AUTOMATIC ACQUISITION AND USE OF MULTIMODAL MEDICAL DEVICE OBSERVATIONS BASED ON ISO/IEEE 11073 AND HL7 STANDARDS

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ALPER OKCAN

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Prof. Dr. Canan Özgen
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Volkan Atalay
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Asuman Doğaç
Supervisor

Examining Committee Members

Prof. Dr. Özgür Ulusoy (Bilkent,CENG) _____

Prof. Dr. Asuman Doğaç (METU,CENG) _____

Prof. Dr. İ. Hakkı Toroslu (METU,CENG) _____

Assoc. Prof. Dr. Nihan Kesim Çiçekli (METU,CENG) _____

Gökçe Banu Laleci Ertürkmen (METU,SRDC) _____

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Signature:

ABSTRACT

AUTOMATIC ACQUISITION AND USE OF MULTIMODAL MEDICAL DEVICE OBSERVATIONS BASED ON ISO/IEEE 11073 AND HL7 STANDARDS

Okcan, Alper

M.Sc., Department of Computer Engineering

Supervisor: Prof. Dr. Asuman Doğaç

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The delivery of quality healthcare to all citizens at reasonable costs is an important challenge. With the increase in the aging population, the costs of managing chronic diseases increase. Today, healthcare services tend to shift from recovery to prevention. Remote healthcare monitoring is crucial for prevention and monitoring of chronic diseases since they require continuous and long-term monitoring. The advances in networking, mobile communications and medical device technologies offer a great potential to realize remote healthcare monitoring. However, seamless integration of multi-modal medical devices to the existing healthcare information systems is necessary for the automated use of medical device observations in related applications.

The thesis addresses the automatic acquisition and use of multi-modal medical device observations in healthcare information systems. The interoperability of medical devices with healthcare information systems requires both physical connectivity and application level interoperability. Therefore, the thesis concen-

trates on both the medical device domain and the interoperability efforts on the existing healthcare information systems. It provides an interoperability solution based on ISO/IEEE 11073 and HL7 standards. This work is also realized the automatic acquisition and use of multi-modal medical device observations in an intelligent healthcare monitoring and decision support system which is developed as a part of the IST-027074 SAPHIRE project funded by the European Commission.

Keywords: Medical Devices, Semantic Interoperability, Remote Healthcare Monitoring, IEEE 11073, HL7,IHE PCD Profile, Ambient Intelligence, Sensor Networks

ÖZ

ISO/IEEE 11073 VE HL7 STANDARTLARI İLE MEDİKAL CİHAZ GÖZLEMLERİNİN OTOMATİK EDİNİMİ VE KULLANIMI

Okcan, Alper
Yüksek Lisans, Bilgisayar Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Asuman Doğaç

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Sağlık servislerinin tüm vatandaşlara uygun maliyetlerle sağlanması oldukça zordur. Özellikle yaşlı insan nüfusunun artışı ile birlikte kronik hastalıkların bakım maliyetleri de artmaktadır. Günümüzde, iyileştirmeden çok, önleme dayalı sağlık servislerine yönelim vardır. Kronik hastalıkların tedavisi devamlı ve uzun süreli gözlem gerektirdiğinden, uzaktan sağlık gözlemi bu hastalıkların gözlemlenmesi ve önlenmesi için oldukça önemlidir. Bilgisayar ağları, mobil iletişim ve medikal cihaz teknolojilerindeki ilerlemelerle birlikte uzaktan sağlık gözlemi de artık mümkün olmaktadır. Fakat, farklı medikal cihazların mevcut sağlık sistemlerine entegrasyonu, medical cihaz gözlemlerinin ilgili uygulamalarda otomatik kullanımı açısından oldukça önemlidir.

Tez çalışması, farklı medikal cihaz gözlemlerinin sağlık sistemlerince otomatik edinimini ve kullanımını amaçlamaktadır. Medikal cihazların sağlık sistemleriyle birlikte çalışabilirliği hem fiziksel bağlantı hem de uygulama katmanında birlikte çalışabilirlik gerektirir. Bu yüzden, tez çalışması hem medikal cihazları hem de mevcut sağlık sistemlerini incelemektedir. Bu çalışmada ISO/IEEE 11073 ve

HL7 standartlarına bağlı bir çözüm sunulmuştur. Ayrıca bu tez çalışması ile, medikal cihazlardan gelen gözlemlerin, Avrupa Komisyonu tarafından desteklenen IST-027074 SAPHIRE projesi kapsamında gerçekleştirilen akıllı sağlık gözlemi ve karar destek sistemine otomatik entegrasyonu sağlanmıştır.

Anahtar Kelimeler: Medikal Cihazlar, Birlikte Çalışabilirlik, Uzaktan Sağlık Gözlemlemesi, IEEE 11073, HL7, IHE PCD Profili, Çevresel Zeka, Sensör Ağları

To my family

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CHAPTER 1

INTRODUCTION

The delivery of quality healthcare to all citizens at reasonable costs is an important challenge. "Healthcare expenditure in Europe is already significant and rising faster than overall economic growth itself [1]". With the increase in the aging population of Europe, the costs of managing chronic diseases increase. Healthcare services are shifting from concentrating on illness to wellness and recovery to prevention. Remote healthcare monitoring is crucial for prevention and monitoring of chronic diseases since they require continuous, long-term monitoring, rather than episodic assessments [2]. Also, automated monitoring of citizens at their home would decrease the workload of medical practitioners. Therefore, clinical use of medical device observations at remote locations would improve the healthcare workflow, reduce medical errors, reduce healthcare costs and improve the quality of care.

The advances in networking, mobile communications and medical device technologies offer a great potential to realize remote chronic disease monitoring. However, seamless integration of multi-modal medical devices to the existing healthcare systems is an important problem to be solved.

Today, there are several efforts to store and use lifetime clinical data of a patient during medical decision processes. The idea to create an Electronic Health Record (EHR) for a patient which stores all observations made and procedures

performed during the provision of care, requires integration of all healthcare systems to communicate clinical data between each other. The simplest ISO definition of an EHR is defined as "a repository of information regarding the health of a subject of care in computer processable form, stored and transmitted securely, and accessible by multiple authorized users. It has a commonly agreed logical information model which is independent of EHR systems. Its primary purpose is the support of continuing, efficient and quit contains information which is retrospective, concurrent and prospective" [3].

The information in EHRs are generated, stored and used at different places and at different points in time during the lifetime of the patient. Although there is a single logical EHR for a patient storing all of his/her medical information, there may be multiple physical EHRs distributed depending on the architecture choices of different healthcare solutions. The clinical data stored related to the patient may be needed at any instant of time for the treatment of patient. Therefore, interoperability of EHR infrastructures between each other and with other domains such as radiology information systems, diagnostic imaging systems, point of care systems, laboratory information systems must be supported in order to create integrated healthcare systems. All these domains have different special requirements. In addition, most of the systems use existing applications developed by different vendors with different syntax and semantics. Therefore, exchange of standardized messages is required for interoperability of systems.

Medical devices are essential to the practice of modern healthcare services. In addition to the hospitals and specialized care units, medical devices are becoming popular for remote healthcare monitoring (homecare systems) with the latest advances in wireless communication technology. However, despite healthcare systems are becoming more dependent on specialized medical devices, the integration of these devices makes existing communication problems more complex. In recent years the area of medical device communication has seen a convergence of the various disparate health informatics standards efforts to solve the problem of enabling real-time medical device communications. Since medical

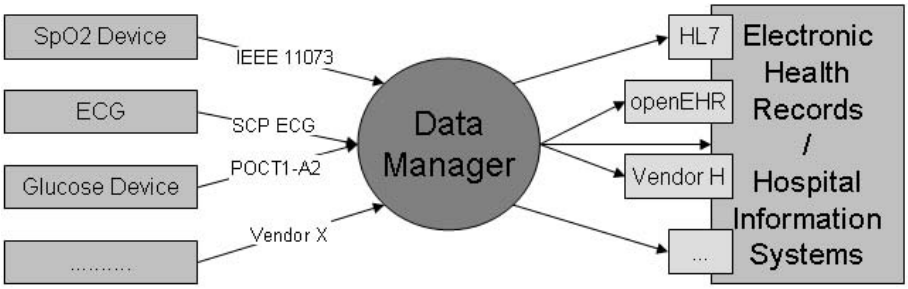

Figure 1.1: Medical Device Observation Communication

devices produce important observations during the provision of care, the seamless communication of medical device derived information into the EHR systems is necessary [4]. Networked medical device systems will support the widespread clinical use of medical device data and produce complete and accurate electronic health records, improve workflow, reduce medical errors, and reduce healthcare costs [5].

The aim of this work is to automate the acquisition and use of multi-modal medical device observations in order to improve the continuity of care. This interoperable communication infrastructure requires both physical connectivity of devices and application level interoperability. "The physical connectivity speaks to reliable and secure data transfer, where a system must detect the presence of a new device and negotiate a communication protocol. Application-level interoperability allows devices to synchronize their operational behavior and working states, understanding each other by means of a common message syntax, data types, encoding rules, and nomenclature [2]". The application level interoperability also includes the seamless communication with the healthcare information systems. Figure 1.1 presents the medical device observation communication architecture. There is a data manager located between two critical interfaces along the communication line. The duty of the data manager is to log, store, process and forward the incoming data to the receiver end. The first critical interface is the device interface which connects the medical devices to the data manager. Once the data is retrieved by the data manager, it must be

forwarded to the receiving end points; hospital information systems, laboratory systems, EHRs, etc. As illustrated in the figure, there are several standardization efforts used within both of the medical device domain and the hospital information systems domain. Therefore, different methods must be facilitated for achieving interoperability along the two interfaces; device interface and the observation reporting interface (ORI).

In order to achieve plug-and-play communication between medical devices, there are various standardization efforts to be detailed within the next chapters. These efforts can also be used to achieve interoperability between the medical devices and the data manager along the device interface. In order to achieve interoperability along the ORI, the hospital information system domain must be analyzed. The thesis work concentrates on both of the interfaces and proposes novel ideas along the device interface. The work developed in the thesis is part of the "Saphire: Intelligent Healthcare Monitoring based on Semantic Interoperability Platform" project, which is funded by the European Commission, under the 6th framework for Research and Development [6].

This thesis is organized as follows: Chapter 2 summarizes the related work by emphasizing the innovative aspects of the proposed solution. In Chapter 3 the main technologies that have been used in this thesis are presented. Chapter 4 is devoted to the description of the solution proposed for achieving automated acquisition and use of medical device observations in healthcare information systems. Chapter 5 describes the realization of the proposed solution within the Saphire project. Finally, Chapter 6 concludes the thesis.

CHAPTER 2

RELATED WORK

The need of an architecture for the automatic acquisition of medical device observations by clinical information systems was identified in early 1980s. The IEEE (Institute of Electrical and Electronic Engineers, USA) developed a standard in this area, called the "Medical Information Bus (MIB)" [7]. This first well-known effort was notified for its low adoption by medical device manufacturers due to low clinical demand, complexity and hardware requirements brought by the standard. IEEE initiated IEEE 1073 group and continued on efforts to standardize and improve lower layers defined in MIB and adding work on upper layers of the seven layer ISO communication model.

CEN also developed two related standards for point-of-care device communication; "ENV 13734:2000 Health informatics - Vital signs information representation" (VITAL) and "ENV 13735:2000 Health informatics - Interoperability of patient connected medical devices" (INTERMED). VITAL standard "addresses the definition and structuring of information that is communicated or referred to in communication between application entities" [8]. The standard specifies the interchange of vital signs information between medical devices and clinical information systems. INTERMED specifically addresses medical devices communication and specifies a communication controller model that should be used by a set of applicable devices given in the standard [9].

"Point-of-Care Connectivity" (POCT) standard provides the basis for multi-vendor, seamless interoperability between point-of-care devices, data managers, and clinical results management systems [10]. This standard specifies interfaces and protocols between medical devices and clinical information systems.

CEN, ISO and IEEE jointly published a single set of standards for point-of-care device communication called ISO/IEEE 11073. The set of standards include the previous work of all the three standardization bodies. Following standards are published within ISO/IEEE 11073 family of standards:

- ISO/IEEE 11073-10101:2004(E) Health Informatics - Point-of-care medical device communication - Part 10101: Nomenclature
- ISO/IEEE 11073-10201:2004(E) Health Informatics - Point-of-care medical device communication - Part 10201: Domain Information Model
- ISO/IEEE 11073-20101:2004(E) Health Informatics - Point-of-care medical device communication - Part 20101: Application Profile - Base Standard
- ISO/IEEE 11073-30200:2004(E) Health Informatics - Point-of-care medical device communication - Part 30200: Transport Profile - Cable Connected
- ISO/IEEE 11073-30300:2004(E) Health Informatics - Point-of-care medical device communication - Part 30300: Transport Profile - Infrared Wireless

Although the work accelerated with this joint family of standards, still adoption of the standards by medical device manufacturers has been slow. Manufacturers prefer to produce proprietary solutions which work exclusively with their vendor specific software. The incompatibility of different vendor products requires duplicate work on the network. The thesis work is based on the joint family of standards of ISO/IEEE 11073.

In addition to the interoperability efforts of medical devices within each other, automatic acquisition of medical device observations by the healthcare information systems is crucial. Hospital information systems are referred as core systems handling basic patient data and keep track of patient stay and phases of treatment in different departments [11]. Today, these systems are also enhanced to provide healthcare services to ease medical practitioners work. As a result, hospital information systems must be capable of communicating clinical data with various healthcare actors such as EHR repositories, public health services, and specialized information systems. Exchange of standardized messages is required for interoperability of different healthcare systems. Groups of system vendors and users started to develop standards for message exchange between clinical systems. One of these consortia was called "Health Level 7" (HL7) with reference to the application layer in the ISO/OSI reference model. HL7 is the most successful and widely in use for hospital information system communication and for interfacing between hospitals, insurance companies and public health organizations [11].

"Data sharing among local hospitals is being increasingly realized with the proliferation of the healthcare information system interoperability standard, Health Level Seven (HL7)" [12]. The thesis work also concentrates on HL7 for interfacing between medical devices and hospital information systems.

There are also ongoing research efforts on medical device interoperability. In [13], a wearable, portable monitoring health system was developed. This work aims to provide plug-and-play sensor units complying with Bluetooth standard. The system evaluates the connection between the data loggers and a set of wearable medical sensors. However, integration of the vital signs data coming from the sensors to the clinical information systems is not addressed in this study.

In a similar work [14], a Bluetooth-enabled personal monitoring system and a plug-and-play pulse oximeter were developed. The architecture proposed consists of a base station, a data logger, and a medical sensor. The communication

between the sensor and the data logger is achieved with Bluetooth technology. The data is forwarded to the base station on which activity viewer software is deployed. The viewer which was used in the prototype was proprietary software that was conformant to the incoming data, therefore semantic interoperability of the incoming data with the clinical application was not considered within this work.

[2] discusses the design and development of a plug-and-play system for home care by adopting IEEE 1073 MIB standard. The prototype developed demonstrates a proof of concept system on which device-to-device interoperability was achieved using MIB. The proposed work in the paper must be enhanced to promote seamless data access by clinical systems.

In [12], an extension was made to forward the data in an HL7 compliant format to the patients EHR in a remote location. A similar approach to this extension is followed within the thesis work. However, the interoperability of vendor specific multi-modal medical devices is an important enhancement of the thesis work.

There are also industry efforts in medical device connectivity area in recent years. IBM Research Center is working on "Personal Care Connect" (PCC) platform in order to facilitate remote monitoring of patients. Currently, PCC platform support only vendors who request to integrate their devices with PCC [15]. In USA, the "Medical Device Plug and Play (MD PnP) interoperability program was established in 2004. MD PnP aims to lead adoption of open standards and technology for networking medical devices to support clinical solutions for improving patient safety and healthcare efficiency [5].

The thesis work proposes to enhance these approaches with respect to two aspects. First, the interconnected medical devices within the previous works must be interoperable with the clinical information systems, laboratory systems, electronic healthcare records, etc. The legacy medical devices must also be considered since there are different vendor specific devices already deployed to different application environments. Therefore, the interoperability of a medical

device that is not conformant to ISO/IEEE 11073 or a specific standard to a clinical information system is also considered within the thesis work.

