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Contact: Ilyoung Chong
DLIT/HUFS
Korea (Rep. of)
Tel: +82 43 217 7004
Fax: +82 43 217 8004
Email: iychong54@gmail.com

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Abstract: This output document provides the revised output text of draft Recommendation ITU-T Y.eHealth-Semantic "Framework to support semantic mediation in eHealth service" at Q4/20 meeting on 6-26 July 2020. The major revisions of the base document (SG20 TD1552) are change of title and text revision of clause 7, 8 and 9 to clarify the semantic mediation of eHealth services.

This is the draft document of draft Recommendation ITU-T Y.eHealth-Semantic "Framework to support semantic mediation in eHealth service" at ITU-T SG 20 meeting on 6-16 July 2020. It has been agreed as a revised draft document based on the input document C785 R1 and C786 R1.

Doc. No.	Source	Document Title	Discussion Issues
SG20-C785 R1	Hankuk University of Foreign Studies (Contributor: Ilyoung CHONG, iychong@hufs.ac.kr)	Output document of draft Recommendation ITU-T Y.eHealth-Semantic "Framework to support semantic mediation in eHealth service", Q4/20 meeting (Virtual, 6-16 July 2020)	This contribution proposes the revised text of the draft Recommendation of Y.eHealth-Semantic. The proposed revisions indicated at the contribution of SG20-C785 have been reviewed, and few additional comments have been discussed: – Change of the document title (Y,eHealth-Semantic) and revision of the scope of the document; – Clause 3: Conventions are added; – Clause 7: addition of requirements to support semantic interoperability in eHealth service; – Clause 8: revision text and figure 8-1; – Clause 8.1, 8.2, 8.3, 8.4, 8.5 and 8.6: revision of text; – Clause 9: addition of new text of 9.1 ad 9.2 – Clause 10: change of title.
SG20-C786 R1	Hankuk University of	Output document of draft Recommendation ITU-T Y.eHealth-Semantic "Framework	New Appendix I ("Appendix I: BOM and CMO model for eHealth Applications") is discussed to include the followings. – I.1 Semantic Base Ontology Model (BOM)

Doc. No.	Source	Document Title	Discussion Issues
	Foreign Studies (Contributor: Ilyoung CHONG, iychong@hufs.ac.kr)	to support semantic mediation in eHealth service", Q4/20 meeting (Virtual, 6-16 July 2020)	– I.2 Core Mediation Ontology (CMO) Model

Draft Recommendation ITU-T Y.eHealth-Semantic

Framework to support semantic mediation of eHealth services

Summary

This document proposes the framework to support semantic mediation of eHealth services in accordance with Y.4452 and ITU Technical Specification D3.3 of FG-DPM.

Keywords

Common Data Model, eHealth; Semantic interoperability; Web of Objects;

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Framework to support semantic mediation of eHealth services

1 Scope

In eHealth service, semantic interoperability will enable the various systems to combine received information with other information resources and to process it in a manner that preserves meaning. Thus, the lack of semantic interoperability between eHealth systems is one of the major obstacles in the provision of cross-border and cross-sector eHealth system. This draft Recommendation describes framework to support ontology based semantic mediation of eHealth services by identifying the followings:

– Overview of semantic data mediation in eHealth service;

– Requirements to support semantic mediation in eHealth services;

– Functional model to support ontology based semantic mediation;

– WoO based semantic interoperability provisioning in eHealth services;

– AI based semantic interoperability provisioning in eHealth services.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.4452] Recommendation ITU-T Y.4552 (2016), *Functional framework of Web of Objects*.

[ITU-T Technical Specification D3.3] ITU-T Technical Specification D3.3 (2019), *Framework to support data interoperability in IoT environments.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

TBD

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

BOM Base Ontology Model

CMO	Core Mediation Ontology
CVO	Composite Virtual Object
RDF	Resource Description Framework
VO	Virtual Object
WoO	Web of Objects

5. Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "is not recommended" indicate a requirement which is not recommended but which is not specifically prohibited. Thus, conformance with this specification can still be claimed even if this requirement is present.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6. Overview of semantic mediation in eHealth service

In eHealth services, semantic interoperability is the ability of applications to exchange data between different eHealth service environments and the use of exchanged data in a meaningful way in multiple eHealth service resources. In general, eHealth data interoperability is concerned with the capability of communications between eHealth service environments that might have different forms including transfer, exchange, transformation, integration of data.

The semantic interoperability among eHealth applications is concerned with enabling different agents, services, and applications to exchange information, data, and knowledge in a meaningful way. Consensus on meaning is required while exchanging the data across eHealth systems. Semantic interoperability defines the true meaning of the contents that are generated by eHealth service resources and mutually agreed by a different eHealth resource that uses these contents. The semantic interoperability will enable different stakeholders to access and understand data unambiguously.

Two important concepts in semantic mediation provisioning of eHealth data can be identified as follows:

- Exchange of data between interoperating eHealth service environments – implies how the service features will be exchanged;
- Use of exchanged eHealth data semantically – implies how the exchanged data can be used in a meaningful and unambiguous way.

