Digital health Interoperability frameworks: use of RM-ODP standards

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Abstract — **It has been ten years since the publication of our first paper reporting on the beginning of a new national e-health interoperability journey in Australia and the interoperability framework developed by National e-health Transition Authority (NEHTA) [1]. Many new technologies, standard efforts and architecture approaches have emerged since then. Many new lessons were also learned by different stakeholders involved in using the framework as a basis for interoperability conversations and e-health solution development. Some of these were reflected in the second version of the NEHTA Interoperability Framework. This paper provides further details regarding this new version of the NEHTA Interoperability Framework, shows in more detail how Reference Model for Open Distributed Systems (RM-ODP) standards were used to provide underpinning foundations for interoperability, and lists some other development in e-health interoperability. Further, the paper describes the use of RM-ODP in other interoperability frameworks and describes links between interoperability frameworks, enterprise and solution architectures and interoperability methodologies.**

Keywords - e-health; digital health; health IT; interoperability; RM-ODP; FHIR

I. Introduction

Most nations are facing the problem of increasing pressure to deliver safe, reliable and effective clinical care, as a result of an aging population, lack of sufficient clinical personnel and aging healthcare infrastructure and resources. This problem is further exacerbated by reliance on paper documents to record, store and exchange clinical information, or the use of older generation, often antiquated, ICT infrastructure and applications.

Many governments see the role of e-health (or health IT or digital health) as a vehicle to address these problems, in particular to reduce unnecessary wastage and improve quality and efficiency of healthcare delivery. Historically, however, health IT has lagged behind the use of IT in other industries such as finance, aviation or telecommunications, where there were significant investments in standards to better support interoperability between different vendor products. This situation began to change over last decade or so, mainly driven by various government and industry initiatives for interoperability, most notably in Europe, USA, Canada and Australia.

In Australia, the main organisation that has been driving the national e-health agenda, the National E-health Transition Authority (NEHTA), has also been leading the national e-health interoperability efforts. One of the early outcomes was the development of the NEHTA interoperability framework. The first version of this specification recommended the use of the RM-ODP standards to provide an architecture underpinning of the framework. This specification was published in 2006 and also reported at the WODPEC workshop at EDOC 2006 [1].

There was a significant further development of this framework leading to the publication of the NEHTA interoperability framework, version 2, or IF2 for short [2]. One aim of this paper is to provide a summary of the key requirements, decisions and components of the IF2 and further use of RM-ODP standards in it.

Many new technologies, standard efforts and architecture approaches have emerged since then. Many new lessons were also learned by different stakeholders involved in using the framework as a basis for an interoperability conversation and e-health solution development in Australia. The second aim of this paper is to provide a summary of these new interoperability developments, highlight the role of RM-ODP in these, and outline a proposal for a new interoperability methodology that can be used to deal with complex national interoperability programs, such as in digital health.

The next section introduces a number of e-health interoperability requirements. Section III provides an overview of the NEHTA IF2, highlighting the rationales for the use of RM-ODP. Section IV provides a detailed description of the structure and key concept and patterns in the IF2. Section V describes the use of RM-ODP standards as an underpinning framework for e-health interoperability frameworks recently developed by standards development organisations. This section also highlights the distinction between interoperability and enterprise and solution architectures and methodologies. Throughout the paper we also mention use of the new e-health interoperability standard developed by HL7, called Fast Health Interoperability Resources (FHIR) [18], as it is increasingly gaining prominence for use in digital health. Section VI concludes the paper and outlines some further work.

II. e-Health Interoperability Requirements

The characteristics of the Australian health system were introduced in our initial paper presented in [1]. In summary, the system has a specific institutional structure and funding model involving a combination of federal, state, territory and local government jurisdictions along with the private sector. This forces the e-health system designers and vendors to take into account the constraints imposed by the legal, regulatory and organisational policies and governance models when designing new e-health systems and their integration with existing systems. This is one interoperability prerequisite for creating a collaborative ecosystem as well as informing the building of fit-for-purpose and sustainable e-health systems.

Interoperability thus needs to be broader in scope than the traditional technology focus, i.e. in terms of serving the purpose of providing better, safer and more efficient healthcare delivery. This broader context is needed because, in e-health systems:

- there are many actors with different skills and knowledge, collaborating as teams required to respect a multitude of clinical and administrative policies, while increasingly relying on the capabilities of new health IT;
- there is an increasing need to support the cross-organisational and cross-jurisdictional nature of healthcare services to ensure continuity and patient-centric healthcare;
- there are constant changes driven by both clinical and technological factors, requiring an approach to treating interoperability as a continual state of readiness to embrace new technologies, clinical knowledge and practices, or changes in legislative and social environments;
- incumbent e-health vendors have struggled to provide open systems with standard API's and content models requiring significant investment in content mapping and customisation to local workflow behaviours.