CHAPTER 3

ENABLING TECHNOLOGIES

This section provides the enabling technologies used in the thesis work. The enabling technologies with respect to different aspects of the interoperability issues between medical device domain and the hospital information systems domain are detailed. First, the ISO/IEEE 11073 standards family is described for the interoperability among the medical devices. HL7 is also detailed in this section to provide information on the acquisition of observation data by the hospital information systems. Finally, Integrating the Healthcare Enterprise (IHE) approach is presented which provides integration profiles for the integration of the two domains.

3.1 ISO/IEEE 11073 Point-of-care Medical Device Communication

The need of an architecture for the automatic acquisition of medical device observations by clinical information systems was identified in early 1980s. Starting with the Medical Information Bus (MIB) developed by IEEE in 1984, there are various standardization efforts in medical device domain. The thesis work concentrates on ISO/IEEE 11073 which was approved in 2003 by CEN, ISO and IEEE as a joint set of standards for point-of-care device communication. The

reason for choosing ISO/IEEE 11073 is not only its widely acceptance but also its complementation efforts with the existing well known standards.

Following standards are published within ISO/IEEE 11073 family of standards:

- ISO/IEEE 11073-10101:2004(E) Health Informatics - Point-of-care medical device communication - Part 10101: Nomenclature
- ISO/IEEE 11073-10201:2004(E) Health Informatics - Point-of-care medical device communication - Part 10201: Domain Information Model
- ISO/IEEE 11073-20101:2004(E) Health Informatics - Point-of-care medical device communication - Part 20101: Application Profile - Base Standard
- ISO/IEEE 11073-30200:2004(E) Health Informatics - Point-of-care medical device communication - Part 30200: Transport Profile - Cable Connected
- ISO/IEEE 11073-30300:2004(E) Health Informatics - Point-of-care medical device communication - Part 30300: Transport Profile - Infrared Wireless

"The ISO/IEEE 11073 standards are partitioned into layers that may be combined as necessary to provide the communications appropriate for a given device [16]". These standards can be analyzed in three areas:

- Device data / semantics (ISO/IEEE 11073-1xxxx series)
- General communication services (ISO/IEEE 11073-2xxxx series)
- Transports (ISO/IEEE 11073-3xxxx series)

"The ISO/IEEE 11073 family is based on an object-oriented systems management paradigm [17]". The medical devices, their measurements, units of

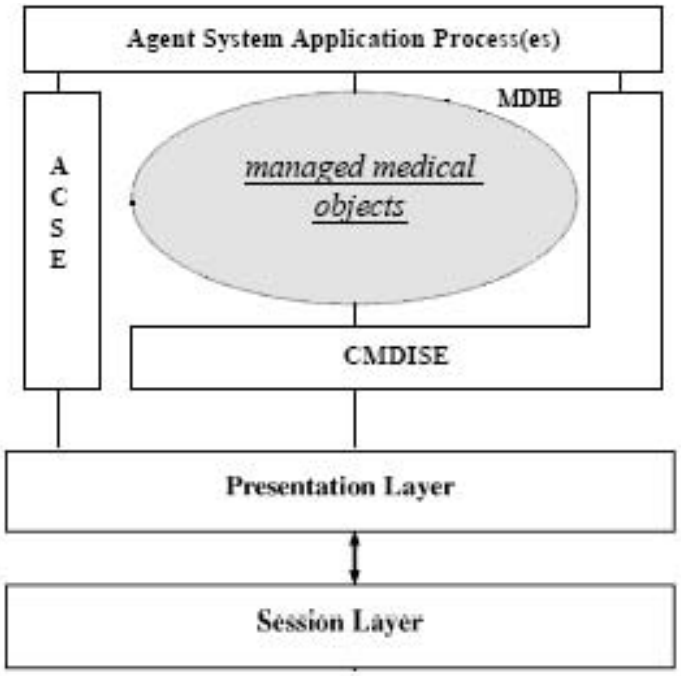

Figure 3.1: Conceptual Model of an ISO/IEEE 11073 Conformant Medical Device

measurements and similar domain related information can be accessed using object access service protocol. The ISO/IEEE 11073 standards use the conceptual model given in Figure 3.1 to define medical devices and they define sub-standards that map the conceptual model to the full seven-layer ISO/OSI reference model [18].

The thesis work concentrates on the interoperability issues of medical devices with the hospital information systems. Therefore, application, presentation and the session layers are of specific interest. The sub-standards used along these layers are "Part 10101: Nomenclature", and "Part 10201: Domain Information Model" standards. These two standards are presented within the next subsections.

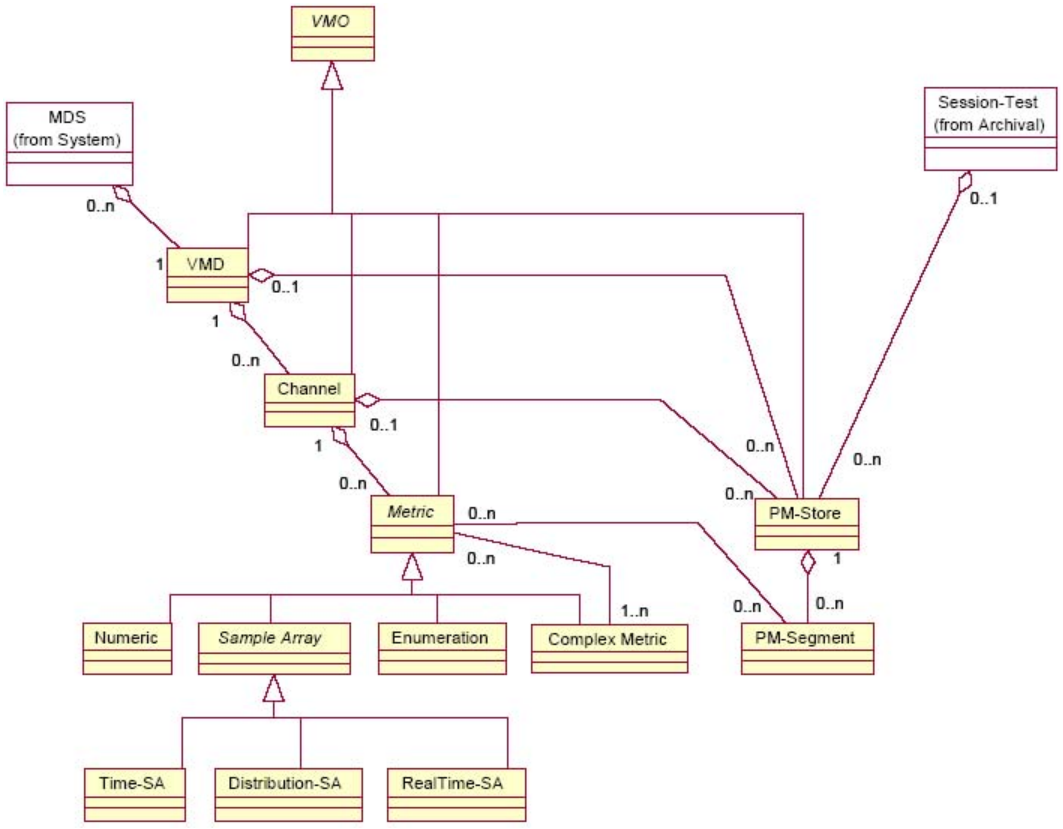

Figure 3.2: ISO/IEEE 11073 Medical Package Conceptual Model

3.1.1 ISO/IEEE 11073 Domain Information Model

"The domain information model (DIM) is an object-oriented model that consists of objects, their attributes, and their methods, which are abstractions of real-world entities in the domain of medical devices [17]."

The medical device domain is subdivided into packages, and each package is defined in the form of object diagrams. The DIM consists of eight packages; medical package, alert package, system package, control package, extended services package, communication package, archival package and patient package. The medical package is important for the thesis work since the medical devices; their channels, their observations, and the data types used for the observations are defined within the medical package. The medical package conceptual model is given in Figure 3.2.

Each object in the medical package model is a Virtual Medical Object (VMO) which is used for consistent naming and identification. The Medical Device System (MDS) in the system package consist of a single Virtual Medical Device (VMD) which is the abstraction of a medical device. The characteristics of the medical device are captured in the VMD object. It is possible to relate multiple channels to the VMD object which are used to group metric objects. For example, one channel of a device can be created to group together the heart rate metrics. A metric is used to represent medical devices qualitative and quantitative measurements. For example, a Numeric object can be used for representing a blood pressure observation of a patient where a Real-time Sample Array is used for representing ECG waveform measurements of a patient.

It is possible to represent a medical device with objects using the DIM. However, in order to define interoperable medical devices, the attributes of these objects must consist of codes that are specified in a data dictionary. The ISO/IEEE 11073 - 10101: Nomenclature is a data dictionary which is used to represent the objects with common codes. This standard is presented in the next subsection.

3.1.2 ISO/IEEE 11073 Nomenclature

"A common data dictionary is the prerequisite for interoperability of medical devices and device systems [19]." The ISO/IEEE Nomenclature is the data dictionary of the attribute fields of the objects of VMOs that represent the medical device domain.

For the nomenclature of devices, for measurements, for body sites where the devices are connected, for alerts, etc., systematic names have been constructed following the methodology described in the European standard CEN ENV 12264 [20]. Each systematic name is constructed by different concepts given in the nomenclature. A set of semantic concepts for differentiating medical devices are given in Table 3.1. Following these semantic concepts, it is possible to classify the medical device and find the specified code for the device. For example, a pulse oximeter (SpO2) is an analyzer and it measures

Table 3.1: Set of Semantic Concepts for Medical Device Differentiation

Base Concepts	**Differentiating Criteria**		
	1st <Device>	**2nd <Has target>**	**3rd <Type>**
Analyzer	Concentration	Airway	MDS
Filter	Electric Potential	Blood	VMD
Calculator	Flow	Body	Channel
...	...	...	...

Systematic name	Common term	Description/Definition	Code
Analyzer			
Analyzer | | |<type>	Generic analyzer	Instrument that analyzes acquired patient information	4100
Analyzer | Concentration [Sat] | Blood |<type>	SpO_2 monitor	Instrument that derives the % of arterial O_2 and pulse rate parameters (blood flow)	4104

Figure 3.3: Nomenclature Attribution Example

the concentration of blood. This device is classified in the nomenclature as "Analyzer|Concentration|Blood|<type>", and the screen shot of the corresponding section in the nomenclature is given in Figure 3.3.

By following the classification schema of the nomenclature, it is possible to find the codes of vital signs medical devices, units of measurement, metrics (measurements and enumerations), body sites, and alerts.

The use of the nomenclature with the DIM is going to be further described within the next sections during the creation of the medical devices conceptual models in ISO/IEEE 11073 and for the specific devices created in the Saphire project.

3.2 Health Level Seven

"Health Level Seven" (HL7) is an American National Standards Institute (ANSI) accredited standards developing organization operating in the healthcare domain [21]. HL7 is particularly produce standards in clinical and administrative domain

excluding the medical device domain. Being the most widely used messaging standard that enables disparate healthcare applications to exchange key clinical data, HL7 develops specifications [21]. "Level Seven" refers to the application level of International Organization for Standardization (ISO) communications model for Open Systems Interconnection (OSI). The issues occur on the application level are data to be exchanged, timing of messages and the communication of errors between applications.

"The messaging standard addresses the interfaces among various systems that send or receive patient admissions/registration, discharge or transfer (ADT) data, queries, resource and patient scheduling, orders, results, clinical observations, billing, master file update information, medical records, scheduling, patient referral, and patient care [22]". Its purpose is to provide a way to integrate heterogeneous systems. Therefore, the messaging standard is important for the thesis work since it addresses clinical observations data exchange and it is currently the most widely deployed standard in the world. The thesis work intends to seamlessly exchange medical device observation data to hospital information systems using HL7.

3.2.1 Message Framework

HL7 messaging standard assumes that events in the real world create the need for data flow among systems. These events are referred as "trigger events". For example, when an observation of a patient is ready, this event creates a data flow between systems to communicate the observation data. HL7 specifies these triggering events and the messages used for these triggering events.

A message is an atomic unit of data transferred between systems [22]. There are different message types defined in HL7 referring to the purpose of the message. For example, "Patient Administration (ADT)" message type is used to transfer administration of a patient between systems. The messages consist of several segments which are used for the grouping of data fields such as "Message Header (MSH)" and "Patient Identifier (PID)". The data fields are sequences

Table 3.2: ADT-A01 Event Segments

ADT*A01*ADT_A01 Segments	**Description**
MSH	Message Header
EVN	Event Type
PID	Patient Identification
[PD1]	Additional Demographics
[ROL]	Role
[NK1]	Next of Kin
PV1	Patient Visit
[PV2]	Patient Visit - Additional Info.
[ROL]	Role
[DB1]	Disability Information
[OBX]	Observation/Result
[AL1]	Allergy Information
[DG1]	Diagnosis Information
[DRG]	Diagnosis Related Group

of characters which conform to an HL7 data type such as "Address (AD)" and "String (ST)". A sample event is given below with construction details:

"An ADT-A01 event is intended to be used for "Admitted" patients only. An A01 event is sent as a result of a patient undergoing the admission process which assigns the patient to a bed. It signals the beginning of a patients stay in a healthcare facility [22]". In Table 3.2, a valid ADT-A01 message structure is given.

The MSH segment is given as a sample segment that is used in ADT-A01 message. MSH segment defines the intent, source, destination, and some specifics of the syntax of a message [22]. Table 3.3 lists the attributes of the MSH segment.

Each data field is set to a specific location in the message segments. The maximum length of these data fields, the data type used for the data fields and data fields optionalities are also specified by the messaging standard. For instance, the third data field of MSH segment, "Sending Application" is specified as a field that uniquely identifies the sending application among all other applications within the network enterprise. HD data type stands for "Hierarchic designator" and it consists of "<Namespace ID (IS)>*<Universal ID

Table 3.3: MSH Segment Attributes

Sequence	Length	Data Type	Optionality	Element Name
1	1	ST	R	Field Separator
2	4	ST	R	Encoding Characters
3	227	HD	O	Sending Application
4	227	HD	O	Sending Facility
5	227	HD	O	Receiving Application
6	227	HD	O	Receiving Facility
7	26	TS	R	Date/Time Of Message
8	40	ST	O	Security
...	...	...	...	...

```
MSH|^~\&|ST01A||CM01A||19940913105001O2||ADT^A01|002988538062171|P|2.2|1|
EVN|A01|199409131050|
PID||88888^^^EMI Primary|99999^^^LAB|U6123456|Howser^Doogie^B^Jr.^Sir^PhD|Babasafa|1961
        0521|Male|Howser^Dog^B^^^|race|123 Looney Toon Way^Ste 123^Toon
Town^CA^95403^USA^Home||(707)578-4098|(707)541-
        2583|English|M|Catholic|3|444-55- 6666|555555555^CA|MothersIdentifier|ethnic|Modesto|N|1|USA||
NK1||Belle^Clara^A^^^|Sister|123 Toon Tower Rd^^Toon
        Town^CA^95403^USA^B|(707)538-9141|(707)234-
        1234|Emergency|19950826|19950830|Daycare|DC|434-32-1232|Toon Daycare
NK1||Belle^Bruce^A^^^|Brother||||Contact|19950826|19950830||DC|
PV1||Inpatient/Acute|1EST^ROOM2^BED^A^FAC01A|||aflav^Flavershum^Alexander^
        ^^Dr.|200^Smuck^Shirley^^^Dr.||MEDICINE/CARDIOLOGY|||||||0003|||||||
        ||||||||||||||||||199508261025|199508301050
DG1||ICD9|10.1|Hopeless Diagnosis|199508271035|Admitting
AL1||FA|ALCODE^Allergic to Roadrunners|10|Sneezing
GT1|||Acme Insurance||100 Looney Street^Disney District^Toon
        City^CA^90505^USA|(709)333-3333|(709)444-
        4444||||Self||19940101|19980101||McKessonHBOC|123 Employer
        Address^Address Line 2^Toon City^CA^90505^USA|(707)555-5555||1||
```

Figure 3.4: A Sample ADT-A01 Message

(ST)>*<Universal ID Type (ID)>" components where IS is a coded value for user-defined tables, ID is a coded value for HL7 tables and ST is a string.