Data aggregation and integration in eHealth services will be the important processes to achieve intelligent and enhanced eHealth service environment. They require well-defined mechanisms for linking semantics such as the automated linking of relevant semantic data sources and the metadata, which enables eHealth data integration and reuse of data. As well as mechanisms for the sharing and reusing of data would be necessary to support the semantic interoperability in eHealth service. The functional model indicated figure 6-1 provides the view to support semantic interoperability among different eHealth service domains. As shown in figure 6-1, the three components are necessary to support semantic interoperability in eHealth services as follows.

- Semantic data mediation of eHealth service;
- Semantic ontologies to describe its linking and alignment of eHealth service'
- API request query translation to support the alignment and management of the source and the target semantic schemas of eHealth service.

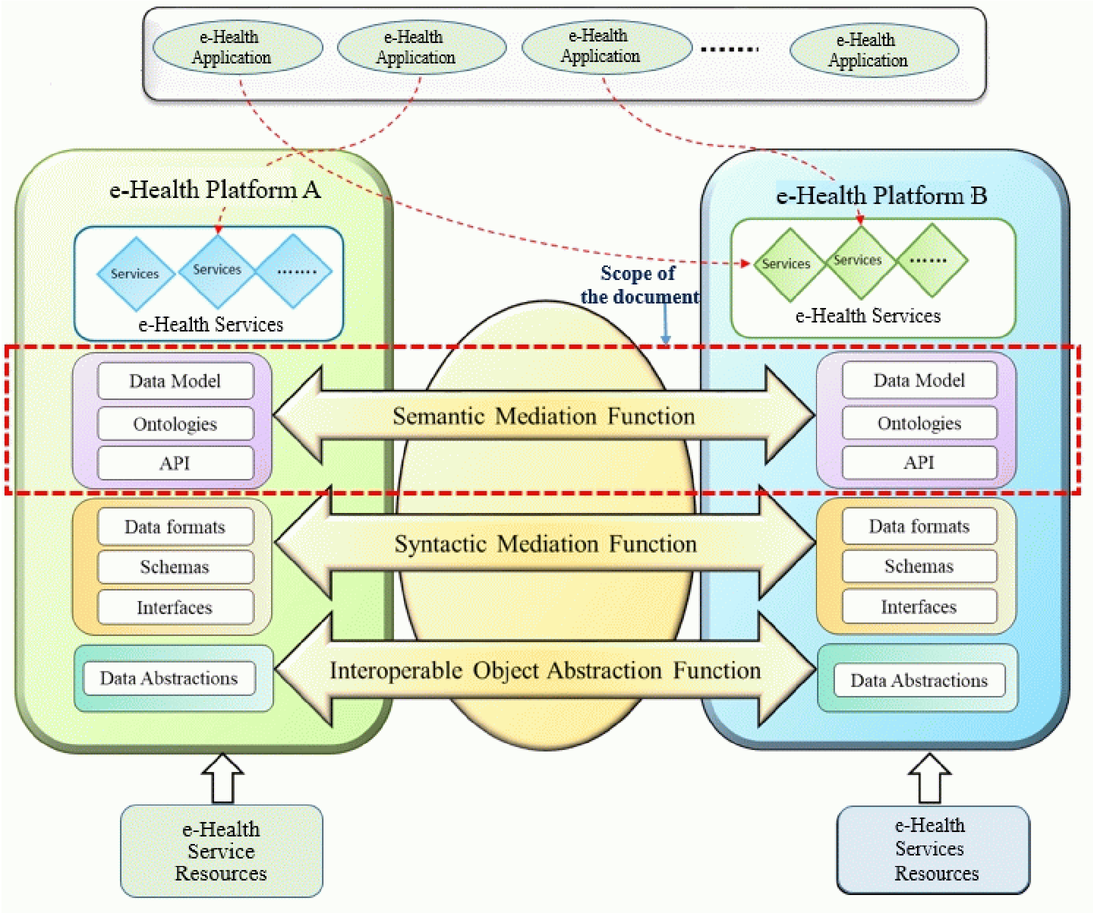

Figure 6-1. A view of semantic interoperability in heterogeneous eHealth platform [in ITU-T Technical Specification D3.3]

7 Requirements to support semantic interoperability in eHealth service

To support semantic interoperability in eHealth service, many considerations are required to be considered. This section highlights some principal requirements to support data interoperability and some requirements with respect to semantic interoperability of eHealth service.

- Semantic eHealth data modelling: The semantic representation of eHealth data is required to express a common understanding across systems. A semantic representation model in eHealth service is necessary to provide the conceptual understanding of data as well the relationship among entities.
- Semantic integration and sharing: Mechanism for the linking of eHealth data based on semantic ontology models are required. The linking mechanism in eHealth are required to be efficient to support dynamic integration and sharing of eHealth data