Our early definition of interoperability presented in [1] needed to be changed in the IF2 to accommodate these requirements, with new definition stating that interoperability is [2]:

> *The continual ability of an organisation (or a system) to use or offer business (or technical) services from or to another organisation (or system) and accordingly, exchange information (or data) with other organisations (or systems) to achieve a specified purpose in a given context.*

It is obvious that standardisation plays an important role, both in terms of technology but also in terms of business processes. For example, it is important to have a common understanding of standard business processes used in the sector, such as of the activities, policies and information sharing, in support of referrals, discharge and care plan processes. The latter is a good example of an interoperability pattern, which was identified as an important enabler for interoperability.

These aspects of interoperability constitute its organisational and information perspectives and they need to be considered alongside the more traditional notion of interoperability referring to technical aspects i.e. capability of machines to exchange data through the exchange of messages. Therefore, interoperability needs to be considered from organisational, information and technical perspectives. There is a common distillation of the concept of interoperability into technical integration as many regard protocols and syntax to be the core of system interconnectivity. Our initial approach to interoperability was in line with the somewhat new IEEE interpretation at the time, considering interoperability 'not so much how machines are working together but how human beings are understanding each other' [12].

III. NEHTA Interoperability Framework 2.0

The NEHTA Interoperability Framework, version 2.0 (IF2) considers interoperability from organisational, information and technical perspectives. This was driven by the need to support conversation between multiple stakeholders when conceptualising, building and operating e-health systems. This separation of concerns was considered vital to dispelling the myth that interoperability was solely a technical issue.

Our initial architecture considerations for constructing IF2 were indeed motivated by the need to support such conversation, relying on:

- agreements on common interoperability concepts and the way they can be structured and used, namely interoperability languages for each of the perspectives
- common interoperability patterns, developed over time and capturing experience from commonly occurring approaches in e-health and reusing them in different contexts

A. Decision for using RM-ODP standards

Our approach in developing the IF2 was based on identifying standards-based architecture frameworks, which would ensure longevity of interoperability descriptions. They should be precise enough to address the variety of concerns in e-health, but should be also amenable for implementation in the existing software tooling environments. Standards ensure shared investments across multiple stakeholders while giving away the availability of solutions customised to requirements. They also ensure a degree of insurance against future evolution by potentially introducing latent capabilities available through the standard but not yet needed in the local solution.

Our initial thought was to consider the use of the TOGAF framework (version 8.1 at the time). It soon became obvious to us that, while TOGAF works well for internal organisational needs, and has a strong architecture development method supporting transition from 'as is' to 'to be' architectures, it is not the best mechanism for support of interoperability, especially at a national level where the co-existence of multiple solution approaches required both agreed foundations as well as detailing where alternative approaches could be taken. The nature of interoperability is very much focused on establishing common modelling languages (from various perspectives) and a reference framework to support the co-existence of multiple architecture approaches and depending upon conformity assurance for assessing interoperability claims. Further, TOGAF 8.1 did not provide modelling languages at the time, which has changed with version 9, through publishing of the architecture content model. Note that our recent review of the content model has still identified its inadequacy in terms of the precision required for downstream modelling and software implementation.

We found that the ISO/ITU-T/IEC standard, RM-ODP [3][5], was the best choice at the time. This was (and still is) a stable standard for several years, after publication in mid 90s, developed based on system theoretic foundations, founded in distributed systems principles, and grounded in strong architecture semantics [6]. It provides a set of precise modelling concepts for each of the viewpoints, is well suited for model-driven engineering and has rich support for conformance and compliance, which is of particular relevance for a national organisation which on one hand needs to ensure consistency of its specifications (through compliance) and on the other hand, provide a rich conformance framework for testing implementations and products against specifications. In addition, the latest revision of the RM-ODP enterprise language offers a rich set of policy and accountability concepts that augment many security frameworks and are the right enterprise modelling tool for supporting enterprise policy expressions in federated environment, such as healthcare.

B. How was RM-ODP used in IF2

We have used RM-ODP, as a true reference framework for describing open distributed systems in e-health according to the concepts and structuring rules defined in the standard. RM-ODP is particularly suitable in situations when there is expectation for the system to support interoperability across multiple organisational domains, which is indeed the requirement for many e-health systems. This can be, for example, done using the concepts of federation as detailed in [7]. Besides, RM-ODP is a technology-neutral reference framework, making it an ideal vehicle to support interoperability requirements, both in terms of the coexistence of different solutions that need to interoperate and also in terms of the evolutionary nature of interoperability over time.

IF2 adopts the ODP viewpoints approach to support the expression of separation of concerns pertinent to various stakeholders in e-health. RM-ODP considers a system from enterprise, information, computational, engineering and technology viewpoints [3], [5]. Note that IF2 uses the term 'perspective' rather than 'viewpoint', to better accommodate the language of various stakeholders involved in e-health. This decision was made after numerous consultations with internal and external stakeholders of NEHTA.

