The Scoping Review of Integration of Heterogeneous Healthcare Systems

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Abstract— The Health Industry is facing two major issues: Integration and Interoperability. Integration of data, which is a process to combine data from different sources into a unified view, has become a serious problem as the volume of data and rate of information exchange increases. The problem of interoperability among healthcare systems models exists; due to working groups defining architectures and information models; implying meaning of data varies in the applications. The research use scoping review methodological analysis, to investigate and recommend how healthcare industry can do integration and interoperability among the heterogeneous systems. Semantic interoperability means guaranteeing exact meaning of exchanged information in an understandable format by any other applications that may use a different standard or model. The benefit of using semantic approaches is that they don't replace the current integration technologies, databases and applications, but add a new layer to the existing infrastructure for communication.

***Index Terms* — Interoperability, HL7, Ontology-Mapping**

I. Introduction

Medical Health Practitioners require access to detailed and complete patient records in order to deliver safe and effective health services. The health records need to be shared in real time within medical practitioners across geographical boundaries. Semantic interoperability of clinical standards is a problem in the health sector across the world. The core drive of the standards is to give interoperability between health applications; an openEHR compliant healthcare application cannot directly communicate with an HL7 compliant healthcare systems, hence ontology matching utilize data overlap for achieving semantic data interoperability [1], [2].

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The success of semantic interoperability of health systems will allow medical practitioners to manage electronic health records of patients regardless of which institution generated clinical sessions. Interoperability plays a major role in describing essential factors in achieving benefits from electronic health record systems to improve quality and safety of patient care, public health, clinical research, and health service management.

The factors that affect integration and interoperability of health systems are semantic and structural heterogeneity [3]. Medical practitioners need to access clinical information of patients in an understandable format; but, this information is distributed in many independent and heterogeneous systems that are semantically incompatible [4]. Interoperability is a sub-set of integration [5].

The health industry is facing two major issues: Integration and Interoperability; HL7 is a messaging standard that exchange medical information between two systems; however HL7 V2.x focused on the transfer of messages from sender to receiver rather than on interoperability; while HL7 V3 target shortcomings of HL7 V2.x targeting semantic interoperability based on Reference Information Model (RIM); HL7 V3 focuses on semantic data interoperability using Systematized Nomenclature of Medicine-Clinical Terms (SNOMED-CT), Logical Observation Identifiers, Names and Codes (LOINC), and HL7 vocabulary, while semantic process interoperability is stagnant research area [6].

II. Literature Review

A. Heterogeneous Systems

The existence of extensive variety of heterogeneous systems requires three important factors to fully integrate a system: data, functions and workflow [7]. A solution approach in building an integration system leverages through facilities provided by middleware and semantic technologies to address interoperability issues [8].

The heterogeneity of integration approaches in the health application systems is an obstruction and compromise data transfer and exchange [9]. Achieving interoperability among heterogeneous health systems is crucial since it will reduce

ISBN: 978-988-19253-8-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

costs linked with the health systems and contribute to effective and efficient patient treatment [10].

Khan, Khattak, & Lee (2012) found that heterogeneity of data between organizations is a multifaceted problem and needs to be solved in order to share data. They also indicate that interoperability is compliant only if the organizations use the same standard, and the problem normally occurs when one use Open Source Electronic Health Records (openEHR), while the other organizations use Health Level Seven (HL7) standard to communicate.

Heterogeneity solution between data and processes makes a way for interoperability between heterogeneous applications. Standards give the base for interoperability between different health systems, including EHR, HIS, etc.; The problem associated with data interoperability arise when two health systems are not compliant to heterogeneous healthcare standards and wants to connect with each other [1].

B. Semantic Interoperability

When you submit your final version (after your paper has The healthcare industry faces a challenge in semantic interoperability; which is ability for the health applications to share information properly interpreted by the receiving application as intended by the transmitting application; Web Services, serve as a catalysts to provide communication between the HIS in providing access to patient information [6].

In the context of this research; interoperability is defined as a capability of an application to utilize and share information or functionality of other applications through a common standard; while integration takes the user's needs of the health information system, the purpose of the application as the point of departure and relate those goals to better efficiency, effectiveness and coordination [5].

Specifying terminologies only cannot solve the semantic interoperability problem. In order to achieve semantic interoperability, a model is needed to support required constructs for semantic interoperability.

One technique explored to achieve semantic process interoperability is utilization of web services; Web Service Modeling Framework (WSMF) gives Web Service Modeling Ontology (WSMO) that includes entities such as ontologies, mediators, web services and goals [6]. Ontologies and terminologies enable exchange of meaning between systems, machines and people [11].

Another technique explored is SOA; a technology that discover services for user request; in SOA services are utilized to develop fast, economical, and interoperable applications; these services has to be expressed semantically in semantic registries so they can be machine comprehensible and be used by applications for interoperability processes [6]. The SOA and WSMF framework can help HL7 V3 standard to achieve semantic process interoperability. SOA may or may not use web services, however web services gives a simple way towards SOA [12]. ESB facilitate SOA implementation and gives Application Programming Interface (API) which can be used to develop services that interact efficiently with each other; ESB enable low cost integration and involves a handful of applications and moderate transaction volumes, while packaged EAI solutions involves large scale integration with enormous different applications and high volume of transactions [12].