A sample ADT-A01 message for ADT-A01 event is given in Figure 3.4.

3.2.2 Observation Reporting Trigger Events

The transaction set required for delivering clinical observations between health-care systems is defined in "Observation Reporting" section of the HL7 Messaging Standard. The trigger events for observation reporting are analyzed since the proper trigger events must be facilitated for the communication of medical device observations.

The observation messages and the trigger events are defined as:

- Unsolicited Observation Message (Event R01)
- Unsolicited Laboratory Observation Message (Event R21)
- Query for Results of Observation (Events R02, R04)
- Unsolicited Point-of-Care Observation Message - Place Order (Event R30)
- Unsolicited New Point-of-Care Observation Message - Search Order (Event R31)
- Unsolicited Pre-ordered Point-of-Care Observation (Event R32)
- Unsolicited Specimen Oriented Observation Message (Event R22)
- Unsolicited Specimen Container Oriented Observation Message (Event R23)
- Unsolicited Order Oriented Observation Message (Event R24)

Within the thesis work, "Unsolicited Observation Message (Event R01)" will be used for the delivery of medical device observations since remote healthcare monitoring requires communication of observation data that is not specifically ordered for a test.

The Unsolicited Observation Message (ORU) message consists of several segments, however, the Observation Result Segment (OBX) segment is important to note since it is possible to construct almost any clinical report as a multi-level hierarchy in this segment [22]. The detailed use of ORU message and the OBX segment is going to be detailed in section 4.3.1. A sample unsolicited transmission of radiology data is given in Figure 3.5.

3.3 Integrating the Healthcare Enterprise

"The Integrating the Healthcare Enterprise (IHE) is an initiative by healthcare professionals and industry to improve the way computer systems in healthcare share information [23]". IHE is not a standard, however, it provides effort and

```
MSH|^~\&|XRAY||CDB||200006021411||ORU^R01|K172|P|...
PID|...
OBR|1|X89-1501^OE|78912^RD|71020^CHEST XRAY AP
LATERAL|||19873290800|||9218^MASTERS^JOHN^B|...
OBX|1|CE|71020&IMP^RADIOLOGIST'S IMPRESSION|4|^MASS LEFT LOWER LOBE|||A|||F|...
OBX|2|CE|71020&IMP|2|^INFILTRATE RIGHT LOWER LOBE|||A|||F|...
OBX|3|CE|71020&IMP|3|^HEART SIZE NORMAL|||N|||F|...
OBX|4|FT|71020&GDT|1|circular density (2 x 2 cm) is seen in the posterior segment of the
LLL. A second, less well-defined infiltrated circulation density is seen in the R mid
lung field and appears to cross the minor fissure#||||||F|...
OBX|5|CE|71020&REC|5|71020^Follow up CXR 1 month||30-45||||F|...
```

Figure 3.5: Unsolicited Observation Message

framework to integrate healthcare systems. Being a joint effort of the Radiological Society of North America (RSNA) [24] and the Healthcare Information and Management Systems Society (HIMSS) [25], the IHE initiative was launched in 1998.

In spite of the existence of the healthcare standards in various domains, the interoperability of the healthcare information systems is problematic. HL7 standard, as introduced in section 3.2, is the most widely adopted healthcare standard. Its wide acceptance is problematic due to the variations in the implementations. For instance, the optionalities in the HL7 standard give also vendors some development independence. Therefore, the standards may also lack interoperability for some use cases. IHE aims to provide information on how to use the existing standards upon different use cases.

There are eight technical frameworks under IHE where "Patient Care Devices (PCD) [26]" technical framework examines the medical device domain. The technical frameworks provide information on how to overcome integration problems by using the existing standards. Under the PCD technical framework, there is a single integration profile, Device Enterprise Communication (DEC) which aims to support communication of PCD data to enterprise applications using consistent semantics [26].

Within the next subsections, the DEC profile is reviewed in order to provide the IHE point of view for the medical device interoperability with the clinical information systems.

3.3.1 IHE Device Enterprise Communication Profile

The Device Enterprise Communication (DEC) profile addresses the need for consistent communication of PCD data to the enterprise. Enterprise recipients of PCD data include, but are not limited to, Clinical Decision Support applications, Clinical Data Repositories (CDRs), Electronic Medical Record applications (EMRs), and Electronic Health Records (EHRs).

The Device Enterprise Communication Integration Profile supports communication of vendor independent, multi-modality Patient Care Device data to Enterprise Applications using consistent semantics. Its aim is to accomplish this by mapping PCD data from proprietary syntax and semantics into a single syntactic and semantic representation for communication to the enterprise. However, IHE have not yet proposed a solution for mapping the proprietary medical device formats to ISO/IEEE 11073 syntax and semantics which is planned to be done with Device Observation Reporter actor. The thesis work proposes a novel solution for the transformation of proprietary medical device formats to ISO/IEEE 11073 syntax and semantics.

The Device Enterprise Communication profile also provides an optional publish/subscribe mechanism for applications to negotiate which PCD messages are communicated to a given application based on negotiated predicates (Device Observation Filter). Options are provided to allow applications to filter particular PCD data of interest. The actors and the transactions of the profile are shown in Figure 3.6.

The actors shown in the figure and their short descriptions are as follows:

- *Device Observation Reporter:* The Device Observation Reporter (DOR) actor receives data from PCDs, including those based on proprietary formats, and maps the received data to transactions providing consistent syntax and semantics.

- *Device Observation Filter:* The Device Observation Filter (DOF) actor is responsible for providing PCD data filtering services based on pub-

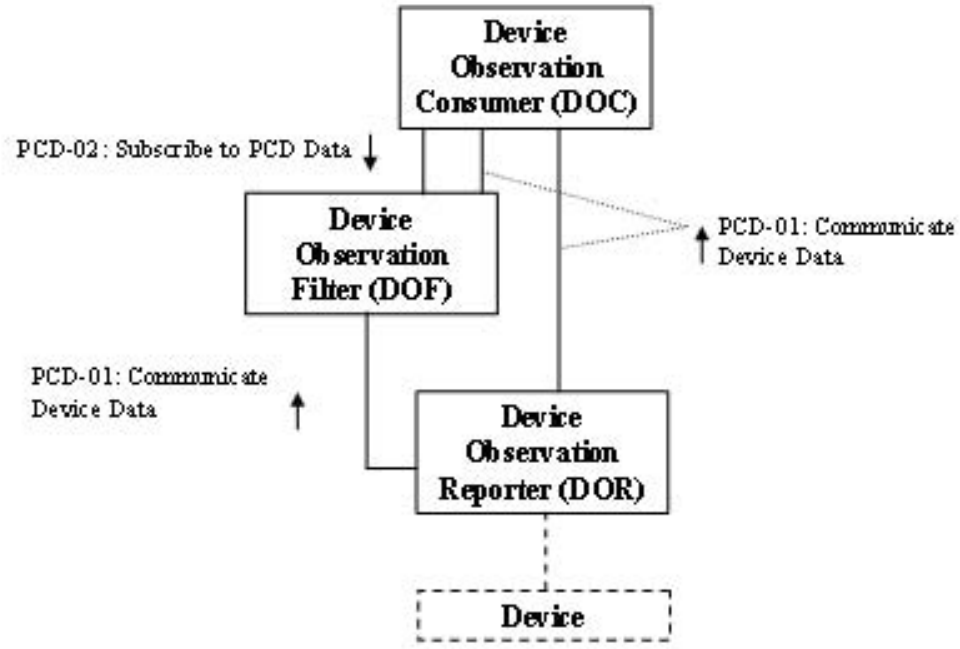

Figure 3.6: Device Enterprise Communication Profile

lish/subscribe predicates negotiated with client applications implementing the Device Observation Consumer.

- *Device Observation Consumer:* The actor responsible for receiving PCD data from the Device Observation Reporter, the Device Observation Filter, or both.

The transactions shown in the figure and their short descriptions are as follows:

- *Communicate PCD Data:* Transmit PCD data to enterprise clients from a Device Observation Reporter or Observation Filter and Receive PCD data by a Device Observation Consumer.

- *Subscribe To PCD Data:* Defines predicate for communication of PCD data from DOF to a Device Observation Consumer.

CHAPTER 4

PROVIDING AUTOMATED ACQUISITION OF MULTIMODAL MEDICAL DEVICE OBSERVATIONS BY HEALTHCARE INFORMATION SYSTEMS

The thesis work aims to provide automatic acquisition and use of multimodal medical device observations in healthcare information systems. Automated use of medical device systems will support the clinical use of medical device observations resulting in improved healthcare workflow, reduced medical errors, reduced healthcare costs and improved quality of care.

4.1 Design Issues

The communication needs of the two domains to be connected lead to development of a three tiered architecture where the medical device observations are retrieved by an intermediate component, a data manager, and forwarded to the related applications. The need of an intermediate component comes from the possible deployment models of the medical devices. In addition to the clinical units, the medical devices can be used at home, at work or mobile with the patient. The data manager is needed to stay connected to the devices in their

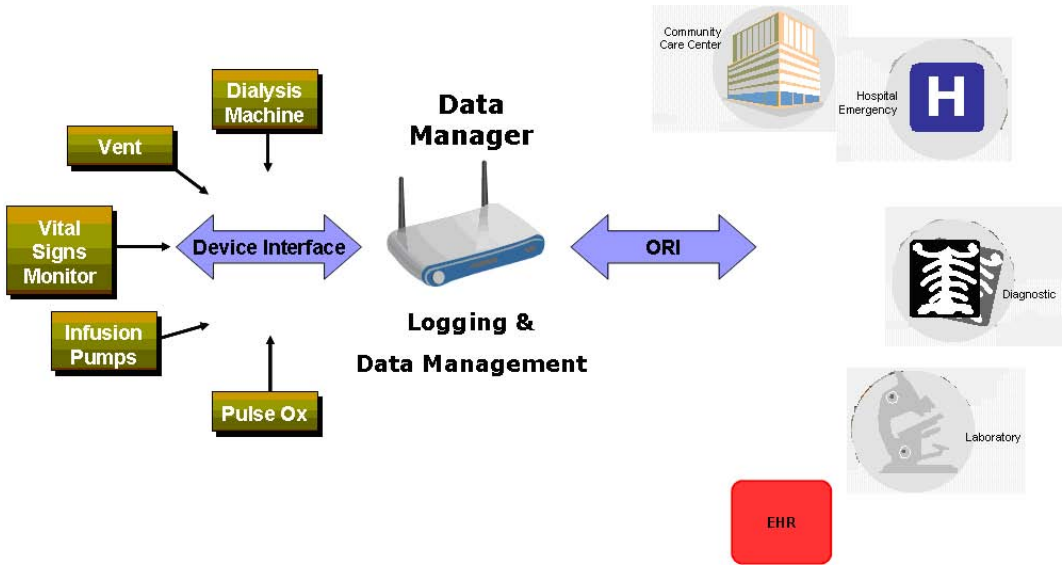

Figure 4.1: Communication Architecture of Related Domains

local vicinity in order to record the observations no matter where the clinical information system is. By making use of the data manager, it would be possible to forward the observations to the receiving applications when the data manager has the connectivity to the applications. When the wireless communication technology is considered, the data manager can easily get connected to the related applications. Another reason for using an intermediate component is the utilization of a processing unit. The data manager can also be used to process the observations, give alarm in emergency cases or do semantic mediation between communicating entities for achieving interoperability. The three tiered communication architecture is shown in Figure 4.1. The two interfaces that are connected to the data manager must be analyzed separately due to the domain specific requirements of the connected entities.

The device interface connects the medical devices to the data manager. There are existing proposals to solve interoperability issues between the medical devices. It is possible to make use of these efforts to facilitate interoperability along the device interface for the communication of medical devices with the data manager. As introduced in section 3, the most suitable way of plug-and-play

communication between the devices is the ISO/IEEE 11073 family of standards. However, additional novel approaches needed in order to provide interoperability of vendor specific proprietary medical devices.

The observation reporting interface (ORI) facilitates the communication between the data manager and the receiving applications. Along the ORI, the thesis work is concentrated on the existing efforts of IHE introduced in section 3 which is based on interoperating HL7 conformant clinical applications. Therefore, the interoperability of ISO/IEEE 11073 conformant models with HL7 based clinical applications is ensured along the ORI. Also, enhancements to the work proposed by IHE are going to be detailed in chapter 6 which are realized within the scope of the thesis and used in the Saphire project.

4.2 Device Interface Interoperability

The ISO/IEEE 11073 family of standards is based on object-oriented conceptual modeling of the medical device domain. As introduced in section 3, it is possible to access medical device, observations, body sites, units of measurement and any vital signs related data using an object access service protocol [17]. By facilitating the use of this family of standards, it is possible to provide interoperability between the connected medical devices. The DIM based conceptual model can also be used along the device interface. However, one of the most important interoperability problems is the low adoption rate of the standards by the manufacturers. The medical devices that have proprietary interfaces working with vendor specific software require duplicate integration efforts on the network. Therefore, in order to achieve interoperability along the device interface for multi-modal medical devices that are conformant to different standards, additional mechanisms must be deployed. Within the thesis work, a mapping tool is developed for the design of medical device conceptual models conforming to ISO/IEEE 11073 standards.

The mapping tool developed enables translating medical device data instances in a proprietary data format, or in any standard sensor representation

format whose schema is defined with XML Schema (XSD) [27] to the ISO/IEEE 11073 format. In order to accomplish this task, the user is guided through a set of steps to create the "Virtual Medical Device" abstraction for the device as defined in the DIM. In other words, the medical device is graphically modeled with the aid of the tool and the corresponding ISO/IEEE 11073 conformant conceptual model is automatically generated.

This section provides the design of the ISO/IEEE 11073 based conceptual model of the medical devices by the mapping tool developed within the thesis work. Each important design phase is detailed in the following sub-sections.

4.2.1 Virtual Medical Object Generation

The medical package objects in the DIM are sub-classes of the Virtual Medical Object (VMO) which is used for consistent naming and identification as detailed in section 3.1. The aim of the tool developed is to create VMOs and specialize each VMO to corresponding sub-classes so that the conceptual model of the medical device that is conformant to ISO/IEEE 11073 standards is created.

The Virtual Medical Device (VMD) object is used for the abstraction of the medical devices. The characteristics of the medical device are captured in the VMD object and it is possible to link device related information such as observation data to the VMD object with other specialized VMOs.

The VMD creation panel is designed based on the medical device classification defined in the ISO/IEEE 11073 - 10101 Nomenclature. The nomenclature is a data dictionary which is used to represent devices, measurements, body sites, alerts, etc. with common codes. Systematic names are used in the nomenclature according to the methodology described in the European standard CEN ENV 12264 [20]. The systematic names are grouped with respect to a set of differentiating semantic links given in the nomenclature. The semantic links used for medical device differentiation are: "Base Concepts", "Has Measured", "Has Target", and "Device Type". According to the functionality of the devices, nine base concepts are identified such as analyzer, meter, regulator and pump. Next,

for each base concept, possible measurements are listed such as concentration, pressure and rate. “Has Target” link focuses on body subsystems such as blood, heart and brain. Finally the device type is specified.

The nomenclature section A.5 lists the base concepts for a medical device as follows:

- Analyzer (devices [or the subsystems of more complexb devices] that manipulate or interpret acquired data in order to produce derivative results.)
- Calculator (devices [or the subsystems of more complex devices] whose primary function is to perform calculations upon raw or derived data)
- Filter (physical particle or chemical filters)
- Generator (devices [or the subsystems of more complex devices] that generate physical quantities such as heat, moisture, electrical activity, etc.)
- Meter (devices [or the subsystems of more complex devices] that perform mensuration or measurement functions on physical properties such as current, electrical potential, flow, etc.)
- Monitor (devices [or the subsystems of more complex devices] that both acquire data and analyze it. Such a device is typically composed of a number of virtual devices (VMDs) that perform the more basic tasks of data acquisition or data analysis. As an example, a patient multiparameter monitor would fall into this device class. This descriptor probably includes most real devices.)
- Pump (devices [or the subsystems of more complex devices] that transfer a liquid or gas from a source or container [to a patient, in the medical device context])
- Regulator (devices [or the subsystems of more complex devices] that maintain or control the flow or parametric balance of gases, liquids, electrical current, or other physiological analogues)

- Stimulator (devices [or the subsystems of more complex devices] that generate physical quantities such as heat, moisture, electrical activity, etc.)
- System (instruments that consist of transducive, analytical, and therapeutic components. An anesthesia system and most ventilators would fall into this device class.)