It is also to be noted that the organisation perspective corresponds to the ODP enterprise viewpoint, while the technical perspective mostly captures the computational viewpoint. Engineering viewpoint concepts are typically realised through various existing middleware and infrastructure solutions, which were considered as given for many e-health specifications at the time. Hence, IF2 does not have an equivalent to an engineering viewpoint, although some elements from the IF2 conformance framework rely on concepts from the engineering (and technology) viewpoints. Subsequent experience in specifying e-health solutions has suggested that the use of engineering and technology viewpoints can indeed be beneficial. The engineering viewpoint can be used to explain the capabilities of underlying infrastructure such as various distribution transparencies, and can be used to compare various vendor offerings, while technology viewpoint would be useful for more expressive conformance framework.

The IF2 then selected a small set of the relevant ODP viewpoint language concepts as a basis for the three interoperability modelling languages, organisation, information and technology. Note that not all of the RM-ODP modelling concepts were adopted, as RM-ODP is a general framework applicable across many field of application. Subsequent experience though, such as the development of the HL7 Service Aware Interoperability Framework (SAIF) [9] and e-health interoperability framework through Standards Australia [16], have identified need for adoption of a broader set of RM-ODP concepts. A more detailed description of these concepts is beyond the scope of this paper, although several such concepts are mentioned in IV.F.

It is also important to emphasise the fact that IF2 has refined some of the RM-ODP modelling concepts, taking into account other relevant standards, as required. An example is the definition of the IF2 business process, taking into account BPMN standard [10].

C. Tooling considerations

The IF2 tool was developed not only as a framework to support communication between people, but also to facilitate relevant downstream software development through communication artefacts that drove design conformant to national specifications. So, another important factor in using the RM-ODP standard is the development and finalisation of the UML for ODP standard at the time.

Although, the ODP viewpoint languages are defined in an abstract way without commitment to a particular concrete notation, one needs to select such a notation in order to write a real, useful model. It does not matter particularly what notation is chosen, as long as the tool chain can handle it and integrate it with others already in use, but it will help the designers to get started if the notation is already familiar [7]. So, UML was chosen as a notation for supporting the ODP modelling concepts, as the most popular language in the software industry. Since UML does not provide a separation of concerns in terms of the RM-ODP language, there was a need to minimally extend it so that the UML tools could support the extension. The UML profile for ODP standard [11] provides a profile that maps the ODP concepts to the UML notation so that they can be manipulated with conventional UML tools. A suitable plug-in to a UML tool allows consistency checking across multiple viewpoints.

The detail of this standard are beyond the scope of thus paper but there are many examples of how this standard can be used provided in [7].

IV. INTEROPERABILITY PERSPECTIVES

We have seen that the IF2 indeed uses the RM-ODP standard as a reference framework for structuring interoperability specifications. In doing so, the IF2 has adopted subset of relevant viewpoints from RM-ODP. Further, in terms of its own modelling concepts, the IF2 uses RM-ODP as a reference framework, selecting only a subset of relevant modelling concepts defined in RM-ODP, which the authors felt relevant for the e-health interoperability requirements at the time. Where required, the IF2 also refines these concepts to suit the specifics of the e-health domain. This section includes a summary of the modelling languages as they are adopted in the IF2 [2]and explains how they are adopted or derived from RM-ODP. Note that the relevant definitional concepts from IF2 are brought in here and referenced as appropriate, to allow easier comparison with the RM ODP concepts.

In future, these IF2 modelling concepts can be further refined and consolidated to reflect new technology and standards developments. For example, there was a recent revision of the RM-ODP enterprise language [8], offering more expressive concepts for defining policy constraints, which would be good candidate to model the problems of delegation of responsibility in the delivery of healthcare.

A. *Organisational perspective*

The organisational perspective addresses the business context as well as legal and policy issues of relevance for understanding, specifying and deploying e-health systems [2]. This perspective supports for the description of business processes, business services, business policies and organisational structures, applicable to the the intra-organisational, inter-organisational and cross-jurisdictional interactions. This also supports the description of both the strategic and operational governance aspects of various corporate and technology structures. This overarching view of the interoperation of healthcare is particularly important as it often goes unstated in the specification, design, and adoption of e-health solutions but the complex nature of the healthcare business (private/public, maturity, funding drivers, public health drivers, range of clinical roles) makes this foundation particularly important to agree upon upfront.

The organisational perspective adopts a set of the ODP enterprise language concepts, as will be introduced next.

The main concept is that of *community*, which defines how some set of participants should behave in order to fulfil their mutual objective. Community thus models collaborative structures formed to meet some *objective* and whose behaviour is defined in terms of community roles, processes and interactions in which they may be involved and policies that apply to roles. Community roles are to be understood as formal parameters in community structure.

Community is defined by a community contract that specifies the above elements of the community. An enterprise specification consists of one or more community contracts and thus an enterprise model of an e-health system would contain one or more communities. In addition, the specification defines a set of enterprise objects (referred to as entities in the IF2), which have a life cycle independent of the community structure, and which fill the community roles, participating in community behaviour. Once in a community, they are compliant with community contract by it and can be used to represent internal state and resources.

