking at the scale and access to the medical record we can categorize the types of HISs along with the examples for each type as following:

1.4.1.1 Clinical/Hospital Systems

A clinical/hospital system serves the needs for one health information, such that the patient’s health record are stored and maintained by the hospital or clinic to support the delivery of health care. Patients don’t usually have access to this information other than in printed form with limited information when requested. This way, the hospital is the entity that manages the health record of their registered patients.
1.4.1.1.1 OSCAR

OSCAR (http://www.oscarcanada.org/) is a suite of applications designed and created at McMaster University (Hamilton, Ontario, Canada), starting in the late 1990s. It is intended for the general practice. OSCAR as a whole package provides several applications such as OSCAR EMR with full billing capabilities, chronic disease management tools, prescription tools, etc.

OSCAR also is integrated with MyOSCAR, a Personal Health Record system which itself is based on the IndivoHealth system. Practitioners using OSCAR can send information to and receive information from MyOSCAR. MyOSCAR has a Web interface which allows patients to control their individual records and access to them.

1.4.1.1.2 PrimaCare

PrimaCare (http://www.primacare.com/) is a Web-based network health system that connects all PrimaCare Medical Centres together. PrimaCare focuses on easing patient and physicians’ communication by allowing patient to make appointment online by selecting physician and time slot. It has been developed in Malaysia by the Primary Care Doctors’ Organisation of Malaysia (PCDOM).

1.4.1.1.3 myCare2x

myCare2x (http://mycare2x.net) is a hospital management system developed in Germany. It has been used in several hospitals in Germany, and has begun to be used in other countries such as Malaysia and the Philippines.

myCare2x is written in PHP scripting language, deployed using Apache Web server and powered by MySQL as database management system. All of these components are community-based open-source projects, and with such architecture myCare2x becomes a Web application which provides the user with ease of access, as a Web browser is all the user needs to access the system.

myCare2x offers complete management functionalities such patient/medical/nursing/ward administration, appointment management, forms/letters and much other. Important thing to be noted here is that it also provides an interface to (some) HL7 v2.x messages and DICOM (Digital Imaging and Communications in Medicine). DICOM is a standard for handling information about medical imaging.

1.4.1.1.4 VistA

VistA (http://www.vistahealth.com/Pages/home.aspx) is an HIS developed and used by the United States Department of Veterans Affairs (VA) system. It was developed using MUMPS language/database and supports many activities such as inpatient management, ambulatory, interoperability for radiology
imaging (called VistA Imaging). Several years ago the code was published as open-source, and there are now several open-source derivative products.

1.4.1.1.5 openMRS

Open Medical Record System (OpenMRS) (http://openmrs.org/) was formed in 2004 as open-source medical record system platform for developing countries. It is supported by various organisations such as Partners in Health (Boston), the Regenstrief Institute (Indianapolis), and South African universities (University of KwaZulu-Natal and University of South Africa).

OpenMRS is based on the principle that information should be stored in a way which makes it easy to summarize and analyse, i.e. minimal use of free text and maximum use of coded information. At its core is a concept dictionary which stores all diagnoses, tests, procedures, drugs and other general questions and potential answers. OpenMRS is a client-server application which means it is designed to work in an environment where many client computers access the same information on a server.

1.4.1.2 PHRs

Personal (or Personally Controlled) Health Record (PHR) systems introduce a new factor into health and healthcare communications. Firstly, they break with the tradition that healthcare records are the property of the care provider and not of the patient or person concerned. Secondly, as Web-based systems they allow access to PHRs from anywhere on the Internet. These systems allow each individual to “own” and oversee his or her PHR. The PHRs collect input directly from the owner (person), who may also allow healthcare providers to have access to his or her PHR. While there are also Personally Controlled Health Record systems that are portable and not web-based (such as PHR for mobile devices; e.g. Nokia Wellness Diary), we are referring to web-based PHR throughout this thesis.

PHRs hold considerable promise for developing nations where Internet access has a broader reach than institutional healthcare. Because PHRs are concerned with the health records of individuals, and not so much with the management of healthcare facilities, they do not use the HL7 v2.x set of communication standards. Instead, they use a more recently introduced messaging standard, the Continuity of Care Record or CCR (ASTM, 2005) or Continuity of Care Document or CCD.

1.4.1.2.1 Indivo

Indivo (http://indivohealth.org) is one type of Personally Controlled Health Records (PCHR), which store patient data and at the same time enable patient to assemble, maintain and manage a secure copy of his or her own medical data (Morales, Casper & Brennan, 2007).

Indivo is a specific implementation of a PCHR that is Web-based, allowing an institution to create and administer a PCHR infrastructure that exceeds the requirements of the USA Health Insurance Portability
and Accountability Act (HIPAA) Privacy and Security Rules (Mandl et al., 2007). As described in Simons et al. (2006), Indivo comprises a three-tier system: data storage tier, business logic tier and user interface.

Indivo version 3 is written in Java for the core mechanism and PHP for the user interface. In terms of interoperability of PCHR with other EHR, Indivo is adopting the CCR and also supports standard coding systems such as LOINC.

A conceptual view of Indivo can be illustrated with following figure:

![Conceptual view of Indivo](image)

Figure 1-4: Conceptual view of Indivo (Mandl et al, 2007)

There are other health systems built upon Indivo, such as Dossia (http://www.dossia.org) and MyOscar (http://myoscar.org).

1.4.1.2.2 Google Health

Perhaps one of the most recent newcomers into the PHR field, Google Health (http://www.google.com/health) was released to public as a beta-test service in early 2008. Users are required to have a valid Google account to be able to use the free service. All users may enter their own notes. Currently (2010) Google has contracts with various national American service providers such as laboratory chains to allow them to directly upload patient results into Google Health (with the permission of each patient).
Developers from Google claim that Google Health is different from other PHRs for its strong privacy and security control and platform strategy. Platform strategy allows Google Health to interoperate with many third-party services, which ideally means easier communication. Users will eventually have the benefits of being able to schedule appointments, or refill prescriptions with third-party services through Google Health.

Google Health is currently accepting incoming data in the CCR format, albeit only a portion of the CCR standard specification is implemented. Google Health’s own documentation of its CCR comprises all information needed to store health information in the PHR.

Users are also able to import their medical records, or convert their paper records if they own one, from Google approved third-party health service into their Google Health profile for some fees as charged by each of these services.

Similar to other web-based PHRs, Google Health requires its users to register an account if they don’t already have “Google Account”. Once they have an account registered to Google Health, they can start creating health profiles. A health profiles describe one person’s health information, which means for one Google Health account, user can create more than one profile, i.e. more than one person’s health profile. This could encourage a person to help create and manage a health profile for somebody else, e.g. spouse or child.

Google Health server itself is divided into two types, a sand-box as to separate developers to work with actual patient data in development and testing phase and the actual server. The sand-box server is called h9 server while the actual server is called Google Health server.

![Figure 1-5: Google Health preview](image)
1.4.1.2.3 Microsoft Health Vault

Another PHR is Microsoft Health Vault(http://www.healthvault.com). Possibly the main characteristic of Health Vault that differentiates it from other similar services is the range of special health devices that are designed to specifically work with Health Vault. A simple device such as blood pressure monitor and weight scale can be synchronized to Health Vault.

According to its documentation, Health Vault is accepting the CCR as well as CCD to store clinical documents. Internally, Health Vault is storing all health information in the entity called HealthVault object, and the mappings from the CCR to this object are documented at the developers’ site.

Microsoft Health Vault also requires user to register in their server before they can start entering health profile to the system.

1.4.1.2.4 Smart PHR

SmartPHR(http://www.smartphr.com) is a subscription-based PHR, which means that the user will have to pay fees to enjoy the service. SmartPHR is also a web-based PHR, where all patients’ information is stored securely in the remote server and accessible by any web-connected devices.

It is promoting the use of HL7 CCD as their document structure and permits patients to export their most recent CCDs to USB key fobs, record banks, or print out and store them at home.

1.4.2 Basis of communication

In contrast with the communication basis in general case where English language is widely used for this purpose, by using information technologies separate set of standards are required which includes the vocabulary (or domain) standards and also messaging standards.

1.4.2.1 Messaging Standards

Messaging standards ensure that two information systems communicate with the same format to reduce or even eliminate possible ambiguous interpretation and also less time consuming. There are several standards developed by organizations such as:

1.4.2.1.1 HL 7

As mentioned earlier in Problem Statement, Health Level 7 (HL7) aimed to achieve interoperability in health information technology.

Even before 1999, HL7 greatly assisted the development of the automation of healthcare and deployment of information systems as one of the first initiatives actively working on developing
universally recognized standards (Quinn, 1999). Now, most of the HL7 standards are approved by international standard organizations such as ISO and ANSI.

HL7 is also engaging itself to work with a health document standard (HL7 CDA), visual integration (CCOW / Visual Integration), electronic attachment (Claims Attachment) and other health care related standards.

Generally, HL7 messages are transferred between health systems using TCP/IP sockets - one for outgoing messages and another for incoming messages - between the hospital’s interface manager and local HL7 clinical applications. All messages received are acknowledged according to the HL7 protocols.

HL7 v2.x and HL7 v3 are the two most well-known standards, each with very distinctive characteristics. HL7 v2.x is a message-based standard using ‘pipes’ and ‘hats’ encoding to store information. HL7 v2.x versions are compatible and more widely used, as version 2 was introduced much earlier than HL7 v3, and there were no other standards as sophisticated at the time. The HL7 v3 standard defines models for messages, documents and services based on Reference Model (RIM). In practice, the most widely adopted part of the HL7 v3 standard is the CDA (Clinical Document Architecture); the CDA is an XML-based clinical document for data exchange. More discussion of HL7 v3 CDA is in section HL7 v3.0 CDA.

Each HL7 v2.x message is structured with a tag to identify the field (or referred as segment) followed by the actual message content.

<table>
<thead>
<tr>
<th>MSH</th>
<th>Message Header Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>[</td>
<td></td>
</tr>
<tr>
<td>EVN</td>
<td>Event type segment</td>
</tr>
<tr>
<td>PID</td>
<td>Patient Identification segment</td>
</tr>
<tr>
<td>[PD1]</td>
<td>Patient Additional Demographic segment</td>
</tr>
<tr>
<td>[PV1]</td>
<td>Patient Visit segment</td>
</tr>
<tr>
<td>]</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 1-6: HL7 v2.x ADT (Admission, Discharge and Transfer) Structure*
The following figure shows a sample of a HL7 ADT message format that conforms to HL7 v2.3.1.

```
MSH|\&|APP|APP|MYapp1|Myapp2|200309121053||ADT^A08|1063360560218C000.1.|P|2.3||AL|NE
EVN|A08|200309121053||10432
PID||000698172^^^^U|000698172^^^M^D~7652981726^^^^M^N~03C0021227^^^^X~03P0065142^^^^X~UV01-1064^^^^X~U00-11766^^^^X~C01-2297^^^^X~A01-17865^^^^X~M98-4077^^^^X|BROWN^TINA^^^MRS|19270204|F||7 James Road^Basilmirt^CARFIFF^^CF4 0TE||0101 465
76254||2||6125261719| || || ||00000000
PD1||MARSEDON HEALTH CENTRE^^?|G8327615^PRESTLEY
PV1||
```

Figure 1-7: Example of HL7 v2.x ADT Message
The next figure shows one sample of a HL7 v3 message.

```xml
<POLB_IN224200 ITSVersion="XML_1.0" xmlns="urn:hl7-org:v3"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <id root="2.16.840.1.113883.19.1122.7" extension="CNTRL-3456"/>
  <creationTime value="200202150930-0400"/>
  <!-- The version of the datatypes/RIM/vocabulary used is that of May 2006 -->
  <versionCode code="2006-05"/>
  <!-- interaction id= Observation Event Complete, w/o Receiver Responsibilities -->
  <interactionId root="2.16.840.1.113883.1.6" extension="POLB_IN224200"/>
  <processingCode code="P"/>
  <processingModeCode nullFlavor="OTH"/>
  <acceptAckCode code="ER"/>
  <receiver typeCode="RCV">
    <device classCode="DEV" determinerCode="INSTANCE">
      <id extension="GHH LAB" root="2.16.840.1.113883.19.1122.1"/>
      <asLocatedEntity classCode="LOCE">
        <location classCode="PLC" determinerCode="INSTANCE">
          <id root="2.16.840.1.113883.19.1122.2" extension="ELAB-3"/>
        </location>
        </asLocatedEntity>
      </device>
    </receiver>
    <sender typeCode="SND">
      <device classCode="DEV" determinerCode="INSTANCE">
        <id root="2.16.840.1.113883.19.1122.1" extension="GHH OE"/>
        <asLocatedEntity classCode="LOCE">
          <location classCode="PLC" determinerCode="INSTANCE">
            <id root="2.16.840.1.113883.19.1122.2" extension="BLDG24"/>
          </location>
        </asLocatedEntity>
      </device>
    </sender>
  </receiver>
</POLB_IN224200>
```

Figure 1-8: Sample HL7 v3 message
Clinical HISs, as mentioned in 1.4.1. Clinical/Hospital System, use HL7 messaging standard to send patients’ information in real time among departments inside the health institution. However some of the mentioned HISs have not fully implemented the whole HL7 standard, such as myCare2x which at the moment only supports some of them.

HL7 itself while a sophisticated and carefully designed messaging standard, is not of ‘plug and play’ concept. This is due to different interpretations of the HL7 standard by different vendors, different customer requirements that does not fit in HL7 exactly, or various other reasons. This can cause in some intended values to appear in different segments for different systems, or missing mandatory value. Many HL7 interface engine are developed to mitigate these problems.

1.4.2.1.2 CCR

The Continuity of Care Record (CCR) is a standard specification developed jointly by ASTM International, the Massachusetts Medical Society (MMS), the Health Information Management and Systems Society (HIMSS), and the American Academy of Family Physicians (AAFP).

The CCR was developed and enhanced in response to the need to organize and make transportable a set of basic patient information consisting of the most relevant and timely facts about a patient’s condition. Briefly, these include patient and provider information, insurance information, patient’s health status (e.g., allergies, medications, vital signs, diagnoses, and recent procedures), recent care provided, as well as recommendations for future care (care plan) and the reason for referral or transfer. This minimum data set will enhance the continuity of care by providing a method for communicating the most relevant information about a patient and providing both context and support for the electronic health record (EHR) through extensions.

Unlike many other standards, clinicians were actively involved in creation of the CCR and were integral to defining its form and content (Ferranti et al., 2006). Ideally, the content for any individual CCR is defined by the provider who knows the patient well.

According to Ferranti et al. (2006) one advantage the CCR version 1 has over other standards is its light-weight, easy implemented approach, and also its focus on exchange of health summaries. CCR underwent a significant change from version 1 to 1a whereby the data model changed from document-based to object-relational data model. While it enhances level of detail of the CCR, implementation of this version became more complex compared to the previous version.

Two figures which follow show the conceptual model of the CCR and a sample the CCR record document.
<table>
<thead>
<tr>
<th>Document Identifying Information</th>
<th>Optional Extension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Identifying Information</td>
<td>Optional Extension</td>
</tr>
<tr>
<td>Insurance and Financial Info</td>
<td>Extension: Eligibility, Co-payment, etc.</td>
</tr>
<tr>
<td>Health Status of Patient</td>
<td>Extension: Disease Management-specific Info</td>
</tr>
<tr>
<td></td>
<td>Extension: Personal Health Record Info Documented by the Patient</td>
</tr>
<tr>
<td></td>
<td>Extension: Immuizations</td>
</tr>
<tr>
<td></td>
<td>Extension: Vital Signs</td>
</tr>
<tr>
<td></td>
<td>Extension: Lab Results</td>
</tr>
<tr>
<td></td>
<td>Extension: Procedures/Assessments</td>
</tr>
<tr>
<td></td>
<td>Extension: Current Medications</td>
</tr>
<tr>
<td></td>
<td>Extension: Diagnosis/Problems/Conditions</td>
</tr>
<tr>
<td></td>
<td>Extension: Adverse Reaction/Alerts</td>
</tr>
<tr>
<td></td>
<td>Extension: Med. Specialty-specific Info</td>
</tr>
<tr>
<td></td>
<td>Extension: Personal Health Record Info Documented by the Patient</td>
</tr>
<tr>
<td></td>
<td>Extension: Immunizations</td>
</tr>
<tr>
<td></td>
<td>Extension: Vital Signs</td>
</tr>
<tr>
<td></td>
<td>Extension: Lab Results</td>
</tr>
<tr>
<td></td>
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<td></td>
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</tr>
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<td></td>
<td>Extension: Diagnosis/Problems/Conditions</td>
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<td></td>
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<td></td>
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<td>Extension: Personal Health Record Info Documented by the Patient</td>
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<tr>
<td></td>
<td>Extension: Immunizations</td>
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<td></td>
<td>Extension: Vital Signs</td>
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<tr>
<td></td>
<td>Extension: Lab Results</td>
</tr>
<tr>
<td></td>
<td>Extension: Procedures/Assessments</td>
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<tr>
<td></td>
<td>Extension: Current Medications</td>
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<td>Extension: Diagnosis/Problems/Conditions</td>
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<td></td>
<td>Extension: Adverse Reaction/Alerts</td>
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<td></td>
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<td></td>
<td>Extension: Personal Health Record Info Documented by the Patient</td>
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<td></td>
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<td>Extension: Med. Specialty-specific Info</td>
</tr>
<tr>
<td></td>
<td>Extension: Personal Health Record Info Documented by the Patient</td>
</tr>
</tbody>
</table>

Mandated Core Elements of the CCR

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Figure 1-9: Conceptual Model of the CCR version 2.1b [www.astm.org/COMMIT/E31_ConceptPaper.doc - accessed 06/11/2009]

```xml
<FamilyHistory>
  <FamilyProblemHistory>
    <CCRDatablockID>BB0001</CCRDatablockID>
    <DateTime>
      <Type><Text>Onset</Text></Type>
      <Age>
        <Value>57</Value>
        <Units><Unit>Years</Unit></Units>
      </Age>
    </DateTime>
    <Source><Actor><ActorID>AA0002</ActorID></Actor></Source>
    <!-- Note: AA0002 is a code referencing the physician who entered the data -->
    <FamilyMember>
      <ActorID>AA0002</ActorID>
      <ActorRole><Text>Father</Text></ActorRole>
      <HealthStatus>
        <Description><Text>Deceased</Text></Description>
        <CauseOfDeath><Text>Yes</Text></CauseOfDeath>
        <Source><Actor><ActorID>AA0002</ActorID></Actor></Source>
      </HealthStatus>
      <Source><Actor><ActorID>AA0002</ActorID></Actor></Source>
    </FamilyMember>
    <Problem>
      <Type><Text>Diagnosis</Text></Type>
      <Description>
        <Text>Myocardial Infarction</Text>
      </Description>
      <Code>
        <Value>22298005</Value>
        <CodingSystem>SNOMED CT</CodingSystem>
        <Version>2005</Version>
      </Code>
      <Source><Actor><ActorID>AA0002</ActorID></Actor></Source>
    </Problem>
  </FamilyProblemHistory>
</FamilyHistory>
```

Figure 1-10: Sample of the CCR (Ferranti et al., 2006)
One important thing to note about the CCR is that it is not designed to be a complete EHR, rather an overview or ‘snapshot’ or patient health summary, to address the need for continuity of care from one provider or practitioner to any other practitioner. For example it does not list symptoms as its primary function. Rather it lists diagnoses and the “Reason for Referral” to the next provider or diagnostician.

Due to the way it’s structured to collect the snapshots of patient health summary, many personally controlled health record systems adapted to this standard - such as Google Health and Microsoft Health Vault.

1.4.2.1.3 EDI

Electronic Data Interchange (EDI) promotes the transfer of structured data by an agreed message standard from one computer system to another without human intervention. EDI is used by the vast majority of electronic commerce transactions in the world.

EDI was one of the pioneer message standards in communicating health information (Branger & Duisterhout, 1991), and since then brought promising potential of improving quality of health care.

1.4.2.2 Health Record Standard

A health record standard is a standard to define how health information regarding patient should be structured for easier storing, transportation and preserve information as a whole. Though there are many standards involved in medical records, only those that describe general patient health information are explained here.

1.4.2.2.1 XML

The eXtensible Markup Language (XML) was proposed by the World Wide Web Consortium (W3C) to provide structured information to the Web. XML can be used in many different domains non-exclusive to health care. XML allows a standard way of searching, displaying, manipulating, and exchanging data on the Web. It can also be used to identify, exchange, and process distributed data in different applications (Zisman, 2000).

XML can be said to be the root of other data structure standards because other standards are actually extending XML and structuring it to be applicable in the health industry. The HL7 CDA, the CCR and ASTM E1384 are examples of derived standards. As signified by the name, XML uses mark-up language in forms of tags similar to HTML but with no predefined tags. Users are to create their own tags, thus providing huge flexibility which can be used in many forms of applications.
1.4.2.2 HL 7 v3.0 CDA

A CDA (Clinical Document Architecture) is a document mark-up standard that specifies the structure and semantics of a clinical document (such as a discharge summary or progress note) for the purpose of exchange. A CDA document is a set of complete information objects that can include text, images, sounds, and other multimedia content. It can also be transferred within a message and can exist independently, outside the transferring message (Dolin et al., 2005).

A CDA document has a header and a body. The header identifies and classifies the document and provides information on authentication, the encounter, the patient and the involved providers.

The first release of HL7 CDA in 2000 represented the first specification derived from the HL7 Reference Information Model (RIM) (Dolin et al., 2001). RIM is a large, pictorial representation of the HL7 clinical data (domains) and identifies the life cycle that a message or groups of related messages will carry. It is a shared model between all domains and, as such, is the model from which all domains create their messages. The RIM is an ANSI approved standard.

The second release of HL7 CDA was approved by ANSI in 2005. The main difference from the first release is that in the CDA R2 both header and body are fully RIM derived whereas only the header is derived from RIM in R1. The CDA also uses HL7 V3 data types to provide mechanism of adopting standard vocabulary systems.

An example of HL7 CDA R2 object model can be seen in the following figure that shows portions of the header, document body, and the connections among them.