The first semantic link is based on the concept performs (typically afferent functions, particularly measurement, but also efferent functions such as regulation). The devices are, therefore, classified into a number of possible categories based on the functionality they perform.

"Has Measured Property":

- Concentration
- Electrical Potential
- Flow
- Multi-Parameter
- Negative
- Oxy
- Pressure
- Rate
- Resistance
- Temperature
- Volume

Measurements are typically focused or targeted on body subsystems. This category is secondary to function because devices typically can measure or effectuate at multiple sites (singly or in parallel). Within each class of device, the

secondary semantic link refers to the primary body system that the device is monitoring or affecting.

"Has Target":

- Airway
- Blood
- Body
- Brain
- Gas
- Heart
- Infusion
- Intra-Aorta
- Lung
- Multi-Gas
- Muscle
- Physiologic
- Renal
- Resp
- Skin/Tissue
- Urine

As shown in Figure 4.2, the user selects the relevant semantic links in order to see the resulting device list and select the appropriate one for the sensor to be created.

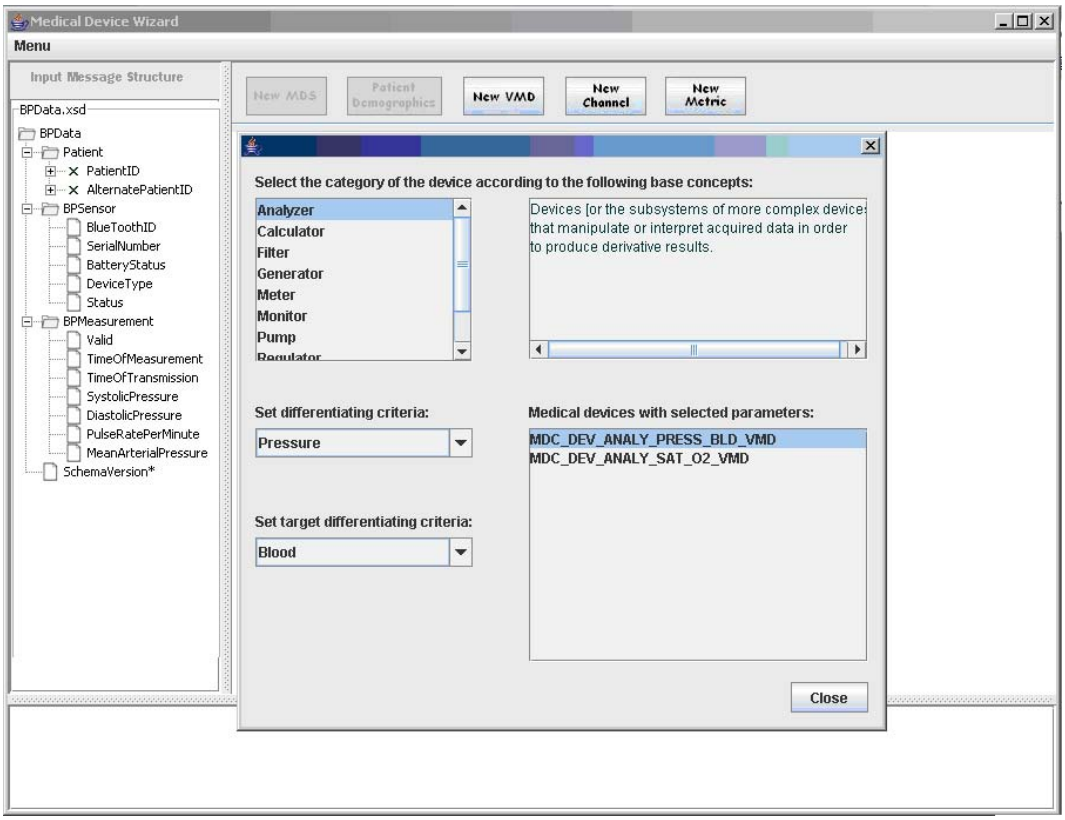

Figure 4.2: Virtual Medical Device Creation

It is possible to access the medical device generated using an object access service protocol. However, in order to achieve full interoperability between communicating entities, the attributes of these objects must consist of codes that are specified in a data dictionary. For example, a blood pressure analyzer is defined as a "VMD" object which basically represents the medical device generated. In order to make this representation machine processable, the analyzer concept must have been defined in a data dictionary and its code must be annotated with the generated "VMD" object. Therefore, the tool developed annotates the selected medical devices nomenclature code with the created VMD object. By defining each DIM conformant object with nomenclature based codes, machine processable representation of medical devices is achieved.

The design of the VMD follows the design of the measurement containers. Detailed information related to the medical objects of the DIM can be found

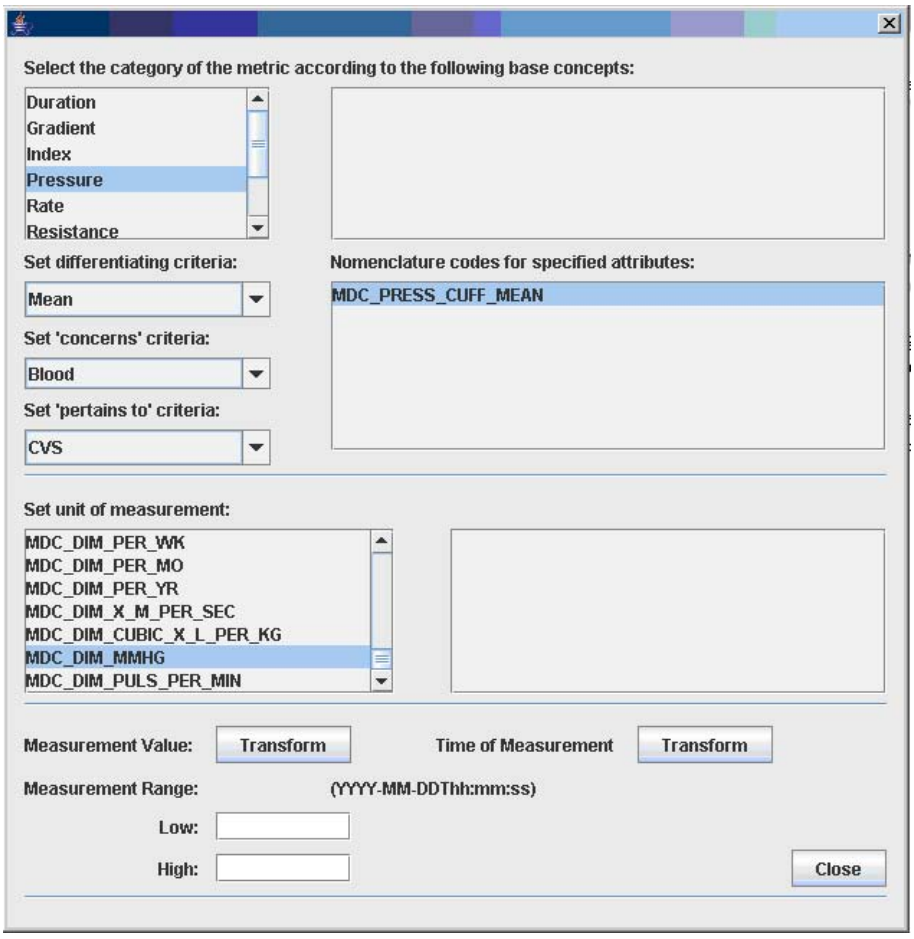

Figure 4.3: Numeric Metric Creation

in section 3.1.1. Figure 4.3 shows a sample metric creation of type Numeric. Similar to classification of medical devices, various semantic links are used in order to classify the measurements of medical devices. The tool follows each semantic link and lets users to define the measurements that are linked with the VMD. The measurement container design requires additional effort since there is a need of different data type representations in the DIM. While using a simple "Numeric" object is adequate for representing blood pressure, a "Real-time Sample Array" must be used in order to represent waveform observation of an electrocardiograph. The user is free to choose each specified "Metric" object in the DIM. The same procedure is also applied to let users define units of measurement, body sites and rest of the objects defined in the DIM.

4.2.2 Defining Data Mediation from Proprietary Messages

As introduced earlier, the mapping tool is developed in order to model the vendor specific medical devices in ISO/IEEE 11073 conformant conceptual models. The design of the conceptual model is given in section 4.2.1. The mediation between the medical device proprietary message schema and the DIM is needed in order to finalize the design process.

The mediation between the values of the attributes and the proprietary message are allowed by our tool so that in real-time the values of these attributes are automatically set to values coming from the proprietary message of the medical device. The tool accepts any proprietary message represented in "Extensible Markup Language" (XML) [28] format. The proprietary messages of various medical devices can be encoded in different formats. Therefore, an XML wrapper for the medical device message format might be needed. The tool developed expects input in XML format because it is easier to wrap a proprietary message to an XML document since it is self describing, hierarchical and flexible.

The tool takes the XML schema as an input which represents the proprietary message schema of the medical device and allows users to graphically define mappings between the entities of the message schema and the generated ISO/IEEE 11073 conformant medical device model. The panel on the left side of the tool presents the proprietary message schema of the medical device as shown in Figure 4.4.

The proprietary message nodes are mapped to the designed conceptual model by the user. Figure 4.5 illustrates the mapping of a proprietary message to an observation value attribute of a numeric object. The "SystolicPressure" node is directly copied to the target attribute. The tool allows any data transformation between the proprietary message schema and the designed conceptual model by making use of JavaScripts [29].

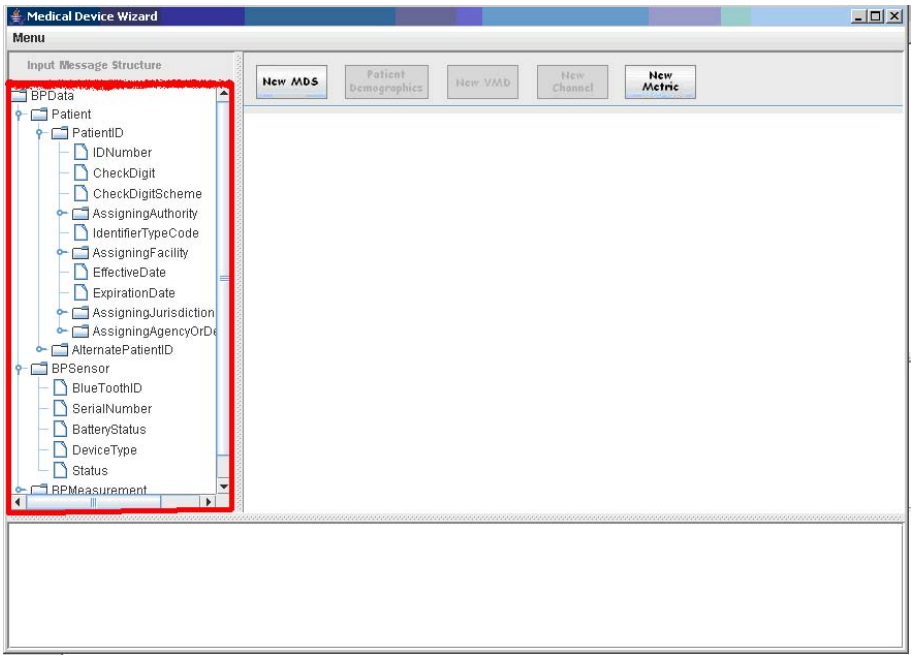

Figure 4.4: Proprietary Message Schema Panel

4.2.3 Data Mediation in the Mapping Engine

The designed conceptual model of the medical device with the mappings from the proprietary message format is represented in XML format by the tool where each object corresponds to an XML Node. Part of a mapping file representing the conceptual model of a blood pressure sensor is shown in Figure 4.6. For the attributes that require input from the proprietary message, a "mapping" XML Node is generated and the semantics of the mapping, the inputs, the path of the inputs in the proprietary message and the data transformations are described within this node. The mapping file generated is used by the mapping engine developed. The XML message coming from the medical device in proprietary format is mapped to the ISO/IEEE 11073 conformant model in real time using the transformations in the mapping file.

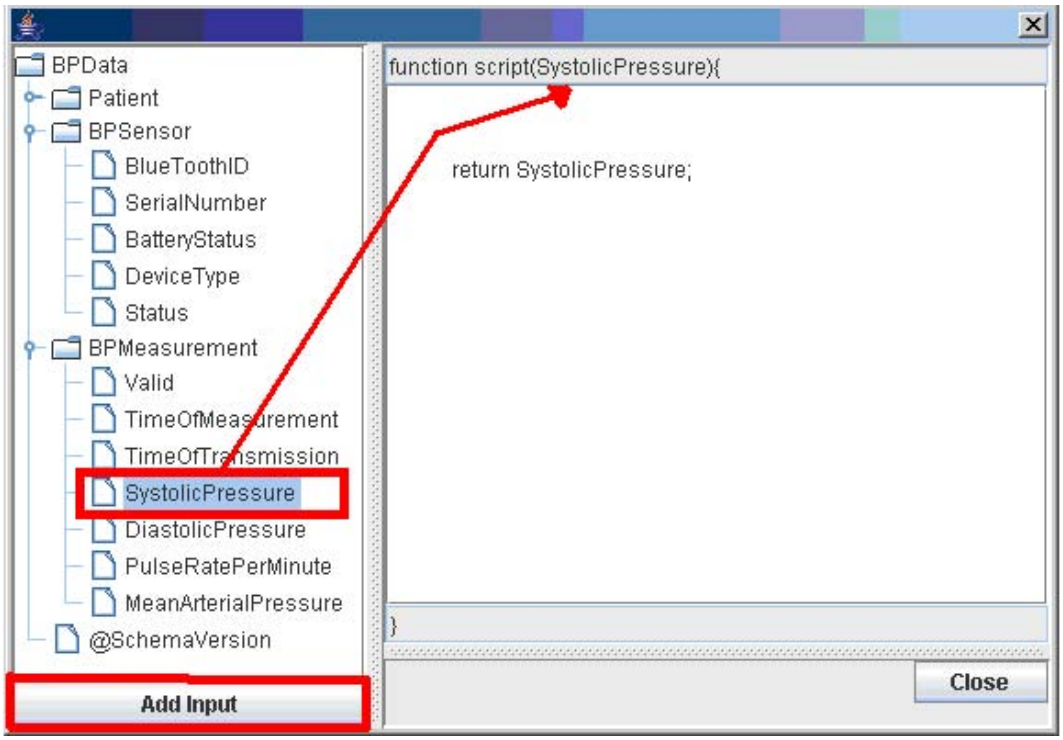

Figure 4.5: Data Transformation for Systolic Blood Pressure

4.3 Observation Reporting Interface Interoperability

Automated acquisition of multi-modal medical device observations also requires semantic interoperability along the observation reporting interface (ORI). Once the data retrieved by the data manager in ISO/IEEE 11073 syntax and semantics, it must be forwarded to the receiver ends; hospital information systems, laboratory systems, EHRs, etc. Therefore, the semantic interoperability along the observation reporting interface is strictly dependent on the existing protocols used within the hospital information systems. As introduced earlier, HL7 is the most widely used messaging standard that enables disparate healthcare applications to exchange key clinical data [21]. "Standardizing an observation reporting interface between these two environments will reduce the cost and complexity of deploying systems that automatically capture medical device data into HL7 based clinical applications, and thus will allow this capability to be more generally used in clinical environments, ultimately resulting in increased patient

```
<?xml version="1.0" encoding="UTF-8"?>
<MDS type="ieee.dim.system.SimpleMDS">
    <VMD type="ieee.dim.medical.VirtualMedicalDevice">
        <labelString>MDC_DEV_ANALY_PRESS_BLD_VMD</labelString>
        <systemType type="ieee.dim.types.TYPE">
            <code>4174</code>
            <NomPartition type="ieee.dim.types.NomPartition">
                <nomPartition>1</nomPartition>
            </NomPartition>
        </systemType>
        <Channel type="ieee.dim.medical.Channel">
            <channelID>1</channelID>
            <Metric type="ieee.dim.medical.metric.Numeric">
                <!-- systolic -->
                <unitCode>3872</unitCode>
                <unitLabel>MDC_DIM_MMHG</unitLabel>
                <metricID>19229</metricID>
                <labelString>MDC_PRESS_CUFF_SYS</labelString>
                <observationValue type="ieee.dim.types.NuObsValue">
                    <unitCode>3872</unitCode>
                    <metricID>19229</metricID>
                    <value>
                        <mapping>
                            <input>BPData|BPMeasurement|SystolicPressure</input>
                            <function>function Copy(arg0){return arg0;}</function>
                        </mapping>
                    </value>
                    <state type="ieee.dim.types.MeasurementStatus">
                        <status>
                            <mapping>
                                <input>BPData|BPMeasurement|Valid</input>
                                <function>function isValid(arg0){ if(arg0==true)
                                        return 8; else return 0;}</function>
                            </mapping>
                        </status>
                    </state>
                </observationValue>
```

Figure 4.6: Part of a Mapping File Representing Blood Pressure Sensor

safety and quality of care [4]". The thesis work intends to seamlessly exchange medical device observations to hospital information systems using HL7.