The IF2 also adopts the ODP concept of policy, defined in terms of rules, which is a constraint on a system specification. In the enterprise viewpoint the specific type of policies are obligations, permissions and prohibitions, as formalised in deontic logic. The enterprise policies that define constraints on the community roles with which enterprise objects need to comply, as well as on the behaviour in which roles are involved, such as processes and interactions.

One key enterprise modelling concept of major significance for organisational interoperability is that of *federation*. Federation models a collaborative structure between two or more communities and is key for specifying, for example, how two organisations can collaborate while maintaining their fundamental autonomy. Federation is a special type of community formed by a *federation contract* between two or more communities.

A *business service* is a particular abstraction of behaviour expressing the guarantees of service providers [2]. Typically, such guarantees are expressed in terms of service offers, which, if accepted by service users, form the basis of a service level agreement. The guarantees involve policies that apply to the service providers and, if a consumer accepts the service offer, this includes relevant policies applied to them. This then yields the formation of a service level agreement or a contract, including applicable legal considerations, as defined in legally valid business contracts.

A *business process* is a specific type of behaviour specifying flow of data and control between steps in the process. The roles involved may or may not be identified, depending on circumstances. RM-ODP defines a process as ‘a collection of steps taking place in a prescribed manner’ [8]. The IF2 has provided further refinement of the concept to reflect specific developments from the BPMN standard [10] and it provides additional specification, and defines a business process as a structured style of behaviour usually described in terms of a number of related concepts, including [2]:

- the constituent business steps;
  - each business step can have one or more input artefacts and one or more output artefacts;
  - these steps can be atomic, unable to be decomposed into other business steps; these kind of business steps are referred to as business functions;
  - they can also be composed of other business steps or separate business processes; the constituent processes are sometimes referred to as sub-process;
  - they may be assigned to roles which are responsible for the enacting of the step.
- control flow between business steps, which can support sequential and parallel execution of business processes and make use of different types of control flow operators;
- data flow between business steps, describing how information artefacts are passed from outputs of one (or more) business step to the inputs of one (or more) other business steps, dependent or independent of control flow;
- refinement operators, describing how one business step can be implemented as a separate, lower level business process.

The organisational perspective also adopts several concepts for *accountability* from the RM-ODP enterprise language [8]. These are

- *Party* - a special kind of enterprise object (referred to as entity in IF2) with emphasis on its legal requirements.
- *Delegation* - the action that assigns authority, responsibility or function to others.
- *Principal* - a party that has delegated authority, responsibility or function to another party.
- *Agent* - a party that has been delegated authority, responsibility or function.
- *Evaluation* - an action that assesses the value of something. The value is linked to the notion of quality that in health has the dimensions of safety, effectiveness, patient centeredness, timeliness, equity and efficiency.

The IF2 also adopts the concept of *location* from RM-ODP foundational concepts [3] but is treated as an enterprise concern in this perspective. This is because it is important to describe the location of healthcare organisations, location of body part which is subject to care, as well as location in time when care was given, is being given or is to be given. Location thus can have spatial properties focusing on how various artefacts or actors are assigned to physical locations or temporal properties such as when scheduling actions for clinical treatment. In RM-ODP (and IF2), *location in space* is an interval of arbitrary size in space at which an action can occur. Location in time is an interval of arbitrary size in time at which an action can occur [3].

IF2 also adopts the concept of evaluation from the RM-ODP enterprise languages. *Evaluation* is an action that assesses the value of something. The value is linked to the notion of quality that in health has the dimensions of safety, effectiveness, patient centeredness, timeliness, equity and efficiency.

In addition to these modelling concepts, the IF2 has identified a number of organisational patterns. These are legislative, regulatory and enterprise policies; policy conflict resolution; certification; awareness and change management; monitoring and auditing; standard business processes; governance approaches and models; cost and value assessment and corporate memory. Note that the first version of IF only had four such patterns, demonstrating the evolutionary character of the NEHTA Interoperability Framework. It is expected that new organisational patterns will be identified and documented as they are identified from experience.

The organisational patterns are mapped into the core organisational concepts introduced from the ODP Enterprise Language. This ensures a pragmatic approach to addressing specific problems, while preserving precision (and compatibility) of expression.

B. *Information perspective*

The IF2 addresses the semantics of information of relevance for understanding, specifying and deploying e-health systems. This perspective allows for the description of key information components and their relationships. Typically, the information components will represent certain artefacts in the organisational perspective. Note that the information perspective is not meant to replace the existing clinical informatics models or introduce a new information model but rather facilitate the co-existence of different information modelling approaches through a common reference point [2]. The following is a minimal set of information modelling concepts identified in IF2.