- Semantic annotation of eHealth data: A semantic annotation mechanism is required to support the annotation of eHealth data coming from heterogeneous sources. Semantic annotation in eHealth service is required to be supported with a well-defined set of metadata to express the features diverse eHealth data.
- Semantic eHealth data management: The abstract semantic representations of eHealth data are required to be managed through a management services. A suit of well-defined eHealth service is required to manage the data allowing its access, retrieval and storage operations.
- Semantic Ontology alignment and mapping of eHealth service: It is reuired to provide improved ontology alignment in order to support semantic eHealth data interoperability. The ontology alignment techniques with enhanced accuracies can enable and improve interoperability across different eHealth service resources.
- Semantic representation of eHealth knowledge: In providing rules with eHealth knowledge representation supports reasoning on the data which enhances its value. Information model defines the format to contain the eHealth information. It is required to be semantically rich and expressive enough to represent different forms of the objects being maintained. It should also scale well in evolving eHealth service technology. EHealth information model should be flexible enough to represent semantic information. Ontologies in eHealth service provide an option to exchange the eHealth knowledge by giving the semantics required and enhancing the data in the information model.
- Semantic eHealth data transformation: Mechanism for the transformation of a semantic format to another is required. In case of domain specific eHealth service model, it is necessary to provide transformation service among heterogeneous semantic eHealth data models.
- Reference of eHealth context: The reference is made to semantic interoperability as the systems' capacity, with the support of ICT applications, to exchange, understand and act upon data related to a citizen/patient and other health data, information and knowledge between clinicians, patients and other actors/systems using diverse languages and information coding systems within and between health systems.
- A key component of operational semantic interoperability: One needs to differentiate between different types and categories of semantic components although the same semantic components can be classified in different categories:
    - What one means (ontology);
    - How one says it (languages, terminologies and code systems)'
    - How one finds it (interface).

8 Functional model to support ontology based semantic mediation of eHealth services

The core components of functional model to support the ontology based semantic mediation of eHealth service include the registration of the semantic data description, semantic translation and query processing, semantic annotation and liking and the validation of semantic alignments. Figure 8-1 shows core components of the eHealth semantic mediation model.

- eHealth semantic data description registration;
- semantic data translation function;
- API request query translation;
- semantic data annotation function;
- semantic data alignment and linking function;

– semantic data validation function;

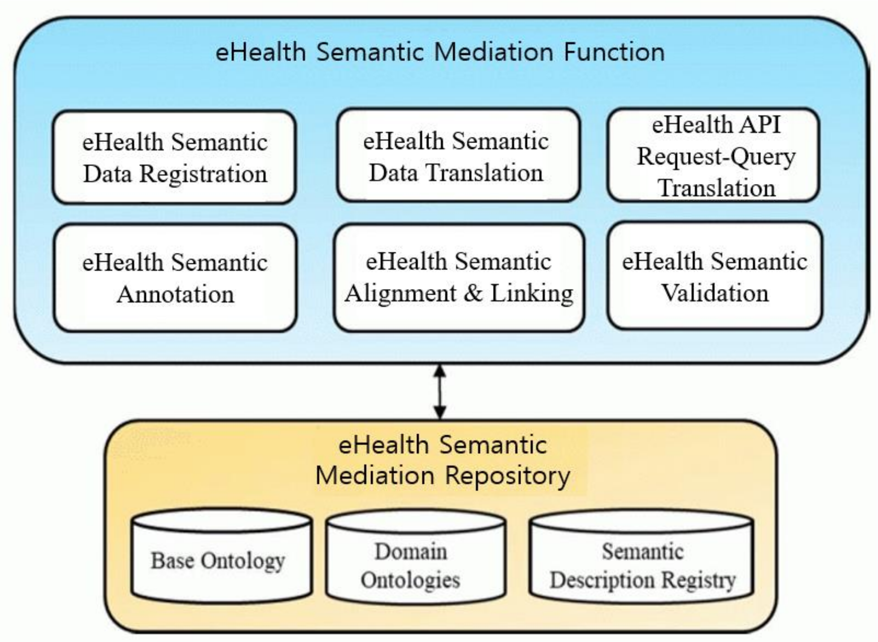

Figure 8-1 Functional components of semantic interoperability model in eHealth service

8.1 eHealth semantic data registration function

This function enables a record of eHealth semantic formats that can be used by semantic translation function. The eHealth semantic registration function performs two core functionalities, ontology discovery and ontology registration management.

– eHealth ontology discovery;
– eHealth ontology registration management.

The first one is the ontology discovery service which provides the search and matching of ontology records in the semantic description registry. The ontology discovery function is implemented with a request interface to query the ontology instances. The second one is the ontology registration management service which provides the functional capability to register and manage the semantic ontology models. The registration requires the hierarchical terminologies of the ontologies that can be interacted during the search in the registry database.

The sequence of operations between the semantic data description registration services and the ontology discovery and ontology graph management has been shown in the following figures, where the process for the semantic description registration and the process of semantic description retrieval from the base ontology registry has been presented. The ontology registration management service provides the request interface and queries the base ontology repository for semantic registrations. The eHealth semantic registry description registry has been also implemented providing the mapping of semantic IDs and semantic description in RDF format. Domain ontology endpoints are established to host domain RDF graphs.

8.2 Semantic data description translation function

The semantic data description translation function provides the translation of object formats to base semantic data formats. The functional capabilities of semantic data translation function (as shown in Figure 8-1 are as follows:

- Base ontology translator: delivers the functional capability of translation of concepts from a domain ontology model to the base ontology model;
- Data model: provides the capability to express the semantic data meaning of the exchanged data using the information objects.

A semantic data model indicated in ITU-T Technical Specification D3.3 is applied to describe the data using semantic information regarding the data. The meaning of data differs from one context to another context. The eHealth semantic information of the meaning based on the context of the data. Different applications use same data differently based on the specification of the domain. A semantic data model of eHealth is an abstract model that defines the meaning of a data by using the relationship between eHealth objects within the context of eHealth service.