There are various approaches to provide interoperability between medical devices and the hospital information systems. The "Point-of-Care Connectivity (POCT)" standard, "ISO/IEEE 11073-60101: Application Gateway" draft and the IHE PCD technical framework specifies interfaces and protocols between ISO/IEEE 11073 conformant medical devices and HL7 based hospital information systems. The medical package of DIM is mapped to HL7 Observation Reporting messages by these standardization efforts. The same approach is used within the thesis work for providing interoperability along the ORI. This section provides the implementation details for the interoperability along the ORI.

As introduced in section 3.2.2, "Unsolicited Observation Message (Event R01)" is used for the delivery of medical device observations since remote healthcare monitoring requires communication of observation data that is not specifically ordered for a test. The segments of the Unsolicited Observation Message (ORU) are analyzed and the mappings between DIM objects and the ORU segments are developed.

4.3.1 HL7 Unsolicited Observation Message

The Observation Result Segment (OBX) is used to construct almost any clinical report as a multi-level hierarchy [22]. The idea is to represent the medical package conceptual model tree in the OBX segment of the HL7 ORU message. The data fields of the OBX segment are given in Table 4.1. The mapping procedure proposed by IHE and developed within the thesis work is detailed for each important data field of OBX segment below.

- *OBX-1 Set ID - OBX:* This field is the sequence number of the OBX in the message. Upon construction, for each new OBX segment (each new observation), the sequence number is incremented.

- *OBX-2 Value Type:* The value type field gives the data type used for the observation value given in field OBX-5. For example, if the observation data is modeled using "Numeric" object in the ISO/IEEE 11073 DIM, than the value of OBX-2 must be "NM".

- *OBX-3 Observation Identifier:* This field identifies the type of the medical device providing the observation values. The preferred format is an MDC value. The systematic coded values for medical devices are passed to this field upon mapping. For example, for a pulse oximeter, "150456*MDC_PULS_OXIM_SAT_O2*MDC" is used as the device type identifier. These values are automatically inserted by the mapping tool developed during conceptual model creation.

Table 4.1: OBX Segment Details

Seq	Len	DT	Usage	Card	Element name
1	4	SI	R	[1..1]	Set ID - OBX
2	2	ID	C	[0..1]	Value Type
3	250	CE	R	[1..1]	Observation Identifier
4	20	ST	R	[1..1]	Observation Sub-ID
5	99999	Varies	C	[0..1]	Observation Value
6	250	CE	C	[0..1]	Units
7	60	ST	CE	[0..1]	References Range
8	5	IS	CE	[0..1]	Abnormal Flags
9	5	NM	X	[0..0]	Probability
10	2	ID	CE	[0..1]	Nature of Abnormal Test
11	1	ID	R	[1..1]	Observation Result Status
12	26	TS	X	[0..0]	Effective Date of Reference Range
13	20	ST	X	[0..0]	User Defined Access Checks
14	26	TS	RE	[0..1]	Date/Time of the Observation
15	250	CE	RE	[0..1]	Producer's ID
16	250	XCN	RE	[0..1]	Responsible Observer
17	250	CE	RE	[0..1]	Observation Method
18	22	EI	RE	[0..1]	Equipment Instance Identifier
19	26	TS	CE	[0..1]	Date/Time of the Analysis
20	705	CWE	RE	[0..*]	Observation Site

- *OBX-4 Observation Sub-ID:* This field is used to distinguish between multiple OBX segments by providing an unambiguous mapping from the medical package of DIM. A dotted notation is followed to identify each OBX as follows: <MDS><VMD><Channel><Metric>. For example, "1.1.2.1" represents the first MDS, first VMD, second Channel and the first observation.

- *OBX-5 Observation Value:* This field contains the value observed by the medical device. OBX-2 value represents the data type used for this observation value.

- *OBX-6 Units:* This field presents the data units of the observation. "Percentage", "Millimeter" and "Pulse per Minute" are examples of observation units. These units of measurements are also represented in nomen-

clature codes. For example, "262688*MDC_DIM_PERCENT*MDC" is a coded unit for "Percentage". These coded values are also already captured with the mapping tool along the device interface.

- *OBX-11 Observation Result Status:* This field is filled according to the measurement status of the device for the observation.

- *OBX-14 Date/Time of the Observation:* Time of the observation is passed to the clinical information systems through this field.

- *OBX-20 Observation Site:* This field is used to represent the body site on which the observation is generated. For example, "460274*MDC_HEAD_EAR_R*MDC" represents the right ear of the patient.

CHAPTER 5

REALIZATION OF THE CONCEPTS FOR THE AUTOMATED USE OF MEDICAL DEVICE OBSERVATIONS IN THE SAPHIRE PROJECT

The Saphire project aims to develop an intelligent healthcare monitoring and decision support system to address the problem of an ever-increasing workload in medical fields due to the increasing percentage of elderly people in Europes population [6]. In the Saphire project, the patient monitoring is achieved by using agent technology where the "agent behavior" is supported by intelligent decision support systems based on clinical practice guidelines.

The interoperability problem that needs to be addressed to develop an effective intelligent healthcare monitoring tool is as follows: the data coming from the wireless medical sensors are either in proprietary format (for example, for electrocardiogram data, Philips XML ECG Data Format) or when they conform to a standard, this still does not solve the interoperability problem since there are very many standards (again for electrocardiogram data, the available standards include: SCP-ECP, US Food and Drug Administration FDA/HL7 Annotated ECG, I-Med and ecgML). Furthermore, interoperability of data coming from

various wireless medical sensors is also essential to infer information by combining data coming from various sensors. The technical interoperability problem of accessing multimodal medical device data is addressed in the Saphire project by the work achieved in this thesis. The medical sensors used in the project and the realization of the concepts proposed within the thesis work to provide interoperability between the sensors and the clinical information systems are presented in this chapter.

5.1 Saphire Medical Sensors

There are two medical sensors integrated to the system so far in the Saphire project; blood pressure and pulse oximeter sensors. Both of the devices use vendor specific proprietary software. In this section, the corresponding mapping efforts from these proprietary systems to ISO/IEEE 11073 based conceptual models by the tools described so far are given. The design of the blood pressure sensor is described step by step in this section.

The schema of the blood pressure sensor consists of three main elements. The first element identifies the patient; the second one represents the sensor identification data and the third element represents the sensor measurements.

The medical device system (MDS) for the blood pressure sensor is created by the mapping tool as described in section 4.2. In this section, step-by-step device creation with the mapping tool is given. First of all, the input XML schema file given in Appendix A is parsed by the mapping tool. The schema file is parsed and displayed on the left panel of the tool (Figure 5.1).

The medical device system to be created for the Blood Pressure Sensor in Saphire is a simple medical device which refers to a single sensor that does not process integrated data coming from another device. Therefore, "Simple Medical Device" is selected by the user when he clicks the "New MDS" button (Figure 5.2).

After the medical device system is initialized, the user is able to define new "VMDs", or related objects that are linked with the "MDS" such as patient

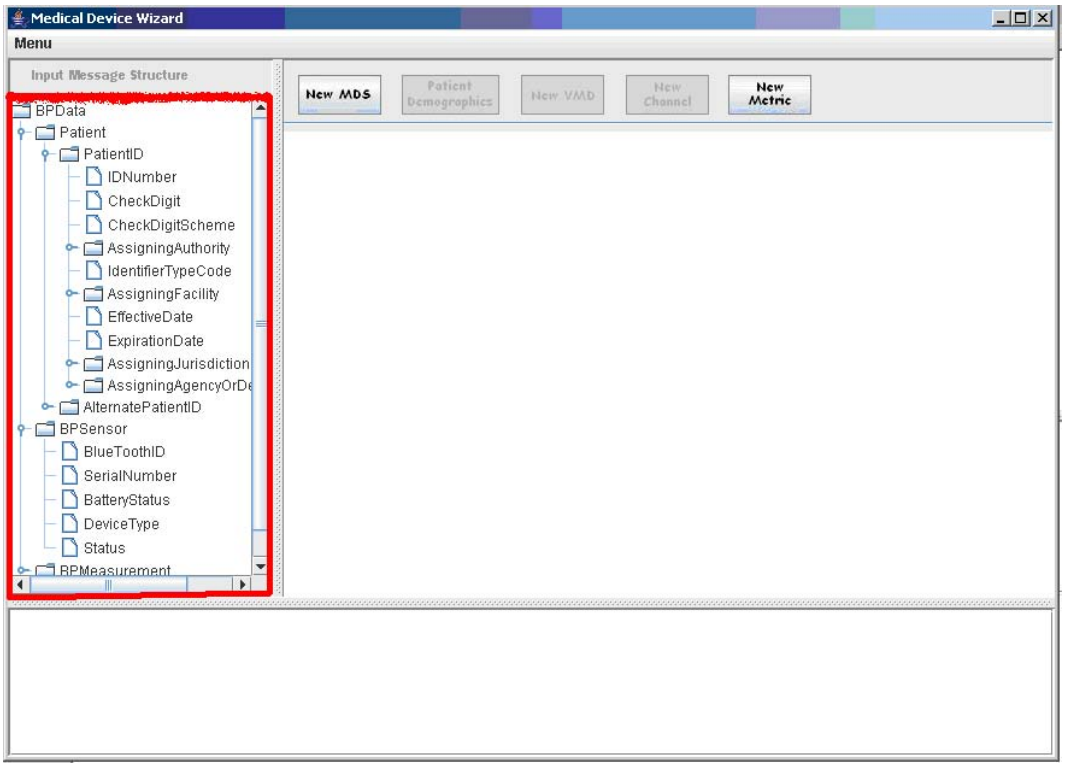

Figure 5.1: Step 1 - Display Input XML Schema

demographic data. Figure 5.3 illustrates a screen shot when the user selects to define patient demographics object and creates a transformation for patient identifier.

The transformation for the patient identifier is a copy function in this case. Therefore, the "BPData|Patient|PatientID|IDNumber" attribute of device instance is just copied for the value of the patient identifier in ISO/IEEE 11073 domain. A sample data transformation is given in (Figure 4.5).

The mapping tool lets the users to define unlimited number of VMDs for the medical device system created. For the blood pressure sensor in Saphire, there is a single corresponding VMD. The device is created as shown in Figure 5.4. The blood pressure sensor data is an "Analyzer", its "Has Measured" property is "Pressure" and the "Target Semantic Link" is "Blood". Once these properties are selected in the menu shown in Figure 5.4, the corresponding device in ISO/IEEE 11073 domains appears for the user (MDC_DEV_ANALY_PRESS_-

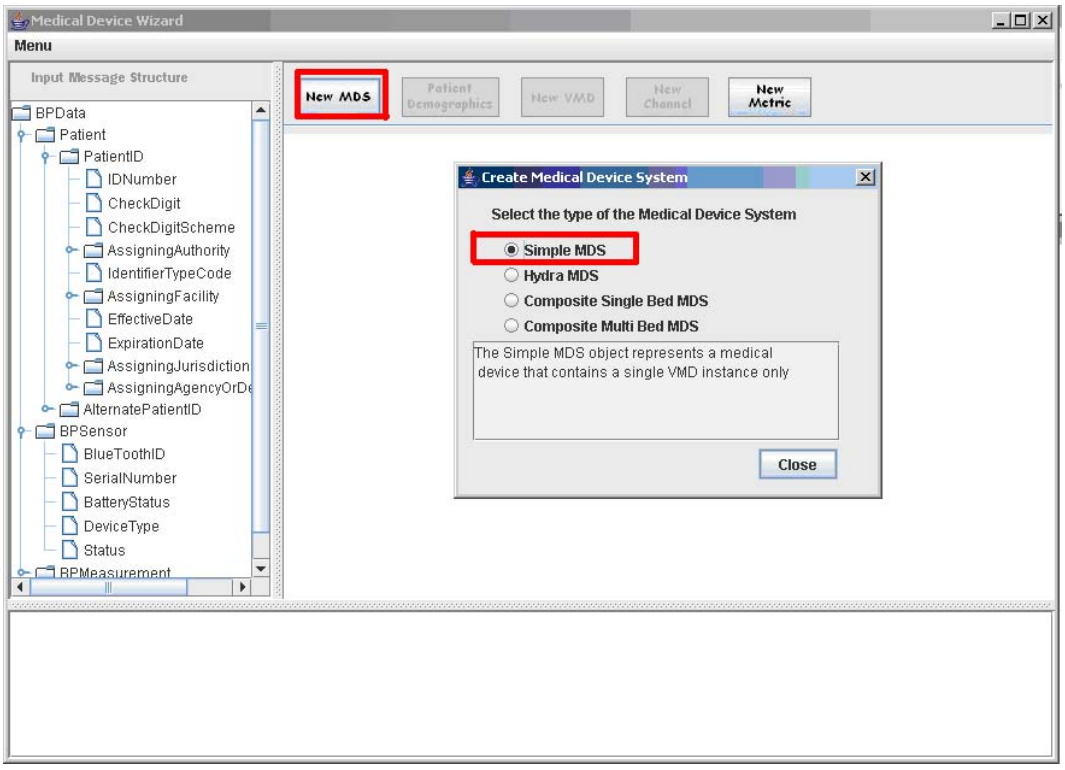

Figure 5.2: Medical Device System Type Selection

BLD).