An *information component* is the key modelling concept from the information perspective. It represents an element of information that corresponds to some concept in the real world, e.g. demographic information about an individual. This concept is equivalent to the RM-ODP information object, but IF2 adds further categories, i.e.[2]

- a simple, foundation component (based on standard data types, e.g. integer, string, date or quantity); or
- a complex structure that consists of a set of information components such as contact details for an individual, or even Electronic Health Records (EHR).

A *relationship* between information components expresses some associations between things in the real world that they represent [3]. IF2 further refines this concept by defining specialised relationships such as [2]:

- *composition* being a special kind of relationship of several information components into complex structures.
- *mappings* between different information components that can, for example, be used to assign semantic relationships between concepts or terms from different clinical term sets.

A *constraint* represents restrictions or rules that can apply to information components, such as a valid range of numbers representing blood pressure.

A *constrained structure* is a complex structure to which some restrictions or rules apply.

An *archetype* is a specific instance of a constrained structure, modelling clinical or other domain-specific concepts by defining the structure and business rules of the concept [13]. Archetypes may define simple constrained structures such as ‘blood pressure’ or ‘address’, or more complex constrained structures such as ‘family history’ or ‘microbiology result’.

A *value domain* is another use of constraint. A value domain constrains data elements to a set of specific permissible values, e.g. severity can be restricted to be one of ‘mild’, ‘disabling’ or ‘life threatening’. Another value domain constraint is the recommended use of concepts from a terminology, e.g. Systematized Nomenclature of Medicine (SNOMED) CT [2].

IF2 also introduced two modelling concepts needed for identification of entities in the real world based on the RM-ODP definition. *Name* can be defined as a term, which, in a given naming context, refers to an entity [3]. *Nomenclature* refers to a method of assigning names to entities as in SNOMED-CT.

A related concept to a name is an *identifier*. It is defined as an unambiguous name in a given context [3]. Examples of identifiers are those used to refer to individuals in a health context or to refer to health service professionals (both individual providers and organisations).

Finally, an *information model* will consist of a number of information components, to which various types of constraints can be applied and which are related to each other through different kinds of relationships. Examples of such information models are models for pathology, medications, immunisations, discharge and referrals.

The IF2 also identified several information patterns, namely: information policies; meta-data; temporal dependency; information quality; scope of application and information transformation [2]. Their description is however beyond the scope of this paper.

C. *Technical perspective*

The technical perspective is concerned with developing applications and services that implement enterprise models developed from the organisational perspectives and handle information components developed from the information perspective. The IF2 defines a number of modelling concepts, namely [2]:

- *Software component* – a software entity that makes one or more functions available to other components. Some of these functions or their aggregations can be used to support the implementation of services;
- *Service* – this concept is used to specify functionality of relevance for business; typically, a service will

implement the business logic of the corresponding business service description identified in the organisational perspective and can make use of one of more software components. This is sometimes referred to as a technical service ;

- *Service interface* – provides a mechanism for accessing functions provided by service;
- *Service composition* – a way of establishing a behavioural relationship between several services, including various constraints on them, with the aim of supporting a more complex business activity such as a business process or business collaboration; there are various technical ways of composing services, such as orchestration and choreography;
- *Action* – represents something that happens; for example, a communication between two parties is considered an action as well as communication between two objects. There may be more than one objects or parties involved in an action;
- *Event* – represents an occurrence of an action in the real world. An event can be generated by actions of software components or actors (identified in the enterprise perspective) or from the environment external to the components;
- *Message* – a unit of communication between software components, including those components that involve direct interaction with end-users;
- *Interaction* – a set of related actions, which occur at two or more software components, or two or more services and which describe some cause-effect relationship between their behaviours.

Note that, strictly speaking, only the concept of action and event were adopted from the RM-ODP standards. Other concepts were influenced by different SOA standards, such as OASIS SOA Reference Architecture Framework [21], which are semantically similar to the concepts of computational objects and computational interfaces. Further, the concept of message was influenced by the HL7 messaging standards.

The IF2 also identified several technical interoperability patterns, namely: multiple delivery/access channels; style of component interactions; technical quality; and technical architecture styles [2]. Their description is however beyond the scope of this paper.

D. Conformance, compliance and accreditation

The interoperability concepts and interoperability patterns presented in the three previous sections are developed to support a common architecture language for developing specific e-health solution architectures. One can say that they constitute necessary but not sufficient conditions for interoperability. What is also needed is a strategy for verifying that the implemented systems satisfy the design specifications, that health professionals meet competence expectations for using the systems, and finally, providing assurances to all concerned to that effect [2]. To this end, the IF2 specification includes a detailed framework to support a broad range of conformity assurance functions. This includes support for conformance, compliance and accreditation (CCA for short), introduced here as defined in the IF2 [2]. The concepts of conformance and compliance are adopted from the RM-ODP standards [3]. These are aligned with conformity assurance standards, ISO17001 [4], Conformance, compliance and accreditation aspects are described next.

