Architectural Interoperability Framework

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Abstract- Based on the long-term work of scientific institutions and SDOs dedicated to system architectures, an interoperability framework is presented to help navigating through existing, emerging and even future standards for comprehensive interoperability of health and social services. HL7 artifacts as well as work product of competing organizations are classified and semi-formally interrelated. The methodology is proven in many standard developments and health information systems implementation projects

I. Introduction

The IHIC 2011 has been dedicated to "The Tomorrowland of Health", thereby covering the next generation architecture, personal health, formal modeling and automated design, development and implementation, but also the meaningful use of information integrated in the business of the involved domains. Such an approach has to be sustainable, future-proof, open, scalable, intelligent, user accepted, personalized, multi-disciplinary, business focused, formally represented, which leads to system oriented, architecture centric, model driven solutions. The paper intends to address those properties by defining them, discussing good modeling guidelines, deriving an interoperability framework used as classification schema, classifying existing and emerging artifacts and formally interrelating them in the extended version of this contribution.

II. Principles for Properly Modeling Advanced Interoperability in Health

A model is an unambiguous, abstract conception of some parts or aspects of the real world corresponding to the modeling goals [1]. Hereby, the domain of discourse (which is in the enterprise view the real world domain represented by the related specialty's ontology), the business objectives, and the stakeholders involved have to be defined. As modeling is not an end in itself but has to serve the business under consideration, the relevant stakeholders define the provided view of the model as well as the way of structuring and naming the concepts of the problem space. First capturing key concepts and key relations at a high level of abstraction, different abstraction levels should be used iteratively, where the first iteration is performed in a top-down manner [1]. By that way, conceptual integrity of the model is provided, i.e. the degree to which a model can be easily understood by somebody with limited knowledge and understanding of a model even in its yet unknown parts, despite its complexity. For ensuring conceptual integrity, design principles such as orthogonality (not linking independent aspects), generality (not introducing multiple similar functions), parsimony (not introducing irrelevant aspects), and propriety (not restricting inherent aspects) have to be recognized. A good modeling process offers different ways for both modeling concepts and relations and structuring and visualizing models [1]. Nevertheless, the different resulting models shall be consistent and coherent.

The aforementioned principles exclude an approach for an architecture model starting with technology related views (such as HL7 messaging artifacts), modeling different domains in on model by ignoring the special character of inter-domain associations, re-engineering the reality from the implemented artifacts' basis, etc. – all aspects unfortunately met by the early SAEAF approach.

III. Architectural Interoperability Framework

Personalized systems for realizing health services independent of time, location of actors and resources requires to meeting connectivity as well as pervasive and ubiquitous services, realized by mobile, pervasive and autonomous technologies. The latter require a formal representation of the underlying concepts and relations to automate design, development and implementation of solutions. In this section, the characteristics of personal health systems mentioned in the Introduction as well as the way to get them will be analyzed. A scalable, sustainable and future-proof approach implies the possible integration of something

- not completely known in structure and behavior including the way of describing it,
- having been excluded in earlier considerations,
- covering aspects from other disciplines with different knowledge spaces and knowledge representation (KR) means.

The only approach for successfully meeting the aforementioned requirements is the consideration of something as a system, interacting with its environment, from which it is separated through the system boundaries. This universal engineering methodology, which has been early adapted to any type of system such as technical, living, economical, social, etc., in system theory and cybernetics of the sixties. It can be recursively refined or appropriately extended according to the modeling goals, i.e. the requirements of the domain of discourse. Meanwhile, this approach is also used in newest specifications around SOA architectural models, frameworks and development processes such as [2, 3]. However this is still done in a restricted way, explicitly excluding non-IT systems [3]. For more information, see [4].

First some definitions, commonly but not consistently used, should be introduced. As the interoperability we have to deal with is not limited to computer systems or technical systems in general, interoperability motivated by common interest simply defines ability, capability and skills for collaboration between two or more principals (person, organization, system, device, application, component) to meet common business objectives. Depending on interoperability prerequisites shared in the context of the information cycle, the following different interoperability levels might be sufficient for realizing comprehensive interoperability: structural, syntactic, semantic or service interoperability [5]. The architecture of a system is defined by its components, their functions and their relations. A model is a partial representation of reality. It is restricted to attributes the modeller is interested in. Defining the pragmatic aspect of a model, the interest is depending on the addressed audience, the reason and the purpose of modelling the reality and using the resulting model for a certain purpose and for a certain time instead of the original. Therefore, the model as a result of an interpretation must be interpreted itself [6]. A reference model is a general model describing a class of facts of a domain of discourse. It enables the derivation of instances and can be used for comparing different models dealing with instances of the same class of facts. As development patterns, it enables the reuse of specifications. While a reference model describes the concepts and relations of the components of interest in a domain using a common language agreed on, the reference architecture models the abstract architectural components within a domain including the foundations of those components in a platform-independent way [3]. It presents the principles for building a system within a certain domain, not being bound to a certain terminology formalized by certain ontology and the expression/abstraction level finally selected. It enables the architectural modeling of a specific system class. Domain crossing multi-disciplinary interoperability requires an n-dimensional ontology space. Beside the – unfortunately undefined – abstraction level of a newest reference architecture models (e.g. [2, 3]), which would be better described as granularity level or composition/decomposition dimension (e.g. GCM's Business Concepts, Relation Networks, Aggregations, Details), the domain-specific perspectives on a system, represented by domain ontologies, must be considered as well. Such architectural approach is provided by architectural frameworks. Following, a system-theoretical approach to an architectural framework model is introduced in some detail. For more information see [5].