![Figure 1-11: HL7 CDA R2](image)
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The next figure shows the XML view of a CDA

```xml
<?xml version="1.0" encoding="UTF-8"?>
  <nl:ActingAuthor>
    <nl:AssignedPerson>
      <nl:Name>
        <nl:family>Smith</nl:family>
        <nl:given>James</nl:given>
      </nl:Name>
      <nl:Role>
        <nl:nc:Code system="urn:hl7:atlas:CDA:2016:03" code="MD" extension=""/>
      </nl:Role>
    </nl:AssignedPerson>
    <nl:AssignedEntity>
      <nl:time value="2006-05-01"/>
      <nl:signatureCode code="8"/>
    </nl:AssignedEntity>
    <nl:id extension="3" root="1.3.6.1.4.1.2835.1"/>
    <nl:streetAddressLine>120 Newton Road</nl:streetAddressLine>
    <nl:city>St. John's</nl:city>
    <nl:state>NS</nl:state>
    <nl:postalCode>AB6 7AB</nl:postalCode>
    <nl:country>Canada</nl:country>
  </nl:ActingAuthor>
  <nl:authenticator>
    <nl:AssignedEntity>
      <nl:time value="2006-05-01"/>
      <nl:signatureCode code="8"/>
    </nl:AssignedEntity>
    <nl:streetAddressLine>120 Newton Road</nl:streetAddressLine>
    <nl:city>St. John's</nl:city>
    <nl:state>NS</nl:state>
    <nl:postalCode>AB6 7AB</nl:postalCode>
    <nl:country>Canada</nl:country>
  </nl:authenticator>
  <nl:authenticator2>
    <nl:AssignedEntity>
      <nl:time value="2006-05-01"/>
      <nl:signatureCode code="8"/>
    </nl:AssignedEntity>
    <nl:streetAddressLine>120 Newton Road</nl:streetAddressLine>
    <nl:city>St. John's</nl:city>
    <nl:state>NS</nl:state>
    <nl:postalCode>AB6 7AB</nl:postalCode>
    <nl:country>Canada</nl:country>
  </nl:authenticator2>
  <nl:authenticator3>
    <nl:AssignedEntity>
      <nl:time value="2006-05-01"/>
      <nl:signatureCode code="8"/>
    </nl:AssignedEntity>
    <nl:streetAddressLine>120 Newton Road</nl:streetAddressLine>
    <nl:city>St. John's</nl:city>
    <nl:state>NS</nl:state>
    <nl:postalCode>AB6 7AB</nl:postalCode>
    <nl:country>Canada</nl:country>
  </nl:authenticator3>
  <nl:communicator>
    <nl:AssignedEntity>
      <nl:time value="2006-05-01"/>
      <nl:signatureCode code="8"/>
    </nl:AssignedEntity>
    <nl:streetAddressLine>120 Newton Road</nl:streetAddressLine>
    <nl:city>St. John's</nl:city>
    <nl:state>NS</nl:state>
    <nl:postalCode>AB6 7AB</nl:postalCode>
    <nl:country>Canada</nl:country>
  </nl:communicator>
  <nl:effectiveTime value="2006-05-01"/>
  <nl:identifier>
    <nl:code system="urn:hl7:atlas:CDA:2016:03" code="NA"/>
    <nl:codeSystem value="urn:hl7:atlas:CDA:2016:03"/>
    <nl:versionNumber value="1"/>
    <nl:extension>
      <nl:code system="urn:hl7:atlas:CDA:2016:03" code=""/>
      <nl:codeSystem value="urn:hl7:atlas:CDA:2016:03"/>
      <nl:versionNumber value="1"/>
    </nl:extension>
    <nl:templateId>
      <nl:code system="urn:hl7:atlas:CDA:2016:03" code=""/>
      <nl:codeSystem value="urn:hl7:atlas:CDA:2016:03"/>
      <nl:versionNumber value="1"/>
    </nl:templateId>
    <nl:title>
      <nl:code system="urn:hl7:atlas:CDA:2016:03" code=""/>
      <nl:codeSystem value="urn:hl7:atlas:CDA:2016:03"/>
      <nl:versionNumber value="1"/>
    </nl:title>
    <nl:languageCode value="en-CA"/>
    <nl:scriptId value="urn:hl7:atlas:CDA:2016:03"/>
    <nl:effectiveTime value="2006-05-01"/>
    <nl:identifier/>
    <nl:templateId/>
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Vocabularies in health systems are collections of distinct medical terms (in English up to now). They attempt to be complete. If all medical records and communications agreed on and used the same vocabulary, then the potential for misunderstanding would be reduced. Vocabularies allow encoding of discrete information in a meaningful way, increasing efficiency and consistency in clinical data collection.

1.4.2.3.1 ICD

International Classification of Diseases and Related Health Problem (ICD) historically already began in the 17\textsuperscript{th} century, although back then it was used to code disease related to fatal conditions. ICD has gone through many revisions since then, and finally in 1983 the WHO took control of ICD, and the project working on 10\textsuperscript{th} revision of ICD began in 1983. In 1993 the 10\textsuperscript{th} revision came out and was implemented globally.

The purpose of ICD is to permit systematic recording analysis, interpretation and comparison of mortality and morbidity data collected in different countries or areas and at different times. The ICD is used to translate diagnoses of diseases and other health problems from words into an alphanumeric code, which permits easy storage, retrieval and analysis of data (ICD 10\textsuperscript{th} Rev Vol. 2, 2004).
1.4.2.3.2 SNOMED CT

Systematized Nomenclature of Medicine (SNOMED) has been under development by the College of
American Pathologists since the 1970s. It was designed to address deficiencies of existing terminologies
at that time by developing new, more comprehensive thesauri (Mayo Clin Proc, 2006). In the 1980s, an
equivalent standard bearing the name Clinical Terms began as Read Codes and gained popularity in the
UK. Both of them are comprehensive controlled medical terminologies with reference properties that
support enumerative and compositional functionality.

In 1999, the College of American Pathologists and the National Health Service in UK agreed to merge
those two standards and come up with the name SNOMED CT. The merging of these two results is a
highly comprehensive terminology (Stearns et al, 2001).

1.4.2.3.3 RxNorm

RxNorm, a standardized nomenclature for clinical drugs and drug delivery devices, is produced by the
National Library of Medicine (NLM). In this context, a clinical drug is a pharmaceutical product given to
(or taken by) a patient with a therapeutic or diagnostic intent. A drug delivery device is a pack that
contains multiple clinical drugs or clinical drugs designed to be administered in a specified sequence. In
RxNorm, the name of a clinical drug combines its ingredients, strengths, and/or form.

The use of RxNorm is supported by messaging standard such as HL7 v2.x and CCR. Google Health also
specifically stated that their server support the use of RxNorm for drugs coding system.

1.4.2.3.4 LOINC

Logical Observation Identifier Names and Codes (LOINC) is a database, covering at least 98% of the
average laboratory’s tests; its intention is to simplify transmission of lab results across systems greatly
(Forrey, 1996).

In the fifth release of the LOINC database, there are already approximately 6300 test observations in
forms of codes, names and synonyms. The LOINC database is freely accessible on the internet for public
use.

In conjunction with LOINC, the Regenstrief Institute (Indianapolis, Indiana, USA) provides a windows-
based mapping utility called Regenstrief LOINC Mapping Assistant (RELMA) to facilitate searching
through LOINC database either by installing RELMA program or by running it through a browser.
(http://loinc.org/relma)
1.4.2.3.5 ICPC-2

ICPC stands for International Classification for Primary Care and was first published in 1987 by WONCA (World Organization of National Colleges, Academies and Academic Associations of General Practitioners/Family Physicians) International Classification Committee (WICC) as ICPC-1 and later published in 1998 as ICPC-2. ICPC-2 contains 17 chapters.

The main purpose of ICPC is to order the domain of family practice, for better understanding of its content. It covers the relationships between reasons for encounter and diagnoses, together with the diagnostic and therapeutic interventions, at the start and during follow-up of episodes of care (‘transitions’), and form the basis for knowledge of morbidity patterns in family practice (Okkes et al. 2002).

There exist many health systems with many characteristics and scope to fit the need of different health organizations. Some are enterprise systems designed to manage information in large institutions while there are some doing only specific tasks, such as OSPACS which is an ultrasound image management system (Scott et al., 2008).

1.4.3 Problems with Current IT Communication

We have discussed the limitations with communication in general case such as direct communications between practitioners in sections above. We also found that the problems arising from direct communication can be cured with the help of information systems, such as patient’s information is accessible anytime and anywhere without having to call other practitioner which may not be available at that moment. However, by using information system there are some notable limitations that hinders the full utilization of the information systems.

1.4.3.1 Integration Issues

As discussed earlier, general practices, hospitals and clinics do not really communicate well with each other. The communication levels are too shallow and do not provide sufficient information to convey complete understanding of the treated patient. When it comes to computerization, developing a health care system to be used uniformly everywhere is close to impossible because of many factors such as cultural differences, laws and regulations, etc. This leadsto many types of health care management systems implemented in various hospitals or other health organizations, hence communication becomes an issue.

One of the examples of communication and integration failure is lack of comparable data, which can directly impact patient care. A simple study case for this example: the use by physical therapists of a pain scale that ranges from 1 to 4, and another used by nurses that ranges from 1 to 10. Obviously, pain
designated at ‘level 3’ carries vastly different meanings to these professionals (Rada, 2001).

Comparability requires that the meaning of data is consistent when shared among different parties. Standard healthcare vocabularies would assure that data shared across systems are comparable at the most detailed level.

Taking example from Indonesia’s health care systems, communicating health information between health institutions are done by summarizing the health information from local data storage (either paper or electronic) onto paper, before handed over physically to the other institution, which costs some extra effort and is time consuming.

1.4.3.2 Different standards

There are many HIS running throughout different regions or at different levels of health providers, this in turn affects what kind of standards they are using, in particular the structure of health records and communication standards.

The use of different standards can be limiting, as communication is only possible between systems which agree to the same or inter-operable standards.

Forcing different systems to adopt the same standard is not the perfect solution because each system tried to adopt standard that is correct in their own context. Hospital systems, for example, are using HL7 because of the need to communicate real time information across departments while Personal Health Record systems are more interested in the snapshot of patient’s health record and chose to adopt CCR which serves the same purpose.

1.4.3.3 Cost

Implementing a HIS can be very expensive. In Australia, for example, health is already one of the most expensive sectors of the economy, at 9.3% of GDP; and by 2045 this allocation is predicted to rise to at least 16% (Westbrook et al. 2009).

High-cost HISs are not very suitable, especially for developing countries such as Indonesia where ICT is not yet well developed and which has a low health budget of 2.2% of GDP (WHO recommended 5%) (http://www.depkes.go.id/downloads/SKN+.PDF).

Integrating Health Information of disparate sources is a very heavy task. According to Detmer et al. (2008), “there is a general lack of affordable, out-of-the-box integration solutions to handle cleansing, formatting, and mapping of health information from multiple sources into coherent and meaningful format.” Usually the cost of connecting existing health systems to other systems exceeds the planned budget.
1.5 Analysis of Other Available Solutions

As part of an effort to integrate different health care systems implementing different standards, there has been other work in the related field to translate between different widely-used standards, such as HL7 v2.x and CCR.

Wide ranges of interface engines to help integrating different HISs are out in the market (though mostly are aimed for HL7 due to its non-plug-and-play nature). Some of them for example: Iguana Interface Engine (http://www.interfaceware.com/iguana.html) and CorePoint Integration Engine (used to be called NeoTool) (http://www.corepointthehealth.com/). Iguana expands the limitations of most of conventional integration engine that focuses too much on HL7 by supporting a lot more formats such as XML (as the underlying format used by CCR), X12 and many others, allowing ‘endless integration possibilities’. And the latter explicitly claims that it supports HL7 CCD and CCR format, though there is no evident of the result shown in their websites to prove their advertised capabilities.

Aquifer CCRViewPort (http://www.continuityofcarerecord.info/) is a free web tool offered by Solventus (http://www.solventus.com) to helps practitioners create/view/send CCR profile of their patient for the purpose of referrals. One of the notable features of the CCRViewPort is the automatic conversion from HL7 v2.x into CCR, where the practitioner can import a HL7 file into the CCRViewPort and the CCR version of the message is displayed on the browser.

The converter was able to extract portions of HL7 v2.x message into CCR main elements such as AL1 segment into Alerts and PID into Patient. The CCR can be further edited to allow user to add missing values. The system itself is still a beta but hints the importance of translation between HL7 and CCR messages, albeit the system allows only HL7 to CCR translation.

1.6 Proposed Solution

As being mentioned earlier, Indonesia and other developing countries are facing the problems of having one integrated health care system due to several factors such as cost, geographically scattered locations and low IT coverage in rural areas.

1.6.1 A PHR as a way to EHRs in Developing Countries

Full computerization of hospitals requires great sums of money, and the final result does not ensure fully integrated health information network as envisioned by SIKNAS, the National Health System. By looking at centralized PHRs such as Google Health, it could be a potential cost-saving approach to have an integrated health information databank to which all different hospital systems can connect in as many ways as possible. A PHR promotes high availability, ease of access and faster way of accessing data.
A centralized PHR is also in line with the vision of the National Health System designed by Ministry of Health of Indonesia, as can be seen from Chapter 2 Section A.5: Manajemen dan Informasi Kesehatan (Management of Health Information) (http://www.depkes.go.id/downloads/SKN%20final.pdf), stating that some of the problems that are faced by the nation include data and health information which are not available in real time.

Referring back to section 1.2.1. History of health care in Indonesia, one of the figures shows the single point of common information data centre accessed by hospitals and clinics looks very similar to our proposed solution. This shows that the development of information systems for health care is moving to integrated health information sharing, and we provide a possibly more affordable solution to the same problem.

### 1.6.2 Integrate a PHR with Existing HISs

Among available health systems, those systems bearing the title of open-source should have greater popularity and demand because they represent a real cost-saving choice in the field compared to more expensive proprietary software (Yi et al., 2008). In developing countries such as Indonesia whose budget in health sector is still minimal, as discussed earlier, such open-source health systems can be seen as a useful choice. myCare2x as one of the complete suites of HIS for hospitals could be one of those.

In conjunction to hospital HIS we are going to choose a PHR and we will try to link the two of them together in a seamless communication manner. The chosen PHR must also be open-source and extendable. Google Health provides the capability of extension and it is up to this point free to use. Another major point of Google Health is that it is also envisioning integrated health care systems across all levels of health care providers to the Google Health.

### 1.6.3 Introduce Middleware/Gateway for Integration

As noted with the limitations of each HIS to exchange messages with others (because each HIS establishes its own standard), we are going to introduce middleware to mediate communication between the chosen HISs. There are many middleware options that provide such a function, however, MIRTH is one middleware that is specifically trying to address health care interoperability and is also open-source.

MIRTH (http://www.mirthcorp.com/) is a gateway application written in Java to empower health care interoperability. It supports HL7 v.2.x, XML, DICOM, and EDI among other standards. Currently (2011) it does not support the CCR, at least not explicitly.

The main purpose of the gateway is for us to put our translation package in its framework and let the gateway handle the input and destination routing while our package specifically do the translation.
1.6.4 Choose Communication Standards for Integration

Among the many standards mentioned above, the CCR is the one that captures patient information at any given point of time in a simple and structured format. While HL7 v2.x is an extensively used health messaging standard, it also comprises many different standard specifications, and many HISs fail to implement all of them. This results in many HISs not inter-operating with each other because they implement different parts of different versions of the HL7 v2.x standard.

The CCR is based on the all-familiar XML format and at this time is supported by Google Health, IndivoHealth, Dossia and Microsoft Health Vault among others, which is also a main reason we are aiming at this standard.

MIRTH as the gateway does not yet support the CCR, nor does myCare2x. By trying to implement the CCR translation in MIRTH, we are looking into a well-established gateway to redirect and translate any messaging standard from any HIS, which means that every HIS (PHR included) does not have to worry about what kind of messaging standard they are using; instead they will ask the middleware to handle all communication as a mediator, thus eliminating the fuss from the HIS side.
2 METHODOLOGY

2.1 Survey to establish current status of HISs in Indonesia

To provide greater depth of understanding the current HIS solution in a developing country such as Indonesia, and also to support this proposal, a brief investigation of the conditions of health care providers in the field is conducted.

This sort of interview is not carried out to provide us with statistical data, but rather to confirm the existence of the problem as mentioned in 1.1 Problem Statement, i.e. poor level computerization in hospitals and limited or no integration between different systems. (Statistical confirmation comes from the Ministry of Health as described above.)

The method applied for this research is phone interview to different levels of health provider with sets of questions; some related to general procedure or practice of the health provider and some related to the use of IT to conduct activities. Below is the interview question sheet used.
Survey on Communications methods in Indonesian Healthcare Facilities

General

- Name (of institution): _____________________________
- Address: ________________________________
- Phone: ________________________________
- Email: ________________________________

- Type of the institution, private/government funded, clinic/hospital, etc?
  __________________________________________________________
  __________________________________________________________
  __________________________________________________________

- What are the services provided by the hospital/clinic/practice currently?
  __________________________________________________________
  __________________________________________________________
  __________________________________________________________

- How many of:
  - Doctors: __
  - Nurses: __
  - Beds: __
  - Outpatients / Month: __
  - Inpatients / Month: ___

Figure 2-1: First page of interview form
The results of these interviews should confirm the status of HISs and healthcare communications among providers in Indonesia as a representative developing nation. The results should thus confirm the need not only for HISs, but also for standardized communications among healthcare providers (and their HISs).
2.2 Requirements

By examining the problems that we find with integration and communication issues of health care information systems, we derive the following requirements for successful communications between different EHR and messaging standards.

2.2.1 Communication gateway

To achieve the highest level of interoperability among HISs, it is of utmost importance to be able to communicate health information in a seamless way using an agreed communication protocol and document standard. While this is a seemingly perfect solution for this matter, the growing numbers of standards become a great obstacle that prevents many HISs from communicating with each other.

Thus, the proposed solution requires a communication server that acts to mediate communication between different HISs that transmit messages in various standards. This way, all HISs that use the communication gateway can be completely independent of the types of standards the other HISs are using; this will all be handled by the communication gateway.

An ideal communication gateway to facilitate the communication between HIS would be a single point of interaction that sits in the middle and has the following properties:

A. Translation between different types of messages

B. Message handling

C. Supports many transmission protocols

D. Platform independent

E. Modular architecture

F. Open source

G. High level of reliability

2.2.1.1 Translation between different types of messages

One of the main concerns in the translation process of standards is the difference of original intents of each of the standards such as HL7 v2.x and the CCR. HL7 v2.x is designed to communicate real-time patient information (patient is admitted, discharged, moved to another ward, etc.), while the CCR is designed to capture the summary of patient information. According to Shaver (2006), the difference between the standards boils down to the facts that HL7 is focused on intra-facility, real time data
movement — what is happening now? — while the CCR is focused on inter-facility, “summarized” data movement — what happened before now or up to now?

2.2.1.2 Message handling

Due to many different types of messages from various sources coming to the communication gateway, sophisticated message handling becomes a crucial factor in the performance of the gateway. The protocol of deciding which message input to be translated to which standard, what and where is the message’s destination, and how the message should be sent, should exist and be easily modifiable.

Message handling where there is no need for user (doctor, patient or even IT administrator) involvement in the process is very desirable. This is in keeping with better delivery of quality care; when most tasks are automated, delays while a system is waiting for user input can be avoided, thus saving a lot of time.

2.2.1.3 Supports many transmission protocols

Since the gateway will be dealing with many types of HIS that operate on different platforms, having a selection of transmission protocols is essential to ensure that the gateway is capable of receiving or sending messages in many transmission protocols. Some of the popular transmission protocols are: HTTP, FTP, LLP, disk files and TCP.

2.2.1.4 Platform independent

The gateway should be independent of the operating system each of the clients might use, or what types of browser the client might use to access the server in terms of Web-based access.

2.2.1.5 Modular architecture

The use of modular architecture will improve the scalability of the system. Using a modular approach, further extension to the system (which is likely to happen) can be made possible without disturbing the original system and without much hassle.

2.2.1.6 Open source

While proprietary packages offer better support from their developer, open-source is preferred because we are looking for a low-cost solution and at the same time hope to achieve the desired results. Open source packages are also more transparent in case developers seek the actual source code of the program.
Transformation between HL7 and CCR

One example application of successful open-source systems integration in Health Care is Epivue application framework, which is “composed exclusively of publicly available open-source technologies, can serve as a prototype for building low-cost public health visualization and assessment systems.” (Yi et al., 2008)

2.2.1.7 High level of reliability

Being a communication server, a high level of reliability cannot be ignored. The system is expected to be up most of the time (commercial expectations range from 99 to 99.99% of uptime compared to downtime), and always perform at highest efficiency and effectiveness. All system errors and faults must be reported and the system must decide whether to continue the operation or to abort the whole operation.

2.2.2 Hospital Health Information System (HIS)

We require a Hospital Information System or a general Health Information System to test the proposed solution. The required attributes of such are hereby listed and explained in detail.

2.2.2.1 Open source

The reason is explained in the section above. Alternatively, we could use a HIS to which we have continual access.

2.2.2.2 Standards compliance

The required HIS should work with widely acknowledged standards. The HIS should be able to read and write patient health information in an internationally recognized standard, preferably HL7 or CCR.

2.2.2.3 Support communication channel

In order to communicate and share the information of certain patient the HIS should support at least one communication channel. Some popular communication channels are HTTP, FTP, LLP, SMS, etc.

2.2.2.4 Implementation ready

The HIS chosen for the testing must have been deployed and running in a real world application to ensure its readiness and completeness to handle daily hospital or general practice activity. Such a requirement is to make sure that the proposed solution is real-world applicable by the end of this project.
2.2.3  PHR

The PHR involved in the interoperability solution shall have the same requirements as the HIS described above, with additional points.

2.2.3.1  High Reliability and Availability

Since almost every PHR is web-based and managed by a third party (not hospital), reliability and availability must be at the level where a patient’s data must be easily accessible, but with secure and controlled access, and the PHR provider should be able to ensure maximum system uptime.

2.3  Design of the Mapping

To translate between the two popular standards; CCR and HL7 v2.x, we establish meaningful mapping that match each elements in each standards that correlate to each other. We started with CCR to HL7 v2.x translation before we design the translation of the opposite direction.

2.3.1  CCR to HL7 v2.x Translation

When translating from CCR to HL7 v2.x, we consider how the CCR is structured as an input and also looking for the factors that challenge the translation for a correct and meaningful HL7 v2.x message.

2.3.1.1  CCR Input Structure

CCR input for the translation follows the standard description as published by ASTM E 2369 – 05 (Standard Specification for Continuity of Care Record, ASTM 2005). See the figure below.
A CCR message can be essentially divided into 3 main parts: header, body and footer. Unique identifier, version and language used for the CCR, purpose of the record, to which patient the record belongs to, as well as information about the sender and recipient for the message are located at the header. At the body, actual information regarding the patient is listed according to main categories presented by the CCR standard specification. Footer is used to store all the actor references from the body and header to normalize the CCR, as well as storing other references, comments and signature that is also linked from upper part of the CCR.

Currently there is only version 1.0 released by ASTM, and an XML schema in .xsd format is also provided by the ASTM which be used to help define an XML representation for the CCR data elements (http://www.astm.org/Standards/E2369.htm).
Google declared its customized CCR specification as a subset of the original CCR. The most notable differences are the absence of some main elements of the original CCR such as Advance Directives, Encounters, Plan of Care, etc. See the figure below.

Figure 2-4: Google Health's CCR specification (http://code.google.com/apis/health/ccrg_reference.html)
Since it is a subset, we will be focusing on looking at the full specification of the CCR according to the ASTM rather than narrowing our perspective to only accommodate Google’s CCR specification.

2.3.1.2 CCR -> HL7 v2.x Mapping Table

Remembering that the HL7 v2.X and the CCR standards have been developed for different purposes and scenarios, they will never match perfectly. Each has some functionality and some elements which are not present in the other.

To establish a consistent translation between the CCR and HL7, copies of the standard descriptions were used, for HL7 specifically HL7 version 2.5. Each CCR element was studied, not only for its name, but also for its context and intended usage. Then the HL7 v2.5 documentation was searched for a corresponding element (segment, field, etc.).

In some cases there are several segments in HL7 which can be used for an element in CCR, for example for <Medication>. Since there are several similar segments in HL7 dealing with drugs or medicine (RXG, RXA, RXE, RXO, etc.) some consideration is necessary in order to choose the most suitable HL7 segment for <Medication> mapping.

Looking at the similar segments, they all have rather the same field structure but serve different purposes: RXA for Pharmacy Administration, RXE for Encoded Order, RXG for Pharmacy Give (drugs to patient), and so forth. None of them match the information in CCR <Medication> exactly; they all lack (different) fields. By looking at their intended purposes we narrowed our decisions to two segments: RXG (Pharmacy Give) and RXO (Pharmacy Order). Since there is no explicit indicator in CCR <Medication> to determine whether the medications are “given to the patient” (in which case RXG is more appropriate) or “requested for patient” (RXO), some assumption has to be made. Here we assumed that <Medication> is ‘given to the patient”; thus we will make use of RXG as the matching segment. If in the future some sort of indication can be shown explicitly in CCR, RXO and RXG can be used interchangeably by checking this indicator. RXG contains several of the appropriate fields, but not all; for example, <Route> cannot be found anywhere in RXG; for <Route> the closest matching HL7 field is in the segment RXR.

The following table shows the closest match between the CCR high-level elements and HL7 v2.5 message segments. HL7 segments which are not mentioned do not carry information relevant to the CCR.

<table>
<thead>
<tr>
<th>HL7 Segment</th>
<th>HL7 Segment Description</th>
<th>CCR Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSH</td>
<td>Message Header</td>
<td>&lt;From&gt;,&lt;To&gt;</td>
</tr>
<tr>
<td>PID</td>
<td>Patient Identification</td>
<td>&lt;Patient&gt;</td>
</tr>
<tr>
<td>IN1</td>
<td>Insurance</td>
<td>&lt;Payers&gt;</td>
</tr>
<tr>
<td>AL1</td>
<td>Allergy</td>
<td>&lt;Alerts&gt;</td>
</tr>
<tr>
<td>PR1</td>
<td>Procedures</td>
<td>&lt;Procedures&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Furthermore, to translate a CCR message into HL7, the result should be a HL7 message. HL7 v2.5 recognizes numerous message types, each comprising a collection of segments. We originally thought that the HL7 message ORU^R01 (Observation Report Unsolicited for transmitting laboratory results to other systems) was the closest match to the CCR. However, the ORU^R01 lacked numerous elements which are present in the CCR. Later it was discovered that the HL7 REF (REFerral) message fits more closely to the CCR, but even that lacks a few items which are present in the CCR. So the final output from the CCR-to-HL7 translation would be an “extended” REF message. See Section 2.3.2.2 below.

There are however several issues that have to be addressed when using the translation table:

Section 2.3.1.2.1 Actor link in the CCR

To prevent actor details from appearing multiple times in CCR, all actors (or individuals) are normalized within in the CCR. According to the ASTM specification (2005), normalized means that everything about each individual, organization, location, or system is listed once, and only once, in the CCR and any data that are from, about, or in reference to that individual, organization, location, or system are then linked within the CCR to that one listing.

While this brilliantly shortens the length of the message, a simple map table will not be able to differentiate which information of an individual should go to which segment in HL7. For example, if we are mapping an Actor’s telephone number to HL7, we can insert that number in the PID segment. But, that will only work if that particular Actor is the patient; if the said Actor is actually the Attending Doctor, then the phone number should go to the PV1 segment. And the only way to determine whether the Actor is a patient, a doctor, or other individual, is to trace it back to the CCR body and find out from which element that Actor is linked.
A simple map that shows one-to-one translation between the CCR and HL7 will not suffice to do this. The map table structure has to be changed to smartly distinguish between different actors and afterwards be able to decide where a particular piece of Actor information should go. This however increases the complexity of the map table, although we want an implementing system to easily read the map and understand how the map works.

Another solution is to parse the input file and denormalize the CCR input. Denormalizing the CCR here means to replace every actor link inside the CCR body (except for <Source>, will be explained later) with the actual detailed information regarding that actor, i.e. the content of the corresponding <Actor>. Then, the mapping table can point to specific actor details in the CCR element, such as Patient>Actor>Gender instead of Patient>ActorLink. This solution will allow the map table structure to remain the same, where each element in the CCR will point to exactly one field in HL7.

<Source> elements are not replaced because in almost every <Source> element there is a link to corresponding <Actor> responsible as the source, causing the program to reiterate and replace the actor link with <Actor>. And since there is no matching pair for <Source> tag in HL7 it is safe to ignore the <Source> tags.

### 2.3.1.2.2 Huge Number of CCR Elements

Following the XML schema (XSD) provided by ASTM to help developers better understand the CCR and implement it into their system, we can see that the number of possible CCR elements is too large. Almost all elements in the CCR are layered complex types that ultimately lead to hundreds of thousands or even more possibilities.

Most CCR elements use CodedDescriptionType; a type that is used within the CCR to support the use of either simple text strings or complete, detailed tagging and coding of discrete data (ASTM, 2005).

In the actual implementation, most text-based values are placed within this CodedDescriptionType, but only by putting the values under <Text> sub-element tag, and not the other tags provided by CodedDescriptionType.

Thus, a proposed map table can be seen from the following figure.
The original format of the map is a comma separated value (.csv) file, as shown below, because it is easier to programmatically read a .csv file than a spreadsheet file.
2.3.2 The HL7 v2.x to CCR translation

The process of designing the translation from HL7 v2.x to CCR is also similar to the counterpart; we started with analysing HL7 v2.x input structure and proceed with the mapping table.

2.3.2.1 The HL7 v2.x Input Structure

The input to this prototype will be a HL7 v2.x message because it is aimed towards linking systems that normally work in separate scopes, i.e. a hospital system with personal health record system. HISs which support HL7 v2.x are predominant over those which support HL v3. In countries such as Indonesia there are currently no systems which support HL7 v3.

The preferred message type for our translation package is REF message because it resembles the CCR profile the most (we can match most of the CCR elements to REF segments), even though it is possible to translate other HL7 v2.x messages as long as they contains segments that are recognized in the mapping table.

The messages coming to our prototype must be validated against HL7 v2.x specification, as validation is not part of the prototype’s features. Because of this, there must be a way to ensure every message transmitted to our prototype to be a valid HL7 message. This can be achieved by using middleware (Mirth) that can validate HL7 message. Further discussion of this can be seen in section 2.4.

Due to this, HL7 messages that are customized to fit certain profiles of some health organization might not be correctly translated fully by our package, as we are strictly following the original HL7 v2.x messages specification.

2.3.2.2 HL7 v2.x -> CCR Mapping Table

To have uniform model of mapping table, the same format of mapping table will be applied to HL7 v2.x -> CCR translation, with some necessary modifications.

As mentioned in section 2.3.1.2.2, there are many possible ways to represent a single item in the CCR, thus the function of wild card (*). In this case however, a specific tag to place the value is necessary, which is why there are no wild card (*) characters allowed in the mapping table.

There is also field for special flag as well for some cases where there are extra values to be inserted or unique values to be generated such as CCRDocumentObjectID or CCRDataObjectID. The special flag also allows conditional mapping to extend flexibility of the mapping.

The special flag column allows more values by separating each of the values by pipe delimiter (|) and allow chaining of different flags with ampersand (&). These will be explained in detail in 3.2.5.2

Converting HL7 v2.x to CCR
Figure 2-7: Spread sheet presentation of the map table

<table>
<thead>
<tr>
<th>From ActOrLink ActOrID</th>
<th>From ActOrLink ActOrRole</th>
<th>To ActOrLink ActOrID</th>
<th>To ActOrLink ActOrRole</th>
<th>Language Text</th>
<th>PID</th>
<th>Special Flag</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSH</td>
<td>MSH</td>
<td>MSH</td>
<td>MSH</td>
<td>MSH 19 2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Patient</td>
<td>Person</td>
<td>CurrentNameGiven</td>
<td>PID 3 1</td>
<td>Person</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>CurrentNameMiddle</td>
<td>PID 6 3</td>
<td>Person</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>CurrentNameFamily</td>
<td>PID 5 1</td>
<td>Person</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>CurrentNameSuffix</td>
<td>PID 5 4</td>
<td>Person</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Person</td>
<td>CurrentNameTitle</td>
<td>PID 5 5</td>
<td>Person</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Author</td>
<td>Person</td>
<td>DateOfBirth</td>
<td>PID 7 1</td>
<td>Person</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Author</td>
<td>Person</td>
<td>Gender</td>
<td>PID 8 1</td>
<td>Person</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Author</td>
<td>Address</td>
<td>Line1</td>
<td>PID 11 1</td>
<td>Address</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Author</td>
<td>Address</td>
<td>Line2</td>
<td>PID 11 2</td>
<td>Address</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Author</td>
<td>Address</td>
<td>City</td>
<td>PID 11 3</td>
<td>Address</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Author</td>
<td>Address</td>
<td>State</td>
<td>Province</td>
<td>PID 11 4</td>
<td>Address</td>
<td>11</td>
</tr>
<tr>
<td>Author</td>
<td>Address</td>
<td>Country</td>
<td>PID 11 6</td>
<td>Address</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Author</td>
<td>Address</td>
<td>PostalCode</td>
<td>PID 11 5</td>
<td>Address</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Author</td>
<td>Telephone</td>
<td>Value</td>
<td>PID 13 11</td>
<td>Telephone</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Author</td>
<td>Telephone</td>
<td>Type</td>
<td>Text</td>
<td>PID 13 11</td>
<td>Telephone</td>
<td>13</td>
</tr>
<tr>
<td>Author</td>
<td>Email</td>
<td>Value</td>
<td>PID 15 5</td>
<td>Email</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Body</td>
<td>Medication</td>
<td>Product</td>
<td>RXG 4 2</td>
<td>Medication</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Body</td>
<td>Medication</td>
<td>Product</td>
<td>Code</td>
<td>CodingSystem</td>
<td>RXG 4 1</td>
<td>Medication</td>
</tr>
<tr>
<td>Body</td>
<td>Medication</td>
<td>Directions</td>
<td>Direction</td>
<td>Frequency</td>
<td>Value</td>
<td>RXG 14 1</td>
</tr>
<tr>
<td>Body</td>
<td>Medication</td>
<td>Directions</td>
<td>Direction</td>
<td>Dose</td>
<td>Value</td>
<td>RXG 15 1</td>
</tr>
<tr>
<td>Body</td>
<td>Medication</td>
<td>Product</td>
<td>Strength</td>
<td>Value</td>
<td>RXG 17 1</td>
<td>Medication</td>
</tr>
<tr>
<td>Body</td>
<td>Procedure</td>
<td>Procedure</td>
<td>Name</td>
<td>Description</td>
<td>Text</td>
<td>RXG 17 1</td>
</tr>
<tr>
<td>Body</td>
<td>Procedure</td>
<td>Procedure</td>
<td>Name</td>
<td>Description</td>
<td>Code</td>
<td>Value</td>
</tr>
<tr>
<td>Body</td>
<td>Procedure</td>
<td>Procedure</td>
<td>Name</td>
<td>Description</td>
<td>Code</td>
<td>CodingSystem</td>
</tr>
<tr>
<td>Body</td>
<td>Procedure</td>
<td>Procedure</td>
<td>Name</td>
<td>Description</td>
<td>Code</td>
<td>CodingSystem</td>
</tr>
<tr>
<td>Body</td>
<td>Procedure</td>
<td>Procedure</td>
<td>Name</td>
<td>Description</td>
<td>Code</td>
<td>Value</td>
</tr>
<tr>
<td>Body</td>
<td>Procedure</td>
<td>Procedure</td>
<td>Name</td>
<td>Description</td>
<td>Code</td>
<td>Value</td>
</tr>
</tbody>
</table>

Figure 2-8: CSV presentation of the map table

1 // This is a comment...
2 // Start of CCR Elements, Start of HL7 Fields, Special Flag...
3 From: ActOrLink, ActOrID: MSH 1, 1
4 From: ActOrLink, ActOrRole: MSH 3, 1
5 To: ActOrLink, ActOrID: MSH 4, 1
6 To: ActOrLink, ActOrRole: MSH 4, 1
7 Language Text: MSH 19, 2
8 Patient: PID 3, 1
9 Author: Person, Name, CurrentName, Given: PID 5, 2
10 Author: Person, Name, CurrentName, Middle: PID 5, 3
11 Author: Person, Name, CurrentName, Family: PID 5, 4
12 Author: Person, Name, CurrentName, Title: PID 5, 5
13 Author: Person, DateOfBirth: ExactDateTime: PID 7, 1
14 Author: Person, Gender: Text: PID 9, 1
15 Author: Address, Line1: PID 11, 1
16 Author: Address, Line2: PID 11, 2
17 Author: Address, City: PID 11, 3
18 Author: Address, StateProvince: PID 11, 4
19 Author: Address, Country: PID 11, 5
20 Author: Address, PostalCode: PID 11, 6
21 Author: Telephone, Value: PID 13, 11
22 Author: Telephone, Type, Text: PID 13, 11
23 Author: Email, Value: PID 15, 5
24 Body: Medication, Product, ProductName, Text: RXG 4, 2
25 Body: Medication, Product, ProductName, Code, Value: RXG 4, 1
26 Body: Medication, Product, ProductName, Code, CodingSystem, RXG 4, 3
27 Body: Medication, Directions, Direction, Frequency, Value: RXG 14, 1
28 Body: Medication, Directions, Direction, Dose, Value: RXG 16, 1
29 Body: Medication, Medication, Product, Strength, Value: RXG 17, 1
30 Body: Payments, Payment, Provider: Provider: PID, 5, 1
31 Author: Organization, Name: PID 4, 1
2.3.3 Challenges in Mapping

Here we list the challenges and considerations when designing the solution:

2.3.3.1 Algorithms to map between standards

To successfully translate the content between standards (particularly the CCR and HL7 used here), some logic is involved. The main reason behind this is that they’re both specifically designed for different purposes. HL7 is developed to communicate real time health information and the CCR is developed to store patient information in formatted manner but usually not real time data.

This results in more complex mapping between the CCR and HL7, where one field in one standard usually does not have an exact match in the other standard. For example, Advance Directives in the CCR does not have an exact match in any HL7 segment or message type. In another case, one field in one standard can, depending on some condition, be mapped to different fields in the other standard. An example for this is Actors field in the CCR. Actors in the CCR is the collection of all person/organization/HISs involved in one patient health message, thus the solution must be intelligent enough to know which of the Actors is the doctor, patient, hospital, etc. and then map them to the correct field in HL7 message. Going from HL7 to the CCR in the same case, Attending Doctor segment in HL7 (Message-Type: PV1/Segment No: 7), should be stored in Actors section in the CCR for Doctor description, and also stored in Encounters section, and there must be a link from the Encounters section to the Actors section pointing to the same actor.

It is also becoming increasingly difficult to link the Actors in the CCR’s Header and Body section when there are lots of Actors involved (Patient, HealthCare provider, Doctors, Next of Kin), and the description of an Actor role is text based (Spouse/Wife/Husband). Thus, while HL7 has the corresponding Next of Kin (Spouse) segment, deciding which part of the CCR actually contains the information about the spouse can be challenging.

2.3.3.2 No Perfect Equivalent HL7 Message Types to the CCR

Since every message type in the HL7 standard has been developed for a specific purpose (see the exhaustive list of message types in the HL7 documentation), it is seemingly impossible to put all information inside a complete CCR document into one message type.

HL7 ORU^R01 – Unsolicited transmission of an observation message was considered earlier, due to its structure, which mostly depends on the OBX segment. An OBX segment is a segment to define observation results, but can be used to express almost anything. See the following figure.
Figure 2-9: An ORU^R01 with the OBX segment can be used to display any kind of text

However the biggest shortcoming here is that the information contained in OBX will be much less meaningful than if they are to be stored in more closely matching segments (Encounter to PV1, Procedure to PR1). It will also require a lot of modification done to the receiving side for it to process the generated HL7 message.

Another alternative to this is to make use of Z-segments based on HL7 specification. Z-segments is the realization from HL7 standard organization to make HL7 messages as flexible as possible by allowing custom segment/message type starting with Z letter. Z-segments can be inserted anywhere in the HL7 message. A popular approach is to place the Z-segment within a group of segments that contain similar information, such as insurance. Z-segments are also often placed at the end of the message. The advantage of doing so is that this placement prevents systems configured to parse "standard" HL7 format from requiring any configuration modifications in order to process the message.

There is however one message type that resembles CCR documents the most according to our finding, which is REF (Patient Referral) message. Because REF messages are composed to contain comprehensive
patient information for referral reason, they become the HL7 v2.x equivalent to the CCR. The structure of REF message according to HL7 v2.5 (2003) can be seen in the following figure.

<table>
<thead>
<tr>
<th>REF^I12-I15^REF_I12</th>
<th>Patient Referral</th>
<th>Status</th>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSH</td>
<td>Message Header</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>[{ SFT }]</td>
<td>Software segment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[RF1]</td>
<td>Referral Information</td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>[AUT]</td>
<td>Authorization Information</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>[{CTD}]</td>
<td>Contact Data</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>{ --- AUTHORIZATION_CONTACT begin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUT</td>
<td>Authorization Information</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>[{CTD}]</td>
<td>Contact Data</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>--- AUTHORIZATION_CONTACT end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[PRO]</td>
<td>Provider Data</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>[{CTD}]</td>
<td>Contact Data</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>--- PROVIDER_CONTACT end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID</td>
<td>Patient Identification</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>[{NK1}]</td>
<td>Next of Kin/Associated Parties</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[{GT1}]</td>
<td>Guarantor</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[ ]</td>
<td>--- INSURANCE begin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>{ IN1</td>
<td>Insurance</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[IN2]</td>
<td>Insurance Additional Info</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[IN3]</td>
<td>Insurance Addl Info -Cert</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>--- INSURANCE end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ACC]</td>
<td>Accident Information</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[{DG1}]</td>
<td>Diagnosis</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[{DRG}]</td>
<td>Diagnosis Related Group</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[{AL1}]</td>
<td>Allergy Information</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>[ ]</td>
<td>--- PROCEDURE begin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>{ PR1</td>
<td>Procedure</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>[AUT]</td>
<td>Authorization Information</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>[{CTD}]</td>
<td>Contact Data</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>--- AUTHORIZATION_CONTACT end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>--- PROCEDURE end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ ]</td>
<td>--- OBSERVATION begin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>{ OBR</td>
<td>Observation Request</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>[{NTE}]</td>
<td>Notes and Comments</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>--- RESULTS_NOTES begin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>{ OBX</td>
<td>Observation/Result</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>[{NTE}]</td>
<td>Notes and Comments</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>}</td>
<td>--- RESULTS_NOTES end</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[ ]</td>
<td>--- OBSERVATION end</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2-2: REF message structure. Square brackets ([ ]) denote optional segments (or segment groups) while curly brackets ({ }) denote repeating segments (or segment groups).

According to the HL7 v2.5 specification, optional segments and fields are enclosed in brackets [ ] e.g., [NK1] indicates that the next of kin segment is optional. Some segments may, on an optional basis, be repeated within the message. Repeating message options will be displayed with curly brackets { }. For example, {AL1} indicates that the allergy segment may be repeated if needed. These may also be combined, e.g., [[AL1]] indicates the allergy segment is optional and that it may be repeated if needed. The repeating and optional indicator are also possible for group of segments, thus the indicator will affect all segments inside the group.

As seen from the message structure of REF message, the required segments are MSH, PRD (may be repeated) and PID. Most of the optional segments however will be used in most cases because a lot of the information in a CCR message can be mapped to one or another of these segments.

However, even as a closest match, we find that the REF still lacks a few segments needed for translating the CCR to a HL7 message. We have to customize the REF message by adding more segments to it, as in the table below, in order to retain more information in the translation process and thus to make it more meaningful at the same time. By modifying the REF message, most HISs that support HL7 can still obtain most of the information from translated message and might ignore those segments that do not strictly belong to REF message. While this will cause the loss of patient information, with slight modification to the receiving side we can ensure all relevant information is captured and stored accordingly.

<table>
<thead>
<tr>
<th>CCR element</th>
<th>Corresponding HL7 v2.5 segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;Medications&gt;</td>
<td>RXG, RXR</td>
</tr>
<tr>
<td>&lt;Immunizations&gt;</td>
<td>RXA</td>
</tr>
<tr>
<td>&lt;Problems&gt;</td>
<td>PRB</td>
</tr>
</tbody>
</table>

Table 2-3: CCR elements which have no direct equivalent in the HL7 v2.5 REF message, and their equivalent HL7 message segments.
The segments that are not part of the original REF message but added in our specification are **PRB**, **RXA**, **RXG** and **RXR** segment. The complete list of all segments used in this specification with their match in the CCR can be seen in Table 2-1: The CCR and HL7 correlations.

Adding these "missing" segments to the HL7 REF message does break the strict HL7 message definitions, so this is admittedly not a perfect solution.

Alternatively, it would be possible to break a single CCR into multiple related HL7 messages. E.g. if a CCR contains Results or VitalSigns, it will generate HL7 v2.x REF to establish the patient’s profile, plus ORU messages that contain the Results extracted from the CCR elements. Some other message types that can be supported to accommodate the segments used in the translation are VXU for Immunization purpose or Pharmacy/Treatment Administration Message (RAS) (for RXA, RXG, RXR). The advantage of this approach would be to allow the system to follow more closely the specification as intended by the HL7 standards. However, this approach is also significantly more difficult to implement, and we did not attempt it.

### 2.3.3.3 Different versions of the CCR

In the Google Health system, a slightly different version of the CCR is being used to communicate patient data. The Google Health version of the CCR eliminates some of the CCR elements which are not supported by Google Health at this moment. Some of the sections which are omitted in this version are Advance Directives, Encounters, Healthcare Providers and Plan of Care.

Sending a CCR that is valid according to the original ASTM specification is not fully supported by Google Health. We discovered that while Google Health system is supposed to ignore tags that it does not recognize and continue parsing a CCR for known tags, some tags in the CCR caused Google Health to reject the CCR. This issue has been raised with the developer of Google Health, and after consideration the issue was put in the bug list for Google software engineers to fix.

Microsoft Health Vault on the other hand supports the CCR and HL7 CDA /CCR file.

### 2.3.3.4 Different types of Coding Systems

Coding Systems used in HL7 and CCR are quite similar (such as LOINC, ICD-9, RxNorm, and SNOMED). However, HL7 requires the Coding System identifier to be stored in a *user-defined table*. Thus, if there is a Coding System in the CCR which does not exist in this table, after the translation the HL7 message will have unrecognized identifier. The range of Coding System (or User Defined Table in HL7) used by either HL7 message or CCR depends on the sending/receiving HIS facilities. Therefore it is important to make sure that the sending and receiving side uses the same set of Coding Systems.
Problem may also arise if the sender decides not to use any Coding System, e.g. CCR sender sends the Language as combination of tags and free text value (not Coding System): <Language> English </Language>, while the receiving side expects a HL7 v2.x message that requires ISO Coding Systems for the language (ISO 639-x) and vice versa. Thus it is always recommended to use Coding Systems whenever possible inside HL7 message or CCR.

### 2.3.3.5 Multiple Coding Systems in CCR

Multiple Coding Systems are permitted in CCR while in HL7 only one Identifier and one Alternate Identifier can be inserted. Looking at one of the samples that we got from the Google Health h9 server, Google Health will include all Coding Systems which correlate to the value it is trying to describe, for example:

```xml
<Product>
  <ProductName>
    <Text>Aspirin</Text>
    <Code>
      <Value>1082</Value>
      <CodingSystem>FDB_routed</CodingSystem>
    </Code>
    <Code>
      <Value>216092</Value>
      <CodingSystem>FDB_dispensable</CodingSystem>
    </Code>
    <Code>
      <Value>198471</Value>
      <CodingSystem>RxNorm</CodingSystem>
    </Code>
    <Code>
      <Value>94441022073</Value>
      <CodingSystem>NDC</CodingSystem>
    </Code>
    <Code>
      <Value>1076</Value>
      <CodingSystem>FDB</CodingSystem>
    </Code>
  </ProductName>
</Product>
```
The example describes Aspirin using 5 different Coding Systems that Google Health understands, but it is not possible to store all of them into one HL7 message. Therefore only one Coding System will be stored into the HL7 message.

2.3.3.6 Multiple<Test> in <Result>

When translating CCR to HL7, for most mappings one main element is mapped into one segment, e.g. <Patient> will create PID segment, <Encounter> will create PV1 segment. However it is possible to separate test results into different <Result> tags, but in practice all test results that belong to the same category or multiple results for the same test are stored in one <Result> with multiple <Test> tags; thus one <Result> no longer creates one segment of OBX, but possibly more than one depending on the number of the <Test> tags.

Hence we created an exception for <Result> tag to create more than one OBX segment when more than one <Test> child exists.

2.3.3.7 Date format

HL7 and CCR use different methods of representing date and time in their message: HL7 uses the yyyyMMddHHmmss'.SSSS format while CCR uses yyyy-MM-dd'T'HH:mm:ss'Z' format. As an example, 30th December 2001, 09:30:00 is represented as 20011230093000.0000 in HL7 and 2001-12-30T09:30:00Z in CCR.

However, in CCR it is allowed to not have the format as described above, i.e. imprecise date is allowed in the <DateTime> field. When using a precise date, <ExactDateTime> child tag is placed under the <DateTime> but when the date is an approximate value or best guess another form of tag is used (<ApproximateDateTime>) and the value type is a simple text (<ApproximateDateTime><Text>Around December</Text></ApproximateDateTime>). In HL7 however all date values must be stored in numerical values and text such as “Around December” is not compatible.

Therefore all CCR input are required to use <ExactDateTime> whenever possible and other date format that cannot be converted into HL7 date format will be simply ignored to prevent the receiving side parsing the erroneous date format.

2.4 Implementation

After establishing the initial design of our prototype, we proceed into implementation stage following the design we described above.
2.4.1 Choosing base packages

Listed below are the crucial existing components chosen for the solution. Also see section 2.2.2. for more discussion of the considerations involved in choosing aspects of the design.

2.4.1.1 Existing Hospital / General Practice HIS

To support the proposed solution a chosen package for this solution must have the following characteristics:

- Open source, or readily available
- Implementation ready
- Works with at least one standard
- Supports at least one communication channel (HTTP, FTP, etc.)

Among those packages that meet the criteria, we picked myCare2x because it fits the above stated requirements; it is (officially) open-source, it has been implemented in many places (Malaysia, Philippines and Germany) and is using HL7v2.x as communication standard.

2.4.1.2 Existing PHR Packages

Mentioned in our proposed solution, we are trying to tie together several HIS that serve different purpose such as Hospital HIS with PHR. There again, PHR as one of the emerging fields in Health Care offers many types and implementations. To better select the system to be integrated into the solution we sort the advantages of each PHR according to the following criteria:

- Provides access for developers (Developers API)
- Implementation ready
- Works with at least one standard
- Support at least one communication channel (HTTP, FTP, etc.)
- High reliability and availability

Among those, we find that Google Health and Indivo health are among the top candidates that resemble those criteria. We choose Google Health because there is a readily available implementation.
2.4.1.3 Standards

The proposed solution shall be able to translate the content of different standards used in HIS, which includes the translation between:

**HL7 V2.5**

HL7 v2.5 is one of the most widely used communication standard in HIS sector as seen from the discussion of HIS. One of the reasons is that HL7 v2.5 offers the possibility of communicating almost every bit of information one could think of in a more standardized fashion and the worldwide recognition of this standard.

**CCR**

CCR is preferred because of its simplicity and clear way of representing a person’s health information. Its use of simple XML tags and fairly concise standard specification enables fast implementation of the application with minimum loss of performance. The CCR is also popularly used by PHR such as Google Health and Microsoft Health Vault. The CCR referred to here is the CCR specification as defined by ASTM, not its subset as specified by Google Health for their server, though we will be incorporating Google h9 server in our prototype.

**ICPC-2E**

A prototype Portable Problem-Oriented EHR (PPOEHR) has been described by Seo (2010). The PPOEHR utilizes ICPC-2e as the source of medical or healthcare terms to describe a person’s type of problems or procedures or other health-related items. The reason this PHR uses ICPC-2e as its vocabulary is because of the minimal length of the ICPC-2e lists, which is important for a mobile device, and because of its relative completeness to represent conditions that a user might want to record. Since the PPOEHR prototype and its successors are used exclusively for mobile phones, this can test the interoperability of mobile devices with other HISs. The implementation of a translation package for this standard will be a future project.

2.4.1.4 Mirth and programming language

As mentioned above, Mirth as a communication gateway provides a powerful integration function between different systems. The Mirth package contains 3 different applications: Mirth Connect, Mirth Result and Mirth Match. Mirth Connect is the core integration application that handles HL7 messages and tools for developing, testing, deploying and monitoring interfaces. Mirth Result serves as a data repository that can organize and aggregate clinical data across multiple sources. Mirth Match is a plug-in based Master Patient Index (MPI).
The proposed solution itself will use Mirth Connect extensively without the others because Mirth Connect provides the functionality needed to translate the content of different standards.

A Mirth Connect acts as a powerful server that receives messages from various sources, transforms the messages and sends them again to the specified destinations. The overall architecture of Mirth can be seen from the following figure.

![Mirth Architecture](http://www.mirthcorp.com/community/mirth-connect)

Internally, Mirth represents an HL7 object as XML, though it is still possible to use the original HL7 message as a string.
This representation however is not used in our translation package. The reason is, we are aiming for a prototype that can be easily ported into different message gateway services (not exclusive to Mirth, as long as the gateway supports java external libraries), and not every message gateway has the functionality to parse HL7 message into XML form. Hence we are only accepting a normal HL7 message as string, i.e. there is no transformation to the message to be done by the message gateway internally (other than filtering for some case).

The power of Mirth in transforming messages comes from the ability to let the user manipulate each part of the message using JavaScript and a Java library. In every filtration and transformation stage one can use JavaScript to assist in intended tasks. The following figure shows a screenshot of Mirth interface in one of the stages.
Message transformation in Mirth happens in two stages, source transformation and destination transformation. Before undergoing transformation in each stage, every message will go through a filtration process which can be defined by the user or simply ignored by not writing any filtration rule to the message. Detailed transformation steps can be seen in the following figure.
Mirth JavaScript however inherits a few shortcomings such as lack of support of further development, and it is not as well established as other programming languages. Translation between different health standards is much more than a one-to-one mapping, rather a conditional-based mapping, and so would present a significant challenge for JavaScript.

Therefore, to get around this problem the proposed solution will use Java as the coding language. That is, the solution will be in the form of Java customized packages that are imported into Mirth. Unlike JavaScript, Java is a very well-established programming language and supports many types of library to ease in the implementation process.
One of the most important features that Mirth provides is the capability of validating HL7 messages that come through it before sending them to the translation package. Mirth has a strict internal HL7 message parser that can be enabled to filter and validate all incoming HL7 messages. This allows the transformation software to assume that the input is completely correct HL7.

It is also important to note that Mirth complies with sections of ISO-18308:

- COM 2.1: Accepts EHR completely or part of an EHR
- COM 2.5: Rules covering exchange of part or all of the record shall be the same as those for exchanging the complete record.

2.4.2 Choosing the tools

Here we list all implementation tools used to build the solution.

2.4.2.1 IDE

As we discussed in section 2.3.3 (Mirth) the solution inevitably requires extension to the existing software. Thus, a suitable IDE must also be part of the consideration in our design. Since Mirth is solely based on Java programming language we will also focus on Java as our main programming language to do the programming.

There are many comprehensive and advanced IDEs built to support Java programmers, such as NetBeans, Eclipse, JCreator, etc.

But when we are referring to Mirth, there is an instruction on how to set up Mirth source code in Eclipse. Mirth community (forum, support) also always gives examples in Eclipse when guiding Mirth learners to a solution. Eclipse is also tied with NetBeans in terms of technology and ease of use according to Binstock (2008). Thus Eclipse is used as the IDE to do the implementation.

2.4.2.2 HL7 Library

By using a library created to ease HL7 message manipulation we can reduce the time needed to setup the working prototype. We looked at two HL7 libraries; HAPI and LightHL7 library. While both provide much functionality such as message validation, interface to read and write HL7 messages, we find that both libraries are strict when it comes to generating HL7 messages. To generate a HL7 message, one must know exactly which type of message he is using (ORU, ADT, ACK, etc.). Since the CCR $$\Rightarrow$$ HL7 map does not correspond to any single HL7 message type, we must use customized HL7 messages, so certain modifications might be needed before both libraries can work.
With these libraries, adding values to a message subcomponent/component/segment is also limited to function calls, where one must exactly know the subcomponent/component/segment combination. We believe that it is much simpler if we can access the value of each component/subcomponent/segment by array rather than by using the library.

### 2.4.2.3 CCR Library

Since the complete CCR specification exists as an XML schema (.xsd) file, by using JAXB (Java Architectural XML Binding) or similar XML binding library we can bind the XML into a Java class representation. By utilizing the classes derived from the schema we can construct the CCR document in a more structured manner.

However a similar problem to that with the HL7 library arises here, where there is no direct way of reading or writing specific fields/elements inside the document. To easily access each element inside an XML file, it is much simpler to use an XML parser to parse through the document than to use JAXB-generated classes which can get very complicated because of the complexity of the CCR XML schema.

### 2.4.2.4 GData Library

To facilitate connections with the Google Health server to test the prototype, the GData Java client library from Google is used. This library helps connect stand-alone applications with Google Health server in a secure manner. More information about GData can be found at: [http://code.google.com/p/gdata-java-client/](http://code.google.com/p/gdata-java-client/)

List of the libraries from GData that are relevant for our system to connect with Google Health:

1. gdata-base-1.0.jar
2. gdata-client-1.0.jar
3. gdata-client-meta-1.0.jar
4. gdata-core-1.0.jar
5. gdata-health-2.0.jar
6. gdata-health-meta-2.0.jar
7. gdata-media-1.0.jar
8. google-collect-1.0-rc1.jar
2.4.2.5 Other tools

HL7Inspector ([http://sourceforge.net/projects/hl7inspector/](http://sourceforge.net/projects/hl7inspector/)) is a lightweight open-source hl7 editor tool. One of the most useful features that it offers is to send hl7 message through IP sockets. Mirth can receive the message through such a medium, thus providing us with more ways to test the prototype.

7Edit is used to validate HL7 messages and create HL7 sample messages. Because it comes with default definition of HL7 user tables and message templates, it makes creating HL7 messages easier and error-free.

2.4.3 Message system architecture

The following figure explains the high-level design and architecture of the proposed CCR <-> HL7 v2.x message system or gateway.

![Proposed overall solution design](image)

Vocabularies: ICPC-2, LOINC, SNOMED CT, ICD

Looking at the design, the solution is centred on interconnecting different HISs on a stand-alone communication server framework that is Mirth Connect. More discussion on Mirth can be seen in Mirth and programming language.
2.5 Testing and Evaluation Method

Here we describe the files and data used to test our translation package.

2.5.1 The CCR -> HL7 v2.x map

2.5.1.1 Finding and creating test CCR messages

Sample CCR messages were collected from the Web, including examples given with theASTM CCR Specification. The collected CCRs are:

<table>
<thead>
<tr>
<th>CCR Filename</th>
<th>Number of lines</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>ccrsample_allscript.xml</td>
<td>2168</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_capmed.xml</td>
<td>12665</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_emdeon.xml</td>
<td>2883</td>
<td>Web</td>
</tr>
<tr>
<td>ccsample_emds.xml</td>
<td>2416</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_emrec.xml</td>
<td>1237</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_healthvision.xml</td>
<td>2077</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_medcommons.xml</td>
<td>993</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_obeeverywhere.xml</td>
<td>4064</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_recordsforliving.xml</td>
<td>1300</td>
<td>Web</td>
</tr>
<tr>
<td>ccrsample_solventus.xml</td>
<td>2838</td>
<td>Web</td>
</tr>
<tr>
<td>ghealth_ccr.xml</td>
<td>232</td>
<td>Web</td>
</tr>
</tbody>
</table>
2.5.1.2 Confirming that mapped CCR elements are correctly transformed

Using 7edit tool (www.7edit.com), we can identify if there is any error or warning in the transformed message. A sample is shown below. However, as mentioned in 2.3.3. Challenges in Mapping, Coding Systems can be different between the input CCR and 7edit itself; 7edit might not understand the Coding Systems used by the HIS that creates the CCR, and thus display an error message. Such error message is currently ignored.