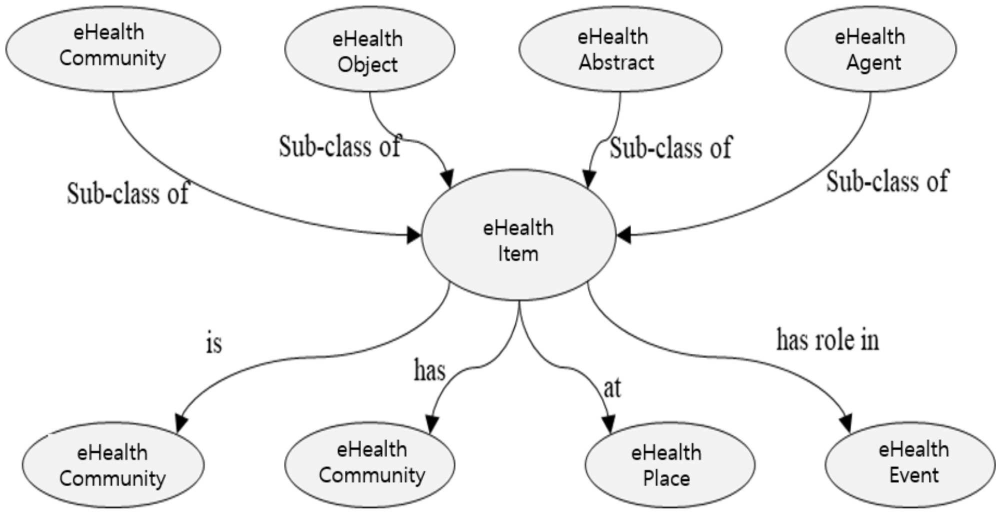

Figure 8-2. A semantic data model of ‘eHealth Item’

8.3 eHealth API Request-query Translation function

The eHealth API Request-query Translation function provides a specialized way to translate the requests to specific API format of eHealth service through provision of an API request translation service, a query formation service and format description service. API Translation service provides the functional capability to translate the API request to a target request format. Query Formation service provides the functional capability to generate new formatted query based the API response formats to be generated. API Formats are the suit of data formats corresponding to heterogeneous API of different platform registered in the query translation system.

8.4 eHealth semantic annotation function

This function enables the annotation of the eHealth data based on the standard ontology and semantic data model indicated in ITU-T Technical Specification D3.3. It provides annotation using the selected annotation description language. Semantic data annotation allows enrichment of content by linking machine processed information to the extracted concept of a semantic ontology. Semantic data annotation allows attaching or adding additional information of the concepts of the ontology to the existing contents. The semantic data annotation changes an isolated ontology into an ontology that can be interpreted, shared and reused by other ontologies.

8.5 Semantic alignment and linking function

The semantic alignment and linking function enables the alignment and management of the source and the target semantic schemas of eHealth services. The functional capabilities of semantic alignment and liking function are illustrated in the Figure 8.3. These mechanisms include Semantic Ontology Manager which includes the capability to manage the ontology aligner, it implemented as service entity of eHealth service to instantiate the ontology aligner by providing the model of source and target ontology data models. Ontology Aligner performs the semantic ontology alignment function. It takes the source and target ontology models and computes the alignment with on the similarity measures and the provided thresholds for each measure, this service returns the alignment results in terms the true mapping achieved through the mapping algorithm. Entity Loader delivers the capability to load the data entities from source and target ontologies. It is implemented with the Jena library, which has been implementation for preprocessing of the ontology entities before they are delivered to the semantic alignment service.

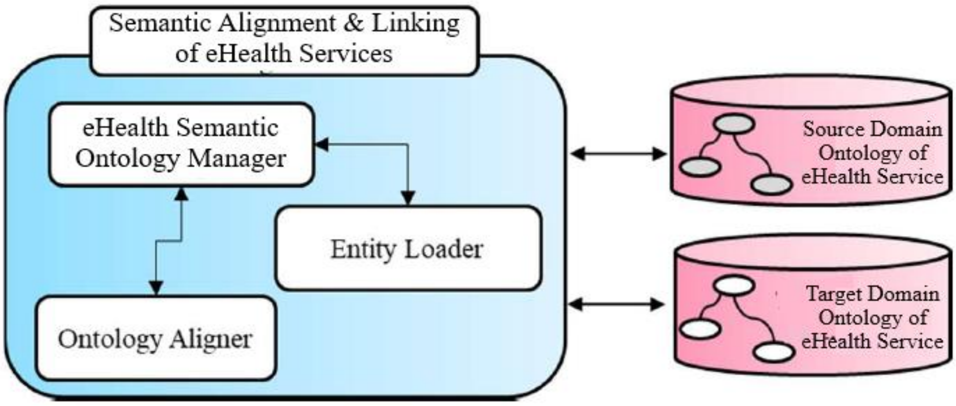

Figure 8-3. Semantic Alignment and linking of eHealth service

Any application that deals with several ontologies must provide a semantic mapping or matching mechanism to ensure the interoperability. When ontologies are matched they are indeed aligned, which represents the correspondence among different ontologies. This kind of correspondence enables heterogeneous ontologies with different semantics to be interoperable. The identified correspondence among ontologies is a set of rules which transform from one to another ontology to enable the integration of the information. The requirement is to find out the correspondence among domains. This correspondence can be detected using the alignment of matching techniques. The alignment function between two eHealth service ontologies defines the confidence among the concepts of two eHealth services. The confidence is also referend as the value of similarity. The mapping of matching techniques generates this similarity value of the semantic between eHealth services. The higher the value between two entities the more exact match is assumed.