Conformance relates an implementation to a specification whether or not the specification is a standard. Conformance is checked based on the observation or test of an implementation/system according to conformance points included in a specification and compares these observations with the specification statement (conformance points) [2].

One standard or specification is *compliant* with another standard or specification if all propositions true in the initial standard are also true in the complying standard [2]. For example, the Web Services security specifications must be compliant with Web Service messaging (SOAP)

Accreditation is a procedure by which an authoritative body gives formal recognition that an organisation or a person is competent to carry out specific tasks. The accreditation function is well established in the domain of testing laboratories. In this case, accreditation bodies, typically at a national level, e.g. National Association of Testing Authorities (NATA) in Australia [14], can accredit testing labs for their competency to undertake testing of products developed by other organisations, e.g. e-health vendors, to determine their conformance to standards and specifications.

It is worth noting that the definition of the CCA framework, defined in the IF2, was the basis for NEHTA setting up a new group to perform CCA functions. This group was involved in further refining and operationalizing the CCA framework and was involved in assisting many e-health vendors in Australia in verifying various aspects of conformity assurance. The compliance aspects on the other hand were relevant when developing new solution architecture in compliance with the principles, language and patterns stated in the IF2.

E. Maturity model

The above sections have highlighted the need to combine multiple interoperability perspectives when discussing interoperability. This combination is inherently complex and the complexity is further exacerbated by a need for a continuous state of readiness for adoption of new technologies, as well as the need for better information quality and the introduction of new clinical/administrative processes and policies. Capability maturity models are applied in other industries to drive quality practices in complex fields of endeavour. This is equally desirable in the health IT community and as a result of this, there was an effort to develop an interoperability maturity model (IMM) for e-health [2]. This maturity model was based on the CMMI framework and it can be regarded as a CMMI constellation. The details of this maturity model however go beyond the scope of this paper and the details are provided in [2].

F. Need for IF2 updates

The IF2 has been used as part of the developments of a number of solution architectures within NEHTA. A good example of how IF2 was used is in the context of medication management as described in detail in [15].

The use of the IF2 through various NEHTA projects and the way the business analysts and architects used it, has identified a need for a number of updates. Most of these updates were to do with improving architecture expression through relying on additional RM-ODP concepts. This is also an opportunity to accommodate some updates within RM-ODP specifications, most notably the new RM-ODP Enterprise Language standard published in 2015.

The first addition is required to support expressions of relationship between concepts in different perspectives. In RM-ODP this is referred to as a *correspondence*. It is particularly important to highlight the fact that often different modelling elements, e.g. enterprise and information objects, can refer to the same entity in the real world but focusing on different abstractions. So, a patient description in the enterprise viewpoint may be concerned with how this patient is part of a clinical care community or process and which policy about their privacy need to be respected by the clinicians, while in the information viewpoint, the information can contain patient demographic detail. This correspondence is particularly important when considering interoperability problems from different perspectives, and ensuring that the different agreements specified at different viewpoints are interlinked with an overarching agreement across viewpoints. Further, when supported by tooling, this correspondence can implement traceability between modelling elements in different viewpoints and can support better interaction between different teams..

There are other concepts from the RM-ODP computational viewpoint that we found of value for supporting modelling of specific health applications, such as telemedicine or medical devices, such as the concept of *multi-party binding, streams and flows* [6][7].

Further, it may be of value adding some specific expression of the engineering viewpoint to support comparing different infrastructure solutions, e.g. the impact of specific security protocols as part of the ODP engineering concept of *channel*, which may be of relevance for federation concerns specified in the enterprise language. These options may be of relevance for procurement purposes.

In addition, the engineering viewpoint is where conformance points needed to be defined, stating where testing of the infrastructure can be done. Conformance points are typically stated in terms of interfaces in the engineering viewpoint, although they can be also specified at a more abstract level, in other viewpoints, in which case these abstract points need to be linked through a set of correspondences to to the engineering interfaces. The technology viewpoint then describes how the conformance requirements are to be documented [7]. This involved expressing conformance statements about tests are to be performed for the conformance statements in the engineering viewpoint.

V. USE OF ODP IN OTHER INTEROPERABILITY FRAMEWORKS

The expressiveness, and also stability, of the RM-ODP standards were a factor in selecting it to be used in digital health interoperability framework efforts. This section presents this use in different, although related, contexts.

A. HL7 Service Aware Interoperability Framework

HL7 International is a Standards Development Organisation involved in developing e-health standards over many decades. They cover messaging standards for the exchange of healthcare information, representation of clinical documents and many clinical application domains such as, for example, clinical decision support systems.

It is the proliferation of HL7's many standards over the years that identified a need for better architecture alignment between these standards and better expression of semantic interoperability from different viewpoints, similarly to the approach identified in the IF2. This in turn identified a need for the development of an interoperability framework strategy that would ensure the delivery of solid consistent specifications, using the same framework.

