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Data Convergence Techniques from Different Health Records into Single Platform- A Survey

Runumi Devi* **and Deepti Mehrotra****

ABSTRACT

Data integration in Electronic Health Records(EHR) Systems has become one of the important task having highest priorities that can be shared not only within hospitals but also across hospitals. Most health care organization's objective of data integration and convergence is to retrieve and exchange information meaningfully and accurately among their disparate healthcare systems. However, the real issue that prevents EHR system integration and convergence is the lack of a common standard amongst the systems. Integration and exchange becomes challenging due to the use of numerous vocabulary standards, content exchange standards and clinical standards . There are numerous structured but uncoded data available in EHR systems which are not mapped to any standard terminologies. In this article, we aim to present issues of integration of Electronic Health Records system, discuss some of the models used for integration and also make an attempt to present a road map for converging EHR systems and exchange of medical information to make them interoperable.

Keywords: Electronic Health Records(EHR), Health Level Seven (HL7), RDF, Archetype Definition Language (ADL),OGSA-DAI.

I. INTRODUCTION

One of the objective of Health and Human Services Department of U.S. is to make interoperability as a common capability between disparate electronic health records systems (EHRs) by the year 2024.The departmentwants interoperability between systems to make possible patient data to be shared among allowed users effortlessly. [6]

In spite of having rapid increase in the adoption of EHR, the main issue that prevent health data exchanges between providers directly is that many EHR systems are not interoperable with one another, thus the question of sharing or exchanging patient information efficiently in such an environment is a far cry. Therefore the biggest challenge till date is how to converge the EHR data into a single platform to make it sharable in an interoperable enviroment ?

II. ELECTRONIC HEALTH RECORDS: THE BASICS

An Electronic Health Record (EHR) system keeps the digital version of patient's records . It is created with an objective of making record available beyond the healthcare organization which originally compile and owns them. information. EHRs are constructed to share patients' information meaningfully and accurately with other health care providers within organization as well as outside organization. Thus they need to keep health information from all care provider whoever is associated with the patient's care.[20] Apart from medical treatment histories, an EHR can contain various information related to patients that may include physical findings made by doctors, lab findings, treatment plan, any referrals to specialist if required,

* Research Scholar, Amity University, Noida,Uttar Pradesh, India, *E-mail: runumisarmah@yahoo.com*
** Professor, Amity School of Engineering Technology, Amity University, Noida,Uttar Pradesh, India, *E-mail: mehdeepti@gmail.com*

immunization dates etc. Evidence-based tools that health care providers can use for making decision about patient's care may also be linked with EHR systems. This will enable EHR while automating and streamlining their workflow.

One of the main characteristic of EHR system is that it is created and maintained by authorized health care providers in a digital format using particular data model and vocabulary standard. This makes information sharing or exchanging difficult with other health care providers across organization. EHR systems are designed for exchanging as well as using the information being exchanged between two or more health care organizations or within single organization. Thus EHR must contain information in a way that can be interpreted meaningfully and accurately amongst clinicians those are involved in patient's care.