Moreover, several other aspects need to be considered for ontology alignment, these include:

- Efficiency consideration of ontology alignment methods;
- Evaluation of the ontology matching;
- The involvement of the user in the matching process.

8.6 eHealth semantic validation

It is important to evaluate the feasibility of the semantic data mediation of eHealth semantic data with a defined schematic ontology. This function performs the test to validate the semantic data structure of the eHealth semantic data in terms of validation test case defined on the bases of semantic ontology. This function is used to verify the semantic conversion of data with a defined schema. It constitutes the mechanism to validate the semantic structure of the data with validation test case defined on the bases of semantic ontology. The functional capabilities of semantic validation function as shown in Figure 8-4 are as follows:

– eHealth Ontology Validator: this functional capability provides the validation function on the provided input test case to validate the semantic alignment;
– eHealth Ontology Test Execution: provides the execution facility to perform the validation for the alignment function.

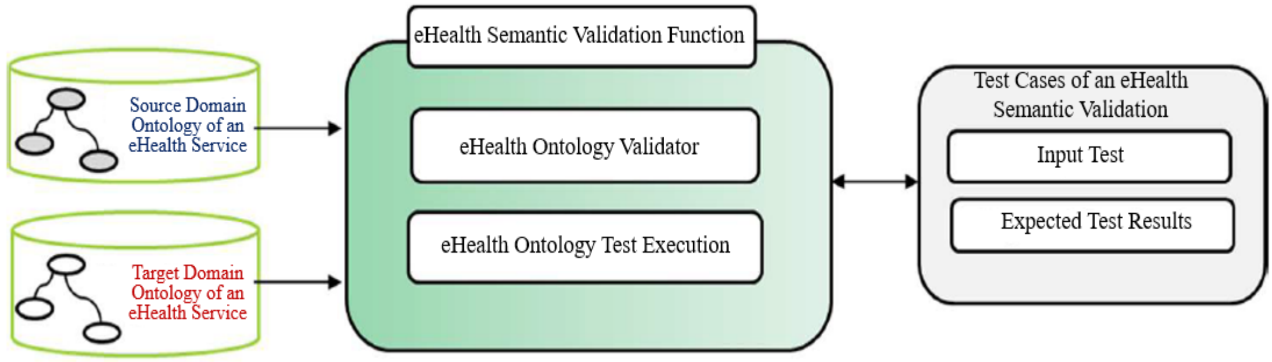

Figure 8-4 Functional components for eHealth Semantic Validation

9. WoO based semantic interoperability provisioning in eHealth services

This section provides details on the Web of Object (WoO) based semantic interoperability provisioning in eHealth applications. Figure 9-1 describes the model of interoperable WoO eHealth service environment. The WoO is based on the following functions as indicated in [ITU-T Y.4452].

- WoO service level supports functions to create and manage eHealth service entities based on [ITU-T Y.4452].
- Composite Virtual Object (CVO) sub-level is responsible for control and management of CVOs, with respect to the functional capabilities of the CVO sub-level based on WoO reference model [ITU-T Y.4452].
- WoO Virtual Object (VO) sub-level provides the functional capabilities responsible for the control and management of VOs [ITU-T Y.4452].
- The registry DB, Template Repository, Information Database enable access to the WoO resources [ITU-T Y.4452].

Figure 9-1 shows the interface which presents the interoperability interface between WoO based eHealth service platform and external eHealth service platform.