The mapping tool lets the users to define unlimited number of measurements done by each VMDs defined. For the blood pressure sensor in Saphire, there are four different measurements:

- Systolic Pressure
- Diastolic Pressure
- Mean Arterial Pressure
- Pulse Rate per Minute

Each of these measurements refer to a metric of type "Numeric" in ISO/IEEE 11073 DIM. Therefore, a numeric observation class is generated for each observation. The numeric metric created for systolic blood pressure is shown in Figures 5.5 and 4.5. In Figure 5.5, the semantic links corresponding to the systolic

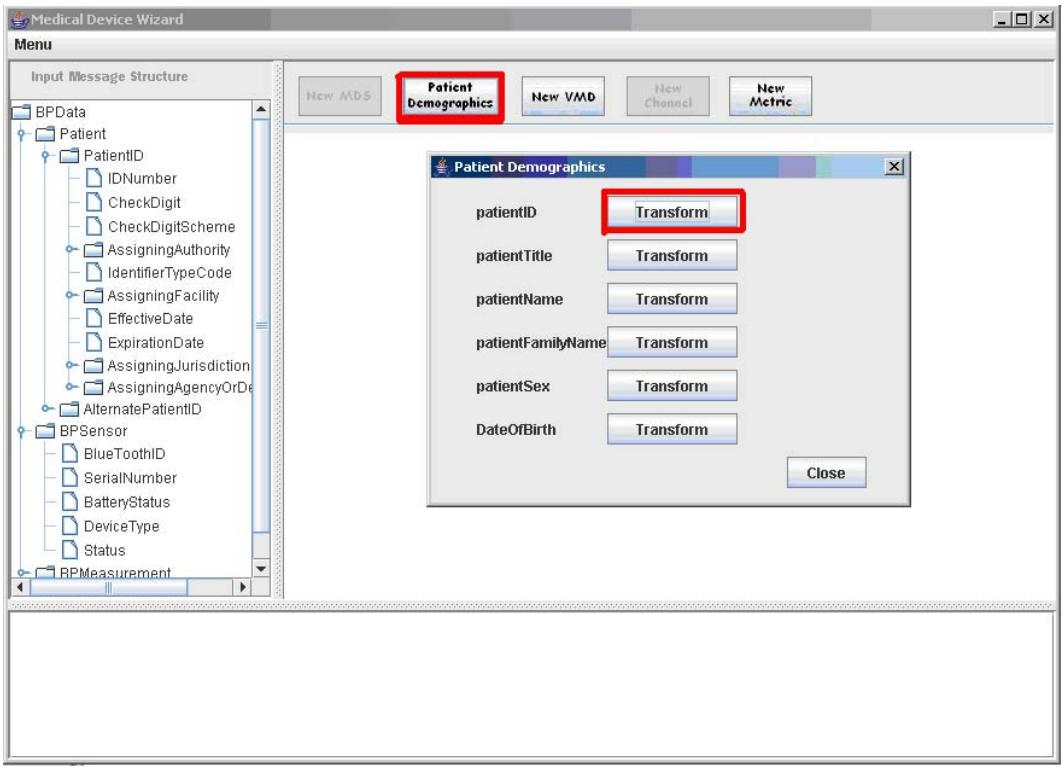

Figure 5.3: Patient Demographics Mapping

blood pressure are chosen by the user. The tool returns (MDC_PRESS_CUFF_-SYS) as the result of the search for "Pressure", "Systolic", "Blood", "CVS" data set. User also selects the units of measurement as mmHg (MDC_DIM_-MMHG). The user defines a data transformation by clicking the "Transform" button for Measurement Value. The SystolicPressure node is selected as input for the measurement value (Figure 4.5).

Similarly, each metric object is created for "Mean Arterial Pressure", "Diastolic Pressure" and "Pulse Rate per Minute" by using the mapping tool. Once all VMDs and corresponding metrics are defined, the mapping file stored. The result of this process is given in Appendix C. Once this mapping is created, for each XML instance representing the blood pressure sensor data, the tool dynamically translates the instance to ISO/IEEE 11073 conformant syntax and semantics.

A sample blood pressure sensor data instance and the corresponding HL7

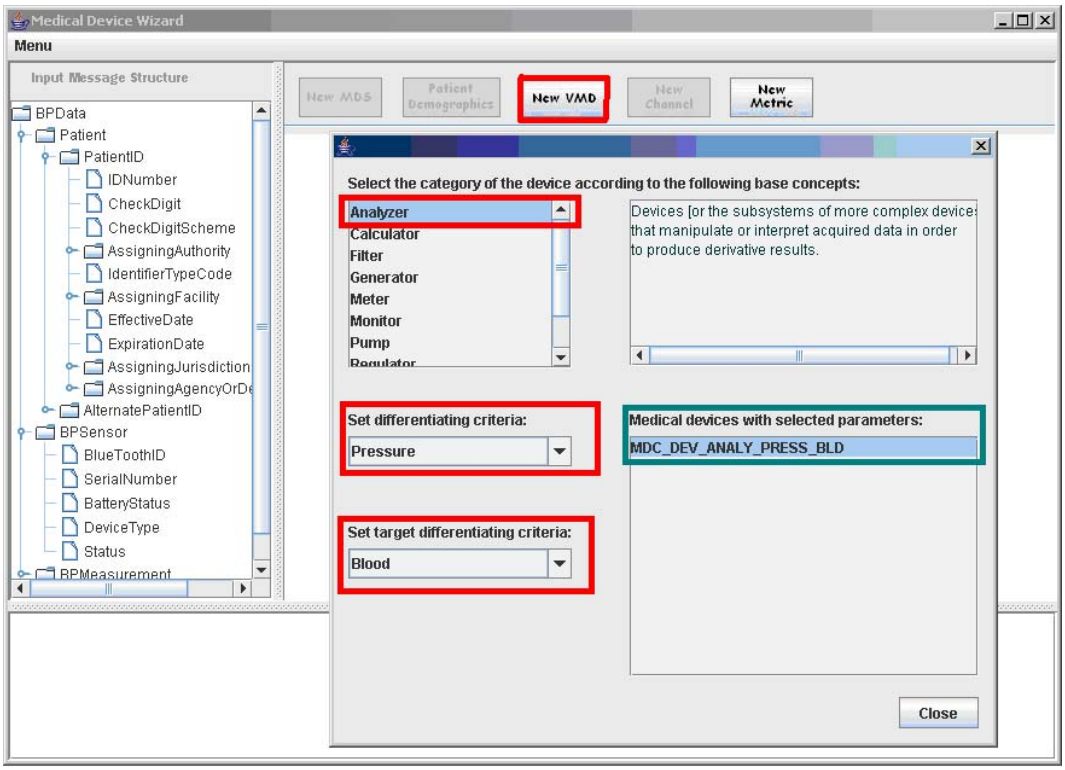

Figure 5.4: Virtual Medical Device Creation for Blood Pressure Sensor

observation message are given in Appendix B and Appendix D.

5.2 Data Mediation between HL7 and GLIF

The clinical decision support system used in the Saphire system are based on clinical practice guidelines. The "Clinical Decision Support" systems aim to assist general practitioners to make clinical decisions and managing medical actions more effectively [30] and are based on clinical practice guidelines. Clinical practice guidelines are the systematically developed statements designed to assist practitioners to make decisions about medical problems, and usually include plans for treatment. There are several computer interpretable models of Clinical Guidelines such as GLIF [31], ASBRU [32], ARDEN [33] and EON [34].

During the execution of a guideline, there is a need to communicate with external applications to retrieve patient data from medical devices or from the

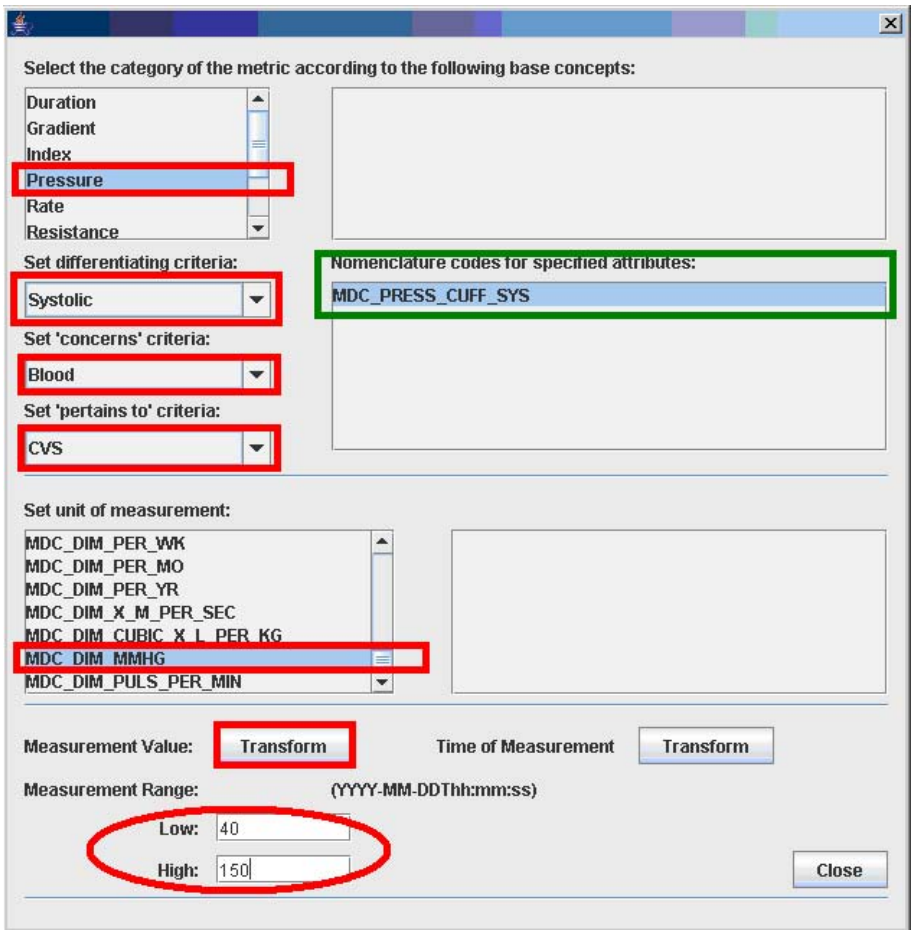

Figure 5.5: Metric Creation for Systolic Blood Pressure

Electronic Health Record (EHR) systems, to initiate medical actions through clinical workflows and to transmit information to alert/reminder systems. In Saphire, we have developed an enhancement along the ORI in order to provide the automated acquisition of multimodal medical device observations to clinical guidelines. The solutions proposed are validated with various guidelines for cardiac diseases expressed in GLIF (Guide Line Interchange Format) model.

In the GLIF model, clinical guidelines are represented as instances of a formal model called *guideline*. The clinical process is represented through an *algorithm*, which is a flowchart of guideline steps, including:

- *Action step* is used for modeling actions to be performed which may include tasks. There are two types of tasks: medically oriented actions such as

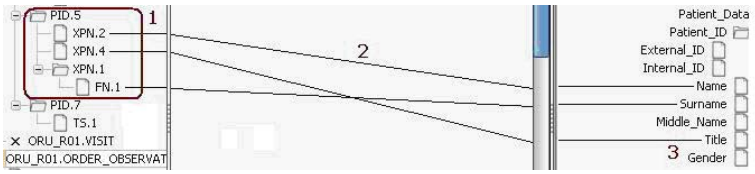

Figure 5.6: Sample Design of an XSL Transformation between HL7 and GLIF

recommendation for a particular course of treatment, and programming-oriented actions such as retrieving data from an electronic patient record or from a medical device.

- *Decision step* represents decision points in the guideline defined in terms of formal expressions.

- *Branch and Synchronization steps* allow modeling multiple simultaneous paths through the guideline.

- *Patient state step* allows labeling patient states.

This section describes the mapping efforts between HL7 and GLIF by providing a sample mapping for translating the blood pressure sensor data generated in the previous section. An XSD Mapping tool developed within the scope of the Saphire project is used in order to define each necessary message field transformation in a user friendly fashion. This tool facilitates defining XSL transformations [35] in order to transform HL7 Unsolicited Observation Messages to GLIF messages. For example, the value of the medical device observation, which is stored inside the "<OBX.5>" element in the HL7 message, can be translated to the GLIF specification as either a "Text_Value" or an "Index_Value" item. A sample design of an XSL tranformation defined within the two domains for patient identification is given in Figure 5.6.

CHAPTER 6

CONCLUSION

Remote healthcare monitoring is crucial for prevention and monitoring of chronic diseases since they require continuous, long-term monitoring, rather than episodic assessments. Clinical use of medical device observations at remote locations would improve the healthcare workflow, reduce medical errors, reduce healthcare costs and improve the quality of care. It is crucial to provide automated acquisition and use of multimodal medical device observations in healthcare information systems.

In the thesis, an interoperability platform is presented which addresses the whole communication line between medical devices and healthcare information systems. For the medical device connectivity ISO/IEEE 11073 standards are used. In addition, the domain information model and the data dictionary of these standards are used in order to capture medical device domain in standards based syntax and semantics. A novel contribution of the thesis work along the device interface is providing the ability to integrate proprietary systems based medical devices to the interoperability platform with the aid of a medical device design and data mapping tool.

The achievement along the observation reporting interface is the realization of the work proposed by IHE PCD and ISO/IEEE 11073 standards for transforming ISO/IEEE 11073 based models to HL7 Version 2.5 messages. Further-

more, the automated acquisiton of multimodal medical device observations in clinical guidelines is achieved by facilitating additional mappings between HL7 and GLIF.

The work developed in the thesis is used for the automatic acquisition and use of multi-modal medical device observations in an intelligent healthcare monitoring and decision support system which is developed as a part of the IST-027074 Saphire project funded by the European Commission.

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APPENDIX A

XML SCHEMA OF BLOOD PRESSURE SENSOR MESSAGES

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema elementFormDefault="qualified" attributeFormDefault="unqualified"
    xmlns:xs="http://www.w3.org/2001/XMLSchema">
    <xs:element name="BPData">
        <xs:complexType>
            <xs:sequence>
                <xs:element name="Patient">
                    <xs:complexType>
                        <xs:sequence>
                            <xs:element name="PatientID" type="HL7_CX_STRUCTUREType"/>
                            <xs:element name="AlternatePatientID" type="HL7_CX_STRUCTUREType"
                                minOccurs="0" maxOccurs="unbounded"/>
                        </xs:sequence>
                    </xs:complexType>
                </xs:element>
                <xs:element name="BPSensor">
                    <xs:complexType>
                        <xs:sequence>
                            <xs:element name="BlueToothID" type="xs:string"/>
                            <xs:element name="SerialNumber" type="xs:string" minOccurs="0"/>
                            <xs:element name="BatteryStatus" type="xs:decimal"/>
                            <xs:element name="DeviceType" type="xs:string"/>
                            <xs:element name="Status" maxOccurs="unbounded"/>
                        </xs:sequence>
                    </xs:complexType>
                </xs:element>
```

```
            <xs:element name="BPMeasurement" maxOccurs="unbounded">
                <xs:complexType>
                    <xs:sequence>
                        <xs:element name="Valid" type="xs:boolean"/>
                        <xs:element name="TimeOfMeasurement" type="xs:dateTime"/>
                        <xs:element name="TimeOfTransmission" type="xs:dateTime"/>
                        <xs:element name="SystolicPressure" type="xs:int"/>
                        <xs:element name="DiastolicPressure" type="xs:int"/>
                        <xs:element name="PulseRatePerMinute" type="xs:int"/>
                        <xs:element name="MeanArterialPressure" type="xs:int"/>
                    </xs:sequence>
                </xs:complexType>
            </xs:element>
        </xs:sequence>
        <xs:attribute name="SchemaVersion" type="xs:decimal" fixed="1.0"/>
    </xs:complexType>
</xs:element>
<xs:element name="HL7_CX_STRUCTURE" type="HL7_CX_STRUCTUREType"/>
<xs:element name="HL7_HD_STRUCTURE" type="HL7_HD_STRUCTUREType"/>
<xs:complexType name="HL7_HD_STRUCTUREType">
    <xs:sequence>
        <xs:element name="NameSpaceID" type="xs:string"/>
        <xs:element name="UniversalID" type="xs:string"/>
        <xs:element name="UniversalIDType" type="xs:string"/>
    </xs:sequence>
</xs:complexType>
<xs:element name="HL7_CWE_STRUCTURE" type="HL7_CWE_STRUCTUREType"/>
<xs:complexType name="HL7_CWE_STRUCTUREType">
    <xs:sequence>
        <xs:element name="Identifier" type="xs:string"/>
        <xs:element name="Text" type="xs:string"/>
        <xs:element name="NameOfCodingSystem" type="xs:string"/>
        <xs:element name="AlternateIdentifier" type="xs:string"/>
        <xs:element name="AlternateText" type="xs:string"/>
        <xs:element name="NameOfAlternateCodingSystem" type="xs:string"/>
        <xs:element name="CodingSystemVersionID" type="xs:string"/>
        <xs:element name="AlternateCodingSystemVersionID" type="xs:string"/>
        <xs:element name="OriginalText" type="xs:string"/>
    </xs:sequence>
</xs:complexType>
<xs:complexType name="HL7_CX_STRUCTUREType">
    <xs:sequence>
        <xs:element name="IDNumber" type="xs:string"/>
        <xs:element name="CheckDigit" type="xs:string" minOccurs="0"/>
        <xs:element name="CheckDigitScheme" type="xs:string" minOccurs="0"/>
        <xs:element name="AssigningAuthority" type="HL7_HD_STRUCTUREType"/>
```