A system model describes the system's behavior according to the processes and activities needed for meeting the business objectives. Iteratively structurally refined to different levels of granularity (aggregation/complexity), it enables the refinement and improvement of the functional model. The composition/decomposition of a system considers its architectural dimension by describing its components, their functions and interrelations. Abstraction process, granularity level and the inclusion of non-IT domains of discourse are weaknesses or missing issues the aforementioned advanced architectural approaches of OMG, OASIS and The Open Group are still suffering from. For describing the different concerns (aspects) of the system, the principles introduced in Section II must apply. In other words, the different domains have to be separately modeled as architectural model and thereafter combined, resulting in a domain dimension of the architectural interoperability framework model. The domain related architecture is represented by domain-specific ontologies which constrain each other, represented through ontology harmonization. As the system has to be implemented as IT solution, the system development process dimension has to be added, altogether forming the well known Generic Component Model (GCM), meanwhile used in a growing series of international standards and interoperability projects. The representation of the development process must of course start with the enterprise view. The representation of a system's architecture in a domain specific context is ruled by that domain's ontology providing the needed meta-data, as mentioned already. For connecting the different instances within and between the aforementioned dimensions, reference models or meta-models are needed, including the driving ontologies and terminologies used for representing concepts as well as mapping between different domain languages. This will be described in some details later on.

The GCM, being based on early OMG/CORBA thoughts, has been offered to HL7 Inc. in the late nineties already. It was also the basis for the T3F proposal of an HL7 architecture project. The "dangers of disappointing results and wasted investment for a variety of reasons including underfunding in amount and duration, lack of understanding of technological futures, excessively redundant activities between science fields or between science fields and industry, lack of appreciation of social/cultural barriers, lack of appropriate organizational structures, inadequate related educational activities, and increased technological ("not invented here") balkanizations rather than interoperability among multiple disciplines" [7] has happened in the HL7 architectural initiative as well.

IV. Model Hierarchies

Systems are architecturally designed according to the granularity (in SOA also called abstraction) level hierarchy, enabling composition/ decomposition of system components forming sub-systems and super-systems. The combination of the GCM granularity levels and the appropriate definition of a system of interest in the discourse domain enable the modeling of any abstraction/ granularity level of real world systems from molecule to community or more general from elementary particle to universe. This holds for any system including the system of ontologies, forming the ontology hierarchy from application ontology through domain ontology and top level (reference) ontology up to the general or philosophical ontology, but also for the system of languages. The aggregation of components at a certain level is ruled by the constraints of the elements at the next level. In other words, for harmonizing different concept representations on one granularity level, the level above must be used. Figure 1 presents a comprehensive system of concept representations in its abstraction/expressivity hierarchy [8], which can be applied to the representation of anything including the GCM.

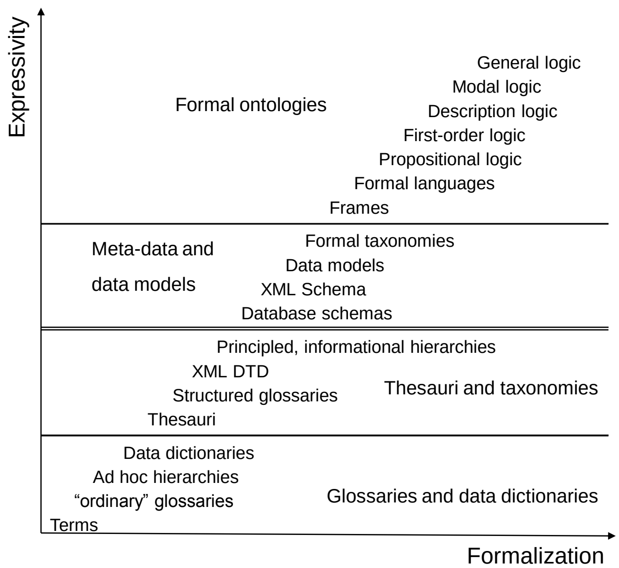

Figure 1. Representation Types (after [8], changed)

For representing concepts, representation means have to be provided including the set of rules for doing this and the rules for representing those rules. So, a system of meta-models has been established, well known for example in the context of graphical languages such as the Unified Modeling Language UML or terminologies and ontologies.

V. Concept Representation for Semantic Interoperability

The following section addresses aspects of knowledge representation at the highest level of formalization. For a wider audience it is possible to skip over this part of the paper without basic losses and to continue with Section VI.