```
  MDN: \\{myCar\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  DHEF: \{myContact\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  MD: \{Referring Provider\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  FID: \{Referring Provider\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  MHA: \{Allergy\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  IMR: \{Medication\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  MF: \{Medication\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  MHR: \{Medication\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  MPA: \{Medication\}T12\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  FPI: \{I\}D\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  MDI: \{I\}D\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  MUG: \{I\}D\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
  WCA: \{I\}D\{20100312 15:40:31\}I\{2,6\}I\{1\}I\{BECDIE UTF-8\}English\{msg:126893\}h
```

Figure 2-15: No errors were found by 7edit for the transformed message
2.5.1.3 Confirming that un-mapped CCR elements are not inserted in the HL7 v2.x output

All unmapped entries are recorded into a text file, this is to help confirm all the elements that do not exist in the map table are not mapped and also to identify other potential elements that can be inserted into mapping table thus improving accuracy of the map table.

As seen from the figure above, all elements starting with ContinuityOfCareRecord.Actors.Actor are included because these are the Actors elements located in the footer. We had already denormalized (see Actor link in the CCR) these information to the upper part of the CCR. Therefore all the Actors located at the footer will be ignored at the translation process.

Figure 2-16: Unmapped entries for CCR to HL7 mapping

As seen from the figure above, all elements starting with ContinuityOfCareRecord.Actors.Actor are included because these are the Actors elements located in the footer. We had already denormalized (see Actor link in the CCR) these information to the upper part of the CCR. Therefore all the Actors located at the footer will be ignored at the translation process.

2.5.2 The HL7 v2.x -> CCR map

2.5.2.1 Finding and creating test HL7 v2.x messages

The HL7 files are collected from sample HL7 messages generated myCare2x HIS, variousWebssources and also created using 7edit tool.
### Table 2-5: HL7 Test Sample

<table>
<thead>
<tr>
<th>HL7 file name</th>
<th>Message Type</th>
<th>Number of segments</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>7editDemo.hl7</td>
<td>ADT^A01</td>
<td>15</td>
<td>7edit sample file</td>
</tr>
<tr>
<td>040522_01_A01_ADT_Admit.hl7</td>
<td>ADT^A01</td>
<td>11</td>
<td>myCare2x sample file</td>
</tr>
<tr>
<td>040522_01_A02_ADT_Transfer.hl7</td>
<td>ADT^A01</td>
<td>4</td>
<td>myCare2x sample file</td>
</tr>
<tr>
<td>040522_01_A03_ADT_Discharge.hl7</td>
<td>ADT^A01</td>
<td>4</td>
<td>myCare2x sample file</td>
</tr>
<tr>
<td>Immunization1.hl7</td>
<td>ORU^R01</td>
<td>60</td>
<td>Web</td>
</tr>
<tr>
<td>LabRoche175257.hl7</td>
<td>ORU^R01</td>
<td>14</td>
<td>myCare2x sample file</td>
</tr>
<tr>
<td>LabRoche175258.hl7</td>
<td>ORU^R01</td>
<td>14</td>
<td>myCare2x sample file</td>
</tr>
<tr>
<td>LabRoche175259.hl7</td>
<td>ORU^R01</td>
<td>14</td>
<td>myCare2x sample file</td>
</tr>
<tr>
<td>Oru_r01.hl7</td>
<td>ORU^R01</td>
<td>4</td>
<td>Web</td>
</tr>
<tr>
<td>NIST_SampleADT.hl7</td>
<td>ADT^A04</td>
<td>4</td>
<td>Web</td>
</tr>
<tr>
<td>custom_REF.hl7</td>
<td>REF^T12</td>
<td>13</td>
<td>Created using 7Edit</td>
</tr>
<tr>
<td>custom_REF2.hl7</td>
<td>REF^T12</td>
<td>16</td>
<td>Created using 7Edit</td>
</tr>
</tbody>
</table>

#### 2.5.2.2 Confirming that mapped HL7 elements are correctly transformed

By comparing the actual input, the map table and xml result of the translation, we can find out whether the map successfully executed. And by viewing the structure of the resulting CCR xml file we can tell whether the translation produces a valid or malformed xml file (is there any unclosed tags, wrong tag names).
Another way to confirm the resulting CCR is to use a XML style-sheet (.xsl) file to view the CCR. We are using the xsl template developed by American Academy of Family Physicians (AAFP) version 2.0 (2007) and licensed under Apache License, version 2.0 (http://www.apache.org/licenses/LICENSE-2.0), as in the following figure.

2.5.2.3 Confirming that un-mapped HL7 elements are not inserted in the CCR output

The unmapped entries are recorded into a text file, and analysed to allow further modifications to the map table if there are map elements that should be inserted into the map table. A sample is shown below.
2.5.3 Compare Results with CCRViewPort by Solventus

While searching current technologies for products potentially similar to our prototype, we encountered Aquifer CCR ViewPort (https://www.solventus.com/aquifer/ccrviewportcontainer.aspx) developed by Solventus. It is a system designed to help healthcare providers create, view and edit CCR files using a Web browser. Currently the system is free of charge, but providers must register themselves at the site and get their username and password before they can start using the system. One of the functionalities it provides to the users is the capability to import an HL7 v2.x message and convert it to a CCR. Even though it is not able to convert CCR to HL7 v2.x translation, we will make use of this system as a comparison with our own HL7 v2.x to CCR module.
3 RESULTS

The first section gives the results of the interviews carried out at healthcare facilities located at different locations in Indonesia in 2010. The questions asked revolved around the state of ICT in terms of health service in the institutions, with participating interviewees from a hospital, a clinic and a laboratory.

3.1 Survey on healthcare communications in Indonesia

Interview 1

Hospital Sumber Kasih is a privately owned hospital located in Surabaya; it does receive some government funding. The Hospital is medium-sized with a reasonable number of staff (25 doctors, 60 nurses; numbers approximate), and 50 beds for inpatients. The hospital handles around 300 inpatients per month.

When asked about computers, the administration admits the use of computers for patient registration and letter processing purposes. The interviewee mentioned the system called AMA for patient registration. Currently there are 4 computers used in administration. Computers are also used in a few other departments such as personnel (human resources) and laboratory units. There is however no communication between those departments because there is no network running between those departments. Communications between all departments are based on paper. For example, a laboratory result, though stored in a computer, must be printed out for use when a doctor needs it. It is noted also that doctors and nurses don't possess computers in their offices.

Communication from hospital to the outside is made possible by writing a formal letter or at the very least, direct communication using phone calls amongst the individuals involved. This shows again the lack here of a role for IT in improving the potential health care quality to people in need.

Patient data is stored locally inside a computer and the data cannot be used for communication at all unless printed out. No communication had been established inside the hospital in terms of IT.

This causes inefficiency of communication whereby everything has to be printed out for any kind of use other than storing the patient data. *The hospital staff hoped that there will be more sophisticated solutions to bypass such procedures, because most of them feel communication is the cause of delay in patient treatment.*
Interview 2

Dr. Gani's Clinic is a small clinic operated by 1 doctor and 1 nurse/helper. The nurse admits that no computer at all is established to handle patient data. Everything is stored in paper format and patient referral to other clinic/hospital is by a letter written by the doctor.

Internal communication was not an issue due to the very small number of personnel in the clinic, however, communication to other health providers such as a bigger clinic or hospital requires the doctor to call or write a letter that consumes a lot of time. Moreover, the carefully written letters are periodically lost.

The clinic usually has to work longer than normal working hours due to lack of manpower. The clinic wishes to have a computer to increase efficiency.

Interview 3

Laboratorium Klinik Utama Johar is a laboratory that provides services to companies and hospitals alike. Currently it has 4 computers all running MS-DOS and used to store patient data and lab result printing. When a lab result is out, the analyst jots down the result on a piece of paper and gives it to administration, which then stores the data in the computer and prints it out again. It handles around 50 patients/day and uses Floppy Disks to store patient data. LAN is available at the hospital, but there is no internet access.

Internal communication inside the laboratory is done by direct communication between individuals and/or paper results of the lab test. Most external communication is done with a letter accompanying the lab test result.

The IT consultant of the Laboratories is looking for a solution that allows the result to be sent electronically to the company or hospital that needs it.

Summary

The health institutions in Indonesia suffer from poor computerization and are not yet integrated into systems. This can be seen from the way communications are carried out about patient information where paper works and direct communication (phone call) plays the major role. There is also no indication of any major improvements to be done in the near future, and no mention of the use of Web-based system brought up by the interviewee.

Referring back to section 1.2.3.4, Indonesian Health Information System, it shows that while improvements are being made to computerize health information system the progress is very slow with very limited resources.
However with Web access growing at much faster rate than the growth of HISs, it clearly introduces the possibility of installing Web PHR to better support health institutions in Indonesia or any other developing countries.

3.2 Implementation of the Map

The map is the critical part of the translation as a way to decide where an element should go from the input to the output. Here we explain our process of creating the mapping for each direction of the translation.

3.2.1 Creating the CCR ⇔ HL7 v2.x Mapping

Following the requirements in section 2.2 (a), a mapping of standards has been created to assist the translation process. The mapping will determine which section of a CCR element should be transformed into which field inside an HL7 message or vice versa.

The main challenge in the creation process of this map is to keep the content of the record/message as well as its relevant location when being translated to another standard or to the closest match when such relevant location cannot be found.

Since the number of possible elements for the CCR and HL7 is bewilderingly large, it is important to narrow the map to include elements that stay at the top of the hierarchy. The justification for this is that by looking at top levels of a specific element it is highly possible to know exactly what kind of information we are dealing with during the translation.

An example for this, consider an element of the CCR with following hierarchy: the

\[
\text{<CCR><Body><Problems><Problem><DateTime><ApproximateDateTime><Text>06/19/2002 – by following the hierarchy up to <DateTime> tag, we can assume the value sitting within will contain date and time value of the problem recorded in the CCR. This will also substantially cut down the number of elements we have to look at. As HL7 does not have an “ApproximateDateTime” concept but does have “DateTime”, we know that CCR elements within <DateTime> should correspond to the HL7 date and time concepts.}
\]

The number of standards supported can also be extended inside the map. While the objective of this research is to do bidirectional translation between the CCR and HL7, more standards can be supported rather easily by adding extra columns to the map table, provided the new standards share similar characteristics with the CCR or HL7. The map is also a very flexible way to do translation, allowing the programmer to add, remove or alter elements inside the map anytime when necessary.
3.2.2 Translation Steps

3.2.2.1 Converting CCR to HL7 v2.x

Every CCR will go through two main processes, initialization and translation. Initialization includes preparing and modifying the CCR file for easier translation and initializing Java’s XMLParser to the CCR. Translation is the process where each element inside the CCR is mapped to HL7 according the map table, producing a HL7 v2.x message at the end.

During initialization every record inside CCR must be scanned for possible illegal characters that could disrupt the translation process, such as characters that might collide with HL7 special characters (by default: |^~\&). These characters must be removed in order to produce valid HL7 message.

The HL7 template where all the mapped result should go is also created at the initialization step. Since we are using REF message as the base template, mandatory segments such as PID are also created even though the values are still empty. At minimum the template will have the following format:

```
MSH|^~\&|||myCare2x^|||REF^T12|1|P|2.6^|||UNICODE UTF-8||
RF1||||||Referring Provider Name^^|||
PID|||||||||||||||||||||||||||||||||||
```

All <Actors> at the footer of CCR are also scanned and saved locally before being used to denormalize the CCR to ease the translation process. Every Actor in the footer is de-referenced back, i.e. every reference to <Actor> is replaced by the content of the <Actor> tag. See the following figures.

```
<Patient>
 <ActorID>MyPatient</ActorID>
</Patient>
<Actors>
 <Actor>
  <ActorObjectID>MyPatient</ActorObjectID>
  <Person>
   <Name>
    <CurrentName>
     <Given>XXX</Given>
     <Family>XXX</Family>
    </CurrentName>
    <DisplayName>XXX XXX</DisplayName>
   </Name>
   <DateOfBirth>
    <ExactDateTime>1924-02-27</ExactDateTime>
   </DateOfBirth>
   <Gender>
    <Text>Female</Text>
   </Gender>
  </Person>
 </Actor>
</Actors>
```

Figure 3-1: CCR before being denormalized
The translation process flow then follows the way XMLParser reads an XML file, from top to bottom, while keeping track of all the visited nodes (or tags) in hierarchical order and match this to the mapping table. Consider an example:

```xml
<Patient>
  <Actor>
    <ActorObjectID>MyPatient</ActorObjectID>
    <Name>
      <CurrentName>
        <Given>XXX</Given>
        <Family>XXX</Family>
      </CurrentName>
      <DisplayName>XXX  XXX</DisplayName>
    </Name>
    <DateOfBirth>
      <ExactDateTime>1924-02-27</ExactDateTime>
    </DateOfBirth>
    <Gender>
      <Text>Female</Text>
    </Gender>
    <Person>
    </Person>
  </Actor>
</Patient>
```

**Figure 3-2: CCR after denormalized**

When the XMLParser reads the value of “Creation DateTime” we will have `ContinuityOfCareRecord.DateTime.Type` to be matched against the map table because we keep track of the tags we have read so far. When reading the value of “2006-04-25T01:01:01Z” the last element
<Type> would have been removed and replaced with <ExactDateTime>
(ContinuityOfCareRecord.DateTime.ExactDateTime).

Most of the mappings are direct one-to-one mapping where the target map location is retrieved from
the map table, and the value is inserted to the location inside the HL7 template.

---

SAMPLE:

ContinuityOfCareRecord.Patient.*.CurrentName.Given – PID.5.2

**DEFINITION:** Map the value from the CCR tags to the PID.5.2

---

However there are also conditional mappings where the value is further examined and additional action
is performed for the value. Using the special flags described in 2.3, Design of the Mapping, we can
achieve different conditional mappings:

1. **ADD Flag** is used when one mapping element will create another map, usually a pre-defined
   value. However, it is also possible to not use predefined value for the Additional map, for
   example by using the same value of the current map.

   **SAMPLE:**

   ContinuityOfCareRecord.Patient.Actor.ActorObjectID – PID.2.1 [ADD|PID.3.1|%]

   **DEFINITION:** Add another map values with the HL7 map as shown in second field of the flag,
   with the same value

---

2. **CNV Flag** is used to convert the current value because of different format used in HL7 and CCR.

   **SAMPLE:**

   ContinuityOfCareRecord.Patient.*.Gender.Text – PID.8 [CNV|Female=F&Male=M]

   **DEFINITION:** If the value matches with one of the value listed in second field of the flag,
   convert that value before mapping.
3. CHK Flag is used when the value can be mapped into different locations, depending on the context. There are two types of the CHK Flag, one is to indicate and list the possible locations (VAL), and one is to signal which of the destination all subsequent values (or queued values) should go (FLG).

**SAMPLE:**

```
ContinuityOfCareRecord.Problems.Problem.Description.Text – ZZZ.PRB.1
[CHK|PRB|VAL|Diagnosis=DG1.3.2&Problem=PRB.3.2]
```

**DEFINITION:** Depends on whether there is already a CHK|PRB|FLG encountered: if FLG is already encountered before this, which of the locations listed in the 4th field is suitable can be decided. The actual mapping is ignored wherever CHK flag is found (ZZZ.PRB.1 is ignored in this case).

**SAMPLE:**

```
ContinuityOfCareRecord.Problems.Problem.Type.Text – ZZZ.PRB.2 [CHK|PRB|FLG]
```

**DEFINITION:** This indicates that the value at this map will decide the location of all other map with CHK|PRB|VAL flag. In relation to the previous example, if the value at this map is “Diagnosis” all queued values or subsequent values will be mapped to DG segment; else if the value is “Problem” the values will be mapped to PRB segment. The actual mapping is also ignored (ZZZ.PRB.2).

In the process of mapping values from CCR to HL7, numbers of segments are created depending on the main elements (<Payers>, <Alerts>, <Medications>, etc.) within the CCR. Several repeating main elements will create several segments of the same type. With the exception for <Results>, if there are multiple <Test> in the Results, multiple OBXs will be created as well.

### 3.2.2.2 Converting HL7 v2.x to CCR

Every HL7 message that comes into the translator is assumed to be a valid HL7 message – see the section above on Mirth codes and filters - and is converted into an HL7 message object. This HL7 message object will have the same characteristics as XMLParser in terms of reading, where values are read from top to bottom using cursor. And by accessing each value in each component of an HL7 segment we determine the location of the CCR where it should be mapped.
Each of the mapped values is stored in a pair of destination and value, such as:

- **From.ActorLink.ActorID** - SwinHealthSystem
- **Patient.ActorID** - 00114455

which have the equivalent representation in XML as:

```xml
<From><ActorLink><ActorID>SwinHealthSystem</ActorID></ActorLink></From>

<Patient><ActorID>00114455</ActorID></Patient>
```

There are also values that are constantly added to the CCR mapped values such as the version of the CCR, CCR creation date, purpose of the CCR (exported record).

The parser will go through the HL7 message and go through every field in each segment that has value, and match the combination of the Segment.Field.Component against the map table that we have. If there is a match, the corresponding CCR element tags are placed in the mapped value along with the value using the representation as shown above.

However, not all translation processes are linear mappings, i.e. one-to-one direct mappings. As described in 2.3. Design of the Mapping, we have special flags in the map table to allow more conditional mapping:

1. **UNQ Flag** is used to generate unique value, mostly for CCRDataObjectID as it cannot be found in HL7 message; this is because almost every main element in the CCR requires such ObjectID, but most HL7 segments are not uniquely identifiable in the same manner.

As of now, CCRObjec7IDs are randomly generated, and according to the ASTM CCR specification, CCRObjectIDs are:

> ...unique IDs used by the generating entity/system to uniquely identify each explicit instance of a CCR and each explicit Data Object. The uniqueness of these ObjectIDs is defined within the generating system. The `<CCRDocumentObjectID>` should ideally be unique across all CCRs through the use of a UUID or OID or other generally accepted universal unique ID mechanism. Data Object IDs must be unique to and within each CCR, but are not considered unique across the universe of all CCRs. A universal unique ID mechanism such as UUID, OID, or other generally accepted universal unique ID mechanism can be used for data object IDs, but is not required. (A2.3.5.4 of CCR Specification)
In this stage of testing the uniqueness of these ObjectIDs is ignored, whereas in the actual implementation the uniqueness must be ensured according to the implementing system’s unique ID mechanism.

**SAMPLE:**

\[AL1.1.1 => \text{Body.Alerts.Alert.CCRDataObjectID [UNQ]}\]

**DEFINITION:** Generate unique value for this CCR Map, the value AL1.1.1 is ignored as it only shows the order of the segment if there is more than one segment for Allergy.

2. **ADD Flag** is used when one mapping element will create another map, usually a pre-defined value. However, it is also possible to not use a predefined value for the Additional map, for example by using the same value of the current map. It is also possible to specify the condition in which the ADD flag should be used, such as ‘only add one more map element IF next component is empty’.

**SAMPLE:**


**DEFINITION:** Add another map value with the CCR map as shown in second field of the flag, with the value of “Attending Doctor”

**SAMPLE:**


**DEFINITION:** Add another map value with the CCR map as shown in the second field of the flag, with the same value as the current map

**SAMPLE:**

**DEFINITION:** Add another map value with the CCR map as shown in the second field of the flag, with the value of “Allergy”, but only IF next component is empty

3. **CHK Flag** is used to check the current map by using the condition already hard-coded into the program. This second field of the flag determines the action to the current map.

**SAMPLE:**

\[
\text{NK1.3.1} \Rightarrow \text{Support.SupportProvider.ActorRole.Code.Value} \\
[\text{CHK | REPLACE\_MAP\_IF\_NEXT\_COMPONENT\_EMPTY} | \text{Body.Support.SupportProvider.ActorRole.Text}]
\]

**DEFINITION:** IF next component is empty, replace the current map with the map shown in the third field

**SAMPLE:**

\[
\text{OBX.5.1} \Rightarrow \text{Results.Result.Test.TestResult.Value} [\text{CHK | OBX | TX.ST.NM}]
\]

**DEFINITION:** Only use this map IF OBX type is one of the type shown in third field. This is because depending of the OBX type (OBX.2.1) different map is used for test result field.

4. **DEF Flag** is used to set the default value for a CCR map if the segment exists, but no value is assigned at the field.

**SAMPLE:**

\[
\text{OBX.5.1} \Rightarrow \text{Results.Result.Test.TestResult.Value} [\text{CHK | OBX | TX.ST.NM}]
\]

**DEFINITION:** Only use this map IF OBX type is one of the type shown in third field. This is because depending of the OBX type (OBX.2.1) different map is used for test result field.

5. Combination of flag is also possible when more than one flag applies to one map. The flags are separated by using ampersand (&).

**SAMPLE:**

\[
\text{PRB.1.1} \Rightarrow \text{Problems.Problem.CCRDataObjectID} \\
[\text{UNQ&ADD} | \text{Body.Problems.Problem.Type.Text} | \text{Problem}]
\]
**DEFINITION:** Generate a unique value for this CCR Map, the value PRB.1.1 is ignored, and add another map value with the CCR map as shown in the second field of the second flag, with the value of “Problem”.

It is possible to extend these flags even further as necessary or chain other combination of the flags when needed. All the maps are stored in the map table, thus making it easier to maintain the combination of the CCR map and special flags.

Aside from the flags, all dates and times are automatically detected and converted to satisfy CCR `<DateTime>` format requirements. They are converted from YYYYMMDDHHMMSS into YYYY-MM-DDTHH:MM:SSZ format to follow the convention as specified by ASTM.

According to the CCR normalization rule, all `<Actor>` info is stored at the footer, and `<ActorID>` link is inserted to the main elements instead; thus all `<Actor>` is being referenced from the footer. For this particular reason all the mapping for Actors are looking very similar, they have `<Actors>` `<Actor>` as the first two element tags.

All unmapped elements are also recorded to a text file to be analysed further and to confirm the validity of the mapping, while the mapped values are stored in a collection and sorted according to the CCR ASTM Specification. See the following figures.
Figure 3-3: CCR output before sorting
In the last step, a proper XML is written by using the Java’s built-in XMLWriter from the list of elements and value pairs that we have. Headers and pre-processing tags are also included in this step, as shown in the following figure.

Figure 3-4: CCR output after sorting
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="ccr.xsl"?>
<ContinuityOfCareRecord xmlns="urn:astm-org:CCR">
  <From>
    <ActorLink>
      <ActorID>mycare2x</ActorID>
      <ActorRole>Demo</ActorRole>
    </ActorLink>
  </From>
  <To>
    <ActorLink>
      <ActorID>Demo</ActorID>
      <ActorRole>Demo</ActorRole>
    </ActorLink>
  </To>
  <Patient>
    <ActorID>1026000</ActorID>
  </Patient>

  <Body>
    <Payers>
      <Payer>
        <PaymentProvider>
          <ActorID>AOK</ActorID>
        </PaymentProvider>
      </Payer>
    </Payers>

    <Encounters>
      <Encounter>
        <CCRDataObjectID>1</CCRDataObjectID>
        <DateTime><ExactDateTime>200405171306</ExactDateTime></DateTime>
      </Encounter>
    </Encounters>
  </Body>

  <Actors>
    <Actor>
      <ActorObjectID>1026000</ActorObjectID>
    </Actor>
    <Actor>
      <ActorObjectID>AOK</ActorObjectID>
    </Actor>
  </Actors>
</ContinuityOfCareRecord>
3.3 The Transformation Java Code

As mentioned before, we are implementing that translation package using Java, as a high level programming language that can be ported into our message gateway in the latter stage. The implementation itself will follow object-oriented design and with configurable settings for testing and deployment phase.

3.3.1 Code and Diagrams for Converting CCR to HL7 v2.x

There are 3 main classes created to perform the translation process from CCR to HL7 messages. Those classes can be seen from the following figure.

![Figure 3-6: Class Diagram (CCR to HL7)]
There are also other classes not listed here that are also used to support the translation process, such as StopWatch (licensed under the Apache License) and HUtil.

The next figure shows a high level sequence diagram of the translation process. The initial process of the translation includes reading the CCR input and validating the input file, denormalizing the CCR input, and initializing the xml parser to the modified CCR. Initialization of HL7Template, the class that represents the actual HL7 output message, follows right after the completion of these steps.

The actual mapping process is done by matching the input elements to the CCR field of the mapping table to get the matching HL7 field/segment/component combination and write this to our HL7Template. The program will always check for special cases such as date conversion, conditional mapping (If ... Then...), repeating elements (OBXs) and coding systems. The resulting HL7 message will be passed back to the calling system, in this case, Mirth.
Figure 3-7: Sequence Diagram (CCR to HL7)
3.3.2 Code and Diagrams for Converting HL7 v2.x to CCR

By adding one more class to handle CCR elements and their values, the class diagram representing the prototype can be seen from the following figure.

![Class Diagram with CCRElement class](image-url)
The next figure explains the translation process from a HL7 message into CCR XML. While most of the classes used in the previous translation are included, the notable difference here is that we introduce CCRElement class to handle XML tag-value pairs to ease manipulation of the mapped result at the later stage.

Each value accessed in the HL7 message is matched against the map table, and the result is stored as a CCRElement. Conditional map is also used here to entertain special cases such as generating CCRDocumentObjectID or similar unique identifier required for CCR.

The collection of CCRElements are sorted to better resemble a valid CCR after the mapping process, before being formatted into correct XML with hierarchical tags and encoded using UTF-8.
Figure 3-9: Sequence Diagram (HL7 to CCR)
3.3.3 Configuration Settings

A .properties file can be found in the root folder of the translation package folder to easily configure the program. The following figure shows the content of the .properties file.