```
            <xs:element name="IdentifierTypeCode" type="xs:string" minOccurs="0"/>
            <xs:element name="AssigningFacility" type="HL7_HD_STRUCTUREType" minOccurs="0"/>
            <xs:element name="EffectiveDate" type="xs:dateTime" minOccurs="0"/>
            <xs:element name="ExpirationDate" type="xs:dateTime" minOccurs="0"/>
            <xs:element name="AssigningJurisdiction" type="HL7_CWE_STRUCTUREType" minOccurs="0"/>
            <xs:element name="AssigningAgencyOrDepartment" type="HL7_CWE_STRUCTUREType" minOccurs="0"/>
        </xs:sequence>
    </xs:complexType>
</xs:schema>
```

APPENDIX B

XML MESSAGE OF A BLOOD PRESSURE SENSOR OBSERVATION

```
<?xml version="1.0" encoding="UTF-8"?>
<BPData>
        <Patient>
            <PatientID>
                <IDNumber>1248327</IDNumber>
                    <AssigningAuthority>
                    <NameSpaceID>METU</NameSpaceID>
                    <UniversalID>SAPHIRE</UniversalID>
                </AssigningAuthority>
            </PatientID>
        </Patient>
        <BPSensor>
            <BlueToothID>blueID</BlueToothID>
            <SerialNumber>Serial1.2.3</SerialNumber>
            <BatteryStatus>23.2</BatteryStatus>
            <DeviceType>23.2</DeviceType>
            <Status>statusOK</Status>
        </BPSensor>
        <BPMeasurement>
            <Valid>true</Valid>
            <TimeOfMeasurement>2006-11-07T11:18:32</TimeOfMeasurement>
            <TimeOfTransmission>2006-11-07T11:19:01</TimeOfTransmission>
            <SystolicPressure>26</SystolicPressure>
            <DiastolicPressure>84</DiastolicPressure>
            <PulseRatePerMinute>5</PulseRatePerMinute>
            <MeanArterialPressure>54</MeanArterialPressure>
```

```
        </BPMeasurement>
</BPData>
```

APPENDIX C

MAPPING FILE GENERATED FOR THE BLOOD PRESSURE SENSOR

```
<?xml version="1.0" encoding="UTF-8"?>
<MDS type="ieee.dim.system.SimpleMDS">
    <VMD type="ieee.dim.medical.VirtualMedicalDevice">
        <labelString>MDC_DEV_ANALY_PRESS_BLD_VMD</labelString>
        <systemType type="ieee.dim.types.TYPE">
            <code>4174</code>
            <NomPartition type="ieee.dim.types.NomPartition">
                <nomPartition>1</nomPartition>
            </NomPartition>
        </systemType>
        <Channel type="ieee.dim.medical.Channel">
            <channelID>1</channelID>
            <Metric type="ieee.dim.medical.metric.Numeric">
                <!-- systolic -->
                <unitCode>3872</unitCode>
                <unitLabel>MDC_DIM_MMHG</unitLabel>
                <metricID>19229</metricID>
                <labelString>MDC_PRESS_CUFF_SYS</labelString>
                <observationValue type="ieee.dim.types.NuObsValue">
                    <unitCode>3872</unitCode>
                    <metricID>19229</metricID>
                    <value>
                        <mapping>
                            <input>BPData|BPMeasurement|SystolicPressure</input>
                            <function>function Copy(arg0){return arg0;}</function>
                        </mapping>
```

```
    </value>
    <state type="ieee.dim.types.MeasurementStatus">
        <status>
            <mapping>
                <input>BPData|BPMeasurement|Valid</input>
                <function>function isValid(arg0){ if(arg0==true)
                          return 8; else return 0;}</function>
            </mapping>
        </status>
    </state>
</observationValue>
<absoluteRange type="ieee.dim.types.AbsoluteRange">
    <lowerValue>0</lowerValue>
    <upperValue>100</upperValue>
</absoluteRange>
<bodySiteLabel>MDC_UPEXT_ARM_UPPER_L</bodySiteLabel>
<bodySiteCode>1781</bodySiteCode>
<metricPartition>
    <NomPartition type="ieee.dim.types.NomPartition">
        <nomPartition>2</nomPartition>
    </NomPartition>
</metricPartition>
<absoluteTime type="ieee.dim.types.AbsoluteTime">
    <!--CCYY-MM-DDThh:mm:ss-->
    <hour>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
                      arg0.substring(11,13);}</function>
        </mapping>
   </hour>
   <day>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
                      arg0.substring(8,10);}</function>
        </mapping>
   </day>
   <second>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
                      arg0.substring(17,19);}</function>
        </mapping>
   </second>
   <year>
```

```
                <mapping>
                    <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                    <function>function Copy(arg0){return
                              arg0.substring(0,3);}</function>
                </mapping>
            </year>
            <month>
                <mapping>
                    <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                    <function>function Copy(arg0){return
                              arg0.substring(5,7);}</function>
                </mapping>
            </month>
            <minute>
                <mapping>
                    <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                    <function>function Copy(arg0){return
                              arg0.substring(14,16);}</function>
                </mapping>
            </minute>
            <century>21</century>
        </absoluteTime>
    </Metric>
    <Metric type="ieee.dim.medical.metric.Numeric"><!-- diastolic -->
        <unitCode>3872</unitCode>
        <unitLabel>MDC_DIM_MMHG</unitLabel>
        <metricID>19230</metricID>
         <labelString>MDC_PRESS_CUFF_DIA</labelString>
         <observationValue type="ieee.dim.types.NuObsValue">
             <unitCode>3872</unitCode>
             <metricID>19230</metricID>
             <value>
                 <mapping>
                     <input>BPData|BPMeasurement|DiastolicPressure</input>
                     <function>function Copy(arg0){return arg0;}</function>
                 </mapping>
             </value>
             <state type="ieee.dim.types.MeasurementStatus">
                 <status>
                    <mapping>
                         <input>BPData|BPMeasurement|Valid</input>
                         <function>function isValid(arg0){if(arg0==true) return 8;
                                   else return 0;}</function>
                     </mapping>
                 </status>
             </state>
```

```
</observationValue>
<absoluteRange type="ieee.dim.types.AbsoluteRange">
    <lowerValue>0</lowerValue>
    <upperValue>100</upperValue>
</absoluteRange>
<bodySiteLabel>MDC_UPEXT_ARM_UPPER_L</bodySiteLabel>
<bodySiteCode>1781</bodySiteCode>
<metricPartition>
    <NomPartition type="ieee.dim.types.NomPartition">
        <nomPartition>2</nomPartition>
    </NomPartition>
</metricPartition>
<absoluteTime type="ieee.dim.types.AbsoluteTime">
    <!--CCYY-MM-DDThh:mm:ss-->
    <hour>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
                      arg0.substring(11,13);}</function>
        </mapping>
    </hour>
    <day>
        <mapping>
           <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
                      arg0.substring(8,10);}</function>
        </mapping>
    </day>
    <second>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
                      arg0.substring(17,19);}</function>
        </mapping>
    </second>
    <year>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
                      arg0.substring(0,3);}</function>
        </mapping>
    </year>
    <month>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return
```

```
                        arg0.substring(5,7);}</function>
            </mapping>
        </month>
        <minute>
            <mapping>
                <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){return
                        arg0.substring(14,16);}</function>
            </mapping>
        </minute>
        <century>21</century>
    </absoluteTime>
</Metric>
<Metric type="ieee.dim.medical.metric.Numeric"><!-- MeanArterialPressure -->
   <unitCode>3872</unitCode>
   <unitLabel>MDC_DIM_MMHG</unitLabel>
   <metricID>19231</metricID>
   <labelString>MDC_PRESS_CUFF_MEAN</labelString>
   <observationValue type="ieee.dim.types.NuObsValue">
       <unitCode>3872</unitCode>
       <metricID>19231</metricID>
       <value>
           <mapping>
               <input>BPData|BPMeasurement|MeanArterialPressure</input>
               <function>function Copy(arg0){return arg0;}</function>
           </mapping>
       </value>
       <state type="ieee.dim.types.MeasurementStatus">
           <status>
               <mapping>
                   <input>BPData|BPMeasurement|Valid</input>
                   <function>function isValid(arg0){ if(arg0==true)
                            return 8; else return 0;}</function>
               </mapping>
           </status>
       </state>
   </observationValue>
   <absoluteRange type="ieee.dim.types.AbsoluteRange">
       <lowerValue>0</lowerValue>
       <upperValue>100</upperValue>
   </absoluteRange>
   <bodySiteLabel>MDC_UPEXT_ARM_UPPER_L</bodySiteLabel>
   <bodySiteCode>1781</bodySiteCode>
   <metricPartition>
       <NomPartition type="ieee.dim.types.NomPartition">
           <nomPartition>2</nomPartition>
```

```
        </NomPartition>
    </metricPartition>
    <absoluteTime type="ieee.dim.types.AbsoluteTime">
         <!--CCYY-MM-DDThh:mm:ss-->
        <hour>
            <mapping>
                <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){return arg0.substring(11,13);}</function>
            </mapping>
        </hour>
        <day>
            <mapping>
                <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){return arg0.substring(8,10);}</function>
            </mapping>
        </day>
        <second>
            <mapping>
                <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){return arg0.substring(17,19);}</function>
            </mapping>
        </second>
        <year>
            <mapping>
                <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){return arg0.substring(0,3);}</function>
            </mapping>
        </year>
        <month>
            <mapping>
                <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){return arg0.substring(5,7);}</function>
            </mapping>
        </month>
        <minute>
            <mapping>
                <input>BPData|BPMeasurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){return arg0.substring(14,16);}</function>
            </mapping>
        </minute>
        <century>21</century>
    </absoluteTime>
</Metric>
<Metric type="ieee.dim.medical.metric.Numeric">
    <!-- PULSE RATE  -->
    <unitCode>2752</unitCode>
```

```
<unitLabel>MDC_DIM_PULS_PER_MIN</unitLabel>
 <metricID>18442</metricID>
<labelString>MDC_PULS_RATE</labelString>
<absoluteTime type="ieee.dim.types.AbsoluteTime">
   <!--CCYY-MM-DDThh:mm:ss-->
   <hour>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return arg0.substring(11,13);}</function>
        </mapping>
    </hour>
    <day>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return arg0.substring(8,10);}</function>
        </mapping>
    </day>
    <second>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return arg0.substring(17,19);}</function>
        </mapping>
    </second>
    <year>
        <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return arg0.substring(0,3);}</function>
        </mapping>
    </year>
    <month>
       <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return arg0.substring(5,7);}</function>
       </mapping>
    </month>
    <minute>
       <mapping>
            <input>BPData|BPMeasurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){return arg0.substring(14,16);}</function>
       </mapping>
    </minute>
    <century>21</century>
</absoluteTime>
<observationValue type="ieee.dim.types.NuObsValue">
    <unitCode>2752</unitCode>
    <metricID>18442</metricID>
```

```
                    <value>
                        <mapping>
                            <input>BPData|BPMeasurement|PulseRatePerMinute</input>
                            <function>function Copy(arg0){return arg0;}</function>
                        </mapping>
                    </value>
                    <state type="ieee.dim.types.MeasurementStatus">
                        <status>
                            <mapping>
                                <input>BPData|BPMeasurement|PulseRatePerMinute</input>
                                <function>function isValid(arg0){ if(arg0==true)
                                          return 8; else return 0;}</function>
                            </mapping>
                        </status>
                    </state>
                </observationValue>
                <absoluteRange type="ieee.dim.types.AbsoluteRange">
                    <lowerValue>0</lowerValue>
                    <upperValue>250</upperValue>
                </absoluteRange>
                <bodySiteLabel>MDC_UPEXT_ARM_UPPER_L</bodySiteLabel>
                <bodySiteCode>1781</bodySiteCode>
                 <metricPartition>
                     <NomPartition type="ieee.dim.types.NomPartition">
                         <nomPartition>2</nomPartition>
                         </NomPartition>
                     </metricPartition>
                </Metric>
            </Channel>
        </VMD>
        <Patient type="ieee.dim.patient.PatientDemographics">
            <patientID>
                <mapping>
                    <input>BPData|Patient|PatientID|IDNumber</input>
                    <function>function Copy(arg0){return arg0;}</function>
                </mapping>
            </patientID>
        </Patient>
    </MDS>
```

APPENDIX D

UNSOLICITED OBSERVATION MESSAGE TRANSFORMED FOR THE BLOOD PRESSURE SENSOR OBSERVATION

MSH|^~\&|SRDCORIGateway^AABB12319231DDCA^EUI-64||UUID||20061107||ORU^R01^ORU_R01|MSG73910|P|2.5|
||NE|NE|TR||||IHE PCD ORU-R01 2006^HL7^2.16.840.1.113883.9.n.m^HL7

PID|||1248327^^^METU^SAPHIRE||null^null|||A

OBR|1|OBR73910^SRDCORIGateway^AABB12319231DDCA^EUI-64|Filler73910^SRDCORIGateway^AABB12319231DDCA^
EUI-64|69710^MDC_DEV_ANALY_PRESS_BLD_VMD^MDC|||20061107111832

OBX|1|NM|150301^MDC_PRESS_CUFF_SYS^MDC|1.1.1.1|26.0|266016^MDC_DIM_MMHG^MDC|10.0-78.0||||W|||
|20061107111832||||460533^MDC_UPEXT_ARM_UPPER_L^MDC

OBX|2|NM|150302^MDC_PRESS_CUFF_DIA^MDC|1.1.1.2|84.0|266016^MDC_DIM_MMHG^MDC|20.0-98.0||||W|||
|20061107111832||||460533^MDC_UPEXT_ARM_UPPER_L^MDC

OBX|3|NM|150303^MDC_PRESS_CUFF_MEAN^MDC|1.1.1.3|54.0|266016^MDC_DIM_MMHG^MDC|20.0-60.0||||W|||
|20061107111832||||460533^MDC_UPEXT_ARM_UPPER_L^MDC

OBX|4|NM|149514^MDC_PULS_RATE^MDC|1.1.1.4|5.0|264896^MDC_DIM_PULS_PER_MIN^MDC|0.0-250.0||||W|||
|20061107111832||||460533^MDC_UPEXT_ARM_UPPER_L^MDC

APPENDIX E

GLIF MESSAGE TRANSFORMED FOR THE BLOOD PRESSURE SENSOR OBSERVATION

```
<?xml version="1.0" encoding="UTF-8"?>
<Data>
        <Patient_Data>
                <Patient_ID>
                        <Internal_ID>1248327</Internal_ID>
                </Patient_ID>
                <Name>Alper</Name>
                <Surname>Okcan</Surname>
                <Title>Mr</Title>
                <Gender>M</Gender>
                <Birth_Information>
                        <Birth_Date>1982-03-31</Birth_Date>
                </Birth_Information>
        </Patient_Data>
        <Observation>
                <Id_OB>150303^MDC_PRESS_CUFF_MEAN</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>54.0</Text_Value>
        </Observation>
        <Observation>
                <Id_OB>150301^MDC_PRESS_CUFF_SYS</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>26.0</Text_Value>
        </Observation>
```