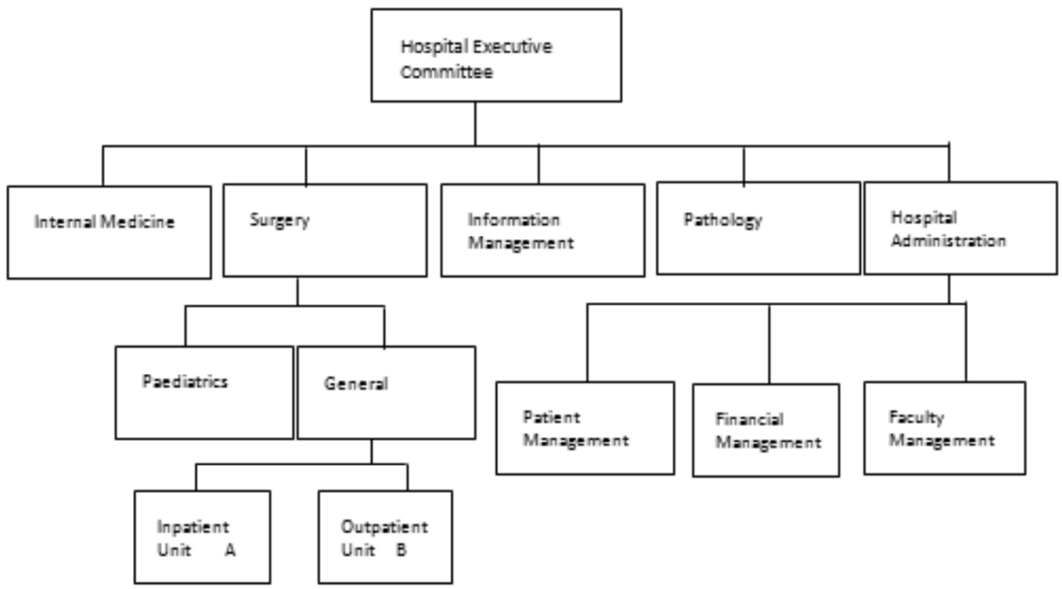

Figure 1: Electronic Health records (EHR) system

Today although all most all top hospitals adopted electronic health records (EHR) Fig.1 solutions for creating and maintain patient information, but still they are relying on paper documents for purposes like doctors' prescription, progress notes, visit notes and some other clinical documents. Moreover, these hospitals also need to rely on paper based documents for maintaining information needed to manage non-clinical systems.

Converging Health record documents into single platform will bring these documents available to users and seamless exchange of these documents with other electronic health care provider will be possible This will make exhaustive medical records accessible to care provider as well as care taker anytime anywhere from their applications..Converging data will enhance patient care, save time both for provider as well as patient and also improve the compliance of regulatory.

III. FEATURES OF EHR INTEGRATION

The convergent EHR systems data will enable better patient care through:[7]

i) A comprehensive medical record for providing a complete medical history of each patient since it is critical for making treatment effective by the provider.

ii) Integration with other health care applications while dealing heterogeneous environments which may include components within organization or between organizations.

iii) Automating various workflows which may include preparation of charts by physicians, coding and release of visit notes etc, which can be effortlessly integrated and converged into a single platform.

iv) Compliance verification for security and privacy by regulatory bodies through access to converged information.

v) Reliable and scalable system that can support additional records, users and all time available service.

IV. CHALLENGES OF EHR DATA INTEROPERABILITY

Following are few factors that make data interoperability of HER systems challenging.

i) Information blocking by vendors: There are vendors who are engaged in information blocking i.e they purposefully lock patient into a system so that they can charge later for exchanging data.

ii) High setting up fee: There are situation where some EHR systems exchange patients' information for which there might be some vendors who will charge high amount for setting up interface engine between systems.

iii) Lack of motivation towards EHR interoperability: For making EHR interoperability an important capability between systems, vendors are not given sufficient motivation.

iv) Variety of EHR Standards: So far there are many EHR standards developed that lead different system to follow different standards. This makes effortless sharing of data more challenging.[6]

v) Unavailability of data sharing rules : There is neither a standard rule nor a regulatory body who can decide how much data should be provided to a particular provider for referral cases. Moreover legal, ethical and professional dimensions should also be taken into consideration for sharing data.[15],[16]. Still there is lack of clarity regarding whether we can share some data or not, if we can share also under what circumstances and with whom and for what purpose.

V. DATA CHARACTERISTICS OF EHR SYSTEMS

Data recorded in EHR system can be broadly classified into following categories:

i) Unstructured: These are free text required to maintain discharge report, visit notes, clinical notes and findings etc.

ii) Structured coded data :These are data that are recorded according to the standard data model and vocabulary used.

iii) Structured uncoded data: Data that are used in assessing the Electronic Health Records(EHRs) forms are part of this category of data.