The interoperability testing mechanism safeguard that diverse systems can co-operate to accomplish business processes, as required by the health institutions; The mechanism to certify interoperability requires testing the ability to communicate and exchange data, testing the ability to parse and extract information from exchanged messages, testing capacity to respond to the extracted information by changing information in the other systems; The initiative on the creation of Integrated Healthcare Enterprise (IHE) has pioneered healthcare testing by achieving real clinical setups [13].

C. Integration

Integration is not about creating one big technical system.

The ultimate data integration system allows loose coupling among heterogeneous data sources and access management while maintaining exchange of data [14].

XML and Web Services are industrial standard for integrating distributed health systems; while XML gives efficient approach in dealing with syntax and structural interoperability, while Web Services give standard to exchange mechanism through varied platforms, applications and networks [15].

SOA serve as a guide for integrating unrelated systems and denote a vision to how business and technology architecture can be integrated [16]. SOA is an integration pattern that suggests open standards and lightweight distributed modules [17]. SOA is intended to permit developers to conquer distributed enterprise computing problems including application integration, security and transaction management [18]. The technology provides application architecture for the interaction of existing health systems and distributed systems [19].

III. RESEARCH METHODOLOGY

The research adopts Scoping Review Methodological Analysis to critically review previous research and experiences as recommended [20]. Scoping Review Methodological Analysis is chosen to synthesize evidence from published papers, and explore literature relevant to health integration in academic journals, books and conference proceedings [21][22].

The researchers Fernandez-luque, Karlsen, Krogstad, Burkow, and Vognild [23] embraces search engines such as: Association for Computing Machinery (ACM), EbscoHost Premier Package, Emerald Management Xtra,

ISBN: 978-988-19253-8-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IEEE Xplore Digital Library, IOPscience and National Research Foundation (NRF) Databases to obtain access to health information and rich platform with integration of health applications and services.

There is a rapid growth of reviews, each using diverse approaches with the aim to collect, assess and present available research proof which includes the following: systematic review, narrative review, conceptual review, rapid review, realistic review, scoping review and meta-analysis [24].

Scoping review methodology seems appropriate since it allows the researcher to get a broad overview over important literature, design a more focused search strategy and research questions [21]. Scoping review map key concepts supporting research range and main bases and types of evidence emerging [25]. The researchers Webster et, al, [26] argues that scoping review is a scheme created to map literature in a specific subject area, lightens key concepts, core sources and types of evidence; it is particularly used for multifaceted topics, which have not been widely studied and for which many different learning designs have been used.

IV. RESEARCH RESULTS

The research used scoping review approach proposed by Arksey and O'Malley framework [27] composed of five important steps, which are: 1. Define research question, 2. Ascertain important studies, 3. Choose articles, 4. Graph the data, and 5. Organize, Encapsulate and report the research outcomes.

A. *Define Research Question*

The research question is outlined as:

- How can we integrate different health information systems designed by different vendors with different programming languages and platforms?
- How can we keep consistence of medical information across different systems that are not integrated?

B. *Ascertain Important Studies*

We searched electronic databases using search terms as identified by research team, and information specialists as inputs [19], [20]. The research journals and conference proceedings published in these databases were found to be sufficient to cover the research.

Search Parameters: Interoperability in healthcare systems, Enterprise Service Bus, Web Services, HL7, SOA, Heterogeneous Data Sources, Healthcare Integration, Semantic interoperability

C. *Choose articles*

6000 articles were retrieved in 2013 and screened for importance based on their titles and abstract. Initial search brought the following number of articles through search engines: Springer retrieved 400, IEEE Xplore retrieved 3250, ACM retrieved 1270, and Google scholar 1080. Studies not published in English were excluded, including studies which avail only abstracts only, and those which do not include integration studies or review in health information systems were also excluded. The included articles were scrutinized to extract information about health integration systems, paradigms and outcomes from different perspectives, including experiences. Articles that met inclusion criteria were retained for scoping review.

D. *Graph the Data*

Table 1 below shows research papers according to each factor on integration of health systems, based on publications, year and technique used.

Table 1 : Integration Table

Publication	Year	Integration Technique
(Martínez-Costa et al., 2009)	2009	Ontology Matching
(Martínez-Costa, Tortosa & Fernández-Breis, 2009)	2009	Semantic Web Technologies and MDE Transform ISO 13606 archetypes into OpenEHR archetypes and vice-versa
(Khan et al., 2012)	2012	Ontology mapping
(Iftikhar, Khan, & Fatima, 2012)	2012	HL7 messaging standards exchange medical information between systems
(Noumeir & Pambrun, 2010)	2010	HL7 v3 is based on web services and XML standards
(Iftikhar, Khan, & Fatima, 2012)	2012	Web Service Modeling Framework (WSMF)
(Azami, Malki & Tahon, 2012)	2012	Mediation architecture based on mediator and adapter components
(Archint & Ngamnij, 2013)	2013	Web Services and Ontology technology SIDI framework solves platform independence of heterogeneous HIS

The Figure 1 below shows the graph of integration and interoperability to observe trends from 2008 to 2014.