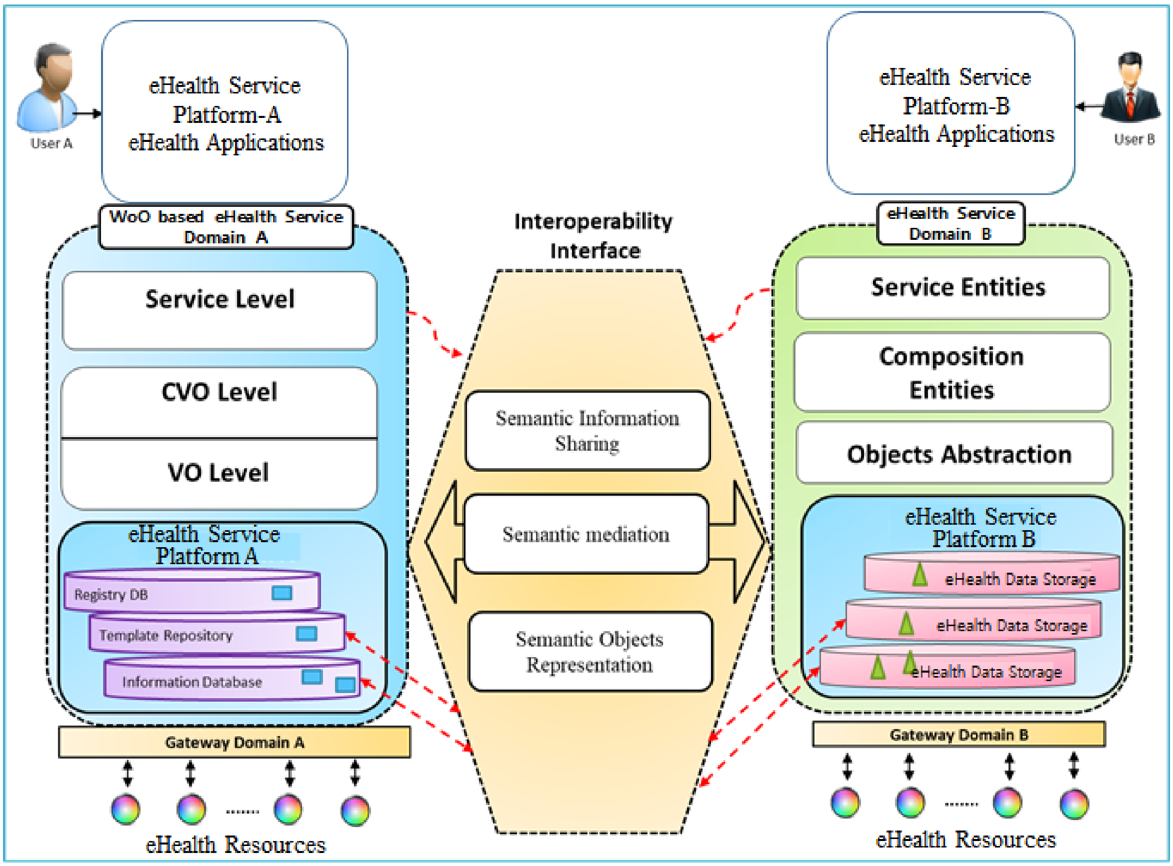

Figure 9-1. Interoperability with Web of Objects (WoO) based eHealth Model

9.1 eHealth Interoperability Interface

It is required that the interoperability interface between WoO based eHealth service(A) and external eHealth service domain (B) allows access of eHealth data and services that are available in any of the eHealth domains. The interoperability interface includes the data representation, translation, sharing mechanisms to enable applications for cross-domain data interoperability. The WoO based interoperability interface enables access to the internal data of the domains and the capabilities for the extraction of eHealth data. The interface needs to provide the semantic interoperability that can provide the following functions.

- Semantic Information Sharing: the semantic information sharing enables access of data and metadata of sensors registered in the domains
- Semantic Mediation: the semantic mediation enables the translation of the data and the metadata of the information model defined by the domain
- Semantic Object Representation : semantic object representation provides the common representation of the sensor observation for the information models defined by the domains.

9.2 External eHealth Servicre platform

Figure 9-1 describes external eHealth service platform on the right side of the illustration. The external eHealth service platform is based on the following functions as indicated in [ITU-T Y.2068].

- The service entities support the service functions based on the service provisioning capabilities indicated in section 8.1 of [ITU-T Y.2068].

- The composition of entities in external eHealth platform will provide eHealth objects orchestration for higher level service workflows based on the application capabilities defined in [ITU-T Y.2068].
- Object abstraction and data handling functions in the external eHealth service platform provides capabilities responsible for the management of object handling based on the data management capabilities in [ITU-T Y.2068].

TBD

10. AI based semantic interoperability provisioning in eHealth services

TBD

Appendix I
BOM and CMO model for eHealth Applications

(This appendix does not form an integral part of this Recommendation.)

I.1 Semantic Base Ontology Model (BOM)

The semantic base ontology consists of the generic concepts to support the semantic interoperability for healthcare applications. It includes the base object entity which represents a Real World Object (RWO). The RWO has the operation mode as it may represent any sensor or actuator, however if the RWO represents any other information this mode will be set to none. A Base Object Element (BOE) is an entity to hold a base object. The BOE can have input features as well as the output features. Each feature has associated metadata with it which presents the details on the BOEs and the operation that can be supported on this abstraction. The Composite Elements (CE) are the entities in the base ontology that will contain the collection of BOE entities. They have also features and the associated metadata. Base Ontology model have interface to the standard W3C SSN ontology and other external ontologies to express and provide interoperable features with existing systems.