```
# Path settings
CCR_INPUT_PATH=/CCR/
HL7_INPUT_PATH=/HL7/
MAP_PATH=/Map/
# Additional settings
WRITE_UNMAPPED_ENTRY=1
USE_STOPWATCH=1
DEBUGGING_MODE=0
# Write the result of translation to a file
# Only write the file name without the type
# Use value 'null' or '0' to turn off
WRITE_TO_FILE=result
```

Figure 3-10: Properties file

Below is the explanation for each of the configuration line:

- **CC_INPUT_PATH** – specify the input path for CCR relative to the root folder. Used when translating CCR to HL7 using input file.

- **HL7_INPUT_PATH** – specify the input path for HL7 relative to the root folder. Used when translating HL7 to CCR using input file.

- **MAP_PATH** – specify the folder with all the mapping files and other necessary files to run the translation.

- **WRITE_UNMAPPED_ENTRY** – can be enabled or disabled, if enabled will write all unmapped entry to a default file location

- **USE_STOPWATCH** – can be enabled or disabled, if enabled will track the time needed to complete the translation

- **DEBUGGING_MODE** – can be enabled or disabled, if enabled will print detailed process of the translation to the console for debugging purpose

- **WRITE_TO_FILE** – can be enabled or disabled, if enabled will save the result of the translation to the specified file location/filename. No file extension should be given (will automatically add file extension).
3.4 The Implementation of the Maps as Mirth Transformers

To allow a more integrated and automated translation process, we are using Mirth Connect (version 1.8.2.x) as the middleware to relay messages between different HISs.

3.4.1 Integration of Translation Packages into Mirth

Our packaged Java library is placed inside Mirth’s external library folder to be recognized by Mirth then called in the transformation process. Supporting files for the library such as the map table, as described in 2.3. Design of the Mapping, are placed in the root directory of the Mirth Connect installation, as shown below.

After specifying both input and output type, translation process can be carried out in different places: source transformer or destination transformer. A source transformer will transform (or translate, in this case) a message in the source channel and a destination transformer will translate the message in an independent channel in destination. Of course a source transformer will affect all destinations, whereas a destination transformer will affect only its own output.

Ideally the translation package should be inserted into a destination transformer, i.e. the destination where the expected output is the translated message. This ensures that only when one of the destinations requires the translated message, we translate the message, because there is a possibility of having multiple destinations, each with its own set of transformation rules (not necessarily our translation). However, when we tried to put the translation package into the destination transformer,
only one message passed through the destination channel, and all subsequent ones were blocked before translation. It is still unclear why this happened.

Thus our translation package is inserted into a source transformation step inside Mirth Connect, and is called for every message received by the source reader we specified for that channel. The following figure shows the JavaScript for invoking the package for a CCR-to-HL7 translation. The package will translate the message, and put the result into a channel map variable that is accessible from a destination connector.

As mentioned in section 2.4.1, we set Mirth to validate any incoming HL7 message for us, ensuring that the translation package receives completely valid HL7 input. Mirth validation is very strict and solely based on the specification provided by HL7 organization; thus every message sent to Mirth has to completely comply with the HL7 specifications.

The translation package however is found to work at much slower speed when deployed inside the Mirth transformer. This happens especially when translating CCR to HL7, where pre-processing the message before the actual translation is more tedious because we have to first denormalize the CCR. Comparing the package when it runs on the development environment outside of the Mirth and the actual implementation of the package inside the Mirth there is a huge gap of processing time, as shown in the following table.
<table>
<thead>
<tr>
<th>CCR Size (in KB)</th>
<th>Number of Lines</th>
<th>Time Taken in IDE (in milliseconds)</th>
<th>Time Taken in Mirth (in milliseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>213</td>
<td>12665</td>
<td>10140</td>
<td>84895</td>
</tr>
<tr>
<td>99</td>
<td>4064</td>
<td>4078</td>
<td>6016</td>
</tr>
<tr>
<td>64</td>
<td>2883</td>
<td>2922</td>
<td>4390</td>
</tr>
<tr>
<td>8</td>
<td>232</td>
<td>265</td>
<td>281</td>
</tr>
</tbody>
</table>

Table 3-1: Speed performance and comparison in IDE and Mirth

From the comparison we can see that as the size of the CCR grows, the difference of performance speed also grows rather exponentially. Thus, in cases where speed is a priority all CCR input has to be reasonably small to prevent the gateway being congested by many large CCR files.

3.4.2 Integration of Translation Packages into Mirth

Since we are developing the translation package outside of the Mirth, there are steps involved to integrate our translation package into the Mirth to allow Mirth to call our library and also connect with Google h9 server using our library.

3.4.2.1 Connecting Mirth to Google Health

To connect to the Google Health h9 server, one must have a Google account and full privileges to that account. Google Health also requires notification of a “profile ID” in order to access a specific health profile stored in their server. Username and password of a registered account in Google Account must be supplied along with the profile ID that identifies whose record our system is trying to access. One account in Google Health can accommodate more than one profile, i.e. more than one person can share the same account and have unique profile ID for each of them under that account.

The GData client library from Google is currently available for several programming languages such as Java, JavaScript, .NET, PHP, Python, Objective-C (for some other Google service, not including Google Health). The library includes functions for authentication as described above. It is possible to communicate directly with Google Health via HTTP requests without using any of the client libraries, however for ease of testing we decided to use the GData library.
Following implementation of GData client library, the authentication of a user’s profile on Google Health server is done by following these steps (http://code.google.com/apis/gdata/docs/auth/overview.html):

1. When the third-party application needs to access a user's Google service, it retrieves the user's login name and password.

2. The third-party application then makes a ClientLogin call to Google's Authorization service.

3. If the Google Authorization service decides additional vetting is necessary, it returns failure response with a CAPTCHA token and challenge, in the form of a URL for a CAPTCHA image.

4. If a CAPTCHA challenge is received, the third-party application displays the CAPTCHA image for the user and solicits an answer from the user.

5. If requested, the user submits an answer to the CAPTCHA challenge.

6. The third-party application makes a new ClientLogin call, this time including the CAPTCHA answer and token (received with the failure response).

7. On a successful login attempt (with or without CAPTCHA challenge), the Google Authorization service returns a token to the application.

8. The application contacts the Google service with a request for data access, referencing the token received from the Google Authorization service.

9. If the Google service recognizes the token, it supplies the requested data access.

The next figure shows the sequence of the steps as described above in a diagram.

![Sequence diagram for authentication](http://code.google.com/apis/accounts/images/ClientLoginDiagram.png)

Because Google Authentication service requires all applications or services that interacts with user’s private data (Google Health profile) to be registered, our prototype will most likely get caught in the CAPTCHA challenge as can be seen from steps 3-6 above because our prototype is not registered. By
using Google Health’s testing server (h9 server) however, any application using client login method is allowed to have access as long as the application stays clear of the actual Google Health’s server. Thus, our prototype will only interact with h9 server for testing purpose.

The differences between Google Health server and h9 can be seen from following table (http://code.google.com/apis/health/getting_started.html):

<table>
<thead>
<tr>
<th></th>
<th>H9 Sandbox</th>
<th>Google Health</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do API requests need to be digitally signed?</td>
<td>NO</td>
<td>YES</td>
<td>Also for testing purposes, the sandbox does not require the use of secure=1 AuthSub tokens. You must register your domain with both Google and Google Health.</td>
</tr>
<tr>
<td>Where should I request an AuthSub token from?</td>
<td><a href="https://www.google.com/h9/authsub">https://www.google.com/h9/authsub</a></td>
<td><a href="https://www.google.com/health/authsub">https://www.google.com/health/authsub</a></td>
<td>Both Google Health and H9 use their own AuthSub handler to issue tokens. <strong>Note:</strong> The other Google Data APIs use /accounts/AuthSubRequest.</td>
</tr>
<tr>
<td>Can I use <a href="http://localhost">http://localhost</a> as AuthSub’s next parameter?</td>
<td>YES</td>
<td>NO</td>
<td><a href="http://localhost">http://localhost</a> has already been registered as a domain on /h9. On /health, you must register your domain with both Google and Google Health and upload an X.509 certificate to sign requests.</td>
</tr>
<tr>
<td>What is the service name for ClientLogin?</td>
<td>Weaver</td>
<td>health</td>
<td></td>
</tr>
</tbody>
</table>

Table 3-2: h9 (Sandbox) and Google Health server comparison
The Google GData client is not recognized by Mirth as a standard IO reader or writer (such as HTTP, FTP, etc.). Since we are using the Java client library to connect with Google Health, we have to find a way put the library as the source (or destination) connector. There is no source connector in Mirth currently that directly supports Java, but Mirth does include a “JavaScript reader/writer” as a recognized connector. By using the JavaScript reader we could import external library just as we use our own package to translate the message. The advantage of this method is that we can set the polling frequency to determine how often we use the library to query the Google Health server.

There is still the problem of sourcing the Google account username and password and the health profile ID. Due to security and privacy concerns, it is not possible for any system to query for username and password from the server itself or bypass such authentication in any way. There are however some possible approaches to this.

• The HL7 input that is going to be converted into CCR can carry such information, and the middleware can process the header of HL7 to extract the username, password and profile ID from the HL7 message. Since this information is patient’s information, it will fit best in the PID segment. However, there is no suitable field in PID according to HL7 specification. The best candidate is “Identity Unknown Indicator” - but that is reserved for Yes/No values.

Thus:

MSH|^~\&||||GoogleHealth_username_password_profileID

This approach however requires the hospital that sends the HL7 message to manage the Google Health account information of the patient, which means letting the hospital store the patient’s Google account information. Another concern is sending an unencrypted password inside a HL7 message which can be intercepted and transparently displayed.

• Another solution is to store account information in MirthMatch, "an enterprise class Entity Identification Service built on open standards and leveraging the strengths of existing open-
source components to provide a powerful, scalable and comprehensive solution capable of handling common healthcare Master Data Management (MDM) patterns such as Enterprise Master Patient Index (EMPI), Master Provider Index, Facility index or simple member list de-duplication” (http://www.mirthcorp.com/products/mirth-match). This product however is still in closed beta testing currently (2011), thus there are still bugs and limited functionality that might hinder the reliability of the system.

- Another solution is to construct a DB outside of Mirth to collect and store patient account details, with every incoming HL7 matched to this database from Mirth. One of the channels in Mirth will match the patient’s information to the database and get the login information before sending the translated CCR to Google Health. This will protect the patient’s login information by not exposing the password unnecessarily and by preventing unauthorized persons from getting the login information.

### 3.4.2.2 Inserting the Google Health connector into a Mirth channel

Google Health connector that we are using is a customized package based heavily on the GData client library developed by Google. It can be used to retrieve the CCR profile of a registered account, or update a CCR profile to Google Health server. As mentioned in the previous section, to associate a Google account with a person we are using a database before authenticating with the h9 server. This replaces the need to save a patient’s Google account in the hospital HIS.

Because every person is uniquely identified by Social Security Number (SSN) or Social Security Identification (SSID) (in the USA), and this information can be captured by HL7 (PID.19.1) and CCR (Actor.IDs.ID) we can put it into the table in the database as the primary key. In case when this value is not available in the incoming HL7 message or CCR, we can use the combination of a person’s first, middle, and last name. See the following figure.
Because this process has to be done in Mirth, we used JavaScript reader (and writer, based on the direction of the translation) to query the database and perform the steps as shown in the figure above.

JavaScript reader is used in a Mirth Channel when we supply our own packages to read from other sources such as a Google Health server. A screenshot of this is shown in the following figure. By invoking our library inside JavaScript reader we can extend the number of sources accepted by Mirth.
After the HL7 message is translated into a CCR, some of the information is also extracted locally into Mirth such as SSN and name of the patient to help with the authentication. Once authentication returns an okay response, the Google Health connector sends the CCR (after converting it to fit in Google Health standard) to the server.

![JavaScript Writer](image)

Figure 3-16: An excerpt of the Destination JavaScript writer to authenticate and send CCR to h9 server

A setup of at least one channel in Mirth is required before we can run our library in Mirth. The settings of a channel mostly depend on what types of source and destination we are expecting. A Database listener is used when we are expecting inputs from database, a file writer is used when the expected output should be placed in specific folder as a file, and so on. myCare2x currently supports directory read and write by using an import and export folder. myCare2x writes outgoing HL7 messages to its code subdirectory /hl7/output, and reads incoming HL7 messages from the subdirectory /hl7/input. Thus the prototype will make use of file writer and reader utility to connect with myCare2x.

### 3.4.3 The CCR -> HL7 transformation process

We show this first diagrammatically, followed by more detailed descriptions.
3.4.3.1 Diagrammatic flow

The above diagram shows the flow of the transformation from source (h9 server), through the translation to the destination (myCare2x):

1. GData API authenticates itself with the patient’s login information in Google Server (h9 sandbox), the process will only move on if h9 server returns positive acknowledgement.

2. GData API retrieves the CCR record from the h9 server for the selected profile.

3. CCR retrieved is sent over to the Transformer of the Source Connector.

4. Using JavaScript, our translation package (HMapper) is invoked and the input CCR is passed to the package for the translation.

5. The translated message (in HL7 message format) proceeds to the Destination Connector. Each of the destinations will filter the output to make sure the message reach the intended destination.

6. If the message passes the filtration process, the message reaches the last stage in the Mirth Connect, connector of the destination. Since myCare2x has its import folder for input and expecting HL7 message as file input, we use File Writer.
7. The HL7 file is written to myCare2x's import folder.

This next diagram shows the flow when using a different source (a MySQL Database):

![Diagram showing the flow of transforming CCR to HL7](image)

1. Database Reader query for the CCR(s) in the Database. Other than CCR itself, other information such as destination of the translated message can also be queried.

2. CCR retrieved is sent over to the Transformer of the Source Connector.

3. Using JavaScript, our translation package (HMapper) is invoked and the input CCR is passed to the package for the translation.

4. The translated message (in HL7 message format) proceeds to the Destination Connector. Each of the destinations will filter the output to make sure the message reach the intended destination.

5. If the message passes the filtration process, the message reaches the last stage in the Mirth Connect, connector of the destination. Since myCare2x has its import folder for input and expecting HL7 message as file input, we use File Writer.

6. The HL7 file is written to myCare2x's import folder.
3.4.3.2 Source of CCR messages

CCR messages ideally come directly from the PHR that is intended to be the main repository of the patient’s health record. We have tested two potential sources of CCR messages.

1. A Google Health server will be the main source of the CCR input.

2. A database can also be used as the source of CCR messages, where Mirth can poll the database at pre-set time intervals.

A database represents an input source that Mirth already understands (using built-in Database Reader in Mirth Connect), while Google's h9 server represents the input that requires modification and an extra library because it is not directly supported by Mirth Connect.

In our implementation, the structure of the table inside the database has the following fields:

```plaintext
'id' int(11) NOT NULL AUTO_INCREMENT,
'date' date NOT NULL,
'record' mediumtext NOT NULL,
```

Figure 3-19: CCR table structure in Database

‘Id’ field is the unique identifier given to each of the CCR in the table, ‘date’ is used to know when is the CCR inserted to the table and the ‘record’ is the actual CCR entry. This is just a minimal design for testing purpose, there are other fields that can be inserted to increase comprehensiveness such as patient id or name, source of CCR information, and also updated/processed field to know whether the message gateway has processed this CCR or not.

For each source input, one channel can be deployed in Mirth, and a suitable connector must be defined for each; we use Database Reader when sourcing CCR messages from a database and JavaScript Reader when GData is used to source CCR messages from Google Health's server (see 3.4.1.4, Inserting the Google Health connector into a Mirth channel). The reason we used JavaScript reader is because we are using GData API library, and JavaScript Reader is the only reader in Mirth that allows an external Java library to be called in the source connector.
3.4.3.3 Transformation in Mirth Channel Source

The transformation happens in the transformer of the source connector, by using JavaScript transformer to call our HMapper library and the rest of the supporting library (MapTable, HL7Template, etc.) to translate the incoming CCR. Using the built-in logger in Mirth, the time taken for each translation can be recorded to help with the testing process.

![Mirth Connect Administrator - https://localhost:8443](image)

The translated message is inserted into channel map – a global variable in Mirth Connect – so the resulting HL7 can be accessed at the next step.

For database input, we can use the normal Mapper to get the CCR out of the result array, by querying the database using the Database Reader.

3.4.3.4 Destination of HL7 output

At the destinations part of the channel, a filter is used to determine where the output should be sent. Because it is possible to have many destinations, each of these destinations will have its own filter to determine whether the result should proceed to that destination or not. The filters can scan a segment in the resulting HL7 message, e.g. MSH for its Receiving Application (MSH.5) or Receiving Facility (MSH.6) and check for the corresponding destination location.

Although Mirth has its own internal parser for HL7 messages, because our resulting CCR is inserted into a channel map, the internal parser cannot be used. But we can use a JavaScript filter and scan the header of the HL7 message.

In our case, when the header of the output HL7 message indicates that current destination is indeed the intended location, a File Writer is invoked to write the output, in our case to the myCare2x HL7 input directory. myCare2x then will handle the HL7 message and process it to that system.
3.4.4 The HL7 -> CCR transformation process

3.4.4.1 Diagrammatic flow

Figure 3-21 - Transforming HL7 to CCR (HL7 Inspector to h9 server)

The above diagram summarizes the transformation process of translating HL7 v2.x messages to CCR messages, using HL7 Inspector as the message source:

1. HL7 Inspector sends a HL7 message using LLP protocol to Mirth web-service at specified port.

2. Mirth Source Connector receives the message and returns acknowledgement message ACK back to HL7 Inspector. The message is now sent to the Transformer.

3. Using JavaScript, HMapper library is called and translates the HL7 message into CCR.

4. The translated message (in CCR message format) proceeds to the Destination Connector. Each of the destinations will filter the output to make sure the message reaches the intended destination.

5. If the message passes the filtration process, the message reaches the last stage in Mirth Connect, the connector of the destination.
6. Using JavaScript writer, GData API library is called and begins authenticating user’s information with the h9 server to verify account details.

7. If authentication successful, the CCR is uploaded to the h9 server, and the profile of the patient is updated in the h9 server.

The next diagram summarizes the transformation process of translating HL7 v2.x messages to CCR messages, using myCare2x export directory (/hl7/output) as the source:

![Figure 3-22 - Transforming HL7 to CCR (myCare2x export directory to h9 server)](image)

1. The File Reader polls the directory for new HL7 messages. The polling frequency can be set to periodically or at specific time (e.g. every 12 AM midnight).

2. File Reader sends the HL7 message to the transformer and then moves the file that has been read to another directory.

3. Using JavaScript, the HMapper library is called and begins translating the HL7 message into CCR.

4. The translated message (in CCR message format) proceeds to the Destination Connector. Each of the destinations will filter the output to make sure the message reaches the intended destination.
5. If the message passes the filtration process, the message reaches the last stage in Mirth Connect, the connector of the destination.

6. Using JavaScript writer, GData API library is called and begins authenticating user’s information with the h9 server to verify account details.

7. If authentication successful, the CCR is uploaded to the h9 server, and the profile of the patient is updated in the h9 server.

### 3.4.4.2 Source of HL7 v2.x messages

The incoming HL7 messages can come from many types of sources, including HTTP (Hyper-Text Transfer Protocol), JMS (Java Messaging Service), LLP (Lower Layer Protocol), Database, file input, etc. Mirth also supports all of these input sources.

For testing purpose we decided to use two different input sources, as indicated above: LLP by using HL7 Inspector and file input from myCare2x’s HL7 output/export directory.

### 3.4.4.3 Transformation in Mirth Channel Source

The same as with the CCR to HL7 transformation, the reverse direction also happens by calling HMapper library in a JavaScript transformer at the source connector.

The resulting CCR message is inserted into the channel map again, and it moves on to the next stage.

### 3.4.4.4 Destination of CCR output

Mirth Connect allows output via the same transmission protocols as the input, e.g. LLP, FTP, HTTP, directories, etc.

Since this project concerns communications between HL7 systems and PHR systems, we selected the Google Health h9 development server as the target for receiving transformed / translated messages. It is important to note that this is not one of the standard Mirth output connectors. See the description in section 3.4.1.3 of the Google Health connector package.

As mentioned above, Google Health, and almost all Web-based PHR systems, requires authentication in the form of user names, login passwords, and in the case of Google also “profile IDs”. This presents a major problem; as such information is not normally included in HL7 – or any other – healthcare messages. See 3.4.2.1.Connecting Mirth to Google Health for a discussion of this problem and of potential solutions.
### 3.5 Test Results

#### 3.5.1 The CCR -> HL7 v2.x Map

Here we list all the tested XML input file elements with their resulting HL7 v2.x message segments. The final mapping table used to produce this result can be found in [Appendices](#).

For easier comparison and to maintain the compactness of the table we align the primary elements of the CCR with the resulting segment in HL7. Each Actor will be denormalized to show the values that are mapped into the HL7 segment.

<table>
<thead>
<tr>
<th>CCR Main Element</th>
<th>HL7 Segment affected</th>
<th>Sample CCR input</th>
<th>Actual HL7 output</th>
</tr>
</thead>
<tbody>
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<td>&lt;Patient&gt;</td>
<td>PID</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;Patient&gt;</td>
<td>PID</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;Actor&gt;</td>
<td>^</td>
</tr>
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<td></td>
<td>&lt;ActorObjectID&gt;</td>
<td>Brown^Terry^Malackiam</td>
</tr>
<tr>
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<td></td>
<td>&lt;ObjectID&gt;</td>
<td>^Sr.^Mr.^^^^^^^^</td>
</tr>
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</tr>
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<td></td>
<td></td>
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    </Type>
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</Patient>

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      </ActorRole>
    </Actor>
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      <Person>
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            <Given>Taylor</Given>
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          </CurrentName>
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          <Line2>80</Line2>
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          <StateProvince>SomeProvince</StateProvince>
          <PostalCode>109930</PostalCode>
        </Address>
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      </ActorRole>
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</Support>
Transformation between HL7 and CCR

Results | 110

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      <Code>
        <Value>SPO</Value>
      </Code>
    </ActorRole>
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          <Payer>
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              <ID>AOK</ID>
            </IDs>
            <PaymentProvider>
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                  <City>Owl City</City>
                  <StateProvince>Prov</StateProvince>
                  <PostalCode>141234</PostalCode>
                  <Country>Belgium</Country>
                </Address>
                <Type>
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                </Type>
              </Actor>
            </PaymentProvider>
          </Payer>
        </Payers>
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    </Type>
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      <Text>Some problem with patient's health</Text>
    </Description>
    <DateTime>
      <Text>2011031145230</Text>
    </DateTime>
  </Problem>
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</DateTime>
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</Problems>

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<Problem>
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</DateTime>
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</Description>
</Problem></Problems>

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</Alert></Alerts>

AL1|1|FA^Food Allergy^SCT^|Some Allergen^CD10AM^|^Severe^|20110311000000|
| <Medications> | RXG | <Medication> | <CCRDataObjectID>MEDICATION.28189</CCRDataObjectID> | <DateTime> | <Type> | <Text>Entered</Text> | <ExactDateTime>2005-04-01T08:00:00Z</ExactDateTime> | <Type> | <Text>Medication</Text> | <Description> | <Text>Mirapex 0.125 mg tablet; 1 tab PO QPM x 30 days; #30; 0 refills; Take 2 hours before bedtime</Text> | <Code> | <Value>5988</Value> | <CodingSystem>Multum</CodingSystem> | </Code> | </Code> | <Value>00009000202</Value> | <CodingSystem>NDC</CodingSystem> | </Code> | </Description> | <Status> | <Text>Active</Text> | </Status> | <Product> | <ProductName>pramipexole</ProductName> | </Product> | <BrandName> | <Text>Mirapex</Text> | </BrandName> | <Strength> | <Value>0.125</Value> | <Units> | <Unit>milligram(s)</Unit> | </Units> | </Strength> | | | RXG|1||30^^^^^^^^^^| | | | ^pramipexole^^^^Mirapex | x|||tab(s)^^^^|||Medication^Mirapex 0.125 mg tablet; 1 tab PO QPM x 30 days; #30; 0 refills; Take 2 hours before bedtime^Patient Instructions^Take 2 hours before bedtime| | | RXR|PO^^^^||| |
<Form>
  <Text>tablet</Text>
</Form>

<Product>
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    <Value>30</Value>
    <Units>
      <Unit>tab(s)</Unit>
    </Units>
  </Quantity>
  <Directions>
    <Direction>
      <Dose>
        <Value>1</Value>
        <Units>
          <Unit>tab(s)</Unit>
        </Units>
      </Dose>
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        <Text>PO</Text>
      </Route>
      <Frequency>
        <Value>QPM</Value>
      </Frequency>
      <Duration>
        <Value>30</Value>
        <Units>
          <Unit>Days</Unit>
        </Units>
      </Duration>
    </Direction>
    <PatientInstructions>
      <Instruction>
        <Text>Take 2 hours before bedtime</Text>
      </Instruction>
    </PatientInstructions>
    <Refills>
      <Refill>
        <Number>0</Number>
      </Refill>
    </Refills>
  </Directions>
</Product>

<Immunizations>
  <Immunization>
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    <DateTime>
      <Type>
        <Text>Start Date</Text>
      </Type>
      <ExactDateTime>1990-06-07T00:00:00Z</ExactDateTime>
    </DateTime>
    <DateTime>
      <Type>
        <Text>End Date</Text>
      </Type>
      <ExactDateTime>1990-06-07T00:00:00Z</ExactDateTime>
    </DateTime>
  </Immunization>
</Immunizations>
<DateTime>
<Description>
<Text>HISTORICAL INFORMATION - FROM PARENT=S WRITTEN RECORD</Text>
</Description>
<Product>
<ProductName>
<Text>HEPB-PEDIATRIC/ADOLESCENT</Text>
</ProductName>
<Code>
<Value>08</Value>
</Code>
</Product>
<Strength>
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<Units>
<Unit>MCG</Unit>
</Units>
</Strength>
</Product>
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</Immunization>
</Immunizations>

<Results> OBX
<Results>
<Result>
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<Description>
<Text>GLUCOSE</Text>
</Description>
<Test>
<Type>
<Text>SN</Text>
</Type>
<Description>
<Text>GLUCOSE</Text>
</Description>
<Code>
<Value>1554-5</Value>
</Code>
>Status>
<Text>F</Text>
</Status>
<TestResult>
<Value>175</Value>
<Units>
<Unit>mg/dl</Unit>
</Units>
</TestResult>
</Test>
</Result>
</Results>

<Procedures> PRD
<Procedures>
<Procedure>
<Type>
<Text>Standard Procedure</Text>
</Type>
</Procedure>
</Procedures>

PRD|1|LN001^Standard Procedure^LN^|Procedure description goes here|20101111150233|
<Value>LN001</Value>
   <CodingSystem>LN</CodingSystem>
   <Type>
      <Description>
         <Text>Procedure description goes here</Text>
      </Description>
      <DateTime>
         <Type>
            <Text>Start date</Text>
         </Type>
         <ExactDateTime>2010-11-11T15:02:33Z</ExactDateTime>
      </DateTime>
      <Practitioners>
         <Practitioner>
            <Actor>
               <ActorObjectID>Dr001</ActorObjectID>
               <Person>
                  <Name><CurrentName>
                     <Family>Koala</Family>
                     <Given>Bear</Given>
                     <Middle>Big</Middle>
                     <Suffix>Jr.</Suffix>
                     <Title>Mr.</Title>
                  </CurrentName></Name>
               </Person>
            </Actor>
         </Practitioner>
      </Practitioners>
   </Procedure>
</Procedures>

<Encounters> PV1
<Encounter>
   <CCRDataObjectID>1</CCRDataObjectID>
   <Locations>
      <Location>
         <Description>
            <Text>IN1 210 2 INN C</Text>
         </Description>
      </Location>
   </Locations>
   <Type>
      <Text>I</Text>
   </Type>
   <Practitioners>
      <Practitioner>
         <Actor>
            <ActorObjectID>Dr.ID</ActorObjectID>
            <Person>
               <Name><CurrentName>
                  <Family>DrName</Family>
                  <Given>DrVorname</Given>
                  <Suffix>Herr</Suffix>
                  <Title>Dr. med.</Title>
               </CurrentName></Name>
            </Person>
         </Actor>
      </Practitioner>
   </Practitioners>
</Encounter>
</Encounters>
<SocialHistoryElement> OBX | <SocialHistoryElement> | CCRDataObjectID>BB0084</CCRDataObjectID> | <Type> | <Text>Infection Screening</Text> |  | <Description> | <Text>Live with someone with HIV or exposed to HIV: Y</Text> |  | <Source> |  | <Actor> |  | <ActorID>ACT0004</ActorID> |  | </Actor> |  | </SocialHistoryElement> |  | OBX|54||CCR_IMPORT^^^|SocialHistoryElement|Infection Screening - Live with someone with HIV or exposed to HIV: Y|||||F||| |

| <FamilyProblemHistory> OBX | <FamilyProblemHistory> | CCRDataObjectID>BB0052</CCRDataObjectID> | <DateTime> | <Type> | <Text>Onset</Text> |  | <ExactDateTime>2005-04-11T16:58:16.000000</ExactDateTime> |  | <Source> |  | <Actor> |  | <ActorID>ACT0004</ActorID> |  | </Actor> |  | </FamilyProblemHistory> |  | OBX|2||CCR_IMPORT^^^|FamilyProblemHistory|Patient, babys father, or anyone in either family - Thalassemia: N|||F|
Transformation between HL7 and CCR  Results

Because some of the mappings require a more conditional approach rather than one-to-one mapping, we designed special flags to assist in those situations. Below is the table that summarizes the special

<table>
<thead>
<tr>
<th>VitalSigns</th>
<th>OBX</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;VitalSigns&gt;</td>
<td>OBX 5</td>
</tr>
</tbody>
</table>
lbs^|20050404|
| <Result>    |      | </VitalSigns> |
| <Test>      |      | <CCRDataObjectID>ID-64923d56-ec9a-470c-888d-5278baaaa0a8</CCRDataObjectID> |
| <Description> |      | <Text>Weight</Text> |
| <Code>      |      | <Value>C0005910</Value> |
| <CodingSystem> UMLS </CodingSystem> |
| <Description> |      | </Source> |
| <Text>Unknown</Text> |      | </Description> |
| <Source>    |      | <TestResult> |
| <Value>170</Value> |      | </Source> |
| <Units>     |      | <Unit>lbs</Unit> |
|            |      | </Units> |
|            |      | </TestResult> |
|            |      | </Test> |
|            |      | </Result> |
|            |      | </VitalSigns> |

Table 3-3: CCR to HL7 test result
flags inserted to our mapping table, with the resulting HL7 output generated for each of these special cases. Because we only want to show the result of conditional mappings, the input field will be kept simple – only the elements that trigger and are affected by the conditional map will be shown.

<table>
<thead>
<tr>
<th>Flag Type</th>
<th>Description</th>
<th>Flag Field</th>
<th>CCR Input</th>
<th>HL7 Output</th>
</tr>
</thead>
</table>
| ADD       | Map additional values to another location, either by using new value or the value encountered in this location | ADD|PID.3.1| % | <Patient>  
  <Actor>  
  <ActorObjectID>SN200001</ActorObjectID>  
  </Actor>  
  </Patient> | PID||SN200001^^  
  ^^^^^|^SN200001  
  ^^^^^|| |
| CNV       | Convert current value into another value | CNV|Female=F&Male=M | <Gender>  
  <Text>Male</Text>  
  </Gender> | PID|||M|||
| CNV%      | Includes mapping into the value (special case for CCR Elements with no direct match in HL7). Used for backwards translation | CNV% | <FamilyMember>  
  <ActorRole>  
  <Text>Father</Text>  
  </ActorRole>  
  </FamilyMember> | OBX|||FamilyMember.ActorRole.Text: Father|
| CHK|FLG | Indicates the current value will decide the map location of other CHK| VAL | <Problem>  
  <Type>  
  <Text>Problem</Text>  
  </Type>  
  </Problem> | See below |
| CHK|| VAL                | CHK|PRB|VAL | | Diagnosis=DG 1.5&Problem=PRB.2 | PRB|201012235622 |
|---|---|---|---|---|---|---|
| Queue or decides the location of the current value depends on whether CHK||FLG has been encountered | <Problem><Type><Text>Problem</Text></Type></Problem> <DateTime><ExactDateTime>2010-12-12T23:56:22Z</ExactDateTime></DateTime></Problem> |

Table 3-4: CCR to HL7 conditional mappings result

For the CHK flag, the FLG and VAL work together to logically map a value into the HL7 segment. If Problem.Type.Text is ‘Problem’ (FLG), then the values after that are placed in PRB (VAL).

3.5.2 The HL7 v2.x -> CCR Map

Here we list all the tested HL7 input file elements with their resulting CCR message sub-elements. The final mapping table used to produce this result can be found in Appendices.

As in the previous section, again we align each segment from the HL7 message with the affected primary element(s) of CCR – some segments will generate more than one primary element in CCR while some do not.

<table>
<thead>
<tr>
<th>HL7 Segment</th>
<th>CCR Main Elements Affected</th>
<th>Sample HL7 Input</th>
<th>Actual CCR output</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRD</td>
<td>&lt;HealthCareProviders&gt;, &lt;Actor&gt;</td>
<td>PRD</td>
<td>^Referring Provider</td>
</tr>
</tbody>
</table>
### Transformation between HL7 and CCR

<table>
<thead>
<tr>
<th>PID</th>
<th>&lt;Patient&gt;, &lt;Actor&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PID</td>
</tr>
<tr>
<td></td>
<td>Rock Well Apt&amp;Rockwell Street^80^Rockwell^SomeProvince^109930^Belgia</td>
</tr>
<tr>
<td></td>
<td>&lt;/Patient&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;Actors&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;Actor&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;Name&gt;</td>
</tr>
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<td></td>
<td>&lt;Family&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;Given&gt;</td>
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<tr>
<td></td>
<td>&lt;Middle&gt;</td>
</tr>
<tr>
<td></td>
<td>&lt;Suffix&gt;Sr.&lt;/Suffix&gt;</td>
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<tr>
<td></td>
<td>&lt;Title&gt;</td>
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<td>&lt;CurrentName&gt;</td>
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<td>&lt;DateOfBirth&gt;</td>
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<td></td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>NK1</td>
<td>&lt;Support&gt;, &lt;Actor&gt;</td>
</tr>
<tr>
<td>-----</td>
<td>------------------</td>
</tr>
<tr>
<td>NK1</td>
<td>1</td>
</tr>
<tr>
<td>SPO^Spouse</td>
<td>Rock Well</td>
</tr>
<tr>
<td>Apt&amp;Rockwell</td>
<td></td>
</tr>
</tbody>
</table>
| Street^80^Rockwell^SomeProvince^109930^Belgia|123-456-789

<table>
<thead>
<tr>
<th>IN1</th>
<th>&lt;Payers&gt;, &lt;Actor&gt;</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1</td>
</tr>
<tr>
<td>Insurance</td>
<td>AOKComp</td>
</tr>
<tr>
<td>City^Prov^141234^Belgiana</td>
<td></td>
</tr>
<tr>
<td>Primary Health Insurance</td>
<td></td>
</tr>
</tbody>
</table>

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  <SupportProvider>
    <ActorID>20110401-19186</ActorID>
    <ActorRole>
      <Text>Spouse</Text>
      <Code>
        <Value>SPO</Value>
      </Code>
    </ActorRole>
    <SupportProvider>
      <Support>
        <Actor>
          <ActorObjectID>20110401-19186</ActorObjectID>
          <Person>
            <Name><CurrentName>
              <Family>Bologna</Family>
              <Given>Taylor</Given>
              <Middle>Larry</Middle>
            </CurrentName></Name>
            <Address>
              <Line1>Rock Well Apt&amp;Rockwell Street</Line1>
              <Line2>80</Line2>
              <City>Rockwell</City>
              <StateProvince>SomeProvince</StateProvince>
              <PostalCode>109930</PostalCode>
              <Country>Belgia</Country>
            </Address>
          </Actor>
        </Support>
      </Support>
    </SupportProvider>
  </SupportProvider>
</Support>
```
<Organization>
    <Name>SuperHealth Ltd.</Name>
</Organization>

<Address>
    <Line1>Rainbow Apt</Line1>
    <City>Owl City</City>
    <StateProvince>Prov</StateProvince>
    <PostalCode>141234</PostalCode>
    <Country>Belgium</Country>
</Address>

<Problem>
    <CCRDataObjectID>20110401-15121</CCRDataObjectID>
    <Type><Text>Diagnosis</Text></Type>
    <Description><Text>Some problem with patient's health</Text></Description>
    <DateTime><Type><Text>Start date</Text></Type><ExactDateTime>2011-03-11T14:52:30Z</ExactDateTime></DateTime>
    <IDs><ID>A</ID></IDs>
</Problem>

<Alert>
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    <Code><Value>FA</Value><CodingSystem>SCT</CodingSystem></Code>
    <Description><Text>Some Allergen</Text></Description>
    <Severity><Text>Severe</Text></Severity>
</Alert>

<Products>
    <Product>20110401-10328</Product>
</Products>
PR1 | <Procedures>, <Actor>

PR1 | 1 | LN001^Standard Procedure^LN | Procedure description goes here | 2010-11-11T15:02:33Z | Dr001^Koala^Bear^Big^Jr.^ Mr.

10521</CCRDataObjectID>
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<Code>
<CodingSystem>ICD10AM</CodingSystem>
</Code>
</Description>
</Product>
</Products>
</Agent>
<DateTime>
<Type>
<Text>Onset Date</Text>
</Type>
<ExactDateTime>2011-03-11T00:00:00Z</ExactDateTime>
</DateTime>
</Alert>
</Alerts>
| OBX | <Results> | OBX|1|SN|1554-S^GLUCOSE^^^POST 12H CFST:MCNC:PT:SER/PLAS:QN|1^175|mg/dl|70_105|H||F |
| PV1 | <Encounters>, <Actor> | PV1|1||IN1^210^2^INN^C|A|Dr.ID^DrName^DrVorname^Herr^Dr. med.^CPNP^24201^Wasserburg^D^8881^ISO|Dr.ID2^DrName^DrSurname^Arein^Dr. med.^PharmD^24201^Wasserburg^L^8882^ISO|MED|N||04005000||K|||||||0100|||||20040517 1306|||
Transformation between HL7 and CCR

Results

17T13:06:00Z</ExactDateTime>
</DateTime>
</Encounter>
</Encounters>
<Actors>
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<CurrentName>
<Family>DrName</Family>
<Given>DrVorname</Given>
<Suffix>Herr</Suffix>
>Title>Dr. med.</Title>
</CurrentName>
</Name>
</Person>
</Actor>
<Actor>
<ActorObjectID>Dr.ID2</ActorObjectID>
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<Name>
<CurrentName>
<Family>DrName</Family>
<Given>DrSurname</Given>
<Suffix>Arein</Suffix>
>Title>Dr. med.</Title>
</CurrentName>
</Name>
</Person>
</Actor>
</Actors>

RXG & RXR

<Medications>
RXG|I||^C^H10^199312100800^199312101800^TM30|RXCUSIV^Custom
IV^LN|1|||IV|||W8&825&A|||H10|100|CC/HR
RXR|IV|||
</Medications>

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</tr>
</thead>
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<tr>
<td></td>
<td>RXA</td>
</tr>
</tbody>
</table>

```xml
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<Rate>CC/HR</Rate>
</Dose>
<Route>
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</Route>
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</Direction>
</Directions>
<Quantity>
<Value>1</Value>
<Units>L</Units>
</Units>
</Quantity>
</Medication>
</Medications>

```xml
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<Immunization>
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<Text>Start Date</Text>
</Type>
<ExactDateTime>1990-06-07T00:00:00Z</ExactDateTime>
</DateTime>
<DateTime>
<Type>
<Text>End Date</Text>
</Type>
<ExactDateTime>1990-06-07T00:00:00Z</ExactDateTime>
</DateTime>
<Description>
<Text>HISTORICAL INFORMATION - FROM PARENT=S WRITTEN RECORD</Text>
</Description>
<Product>
<ProductName>
<Text>HEPB-PEDIATRIC/ADOLESCENT</Text>
</ProductName>
<Code>
<Value>08</Value>
<CodingSystem>CVX</CodingSystem>
</Code>
</Product>
</Immunizations>
```xml