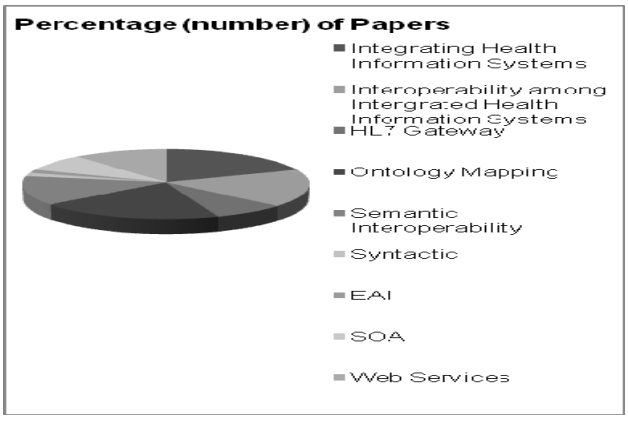

Fig 1: Integration and Interoperability trends

E. *Organize, Encapsulate and Report Research Outcome*

Figure 2 below outline a flow chart of search results after selecting relevant published literature based on the scope of the research study, and a comparative revision carried out on chosen literature

ISBN: 978-988-19253-8-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

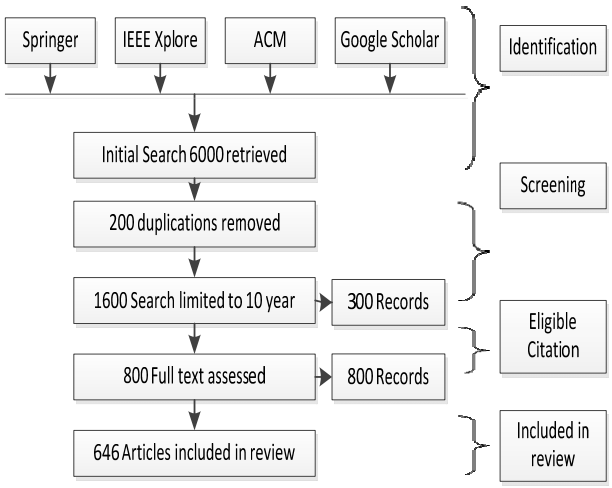

Fig 2: Flow Chart of Search Result

Table 2 below discusses research topic areas according to the number of papers studied and percentage. The largest percentage of studies focused on the topic of ontology mapping (58, 25%). Ontology mapping achieves semantic interoperability between systems that use standards such as openEHR, CEN, SNOMED-CT and information model of HL7 by resolving data level heterogeneity. Integration (54, 24%) allows messaging standards to define how medical information is packaged and shared across systems, and consolidate data from laboratory information system, hospital information systems, and medical centers.

Table 2: Research Topic Areas

Research topic	Percentage (number) of papers
Integrating Health Information Systems	24% (54)
Interoperability among Integrated Health Information Systems	22% (50)
HL7 Gateway	10% (24)
Ontology Mapping	25% (58)
Semantic Interoperability	17% (38)
Syntactic	2% (5)
EAI	2% (5)
SOA	10% (24)
Web Services	14% (32)

Interoperability (50, 22%) is only achieved if heterogeneous health systems are compliant with each other, using the same standard or ensuring precise meaning of exchanged information is understandable by other applications with different standards. Semantic interoperability (38, 17%) is an ability to ensure that health systems share exchanged information properly interpreted by receiving system as transmitted. Web services composed of (32, 14%) play a key role in the integration of systems by representing systems functionality independently of the platform. HL7 gateway and SOA are composed of (24, 10%) on the research topics, while Syntactic and EAI are composed of (5, 2%) respectively, as the lowest percentage.

V. Conclusion

We identified 646 articles for the scoping review published from 2005 until 2015. However, 229 articles provided an inside in the integration of the heterogeneous system in the health sector. The most frequently studied method in the integration of health system is ontology mapping which is a key for semantic interoperability. The scoping review has provided an important high-level synthesis in the integration of heterogeneous health systems research. In particular, it has highlighted a key concept of ontological mapping as an approach to integration and achieving semantic interoperability.

Acknowledgment

Thanks giving to the institution, Tshwane University of Technology, and Faculty of Information and Communication Technology for such great support in research, starting with finance ending with your words of encouragements to keep on writing, and we further extend our thanks giving to the supportive Information Librarian Mrs. Makhanani Cynthia Mashaba from Library and Information Services, Soshanguve Campus.

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ISBN: 978-988-19253-8-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)