Consequently, in 2010, the CTO of HL7 International requested work by the HL7 Architecture Review Board (ARB) to produce the so-called Service Aware Interoperability Framework (SAIF) [9]. Interestingly, the experts on the ARB identified the RM-ODP standard as a good foundation for this work. This is because it has precise semantics used as a reference architecture framework for describing information and behavioural semantics, but also because it is a stable ISO/ITU-T standard that has been developed and published over the last two decades, and also influenced the development of other standards, most notably within the OMG.

As a result, SAIF uses RM-ODP modelling concepts as a way of establishing an architecture language for interoperability, leveraging all five ODP viewpoints.

Further, and similarly to the IF2, SAIF authors have also adopted the precise ODP conformance and compliance framework to support conformity assurance requirements.

In addition, the e-health experience suggested that there would be additional value in further categorising viewpoint concepts into conceptual, logical and implementable perspectives, which are similar to the OMG MDA separation of concerns. The purpose is to provide further separation of concerns between experts involved in specifying requirements (conceptual perspective), producing information/behavior models (logical perspective) and developing message and content specifications using particular technology standards (implementable perspective).

This yields a 5x3 matrix referred to as an Interoperability Specification Matrix (ISM) shown below. The ISM can be used as a starting point for identifying relevant concepts associated with a particular e-health specification, such as for example an e-referral system specification. These concepts can then be arranged according to the ISM matrix structure, resulting in a corresponding Interoperability Specification Template (IST) for e-referral, that can be used to produce many specific instances of e-referral specifications, which may differ from one organisation to another one.

	Enterprise	Information	Computation	Engineering	Technology
Conceptual					
Logical					
Implement.					

Figure 1: Interoperability specification Matrix

For example, a simplified version of an IST for e-referral is shown in Figure 2. It shows that the

- enterprise/conceptual cell might have identify a community model representing referred-to and referrer roles, and their business processes,
- information/logical cell might identify an information model for a referral document,
- computational/logical might identify a specification of interfaces through which component offer services,
- engineering/logical cell can identify reference points stating where testing can be done, and
- technology/implementable cell may identify specific conformance statements specified by the implementer of e-referral messaging (for example, used by testers when testing conformance of a specific vendor's product).

	Enterprise	Information	Computation	Engineering	Technology
Conceptual	Community: {Referrer, Referred-to, Patient, Referral temporal validity }				
Logical		Referral document model; FHIR logical referral document	Computational Interface; pub/ sub	Reference points	Conformance statements
Implement.		CDA referral; FHIR referral resource in JSON	FHIR APIs; Java interface; Java notification service	FHIR Conformance Statement	FHIR test scripts (provided by vendor "ABC")

Figure 2: Interoperability Specification Template: e-referral

In addition to supporting architecture expressions, the SAIF places an emphasis on describing governance concepts. These concepts also make use of the ODP enterprise language, but are organised in terms of the precepts, processes, people and metrics, proposed by Thomas Erl in [22]. Governance was a particular focus of SAIF because HL7 International, as a national standards body, depends upon complex governance policies coordinating internal and external dependencies.

The development of the SAIF also included the authors of the IF2, which facilitated international collaboration. SAIF was published in 2014 [9].

B. *E-health Interoperability Framework*

In response to the SAIF standardisation, Standards Australia initiated work on two e-health handbooks. These involved a number of stakeholders from the Australian e-health community with a focus on the E-health Interoperability Framework [16] and accompanying E-health Architecture Principles [17].

Many of the ideas from the IF2 and SAIF have also influenced the development of these two specifications, with RM-ODP providing underpinning viewpoints and modelling concepts.

Similar to the SAIF, the eHIF adopted an interoperability matrix structured in terms of viewpoints and perspectives. One example is shown in Figure 3, based on [16].

In addition, the eHealth interoperability framework additionally provided an interoperability capability model, which can be used by organisations to support improvement in their interoperability capability. The capability model is based on the well-established CMMI model. Further details can be found in [16].

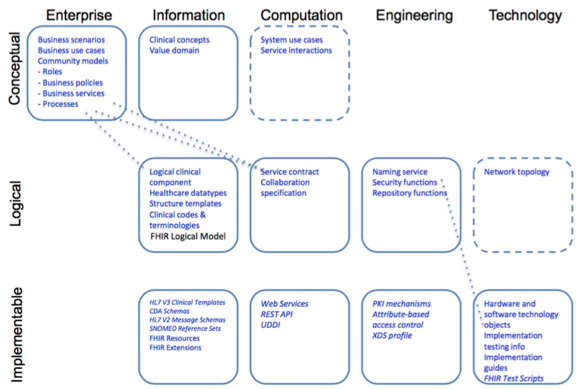

Figure 3: eHIF Interoperability Matrix

C. *Supporting an interoperability methodology*

In view of the multidimensional property of interoperability, the ODP standards can be used to define many types of interoperability agreements to support interoperability outcomes.