Most of the comprehensive information are available from the unstructured data since it allows doctor or clinician to write their document as per their wish. They are not restricted by any constraints during their documentation . However, an automated analysis of unstructured data is challenging and requires application of natural language processing methods. On the other hand, the structured coded data are comparatively easier to process but in terms of expressiveness and credibility, there is limitation . Again for structured uncoded data, enumerable value list are used for encoding information but standard terminology is not linked to that value list. Many forms used in EHR systems contain structured uncoded data. Reusing such data is challenging because of the following reasons:[10]

i) Non-standardized data are always difficult to process.

ii) EHRs lack knowledge management functions.

iii) There is no contextual semantic relationships between data

Availability of high quality patient information influences good health care. However, the patient data resides on multiple disparate provider and EHR systems are not able to fully handle the problems converging and exchanging of information. This is because each EHR system use different format and different vocabularies.

Use of more than one model is used for representing a specific information results in inconsistencies. For example, for representing the location of disease Colitis, one application may use sigmoid or rectum whereas another application may use measurement like 10cm or 30cm. Moreover, true data type is also not reflected by the data type being used in the system. For example, numerical data type may be used for nominal or ordinal attribute which is encoded with numbers.

Health care data is being distributed amongst various organizations that include government agency, insurance agency and various hospitals. This distribution and fragmentation of data creates challenges while integrating and converging data into single platform. This also creates challenge while computing confidence and finding semantics of the derived rule generated from datamining..[2][3]

The metadata schemes of EHR systems are different from each other. This difference in schemes result [17] in incomplete or unsuitable mapping between systems. Data that are platform specific requires translation to make interoperable [18]. During conversion or translation, the incompatibilities may result in information loss which may not be discovered until and unless some undesired incidence occurred.

In some cases different systems may use different formats for the same data. For example for the same data, Insurance Claim system may use different format that Clinical system. One of the instance can be a patient's broken arm, which can be an image in a Clinical System whereas that can be represented as in ICD-9 813.8 in the Claim system.

VI. DATA STANDARDIZATION OF EHR SYSTEM

So far there are many EHR standards[19] developed that lead different systems to follow different standard which does not contribute to the effortless sharing of medical data. EHR standards can be categorized into three broad categories: Vocabulary Standards, Content Exchange Standards and Clinical Standards.

Vocabulary standards: Nomenclature and code set required for describing clinical problems and procedures, medications and allergies are provided by these standards. Some of these vocabulary standards are :

LOINC(Logical Observation Identifiers Names and Codes)

ICD10(International Classification of Diseases)

SNOMED-CT(Systematized Nomenclature of Medicine-Clinical Terms)

CPT 4(Current Procedural Terminilogy)

ATC(Anatomic Therapeutic Chemical Classification of Drugs)

Content Exchange Standards provide standards for sharing clinical information that may include doctor's prescriptions, discharge report and any structured electronic documents. These set of standards define how information needs to be packaged and communicated between parties involved in a communication. Applications can also set the language, structure and data types required for seamless integration between systems using the content exchange standards. Some of the standards are :

Health Level Seven(HL7) Clinical Document Architecture

HL7 2.5.1[24]

Continuity of Care Record (CCR)

Digital Imaging and Communications in Medicine(DICOM)

Clinical Standards are used to capture patient's health information in a more logical manner. Some of the Recommended Healthcare IT standards for India are :

UHID(Unique Health Identifier), CCD(HL7/ASTM),ATC Pharmacologic-Therapeutic Classification Indian Drugs-MIMS/CIMS from CMPmedia, LOINC, HL7 V2.x, HL7 V3.0 RIM, DICOM PS3.0, ISO18308, CEN/TC 251 EN 13606, SNOMED-CT, WHO ICD 10, WHO-PCS, WHO-ICF, DSM, NIC/NOC/NANDA, CDT2, US, ICTM[25][35]

VII. THE MODEL OF DATA INTEGRATION FOR CONVERGENCE

Data integration is the deepest and the core of the work in the integration of the information system construction required for convergence which integrates all kinds of data together and provides favourable transparent access to user interface. Because of the complexity of decentralized data, diverse sources of data location and diverse formats in the integration domain, data integration system needs to support a variety of heterogeneous data access. The data is transparent to the user, when the user request data, only concerned with any interface call what data can be, without concern for the interface is how to achieve access to heterogeneous data. The general data integration system model is shown in figure 2.