```
        <Observation>
                <Id_OB>150302^MDC_PRESS_CUFF_DIA</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>84.00</Text_Value>
        </Observation>
        <Observation>
                <Id_OB>149514^MDC_PULS_RATE</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>5</Text_Value>
        </Observation>
</Data>
```

APPENDIX F

XML SCHEMA OF PULSE OXIMETER MESSAGES

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema elementFormDefault="qualified" attributeFormDefault="unqualified"
    xmlns:xs="http://www.w3.org/2001/XMLSchema">
    <xs:element name="SPO2Data">
        <xs:complexType>
            <xs:sequence>
                <xs:element name="Patient">
                    <xs:complexType>
                        <xs:sequence>
                            <xs:element name="PatientID" type="HL7_CX_STRUCTUREType"/>
                            <xs:element name="AlternatePatientID" type="HL7_CX_STRUCTUREType"
                                minOccurs="0" maxOccurs="unbounded"/>
                        </xs:sequence>
                    </xs:complexType>
                </xs:element>
                <xs:element name="SPO2Sensor">
                    <xs:complexType>
                        <xs:sequence>
                            <xs:element name="BlueToothID" type="xs:string"/>
                            <xs:element name="SerialNumber" type="xs:string" minOccurs="0"/>
                            <xs:element name="BatteryStatus" type="xs:decimal"/>
                            <xs:element name="DeviceType" type="xs:string"/>
                            <xs:element name="Status" type="xs:string" maxOccurs="unbounded"/>
                        </xs:sequence>
                    </xs:complexType>
                </xs:element>
```

```
            <xs:element name="SPO2Measurement" maxOccurs="unbounded">
                <xs:complexType>
                    <xs:sequence>
                        <xs:element name="Valid" type="xs:boolean"/>
                        <xs:element name="TimeOfMeasurement" type="xs:dateTime"/>
                        <xs:element name="TimeOfTransmission" type="xs:dateTime"/>
                        <xs:element name="SPO2" type="xs:int"/>
                        <xs:element name="PulseRatePerMinute" type="xs:int"/>
                        <xs:element name="Pleth" type="xs:int" minOccurs="0" maxOccurs="10"/>
                        <xs:element name="SignalQuality" type="xs:int"/>
                        <xs:element name="SignalAmplification" type="xs:int"/>
                    </xs:sequence>
                </xs:complexType>
            </xs:element>
        </xs:sequence>
        <xs:attribute name="SchemaVersion" type="xs:decimal" fixed="1.0"/>
    </xs:complexType>
</xs:element>
<xs:element name="HL7_CX_STRUCTURE" type="HL7_CX_STRUCTUREType"/>
<xs:element name="HL7_HD_STRUCTURE" type="HL7_HD_STRUCTUREType"/>
<xs:complexType name="HL7_HD_STRUCTUREType">
    <xs:sequence>
        <xs:element name="NameSpaceID" type="xs:string"/>
        <xs:element name="UniversalID" type="xs:string"/>
        <xs:element name="UniversalIDType" type="xs:string"/>
    </xs:sequence>
</xs:complexType>
<xs:element name="HL7_CWE_STRUCTURE" type="HL7_CWE_STRUCTUREType"/>
<xs:complexType name="HL7_CWE_STRUCTUREType">
    <xs:sequence>
        <xs:element name="Identifier" type="xs:string"/>
        <xs:element name="Text" type="xs:string"/>
        <xs:element name="NameOfCodingSystem" type="xs:string"/>
        <xs:element name="AlternateIdentifier" type="xs:string"/>
        <xs:element name="AlternateText" type="xs:string"/>
        <xs:element name="NameOfAlternateCodingSystem" type="xs:string"/>
        <xs:element name="CodingSystemVersionID" type="xs:string"/>
        <xs:element name="AlternateCodingSystemVersionID" type="xs:string"/>
        <xs:element name="OriginalText" type="xs:string"/>
    </xs:sequence>
</xs:complexType>
<xs:complexType name="HL7_CX_STRUCTUREType">
    <xs:sequence>
        <xs:element name="IDNumber" type="xs:string"/>
        <xs:element name="CheckDigit" type="xs:string" minOccurs="0"/>
        <xs:element name="CheckDigitScheme" type="xs:string" minOccurs="0"/>
```

```
            <xs:element name="AssigningAuthority" type="HL7_HD_STRUCTUREType"/>
            <xs:element name="IdentifierTypeCode" type="xs:string" minOccurs="0"/>
            <xs:element name="AssigningFacility" type="HL7_HD_STRUCTUREType" minOccurs="0"/>
            <xs:element name="EffectiveDate" type="xs:dateTime" minOccurs="0"/>
            <xs:element name="ExpirationDate" type="xs:dateTime" minOccurs="0"/>
            <xs:element name="AssigningJurisdiction" type="HL7_CWE_STRUCTUREType" minOccurs="0"/>
            <xs:element name="AssigningAgencyOrDepartment" type="HL7_CWE_STRUCTUREType" minOccurs="0"/>
        </xs:sequence>
    </xs:complexType>
</xs:schema>
```

APPENDIX G

XML MESSAGE OF A PULSE OXIMETER OBSERVATION

```
<SPO2Data>
        <Patient>
                <PatientID>
                        <IDNumber>1248327</IDNumber>
                        <AssigningAuthority>
                                <NameSpaceID>METU</NameSpaceID>
                                <UniversalID>SAPHIRE</UniversalID>
                        </AssigningAuthority>
                </PatientID>
        </Patient>
        <SPO2Sensor>
                <BlueToothID>blueID</BlueToothID>
                <SerialNumber>Serial1.2.3</SerialNumber>
                <BatteryStatus>FULL</BatteryStatus>
                <DeviceType>23.2</DeviceType>
                <Status>OK</Status>
        </SPO2Sensor>
        <SPO2Measurement>
                <Valid>true</Valid>
                <TimeOfMeasurement>2006-11-07T11:18:32</TimeOfMeasurement>
                <TimeOfTransmission>2006-11-07T11:19:01</TimeOfTransmission>
                <SPO2>97</SPO2>
                <PulseRatePerMinute>23</PulseRatePerMinute>
                <Pleth>5</Pleth>
        </SPO2Measurement>
</SPO2Data>
```

APPENDIX H

MAPPING FILE GENERATED FOR THE PULSE OXIMETER SENSOR

```
<MDS type="ieee.dim.system.SimpleMDS">
   <VMD type="ieee.dim.medical.VirtualMedicalDevice">
       <labelString>MDC_DEV_ANALY_SAT_O2_VMD</labelString>
       <systemType type="ieee.dim.types.TYPE">
           <code>4106</code>
           <NomPartition type="ieee.dim.types.NomPartition">
               <nomPartition>1</nomPartition>
           </NomPartition>
       </systemType>
       <Channel type="ieee.dim.medical.Channel">
           <channelID>1</channelID>
           <Metric type="ieee.dim.medical.metric.Numeric">
               <unitCode>544</unitCode>
               <unitLabel>MDC_DIM_PERCENT</unitLabel>
               <metricID>19384</metricID>
               <labelString>MDC_PULS_OXIM_SAT_O2</labelString>
               <absoluteTime type="ieee.dim.types.AbsoluteTime">
               <!--CCYY-MM-DDThh:mm:ss-->
                   <hour>
                       <mapping>
                           <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                           <function>function Copy(arg0){
                                     return arg0.substring(11,13);}</function>
                       </mapping>
                   </hour>
                   <day>
```

```
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(8,10);}</function>
            </mapping>
        </day>
        <second>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(17,19);}</function>
            </mapping>
        </second>
        <year>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(0,3);}</function>
            </mapping>
        </year>
        <month>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(5,7);}</function>
            </mapping>
        </month>
        <minute>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(14,16);}</function>
            </mapping>
        </minute>
        <century>21</century>
    </absoluteTime>
    <observationValue type="ieee.dim.types.NuObsValue">
        <unitCode>544</unitCode>
        <metricID>19384</metricID>
        <value>
            <mapping>
                <input>SPO2Data|SPO2Measurement|SPO2</input>
                <function>function Copy(arg0){return arg0;}</function>
            </mapping>
        </value>
        <state type="ieee.dim.types.MeasurementStatus">
```

```
            <status>
                <mapping>
                    <input>SPO2Data|SPO2Measurement|Valid</input>
                    <function>function isValid(arg0){ if(arg0==true)
                              return 8; else return 0;}</function>
                </mapping>
            </status>
        </state>
    </observationValue>
    <absoluteRange type="ieee.dim.types.AbsoluteRange">
        <lowerValue>0</lowerValue>
        <upperValue>100</upperValue>
    </absoluteRange>
    <bodySiteLabel>MDC_HEAD_EAR_R</bodySiteLabel>
    <bodySiteCode>1522</bodySiteCode>
    <metricPartition>
        <NomPartition type="ieee.dim.types.NomPartition">
            <nomPartition>2</nomPartition>
        </NomPartition>
    </metricPartition>
</Metric>
<Metric type="ieee.dim.medical.metric.Numeric"><!-- PULSE RATE  -->
    <unitCode>2752</unitCode>
    <unitLabel>MDC_DIM_PULS_PER_MIN</unitLabel>
    <metricID>18458</metricID>
    <labelString>MDC_PULS_OXIM_PULS_RATE</labelString>
    <absoluteTime type="ieee.dim.types.AbsoluteTime">
    <!--CCYY-MM-DDThh:mm:ss-->
        <hour>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(11,13);}</function>
            </mapping>
        </hour>
        <day>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(8,10);}</function>
            </mapping>
        </day>
        <second>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
```

```
                    return arg0.substring(17,19);}</function>
            </mapping>
        </second>
        <year>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                    return arg0.substring(0,3);}</function>
            </mapping>
        </year>
        <month>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                    return arg0.substring(5,7);}</function>
            </mapping>
        </month>
        <minute>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                    return arg0.substring(14,16);}</function>
            </mapping>
        </minute>
        <century>21</century>
    </absoluteTime>
    <observationValue type="ieee.dim.types.NuObsValue">
        <unitCode>2752</unitCode>
        <metricID>18458</metricID>
        <value>
            <mapping>
                <input>SPO2Data|SPO2Measurement|PulseRatePerMinute</input>
                <function>function Copy(arg0){return arg0;}</function>
            </mapping>
        </value>
        <state type="ieee.dim.types.MeasurementStatus">
            <status>
                <mapping>
                    <input>SPO2Data|SPO2Measurement|Valid</input>
                    <function>function isValid(arg0){
                        if(arg0==true) return 8; else return 0;}</function>
                </mapping>
            </status>
        </state>
    </observationValue>
    <absoluteRange type="ieee.dim.types.AbsoluteRange">
```

```
        <lowerValue>0</lowerValue>
        <upperValue>250</upperValue>
    </absoluteRange>
    <bodySiteLabel>MDC_HEAD_EAR_R</bodySiteLabel>
    <bodySiteCode>1522</bodySiteCode>
    <metricPartition>
        <NomPartition type="ieee.dim.types.NomPartition">
            <nomPartition>2</nomPartition>
        </NomPartition>
    </metricPartition>
</Metric>
<Metric type="ieee.dim.medical.metric.Numeric"><!-- PLETH  -->
    <unitCode>2752</unitCode>
    <unitLabel>MDC_DIM_PULS_PER_MIN</unitLabel>
    <metricID>19380</metricID>
    <labelString>MDC_PULS_OXIM_PLETH</labelString>
    <absoluteTime type="ieee.dim.types.AbsoluteTime">
    <!--CCYY-MM-DDThh:mm:ss-->
        <hour>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(11,13);}</function>
            </mapping>
        </hour>
        <day>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(8,10);}</function>
            </mapping>
        </day>
        <second>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(17,19);}</function>
            </mapping>
        </second>
        <year>
            <mapping>
                <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
                <function>function Copy(arg0){
                          return arg0.substring(0,3);}</function>
            </mapping>
        </year>
```

```
    <month>
        <mapping>
            <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){
                      return arg0.substring(5,7);}</function>
        </mapping>
    </month>
    <minute>
        <mapping>
            <input>SPO2Data|SPO2Measurement|TimeOfMeasurement</input>
            <function>function Copy(arg0){
                      return arg0.substring(14,16);}</function>
        </mapping>
    </minute>
    <century>21</century>
</absoluteTime>
<observationValue type="ieee.dim.types.NuObsValue">
    <unitCode>2752</unitCode>
    <metricID>19380</metricID>
    <value>
        <mapping>
            <input>SPO2Data|SPO2Measurement|Pleth</input>
            <function>function Copy(arg0){return arg0;}</function>
        </mapping>
    </value>
    <state type="ieee.dim.types.MeasurementStatus">
        <status>
            <mapping>
                <input>SPO2Data|SPO2Measurement|Valid</input>
                <function>function isValid(arg0){
                    if(arg0==true) return 8; else return 0;}</function>
            </mapping>
        </status>
    </state>
</observationValue>
<absoluteRange type="ieee.dim.types.AbsoluteRange">
    <lowerValue>0</lowerValue>
    <upperValue>125</upperValue>
</absoluteRange>
<bodySiteLabel>MDC_HEAD_EAR_R</bodySiteLabel>
<bodySiteCode>1522</bodySiteCode>
<metricPartition>
    <NomPartition type="ieee.dim.types.NomPartition">
        <nomPartition>2</nomPartition>
    </NomPartition>
</metricPartition>
```

```
            </Metric>
        </Channel>
    </VMD>
    <Patient type="ieee.dim.patient.PatientDemographics">
        <patientID>
            <mapping>
                <input>SPO2Data|Patient|PatientID|IDNumber</input>
                <function>function Copy(arg0){return arg0;}</function>
            </mapping>
        </patientID>
        <!--patientTitle>Mr</patientTitle-->
        <!--DateOfBirth type="ieee.dim.types.Date">
            <day>31</day>
            <year>1982</year>
            <month>3</month>
            <century>20</century>
        </DateOfBirth-->
        <!--patientName>alper</patientName-->
        <!--patientFamilyName>okcan</patientFamilyName-->
        <!--PatientSex type="ieee.dim.types.PatientSex">
            <patientSex>1</patientSex>
        </PatientSex-->
    </Patient>
</MDS>
```

APPENDIX I

UNSOLICITED OBSERVATION MESSAGE TRANSFORMED FOR THE PULSE OXIMETER SENSOR OBSERVATION

MSH|^~\&|SRDCORIGateway^AABB12319231DDCA^EUI-64||null^null^UUID||20061107||ORU^R01^ORU_R01|
MSG73354|P|2.5|||NE|NE|TR||||IHE PCD ORU-R01 2006^HL7^2.16.840.1.113883.9.n.m^HL7

PID|||1248327^^^METU^SAPHIRE||null^null|||A

OBR|1|OBR73354^SRDCORIGateway^AABB12319231DDCA^EUI-64|Filler73354^SRDCORIGateway^
AABB12319231DDCA^EUI-64|69642^MDC_DEV_ANALY_SAT_O2_VMD^MDC|||2001107111832

OBX|1|NM|150456^MDC_PULS_OXIM_SAT_O2^MDC|1.1.1.1|97.0|262688^MDC_DIM_PERCENT^MDC|0.0-100.0|
|||W||||2001107111832||||460274^MDC_HEAD_EAR_R^MDC

OBX|2|NM|149530^MDC_PULS_OXIM_PULS_RATE^MDC|1.1.1.2|23.0|264896^MDC_DIM_PULS_PER_MIN^MDC|
0.0-250.0||||W||||2001107111832||||460274^MDC_HEAD_EAR_R^MDC

OBX|3|NM|150452^MDC_PULS_OXIM_PLETH^MDC|1.1.1.3|5.0|264896^MDC_DIM_PULS_PER_MIN^MDC|
0.0-125.0||||W||||2001107111832||||460274^MDC_HEAD_EAR_R^MDC

APPENDIX J

GLIF MESSAGE TRANSFORMED FOR THE PULSE OXIMETER SENSOR OBSERVATION

```
<?xml version="1.0" encoding="UTF-8"?>
<Data>
        <Patient_Data>
                <Patient_ID>
                        <Internal_ID>1248327</Internal_ID>
                </Patient_ID>
                <Name>Alper</Name>
                <Surname>Okcan</Surname>
                <Title>Mr</Title>
                <Gender>M</Gender>
                <Birth_Information>
                        <Birth_Date>1982-03-31</Birth_Date>
                </Birth_Information>
        </Patient_Data>
        <Observation>
                <Id_OB>150456^MDC_PULS_OXIM_SAT_O2</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>97.0</Text_Value>
        </Observation>
        <Observation>
                <Id_OB>149530^MDC_PULS_OXIM_PULS_RATE</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>23.0</Text_Value>
        </Observation>
```

```
        <Observation>
                <Id_OB>150452^MDC_PULS_OXIM_PLETH</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>5.00</Text_Value>
        </Observation>
        <Observation>
                <Id_OB>149514^MDC_PULS_RATE</Id_OB>
                <Severity_OB>0</Severity_OB>
                <Text_Value>5</Text_Value>
        </Observation>
</Data>
```