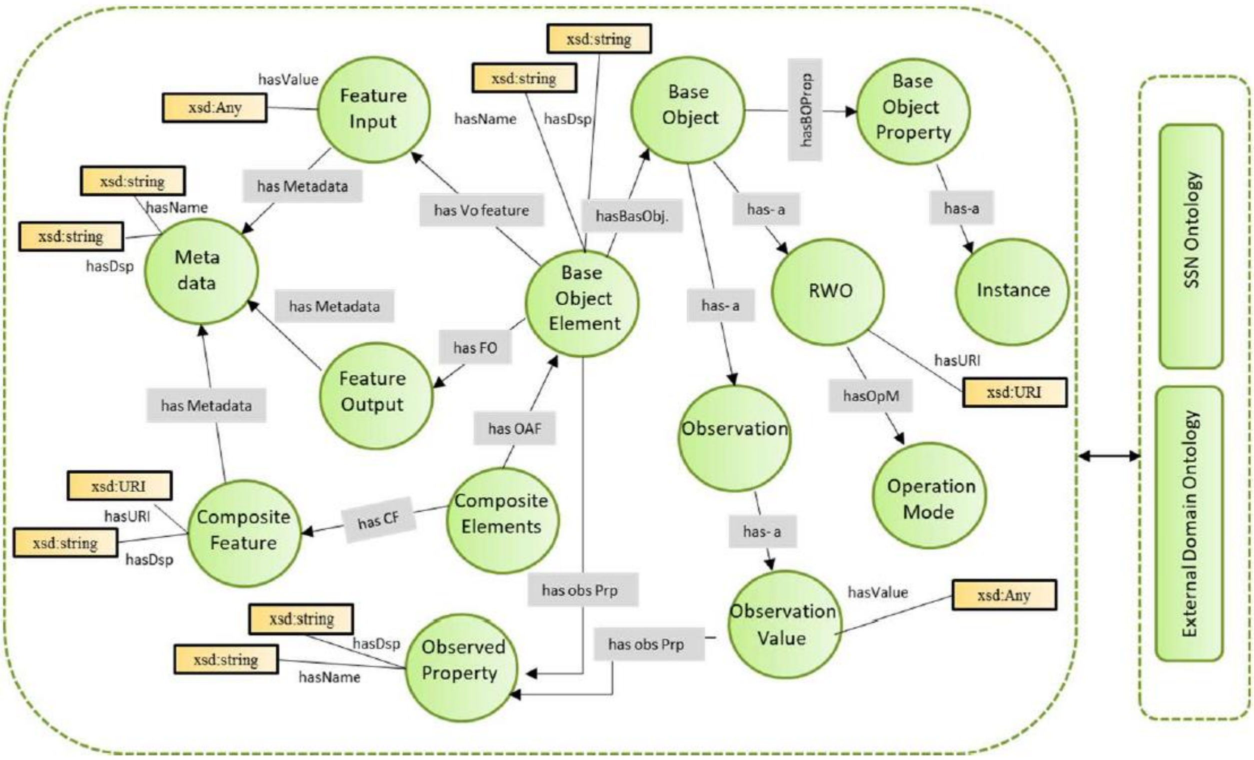

Figure I-1. Base ontology model

I.2 Core Mediation Ontology (CMO) Model

Core Mediation Ontology (CMO) is a mediation design pattern that provides an alignment and arbitration for source and target ontologies. The CMO includes mediation concept which is sub categorized into core data concepts and structure concepts. The core data mediation concepts include, core data mediation, metadata mediation, features mediation, source feature mediation, object mediation, data property mediation, range mediation and domain mediation. These concepts are used to express the alignment through specific algorithm based on the used formats. The CMO also contains the concepts related with the structural mediation among the ontologies to be aligned. From the structural point of view the CMO has mediation concepts like, structure concept, list of aligned sequence, and list of expected match sequence, core domain list, core range list, source sequence concepts, and target sequence concepts.

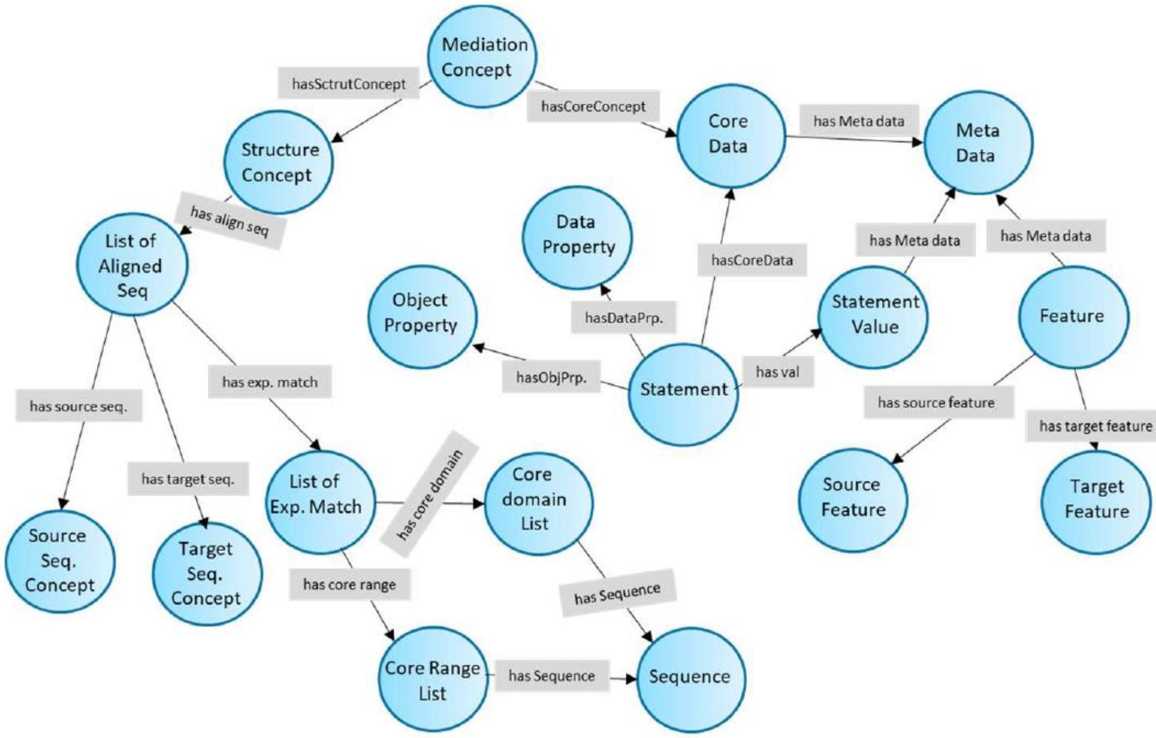

Figure I-2. Core mediation ontology model

To express our interoperability approach we provide an example with semantic alignment and SPARQL query writings. In the following figure shows two information models, J and K which provide information about two different systems, and both follow the base ontology model. As both model express arm concept and their features in slight different ways. To enable semantic interoperability among both systems semantic alignment is required. Figure I-4 shows the code for the semantic alignment with two defined rules the first provides the equivalence of body arm concept to arm and the second describe the relationship has status from the model J is same as is on status in model k. Following the specified mapping the SPARQL queries are modified in the excerpt of Figure I-5.