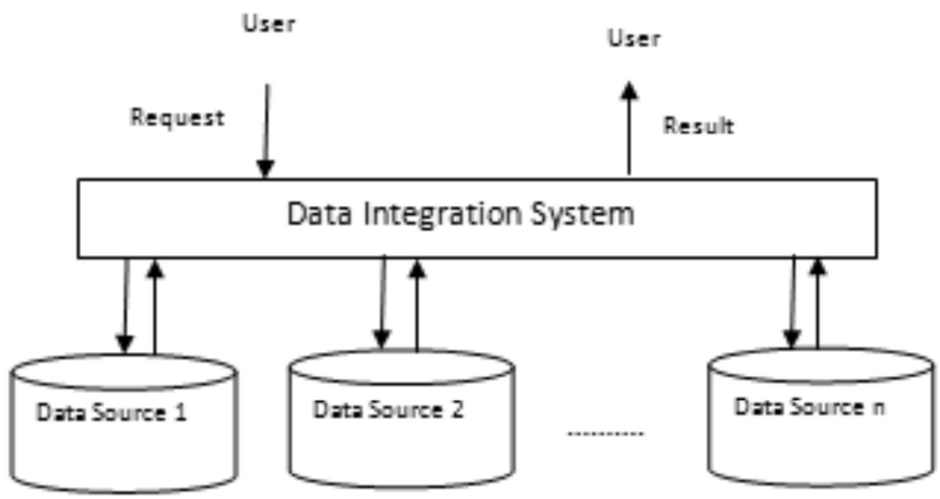

Figure 2: Model of data integration system

In order to effectively manage large amounts of data, according to the need of convenient and fast access to the required data, most of the data model store data using rigorous approaches in the database. However, the database has many different types and each with different data models or access interface, which has made convergence challenging for uniform access among heterogeneous databases. [8] [5]

VIII. VARIOUS TECHNIQUES FOR HEALTH CARE DATA CONVERGENCE

The convergence initiative : History

There were several workshop organized for discussing and contributing towards EHR systems convergence. Some of them are held in Reykjavik, Iceland on 3rd June, 2010, in Oslo, Norway on 28th August, 2011 in Basel, Switzerland on 7th November, 2012 and in Brussels, Belgium on 20th March, 2013[21]

Yongxing Luo et al.[3] present a prototype system for integrating disparate medical resources which is based on Grid technology with OGSA-DAI (Open Grid Services Architecture-Data Access and Integration). A Grid technology deals with sharing of heterogeneous resources that are in distributed environment without making any compromise on underlying heterogeneity of the local databases. OGSA-DAI is a project that deals with developing middleware for providing uniform service interface. Users can access and process various databases that are exposed to the Grid with the help of this service interface. Once the architecture of the prototype system is presented, an analysis is also performed on the implemented system's basic functional components which include metadata model, OGSA-DAI, transaction management and query processing. The implementation shows that various component of the system cooperate with each other for providing uniform accessing and effortless integration of the underlying disparate medical resources.

Teeradache Viangteeravat et al.[4] presented a design and an implementation of prototype for Health Level Seven (HL7) v3-RIM mapping function. This prototype implementation integrate distributed clinical data sources using R-MIM classes . RIM is based unified modeling language (UML) and is the root of all information models which represent HL7 data in a standard way across all domains of healthcare system. The prototype uses R-MIM(Refined Message Information Model) classes to express content for a set of messages from HL7 v3-RIM. These R-MIM classes are represented using Hierarchical Message Description(HMD) to represent the message type or message structure in an organized way. The HMD is communicated between systems with heterogeneous underlying technologies. The prototype was implemented as a plug-in module in CDMS(Clinical Database management Systems) which was further tested for some use case scenarios in disparate distributed clinical data sources across.[9]