Formal specifications of GCM components controlled by formal reference and meta-models require an abstract and sustainable framework. For theoretically modeling systems, the abstract logic framework has been used. The system of logics can be managed like any other system through additional components bound to new concepts increasing the approach's complexity. As any formal language, universal logic expressions contain all semiotic elements and enable the definition of grammars.

Abstract logic is applied in an increasingly wide variety of disciplines. This covers the traditional subjects of philosophy and mathematics, but also newer disciplines such as cognitive science, computer science, artificial intelligence, and linguistics. It enables the description of domain integration, thereby forming the basis of another requirement to realize personalized ubiquitous care – self-organization according to the aforementioned autonomous computing paradigm. Formal methodologies such as typed λ-calculus and modern type theory can be applied [10]. Representing one GCM perspective, a specification for Pure Type Systems (PTSs) is a triple (S, A, R) such that $S \subseteq C$, $A \subseteq S \cdot S$ and $R \subseteq S \cdot S \cdot S$. S is the set of sorts. Sorts are either subsets of the constants (C, applied above) of a system or unary predicates attached to variables appropriately restricting their domain [11]. A is the set of *axioms*, and R is the set of *rules* of the specification, expressed as a set of triples of sorts which determines the function spaces to be constructed in the system, and the sort each function space contains. The specification is called *singly sorted* if A is a (partial) function $S \rightarrow S$, and R is a (partial) function $S \cdot S \rightarrow S$. Informationally, the abstract model of the GCM approach forms a three-dimensional type representation, which corresponds to the improved Barendregt's Lambda Cube consisting of a set of PTSs, additionally refined through parameters, constraints, context, etc. [12]. By that way, the three dimensions' construction rules are created [13].

VI. Navigating through some Standards Using the GCM

Providing a comprehensive architectural interoperability framework, the GCM facilitates the navigation through the standards jungle, also enabling the formal representation of the concepts and their interrelations. Such details are out of scope in the context of an extended abstract presented here, and will be provided in the final version. So, just a taxonomy of some HL7 as well as ISO specifications relevant as integrated part of HL7 work products, but also different architectural approaches have been reflected at the GCM for demonstrating the underlying principles (Figure 2 and 3).

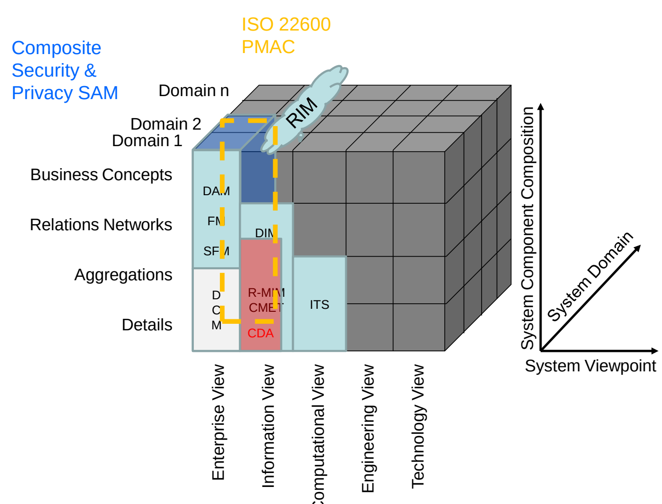

Figure 2. Taxonomy of standards using the GCM

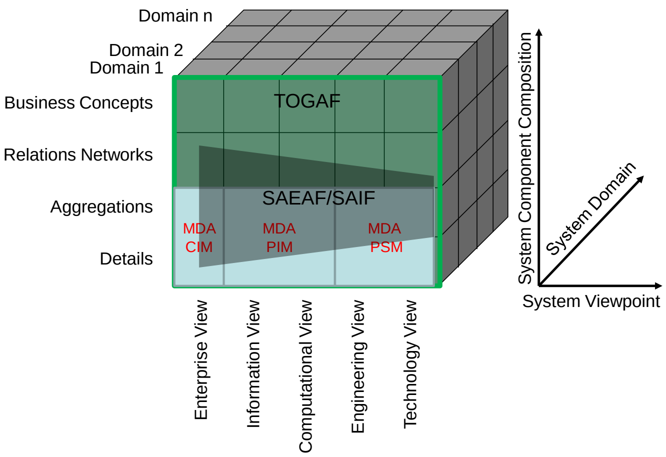

Figure 3. Simplified representation of architectural approaches in the GCM

VII. Discussion

The health paradigm shift towards personal health requires intelligent, pervasive, multi-disciplinary solutions, designed and implemented autonomously at run-time for representing the subject of care's status, expectations, wishes and intentions, and contextual and environmental conditions, defining the business process objectives and optimal actions for meeting them. The solutions have to be based on a system oriented, architecture-centric approach formally representing and managing the domain knowledge. For harmonizing existing standards and specifications, the next level of abstraction has to be used for representing the architecture of the intended system. The advent of architectural models also beyond the ICT environment therefore requires architectural frameworks to harmonize them. The representation of architectures, i.e., the concepts for components, their functions and relations requires corresponding meta-models expressed, e.g., in domain specific ontologies, which have to be harmonized at run-time for achieving adequate interoperability and transformed into ICT ontology.

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