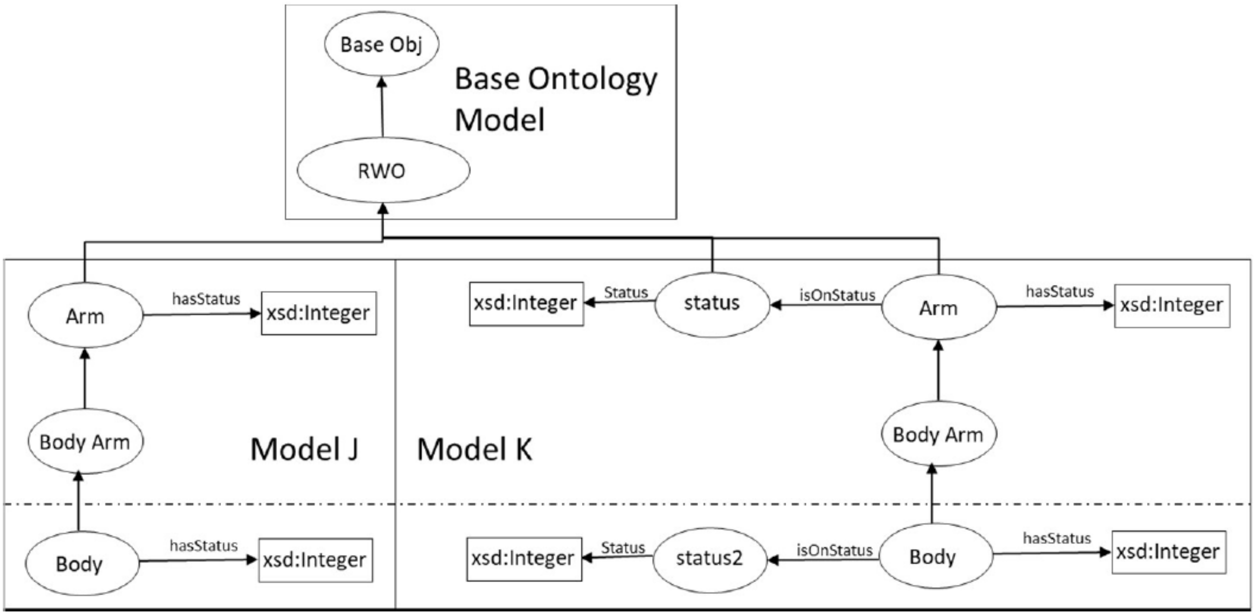

Figure I-3. Mapping of information model using base ontology

```
@prefix : <http://Semanticweb.WoO.org/Interoperability/Improvedalignment#>
@prefix woohs: <http://woo.anlab.org/woohs/1.0/#>
@prefix modelJ: <http://www.anlab.org/semantic_ontologyJ#>
@prefix modelK: <http://www.anlab.org/semantic_ontologyK#>
@prefix xsd: <http://www.w3.org/2001/XMLSchema#>

<http://www.anlab.org/semantic_mappings/plJ-plK#RuleA> a :Cell ;
:conceptEntity1 modelJ:BodyArm;
:conceptEntity2 [ a woohs:Class ;
woohs:and ( modelK:healthNote [ a woohs:AttributeValueRestriction ;
woohs:onAttribute modelB:Arm ;
woohs:comparator woohs:equals ;
woohs:value [ a woohs:Literal ;
woohs:string "true" ;
woohs:type "http://www.w3.org/2001/XMLSchema#boolean" ] ] ) ] ;
:measure "1.0"^^xsd:float ;
:relation "Equivalence" .

<http://www.anlab.org/semantic_mappings/plJ-plK#RuleB> a :Cell ;
:entity1 modelJ:hasState ;
:entity2 [ a woohs:Property ;
woohs:compose ( modelB:isOnState modelB:State ) ] ;
:measure "1.0"^^xsd:float ;
:relation "Equivalence" .
```

Figure I-4. Mapping Rules defined using SPARQL

```
# Initial SPARQL Query
PREFIX modelJ: <http://www.anlab.org/semantic_ontologyJ#>
SELECT ?arm ?state WHERE {
?arm a modelJ:BodyArm ;
modelA:hasState ?state .
}

# Modified SPARQL Query
PREFIX modelK: <http://www.anlab.org/semantic_ontologyK#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
SELECT ?arm ?state
WHERE
{ ?arm a modelk:Arm ;
modelK:hasWearable "true"^^xsd:boolean ;
modelK:isOnState [ modelB:state ?state ] .
}
```

Figure I-5. Modification in the SPARQL query with respect to information model

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