Bhartiya Shalini et al.[14] present an overview of syntactic and semantic interoperability along with challenges of data exchange in interoperable healthcare environment. Interoperability can be defined as the ability of exchange as well as use of information that is being exchanged between two or more systems or system components. If two or more systems are able to communicate and exchanging data with each other, they are considered to be syntactically interoperable. Syntax refers to as grammars to convey semantics and structure for eg XML can be seen as markup language for structured data on the web. This kind of interoperability is often limited to communication protocol and the infrastructure needed for those protocol to operate. Semantic interoperability between systems is the ability to interpret meaningfully and accurately the information being exchanged as defined by the end users of the sender and receiver systems. A common reference model is to be referred by systems to achieve semantic interoperability. In order to gain effective healthcare and reduce clinical risk it is required to have full semantic interoperability[12,13] amongst heterogeneous EHR systems.

In spite of having lot of strategies and approaches for integrating healthcare systems in literature, authors across various articles considered a number of common principles for successful data integration. These common principles are independent of the type of model being integrated as well as independent of the type of healthcare context or type of patient population being served. Following are few consistently and frequently presented principles. [1]

i) Exhaustive service across variety of health care..

ii) Patient centric.

iii) Healthcare delivery must be standardized

iv) Management of performance.

v) Management of Information Systems.

vi) Existence of Organizational Culture

vii) Integration of Physicians

viii) Existence of Governance Structure.

ix) Management of Finance.

Converging EHR records and making them interoperable has always been a big challenge. Catalina Martínez-Costa[22] provided a method which applicable to two standards OpenEHR and ISO EN 13606 named dual-model based approach. i.e an approach for sharing, exchanging and re-using archetypes between

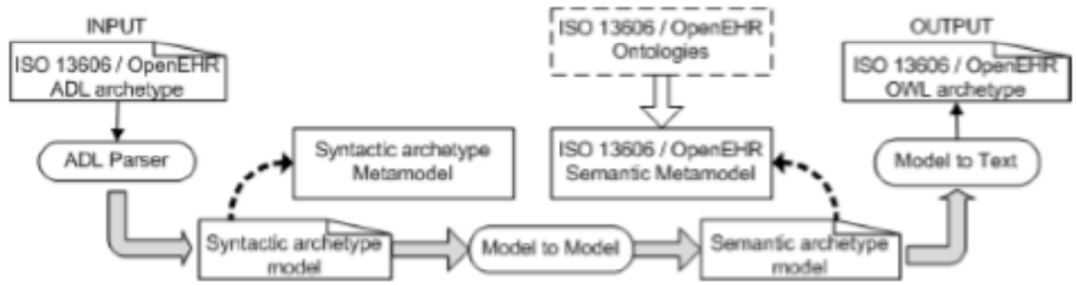

Figure 3: The ADL to OWL transformation model[22]

ISO EN 13606 and OpenEHR. The architecture is based on building two modeling levels: one is information level and the other is knowledge level. The reference model being used provide information level whereas archetype model used provide knowledge level. Archetypes represents clinical concepts built using ADL(Archetype Definition Language) by the domain experts.

There are two main ontologies constructed one for each standard. One is ISO13606-SP/OpenEHR-SP ontology. Clinical data structure and data type defined in the respective standards are represented by this ontology. The other ontology that is constructed is ISO13606-AR/OpenEHR-AR. These ontologies are archetype model and they re-use the SP ones. Semantic interoperability between the two standards i.e ISO EN 13606 and OpenEHR archetype is achieved by designing and implementing a methodology for constructing semantic archetype from syntactic archetype and subsequent transformation of archetypes between both standards.

Amanda Ryan[23] proposes an ontology based method of integrating information model with terminology. This could make possible generation of HL7 message automatically from the SNOMED-CT's concepts structure and relationship. It also addresses the problem of integrating the information model HL7 version 3 to the terminology SNOMED-CT using ontology mapping.

Prasser Fabian et al [26] presented an approach that transform the message streams exchanged between systems following a standard HL7-v2 application level protocol, into a RDF representation. The information system in RDF representation are then loaded into an RDF database system. This approach allows effortless integration of clinical data into semantic biomedical web application.