```xml
<value>.5</value>
```
Many HL7 v2.x fields and segments concern operational matters within a healthcare organization. As such, they have no corresponding counterparts in the CCR, which is focused on the status of the patient. Therefore, such segments have been omitted from the HL7 -> CCR translation table.

In the table above we can see how some fields are actually customized by different HIS to fit their specific requirement, such as the value POST 12H CFST:MCNC:PT:SER/PLAS:QN in OBX.3.5 where according to HL7 specification Alternate Text for Alternate Coding System should be placed. Judging from the string we assume that the sample was taken 12h after (POST) some condition, and also a blood (SERum/PLASma) sample. Following HL7 specification different values are to be separated by caret (^) or ampersand (&), hence we can say that this particular string is not designed according to HL7 specification, rather to fit in specific requirement by the vendor. This string is not included into our CCR as a final result.

We also tested all the conditional mappings for this direction of translation. In the following table we list only the segment triggering the conditional map, and the CCR output affected by this is highlighted for easier observation.
<table>
<thead>
<tr>
<th>Flag Type</th>
<th>Description</th>
<th>Flag Field</th>
<th>HL7 Input</th>
<th>CCR Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNQ</td>
<td>Generate Unique value for this field</td>
<td>UNQ</td>
<td>O8X</td>
<td>1</td>
</tr>
<tr>
<td>ADD</td>
<td>Map additional values to another location, either by using new value or the value encountered in this location</td>
<td>ADD</td>
<td>Actors. Actor.IDs.Type.Text</td>
<td>SSN</td>
</tr>
<tr>
<td>condition</td>
<td>FamilyProblemHistory:AdvanceDirectory:Function:Plan</td>
<td>&lt;Text&gt;Ethnicity&lt;/Text&gt;</td>
<td>&lt;Description&gt; &lt;Text&gt;Caucasian (White) &lt;/Text&gt; &lt;/Description&gt;</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>DEF</td>
<td>Set the default value for a CCR map if the segment exists but no value is assigned at the field</td>
<td>OBX</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>DEF Result</td>
<td>&lt;Result&gt; &lt;CCRDatatableID&gt;20110407-14243&lt;/CCRDatatableID&gt; &lt;Description&gt; &lt;Text&gt;Temperature&lt;/Text&gt; &lt;/Description&gt; &lt;Test&gt; &lt;Type&gt; &lt;Text&gt;Result&lt;/Text&gt; &lt;Description&gt; &lt;Text&gt;Temperature&lt;/Text&gt; &lt;Code&gt; &lt;Value&gt;C0005903&lt;/Value&gt; &lt;CodingSystem&gt;UMLS&lt;/CodingSystem&gt; &lt;/Code&gt; &lt;/Description&gt; &lt;Status&gt; &lt;Text&gt;F&lt;/Text&gt; &lt;/Status&gt; &lt;TestResult&gt; &lt;Value&gt;98.7&lt;/Value&gt; &lt;Units&gt; &lt;Unit&gt; F &lt;/Unit&gt; &lt;/Units&gt; &lt;/TestResult&gt; &lt;/Test&gt; &lt;DateTime&gt; &lt;Type&gt; &lt;Text&gt;Collection start date&lt;/Text&gt; &lt;/Type&gt; &lt;ExactDateTime&gt;2005-04-04T00:00:00Z&lt;/ExactDateTime&gt; &lt;/DateTime&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3-6: HL7 to CCR conditional mappings result

| Combination                  | UNQ&ADD| Body.Problems.Problem.Type.Text | PRB|AD|20101212235622|PRB_001|ET001 |
|------------------------------|--------|---------------------------------|-----|---|------|-------|
| Combination of more than one different flags mentioned above |        |                                 |     |   |      |       |

The UNQ flag, while not very useful at the moment, because it is supposed to generate a unique ID according to the system, gives an idea on how to generate ObjectID according to the ASTM specification, where most of the top elements in the CCR are required to have uniquely identifiable IDs.

3.5.3 Testing the result of the translation with Google h9 server

Following the implementation steps as described in 3.4.2, Integration of Connector Packages into Mirth, below are the results and screen shots that show the outcomes of the translation package when run inside Mirth.
Figure 3-23: File Input (validated with 7Edit)
While the screenshots above only provide the snapshot of the input message and the resulting web UI of Google Health, it shows that our package along with Mirth successfully relays and translates incoming HL7 into the Google Health server (with the format that Google Health understands – CCR). It is important to note, however, that we are still using the Google Health sandbox (h9 server) for this test result.
3.5.4 Translating from one format to the other and back

To more rigorously test the translation algorithm, we translated messages from one format to the other, and then translated the result back into the original format, like a game of “Chinese whispers”. By comparing the original and final messages, we can judge what information was lost or misplaced. These tests were done both ways: HL7 to CCR to HL7, and CCR to HL7 to CCR.

3.5.4.1 HL7 => CCR => HL7

We used HL7 input containing most segments supported by our translation package to do the testing. After the first translation, the resulting CCR was again sent to the translation package as the input for the second translation. The side by side comparison, sorted and separated by segments, can be seen in the following figure.

<table>
<thead>
<tr>
<th>Original HL7 message</th>
<th>Final HL7 message</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSH</td>
<td>~^&amp;</td>
</tr>
<tr>
<td>RF1</td>
<td>A^Accepted</td>
</tr>
<tr>
<td>PRD</td>
<td>RP^Referring Provider</td>
</tr>
<tr>
<td>PID</td>
<td>PatID^01</td>
</tr>
<tr>
<td>NK1</td>
<td>[^Bologna^Taylor^Larry</td>
</tr>
<tr>
<td>IN1</td>
<td>[^AOK^Plan ID</td>
</tr>
<tr>
<td>DG1</td>
<td>[^Some problem with patient’s eye</td>
</tr>
<tr>
<td>AL1</td>
<td>[^FA^Food Allergy^SCT</td>
</tr>
<tr>
<td>PR1</td>
<td>[^LN001^Standard Procedure^LN</td>
</tr>
<tr>
<td>PV1</td>
<td>[^IN1^210^2^INN^C</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>MSH</td>
<td>~^&amp;</td>
</tr>
<tr>
<td>RF1</td>
<td>SwinHealth^L</td>
</tr>
<tr>
<td>PRD</td>
<td>RP^Referring Provider</td>
</tr>
<tr>
<td>PID</td>
<td>[^SN20000001</td>
</tr>
<tr>
<td>NK1</td>
<td>[^Bologna^Taylor^Larry</td>
</tr>
<tr>
<td>IN1</td>
<td>[^AOK^Plan ID</td>
</tr>
<tr>
<td>DG1</td>
<td>[^Some problem with patient’s eye</td>
</tr>
<tr>
<td>AL1</td>
<td>[^FA^Food Allergy^SCT</td>
</tr>
<tr>
<td>PR1</td>
<td>[^LN001^Standard Procedure^LN</td>
</tr>
<tr>
<td>PV1</td>
<td>[^Dr.ID^DrName^DrVorname^Herr^Dr. med.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3-7: Comparison between original HL7 message with resulting HL7 message

Note that, because the CCR is a summary of patient details and results, it has no equivalent to the HL7 v2.5 OBR segment, so that segment is lost in translation. Also, the original HL7 message omits many of the component placeholders (^

3.5.4.2 CCR => HL7 => CCR

The result of this testing is placed in the Appendices due to the large structure of the XML file.

There are some differences between the original and final CCR files. The CCRDataObjectID is different for each element because the ID itself is discarded during the translation into HL7, and then regenerated during the HL7 to CCR translation.

In cases where multiple <IDs> are used, at most one will be kept due to non-repeating field in HL7 segments (unlike <ISG> which are sometimes repeatable). A clear example of this can be seen from the <Payers> in the comparison table. The same case also happen with other multiple tags such as
<DateTime> inside <Result>, because there is only one field in the OBX segment (observation date/time) while there are different date/time for a result of an observation (Ordered, Collected, Performed, etc.) in the CCR. In <Medications>, the CCR offers more detailed information for patient medication than what can be stored in the HL7 RXG segment, such as the date/time of first administered medication, refill instruction and route. Therefore, much of this information is lost in the HL7 output.

Some actors are missing from the footer; these include the information systems used while generating the original CCR, Subscriber and Guarantor for the Payers. They are lost during the translation from CCR to HL7 because we are not able to find an equivalent place in HL7 to store these values. Some details of the Actors are also missing, such as the Address and Telephone numbers of the practitioners and multiple IDs. In HL7 there is no field practitioners' address and phone number.

Some other fields that are missing due to no suitable fields in HL7 message are Patient Instructions (instead of patient instructions can be placed in Description under Medication as can be seen from the CCR examples that we have gathered) and Description under Encounter.

In summary, some CCR elements are lost in translation to HL7 v2.x because the latter does not have any corresponding fields. For example,

- Actor details for organizations
- Actor addresses for medical staff
- Notes or text for Encounter
- Multiple ID's tag
- Refill instruction for Medication

and more.

### 3.5.5 Comparison with Aquifer CCR ViewPort

Aquifer CCR ViewPort ([https://www.solventus.com/aquifer/ccrviewportcontainer.aspx](https://www.solventus.com/aquifer/ccrviewportcontainer.aspx)) is a system to help healthcare providers create CCRs for their patients; it has the capability of importing HL7 v2.x messages and translating them into CCRs. This is clearly a similar functionality to what we have in our prototype; therefore, by using some of the existing HL7 v2.x messages that we used to test our system, we ran the translation on both systems. The table below compares and summarizes the results. The more detailed comparison can be found in [Appendices](#) due to the space needed to compare two XML results side by side.

<table>
<thead>
<tr>
<th>HL7 v2.x Segments</th>
<th>Differences</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID</td>
<td>- Phone numbers are not supported by ViewPort&lt;br&gt;- In some case ViewPort failed</td>
<td>HMapper is able to extract the phone number in the PID segment, while ViewPort fail to do so.</td>
</tr>
<tr>
<td></td>
<td>to extract the address</td>
<td>ViewPort also fail to extract the address in one of our sample file (VXU^V04 message type)</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NK1, PRB, AL1, PR1, RXA, RXG, PRD</td>
<td>- Not included in ViewPort</td>
<td></td>
</tr>
<tr>
<td>IN1</td>
<td>- HMapper and ViewPort extract different fields into the same CCR elements</td>
<td>The slight discrepancy is possibly caused by different understanding of the HL7’s IN1 segment and/or CCR’s Insurance element. Because both standards are not real plug and play standards, different vendors apply different customization to these standards.</td>
</tr>
</tbody>
</table>
| DG1   | - HMapper extracts the DateTime  
- HMapper includes description text, while ViewPort uses code for the description | | |
| PV1   | - ViewPort is able to translate coded value in HL7 into its description before placing it into CCR  
- ViewPort adds ‘Unknown’ to Practitioner | ViewPort has its own HL7 defined table to translate HL7 coding such as ‘U’ to ‘Discharge’, however ViewPort seems to always set ‘Unknown’ to the practitioners, while HMapper is able to extract doctors/practitioner in the PV1 field. | |

Table 3-8: Comparison summary between CCR ViewPort and HMapper

When compared with ViewPort, our prototype stands out in terms of supported segments. The undisclosed source code for the ViewPort made it impossible for us to check whether ViewPort supports other elements which are not supported by our prototype. In some cases, Aquifer fails to parse some of the input file and generates error messages, where our prototype is able to process and produce a CCR message – albeit a CCR with minimal content for unsupported message types (not REF).
4 DISCUSSION

As mentioned in the introduction, integration of PHRs with hospital HISs can help facilitate the availability of a personal health record, which can become a life-time health record. This goal is in line with national health network systems pursued by some countries such as Indonesia (Sistem Kesehatan Nasional or SIKNAS).

As stated by Yi et al. (2008), “The cost and complexity of implementing traditional proprietary solutions, however, will be a limiting factor for software system deployment in public health, especially or agencies with limited resources”, therefore open-source systems are often an appealing choice when building affordable HISs. The high cost of EMRs is also a great concern to users and clinicians according to the survey by Loomis et al. (2002). Bates et al. (2003), representing National Alliance for Primary Care Informatics, also stated that the primary barriers to the adoption of EMR (closely related to HIS) are the costs, turnover of vendors and the lack of common standards.

Having this argument in mind, we built our prototype upon open-sourced systems, which not only is cost-efficient but also makes it easier for the public to redistribute, modify, enhance and analyse our solution. This prototype presents a solution to all the barriers outlined by Bates et al. (2003); open-sourced systems are cost efficient, with little to no cost of software acquisition and backed with strong community support (Kantor et al., 2003). Furthermore, the lack of common standards is overcome by interoperability between the widely used standards (CCR and HL7) to enable ubiquitous health care record access to patients and clinicians alike.

Also, because full computerization of hospitals requires great sums of money, nationally available PHRs such as Google Health can be a potential cost-saving approach to have an integrated health information databank to which all different hospital systems can connect in as many ways as possible. A PHR promotes high availability, ease of access and faster way of accessing data, and if we look at Figure 1-2, a single point of common information accessed by hospitals and clinics as planned by the Ministry of Health of Indonesia looks very similar to our implemented approach.

PHRs in which patients have access to and control of their own health records to certain extent, are also favoured by patients as the key users. Overall patients felt that record access reinforced trust and confidence in doctors and helped them feel like partners in healthcare. Patients using their records improve interactions with healthcare providers, make decisions about their health and improve the quality of the care they receive (Fisher, Vanita & Marlene, 2009).

The Institute of Medicine also delineated 6 ‘aims of improvements’ in which one of the aims stated ‘Patient-centred’ approach must be escalated (Leavitt 2001); this is true for clinical systems as well. The patient himself will become the key of knowing his/her own health information via a personalized health
record server, instead of having multiple healthcare facilities keeping separate records of the same
patient.

By having a translation between HL7 and CCR message standards, one barrier separating hospital or
clinical system from PHRs can be removed, thereby facilitating patient-centred sources of information.
The benefit of this can come in many forms, such as allowing the patient to always have an up-to-date
record in his/her PHR, with ubiquitous access regardless of which health care institution the patient visits.
It is also a cheaper alternative to achieve national health network.

Different from the approach taken by Jian et al. (2007), we present the generic translation between
ASTM CCR and HL7 v2.5 messages - between two widely used standards in health care that are easily
customizable to meet specific requirements. In the case of the Taiwan Medical Template, an EHR of
national scale is designed to meet interoperability requirements with HL7 CDA and ASTM CCR.

While there is collaboration between HL7 and CCR in the form of the Continuity of Care Document
(CCD), in the implementation itself the separation between HL7 and CCR is still visible, with the CCD
referred to as a CCR version of the HL7 standard. The possible cause of this is the complexity in the CCD
inherited from the HL7 RIM itself that causes some vendors who prefer simplicity to retain the CCR.

While conducting our research on feasible technologies that will support our prototype we came across
some gateways that claim to support both CCR and HL7 (or CDA), such as Corepoint Integration Engine
(www.corepoint.com). However, this system is proprietary software, and no test results are made
available from this integration engine for a comparison.

We also looked at openMRS as one of the pioneering (and one of the most successful) health
information systems for developing countries. To support portable data collection in developing
countries, openMRS initiated collaboration with openROSA, an open-source XML Form library for mobile
devices using J2ME technology. In the field, patients' information is collected in XML format using
handheld devices using openROSA. This information is then translated to HL7 v2.x messages for further
use in openMRS. Currently the system is mostly used to aid in HIV and TB cases (which were - and
arguably still are - the main concern of the system) in developing countries, but as suggested by the
developer, openMRS's long term goal is to be an open-source system that supports many health care
activities (Mamlin et al., 2006). Therefore, for critical clinical usage, we feel that the use of the CCR
format in openROSA would be very suitable, considering that the CCR already provides an XML template
of clinical summary data such as allergy, problems, diagnosis, medications, etc. This enhances its
interoperability, and at the same time reduces the amount of workload needed to establish schemas for
clinical summary. Afterwards, the translation from CCR to HL7 messages can be achieved by using our
proposed translation package.

As we described in section 2.5.3, there are other systems capable of making the same conversion, albeit
only in one direction – HL7 v2.x to CCR, for example CCR Viewport developed by Solventus. The CCR
Viewport helps generate CCRs, with HL7 v2.x messages as one of the possible import choices. The system does not restrict which type of HL7 message it can handle; rather it processes the HL7 message according to the segments that it understands – much like the package that we developed ourselves. From the comparison (Table 3-8), even though we encountered CCR ViewPort after we had established our approach, we can see that generally both packages use the same general approach, including mapping HL7 segments to main elements in the CCR, and similar mappings (PID to Patient, IN1 to Insurance, PV1 to Encounters, etc.). In the general comparison, HMapper supports more segments and elements, such as NK1 to Support Provider, RXG to Medication, etc., and also more fields are extracted (e.g. patient’s phone number). However, there are discrepancies between the two translations; in some cases the systems choose different target fields when mapping the values, and they seem to disagree over some segments used for the translation (e.g. Medication, which is a critical element in the CCR).

The logic behind our mapping has been described in the Methods section; even though CCR ViewPort is a free-to-use web service, the system itself is not open-source, thus preventing us from comparing both systems at the implementation level.

The approach that we take into the building the prototype is modular and ‘attachable’ into other existing systems, so long as the existing system supports the same minimal requirements we proposed, such as the message gateway requirements. One possible application of our prototype as an attachment to other system could be the Electronic Health Record – Public Health (EHR-PR) designed by Orlove et al. (2005). We could extend the functionality of the EHR-PR by adding our translation package, with minimal effort, due to the same structure of the design that can be found in both prototypes.
5 CONCLUSIONS AND FUTURE WORK

For a developing country such as Indonesia, achieving an integrated health system on a national scale can be very costly. A possible cost-cutting approach to this is to use open-sourced packages, such as myCare2x and Google Health.

One of the biggest obstacles, however, is the different standards used by HISs and web-based PHRs, most notably HL7 for HISs and CCR for PHRs. HL7 is used in HISs because it can be used to transmit real-time information across different facilities inside a hospital, while the CCR is used to capture snapshots of patient’s health information at specific points in time, and is thus used by PHRs for this purpose.

Therefore, considering the needs of cheaper solutions and translation between standards, we have presented an HL7 ↔ CCR translation package using an open-source message gateway. This translation package, within the gateway, can accept HL7 or CCR from various sources (including HISs or PHR web-servers), translate and send the result to recipient HISs or PHRs.

Due to the different intentions of the two standards, it was found that some constraints must be enforced when translating between HL7 and CCR message formats. For example, an incoming HL7 v2.x message must contain segments listed in 2.3.1.2 CCR -> HL7 v2.x Mapping Table. The REF (Referral) message type is most suitable as the HL7 input for our translation package because it contains most of the segments listed (further customization can be made to the REF to include all the segments), while message types that do not correlate at all with the CCR will fail to generate a proper CCR (such as message type without a PID segment). Other constraints, such as making sure the sender and recipients have the same coding system knowledge (LOINC, SNOMED, RxNorm, etc.), are also important.

As we described in section 2.3.3.2, the translation provided here is not perfect; the CCR -> HL7 translation creates a "modified" REF message which breaks the HL7 message definition. Future work should explore the possibilities of separating an input CCR message into multiple output HL7 messages, with each containing only those segments prescribed in the original HL7 v2.x specifications.

By implementing a customizable map table we have tried to improve the flexibility of the mapping and possibly allow non-programmers to modify the mapping flow. One main reason for this is that HL7 is essentially not a plug-and-play messaging protocol, and most vendors will have different ‘customized’ HL7 messages; thus, a rigidly standardized translation from HL7 to CCR is impossible.

After running the translation package, it was found that performance speed of the translation differs dramatically when executed independently compared to when it is installed into our chosen message gateway Mirth. While it was not clear why this happened, a possible explanation is the fact that the message gateway also runs using the same virtual machine (Mirth Connect is a Java-based message gateway application). Of course, the CCR ↔ HL7 translation package introduced here is not specifically
built for Mirth, thus it is possible to port the package to a more efficient and faster gateway, so long as it supports Java.

Actually running the translation package to convert standards between HIS and Web PHR however is hindered by the authentication process that we have to go through in order to have access to the PHR. In the case of Google Health, this results in the demand for a single patient/user index capable of matching different identifications given to the same person on different systems. In our case, the trial “master patient index” matches the patient id from the HIS, retrieves authentication information and securely connects to the PHR and registers the information.

Any clinical systems implementing the HL7 standard can send a patient’s information summary (REF message preferred) to the PHR through the message gateway, which will translate this HL7 to CCR and send it to the PHR profile associated with the patient. In case a patient decided to visit another hospital, i.e. one with no previous record for that person, the same PHR profile can be accessed by this new hospital system to get all the records updated by previous clinical systems.

This is especially helpful if we take a look at the case described in section 1.2.2.4, where information about a patient is scattered across health institutions. In case of referral a printed EMR can serve as a remedy to help distribute some patient health information between institutions – or between departments of the same institution; however, it is important to realize that the EMR is not a simple replacement of a paper record; it can serve as a very powerful tool to actively participate in clinical care (Coiera, 2003).

The scope of this project has been to create a meaningful translation between HL7 v2.x and CCR in a translation package which can interact with different HISs and PHRs. To make the translation package fully functional within a seamlessly integrated health care service there are some improvements that can be made.

One approach that has not been taken in this research work is to explore the possibilities of creating multiple of HL7 messages out of a CCR to allow ‘more standardised’ result, hence prevents the output of the translation to deviate from the original HL7 v2.x specification.

As seen in the implementation, one of the issues encountered to allow seamless translation of standards between HIS is to identify the person across them. A person that has been registered in different systems (e.g. hospital system and web-based PHR) will have unique identification given him by each system (e.g. patient id in hospital system and profile id/username/password in web-based PHR). A single master patient index (MPI) can be used to match these different identifications because they refer to the same person. Mirth Corp (www.mirthcorp.com) has introduced a product called Mirth Match which can serve as a good starting point to solving this problem.
Speed performance, as can be seen on Table 3-1, shows significance difference when the translation package is executed inside our IDE than when placed in the message gateway. The cause of the slowness in Mirth should be studied and possibly “cured” either within Mirth or with another open-source message gateway.

Since this project is open for input and further improvements by everyone interested in the same field, the working project for the program will be uploaded to [http://code.google.com/a/eclipselabs.org/p/hmapper/](http://code.google.com/a/eclipselabs.org/p/hmapper/) which is an open-source code host provided by Google in collaboration with Eclipse Labs. The author would welcome all improvements and constructive input from everyone.
6 REFERENCES


Binstock, A., 2008. Eclipse 3.3 or NetBeans 6.0? Finally, there’s a decision to make. Available at: http://www.javaworld.com/javaworld/jw-03-2008/jw-03-java-ides0308.html retrieved at 26/05/2010 3:02 PM


Transformation between HL7 and CCR


Shaver, D., 2006. What is the relationship between the Continuity of Care Record (CCR) and HL7 v2.x messaging?. Available at: http://www.hl7standards.com/blog/2006/10/18/what-is-the-relationship-between-the-continuity-of-care-record-ccr-and-hl7-2x-messaging/


## APPENDICES

### 7.1 CCR -> HL7 v2.x Map Table

<table>
<thead>
<tr>
<th>CCR Field</th>
<th>HL7 Field</th>
<th>Special Flag Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>ContinuityOfCareRecord.Language.Text</td>
<td>MSH.18.2</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Date-Time.ExactDateTime</td>
<td>MSH.6</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.Actor.ActorObjectID</td>
<td>PID.2.1</td>
<td>ADD</td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.CurrentName.Given</td>
<td>PID.5.2</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.CurrentName.Middle</td>
<td>PID.5.3</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.CurrentName.Family</td>
<td>PID.5.1</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.CurrentName.Suffix</td>
<td>PID.5.4</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.CurrentName.Title</td>
<td>PID.5.5</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.DateOfBirth.ExactDateTime</td>
<td>PID.7</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.Gender.Text</td>
<td>PID.8</td>
<td>CNV</td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.Actor.Address.Line1</td>
<td>PID.11.1</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.Actor.Address.Line2</td>
<td>PID.11.2</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.Actor.Address.City</td>
<td>PID.11.3</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.Actor.Address.StateProvince</td>
<td>PID.11.4</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.Actor.Address.Country</td>
<td>PID.11.6</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.<em>.Telephone.Type.</em></td>
<td>PID.13.11</td>
<td>PIC</td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.EMail.Value</td>
<td>PID.13.4</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Patient.*.IDs.ID</td>
<td>PID.19</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.From.ActorLink.ActorObjectID</td>
<td>MSH.2.1</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.From.ActorLink.ActorRole.*</td>
<td>MSH.3.1</td>
<td></td>
</tr>
<tr>
<td>Field</td>
<td>Specification</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>---------------</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.To.ActorLink.ActorObjectID</td>
<td>MSH.4.1</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.To.ActorLink.ActorRole. *</td>
<td>MSH.5.1</td>
<td></td>
</tr>
<tr>
<td>ContinuityOfCareRecord.Language.Text</td>
<td>MSH.18.2</td>
<td></td>
</tr>
<tr>
<td>*.Purpose.DateTime.ExactDateTime</td>
<td>RF1.9</td>
<td></td>
</tr>
<tr>
<td><em>.Purpose.Description.</em></td>
<td>RF1.10.2</td>
<td></td>
</tr>
<tr>
<td><em>.Purpose.DateTime.</em></td>
<td>RF1.10.2</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.ActorObjectID</td>
<td>IN1.3.1</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.Organization. *</td>
<td>IN1.4.1</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.Address.Line1</td>
<td>IN1.5.1</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.Address.Line2</td>
<td>IN1.5.2</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.Address.City</td>
<td>IN1.5.3</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.Address.StateProvince</td>
<td>IN1.5.4</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.Address.Country</td>
<td>IN1.5.6</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.PaymentProvider. *.Address.PostalCode</td>
<td>IN1.5.5</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.DateTime.Type.Text</td>
<td>ZZZ.IN1.1</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.DateTime.ExactDateTime</td>
<td>ZZZ.IN1.2</td>
<td></td>
</tr>
<tr>
<td><em>.Payers.Payer.IDs.Type.</em></td>
<td>IN1.2.2</td>
<td></td>
</tr>
<tr>
<td>*.Payers.Payer.IDs.ID</td>
<td>IN1.2.1</td>
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### 7.3 CCR to HL7 to CCR Result

An original CCR message was converted to HL7 v2.5 using the HMapper software. The resulting message was translated back into CCR format with the same package.

The following table compares the original (in its de-normalized form) with the final result. Blank lines have been inserted into the files to align corresponding elements for easier comparison.

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**Payload Information**

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- **CodingSystem**: Multum

**Code**:
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- **CodingSystem**: NDC

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- **Units**: milligram(s)

**Units**:
- **Value**: tab(s)
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Transformation between HL7 and CCR


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| DG1 | HMapper extracts the DateTime of Diagnosis | <Problems>
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          <Family>JONES</Family>
        </CurrentName>
        <DateOfBirth>
          <ExactDateTime>1961-06-15T00:00:00Z</ExactDateTime>
        </DateOfBirth>
        <Gender>
          <Text>M</Text>
        </Gender>
      </Name>
      <DateOfBirth>
        <ExactDateTime>1961-06-15T00:00:00Z</ExactDateTime>
      </DateOfBirth>
      <Gender>
        <Text>M</Text>
      </Gender>
    </Person>
  </Actor>
```
<table>
<thead>
<tr>
<th>RXA</th>
<th>HMapper extracts RXA as Immunizations</th>
<th>None</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Immunizations</td>
</tr>
</tbody>
</table>

The table shows the transformation between HL7 and CCR for an example of a person's record. The RXA column indicates that the HMapper extracts RXA as Immunizations, but the Immunizations column is left empty, indicating no actual Immunization data is present.
<table>
<thead>
<tr>
<th>RXG</th>
<th>- HMapper extracts RXG as Medications</th>
<th>None</th>
</tr>
</thead>
</table>

```xml
<Medication>
  <CCRDataObjectID>20110523-17645</CCRDataObjectID>
  <Product>
    <ProductName>
      <Text>Custom IV</Text>
      <Code>
        <Value>RXCUSIV</Value>
        <CodingSystem>LN</CodingSystem>
      </Code>
    </ProductName>
    <Form>
      <Description>
        <Text>IV</Text>
      </Description>
      <Strength>
        <Value>1</Value>
        <Units)L</Units>
      </Strength>
      <Directions>
        <Direction>
          <Dose>
            <Value>100</Value>
            <Rate>CC/HR</Rate>
          </Dose>
        </Direction>
      </Directions>
    </Form>
  </Product>
</Medication>
```
<table>
<thead>
<tr>
<th>PRD</th>
<th></th>
<th>None</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-</td>
<td>HMapper extracts PRD as Health Care Providers</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

```xml
<Quantity>
  <Value>1</Value>
  <Units>
    <Units>L</Units>
  </Units>
</Quantity>
```

```xml
<Provider>
  <ActorID>RP</ActorID>
  <ActorRole>
    <Text>Referring Provider</Text>
  </ActorRole>
</Provider>
```

```xml
<HealthCareProviders>
  <Provider>
    <ActorID>RP</ActorID>
    <ActorRole>
      <Text>Referring Provider</Text>
    </ActorRole>
  </Provider>
</HealthCareProviders>
```
8 LIST OF PUBLICATION