In the enterprise viewpoint, these may be cross-organisational contracts that are used to structure federations between organisations. In ODP terms, a federation is a special kind of community involving two or more domains. This allows each organisation to maintain its independence and autonomy, as per the rules in each domain, while enabling them to work together according to the rules in the federation contract. Other types of agreement may specify cross-organisational business processes in which both organisations participate and also mutually agreed business services offered and used.

From the information viewpoint, these may include agreement on a shared information model, e.g. specific representations of information resources as per the HL7 CDA or FHIR standards.

The computational viewpoint can specify computational interfaces through which objects offer or consumer services, e.g. RPC style of interactions, one-way notification or publish/subscribe.

The engineering viewpoint can specify the approach to message translation, using for example an interceptor infrastructure component.

The technology agreement can be about the use of particular communication protocols, e.g. a 4G communications requirement or specific media streams for telehealth applications.

These agreements typically cover two parties, but whenever a new party needs to be added to the collaborative arrangement, there may be a need to update existing agreements.

While ODP provides a method for describing these agreements at particular points in time, the standard does not prescribe any methodology that would support organisations as they evolve on their independent interoperability journeys. In general, the problem of supporting interoperability between different organisations over time is a function of many parameters that change over time. These parameters can be included in the various interoperability agreements, even multi-party agreements from different viewpoints as above, but may also include investment constraints and other business constraints. This is depicted in the figure below, which shows three organisations, with their own interoperability trajectories. Each organisation can define its own trajectory and at some points in time, there may be shared intermediate agreements or outcomes, as in the case of the A1 and B1, on the journey to a future state capability of federated companies. Note that the ultimate goal is to support increasingly better alignment and improved ability to interoperate over time among all organisations for a particular business objective.

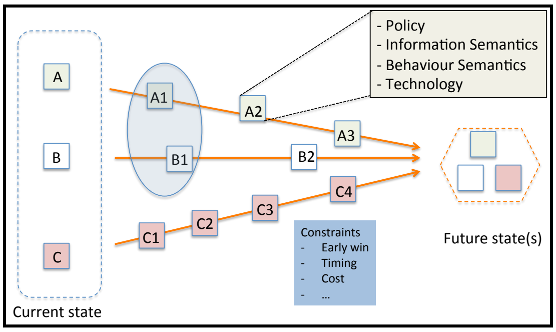

Figure 4: Interoperability methodology

In some cases, it is quite possible that two organisations agree that they cannot support specific agreements (i.e. they agree to disagree) at a particular point in time, but even the fact that this is known is important to avoid possible disputes.

An interoperability methodology also needs to recognise the co-existence of different and independent architecture frameworks that each organisation may have. The interoperability methodology thus makes use of the fact that an interoperability framework defines concepts and patterns across the various viewpoints enabling cross enterprise architecture cohesion, or in fact points of difference. This is shown in figure below that highlights the distinction between interoperability, enterprise and solution architecture methodologies, as described in the IF2 [2].

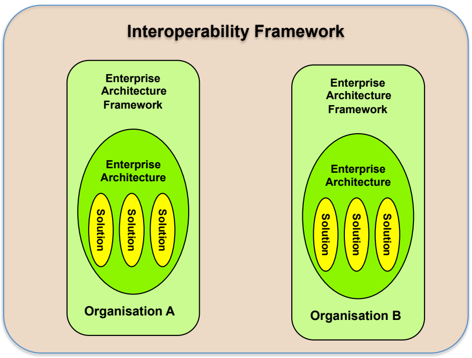

Figure 5: Interoperability and architecture frameworks

VI. Conclusions and Future Directions

This paper has provided a description of the latest development in e-health interoperability reflecting the Australian and international efforts. In particular, the paper provided a summary of the new specification components and also impact of the second version of NEHTA interoperability framework (IF2) publication and activities, since our last report on the topic in 2006 [1]. In particular, the paper presented the role of RM-ODP, to support interoperability efforts and has highlighted its value both as an architecture framework and semantic underpinning to interoperability.

The paper has highlighted the need to develop an interoperability methodology to help multiple organisation define their individual trajectories while taking into account shared agreements between them on their mutually related topics of concern. This is of particular value for solution architects who are facing different type of challenges when tackling interoperability problems, which need to support co-existence of many different solution architectures, with their own life cycles and constraints. There is much work to develop such a methodology to accommodate complexity of federated distributed systems and in particular in the federated health environment such as Australia.

On another theme, we will be looking at how some of the recent HL7 standardisation efforts related to interoperability platforms, in particular FHIR [18], can be positioned in the context of SAIF and specifically RM-ODP. This would be of value to those practitioners who are concerned with supporting co-existence between different digital health technologies, the existing one with significant national and organisational investments, and the new ones that better accommodate new technologies such as REST, mobile and cloud applications. One aim of this work would be to use comprehensive architecture framework of RM-ODP to look at the range of FHIR resources and infrastructure, possibly signalling where future FHIR work may be needed to build a more complete system. In doing so, we intend to consult with the FHIR core team in order to get their input into the analysis.

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