Verbeeck et al [27] presented an approach to map relational databases to RDF for dataset relating to neuroscience. The approach also describes how classes are identified in the original database and builds a complete representation of the domain by linking a standard set of complementary ontologies.

Priyatna et al[28] presented approach that can provide an integrated view as well as access to heterogeneous data sources. The approach uses an ontology which is based on the HL7 v3 RIM(Reference Information Model) and also a set of R2RML mappings. This mapping relate the ontology to the underlying relational database being implemented. The approach also uses query translation engine morph-RDB. The morph-RDB receives connection details to the relational database, R2RML mapping document and a SPARQL query as input. It evaluates the query into the underlying database and the result is then translated back into the format that is required as a result of the SPARQL query evaluation.

Mate et al [29] presented an ontology based approach to express each of the three ETL(Extraction, Transformation and Loading) step with an ontology for simplifying and supporting the mapping, extraction and data transfer process. Three ontologies are created: Source ontology behaves as an inventory of all healthcare data element. It also provides an inventory-to-database-schema mapping since it abstracts database record sets with ontology concepts. The target ontology behaves as a domain ontology because it contains collection of healthcare concepts that are to be loaded into the target database. The metadata of target system is generated from target ontology since it contains not only the syntactic information but also the semantic information. Here the semantic information is linked to each target ontology concept. The mapping ontology acts as a connector between source ontology and target ontology. It contains manually created semantic relationships between medical concepts.

Hajer Baazaoui Zghal and Antonio Moreno[30] presented a system in which based on the analysis of web snippets and past user queries, a modular ontology is built. The system facilitate any search engine to design a semantic layer on the top of syntactic layer. The system automatically builds modular ontology based on user's query. The query is then reformulated using the concepts of the modular ontology for improving information retrieval.

Hong Sun et al [31] presented a two-step approach where step1 maps Relational database to RDF if the source data is stored in a Relational database i.e it maps Relational Database schema to a Data Definition Ontology. 2) maps one RDF to another RDF where semantics are further converted Domain ontology using N3 rules to make the final ontology more expressive.

Chien D C Ta and Tuoi Phan Thi [32], describe some algorithms such as algorithms for identifying semantic relations based on Synonyms, Hyponyms and Hypernyms relations and based on syntax patterns and linguistic. Also an Information Technology Ontology is constructed while extracting the concepts and objects from different sources like Wikipedia,ACM and unstructured files from ACM Digital Library. Natural Language Processing tools are used in order to eliminate unnecessary words. Some of the tools used are OpenNLP for extracting sentences based on English pattern and Stanford Lexical Dependency Parser (SLDP). Thus the concepts in the ontology constructed have semantic relations between each other.

Raghu Anantharangachar et al[33] describe an approach for extracting information from unstructured text that starts with a listing a set of words which are specific to a particular domain termed as semantic lexicons created by domain experts. It also include techniques that identify the most appropriate ontology which should be extended with information from a given text. Once the domain is identified, instance is extracted in the form of triple and creates an RDF node. This RDF node is then appended it to the existing domain ontology.

Delia Rusu et al [34] present an approach for extracting triplets from English sentences in the form of subject-predicate-object. There are some frequently used syntactical parsers for English that are used for generating parse trees from sentences. These include OpenNLP, Stanford Parser, Minipar and Link Parser and Minipar. The approach also presents a triplet extraction algorithm from the parse trees.

IX. ROAD MAP TOWARDS EHR SYSTEMS INTEROPERABILITY

In a workshop organized on the Semantic Technology & Business Conference in San Francisco[11], a discussion was held on EHR systems interoperability and step was taken towards handling interoperability problem. The resolution came in the form of a manifesto, named The Yosemite Manifesto. The recommendation that was part of the manifesto was to use the World Wide Web Consortium's (W3C) RDF (Resource Description Framework) standard model as a universal healthcare exchange language for data interchange in the health domain. It also describe RDF as one of the core technologies of the Semantic Web. Thus RDF can be used as the best available tool for universal healthcare exchange language. The Yosemite Manifesto talks about two road maps to achieve EHR convergence and interoperability is shown in the fig below. First road map which is considered to be the standard approach consider each party to use the same model and vocabulary for achieving interoperability. The second approach consider translation between data models and vocabulary between parties. The approach uses RDF as the initial standard healthcare exchange language to make sure that there must be an RDF mapping possible irrespective of data formats and vocabularies used by the parties. This will enable healthcare information to be interpreted consistently in terms of RDF semantics across formats and vocabulary.

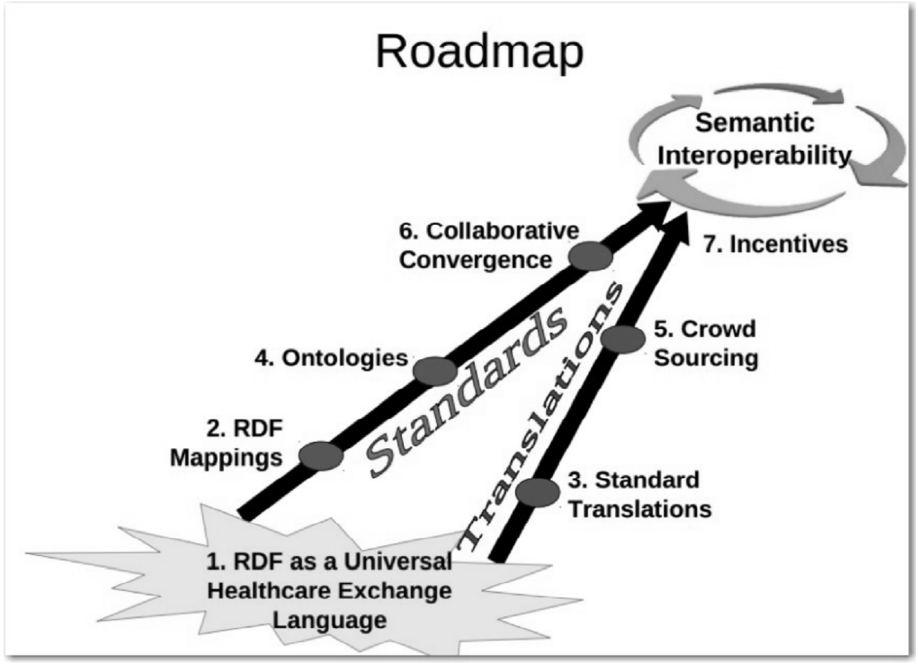

Figure 4: Roadmap for EHR Convergence

X. QUALITY ASSESSMENT

For whatever reason we design an EHR systems convergence model, evaluation of the applied model is essential. The quality of the system being converged depend not only depend on factors like source data quality but it also on the various methods and variables applied for performing the data convergence into single platform.

XI. GENERAL QUALITY CRITERIA

General quality measures include completeness, consistency of the converged system. Completeness considers the amount of missing data whereas consistency takes into account the amount of observations that fail edits and the amount of duplicates present. The matching variables quality is also critical to any of the procedures applied for integration [2].

XII. EVALUATION CRITERIA

To test efficiency of the for EHR system convergence, a query instance can be designed for retrieving all the medical records for a given patient ID. The query instance is then submitted through a client computer which must be in the same local area network. The same instance of the query can be implemented on heterogeneous databases separately for testing the performance of the model and their response time can be compared with that of the joint query that is submitted on the model system. Another measure that can be used for testing the effectiveness of the proposed system is ontology coverage. Ontology coverage represents how many concepts that exist in the source have been extracted successfully i.e Ontology coverage is total number of concepts extracted divided by total number concepts exist. Propose model system should show a comparatively steady performance as the size of data increases. Once data is converged in to a single platform. [3]

XIII. CONCLUSION

In the literature reviewed so far, no unified model or any commonly agreed upon conceptual model for health care systems integration and convergence was found. Despite having diversity of strategies and approaches for health systems integration, authors across various articles have considered a number of common principles for having successful data integration processes and models which are neither dependent of type health care context nor on the type of patient population being served without addressing the semantic part of data. In this scenario, our propose roadmap may prove to an alternative solution for EHR system convergence and seamless data exchange.

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