Household of care in electronic health information exchange systems

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***Abstract*—The Integrating the Healthcare Enterprise advocates for the integration of distributed and heterogeneous health information systems. This is achieved through the development of standards that specifies protocols through which the integrated systems can communicate as profiles. The Integrating the Healthcare Enterprise through its Information Technology Infrastructure Technical Framework Volume 2b Transaction B provides a Patient Identification Segment which provides a way in which a patient's demographic details can be exchanged among the systems within a Health Information Exchange ecosystem. In the South African context however, healthcare services are extended to communities through community healthcare workers that make visits to households. There is therefore a need to manage households in a similar way that patients are managed in a health information exchange systems. The Integrating the Healthcare Enterprise standards currently does not have explicit profiles in their standards that can be utilised in managing households in Health Information Exchange systems. As opposed to patients being treated as subjects of care, households are treated as subjects of care by community healthcare workers. In this paper we present a way which we use to represent households and it follows the Health Level Seven standards format. We also present an implementation of a Enterprise Master Household Index equivalent to a Enterprise Master Patient Index that utilises our proposed profile.**

***Index Terms*—Health Standards, HL7, Health Information Exchange, Systems Integration**

I. Introduction

The Integrating the Healthcare Enterprises (IHE)[9] is an international organisation which develops standards meant to enhance inter-operability among systems within a Electronic Health Information Exchange (HIE). An HIE is a system of systems that participate within a healthcare domain or cross-domains. The standards developed by the organisation have presented the protocols and message profiles that can be used for communication among the systems within Electronic Health Information Exchange (HIE)[17, 6]. HIE "*allows doctors, nurses, pharmacists, other healthcare providers and patients to appropriately access and securely share a patient's vital medical information electronically-improving the speed, quality, safety and cost of patient care*"[4]. The message profiles also include the specifications for representing a patient's demographic information within a message for exchange with other systems. In the South African context however, there is a need to go beyond patient centric systems to systems that can support household demographic information as well. This is so because community health workers are used in South Africa in extending access to healthcare services to even the remotest areas. In this case, instead of treating patients or persons as subjects of care, households in which people belong are treated as subjects of care.

There is therefore a need for a standardised way in which household demographic information can be represented for easier exchange among systems within the HIE. This paper covers this gap by proposing and presenting such a method and also demonstrate it through an implementation.

The paper is organised as follows: In Section II a background which will also cover related works by other researchers attempt to address a similar problem of managing and exchanging household of care information is presented. This will also include profiles that exist within HIE standards that may be reusable for managing and exchanging household of care information. In Section III this paper's approach in representing the household of care demographic information is presented. In Section IV the implementation of a Enterprise Master Patient Index (MPI)[16, 13] equivalent of a system that utilises our proposed way of representing the household of care demographic information is presented. In Section VI a discussion of the tests that were conducted on the implementation of the system is provided and in Section VII conclude the paper is concluded.

II. Background

The main objective of the Health Level Seven [7] standards is to allow seamless communication among heterogeneous health information systems that participate in an HIE. Through IHE's IT Infrastructure Technical Framework Volume 2a, the IHE provides specifications for messages used to exchange patients' information in the Volume document's Section 3.8. IHE refers to such exchanges as Transaction ITI-8. The IHE's technical frameworks are base on the Health Level Sever (HL7) international standards [7]. For household information to be supported, there is a need for an equivalent of such specifications. These will be dealt with in Section III. According to the authors' knowledge, there are currently no research works that attempt to manage household in a standardised manner. This research work therefore is partly aimed at promoting research in this direction. This section however will look at research works that do handle or address household management.

In general, there are research efforts that standardise communications among healthcare devices. The research works that put emphasis on standardisation of the communications among devices include [11, 8, 14].

Among research works that focus on household messages standardisation is the research by Boonchieng, Boonchieng, Senaratana, and Singkaew in [1]. In [1], the household is treated as family with a family head and individuals as members. The three are treated as separate entities. The family entity has the household identifier, members' identifiers and the geographic position. In their design however, considerations were not made for integrating the system with other heterogeneous systems.

Another research that is of relevance to our research work is by Jeremie and Akinyi in [12]. The research does not necessarily focus on systems that manages households. It is instead for the idea of community health workers that bring healthcare services to to households in remote areas. It is therefore necessary for such households' information to be managed electronically and be accessed by health workers using different systems. South Africa has been advocating for community healthcare workers as early as 1997 [2]. Such initiatives need to take advantage of the advancements in technology. This research therefore contributes in this regard by providing a standard way of managing household information in the same way that patient information is managed.

In the next section, a way in which houses hold information can be represented and exchanged among heterogeneous systems is presented.

III. Household Identification Segment (HID)

The focus of the world is to have healthy communities through providing the prevention and early detection of diseases. This requires that health services be taken to the people since many people report to health facilities when they have already contracted a disease. One of the means of taking such services to the people is through the use of the Community Health Worker (CHW). The CHW has become an important resource in rendering health services to communities with shortage of health workers. Data collected by the CHW are valuable for healthcare services and as such should be collected and stored in a structured format that will seamlessly integrate with existing health systems.

The HL7 Patient Identification segment standard was developed to record patient demographic data for interoperability within and across domains. The CSIR has been involved in projects that require the integration of health data collected from designed health institutions and data collected by CHWs as part of the reference implementation of the South Africa Health Normative Standards.

A Master Household Index (MHI) was conceived and developed based on the industry known Master Patient Index (MPI)[16, 13]. The messaging standards based on the IHE profiles were also adopted for the MHI.

The Household Identification Segment (HID) was created to align with the HL7 Patient Identification (PID) standard. It is comprised of 13 data elements which provide the following information as indicated in Table I: HID.2 – Household Identification Number. This is a number issued to the household by a recognized assigning authority. HID.3 –Household Id. This is an application level unique identification number issued by the software vendor.

HID.4–Date of registration. The date format should conform to the ISO/IEC8601 (YYYYMMDDHHSS)[10]. HID.10– This is the geographic coordinates of the location of the household written as latitude and longitude. HID-11–The street address of the household which includes the street name, street number and city. HID.12–A two digit country code. It should conform to ISO 3166 Alpha-2 code. HID.13–Head of household contact number. HID.21–Municipal Account Number. This is the account number issued to the household. It may not be required since some jurisdictions may not have them. HID.22–Electricity Meter Number. This may not be required.

HID.27–Health Facility. This is the health facility at which members of the household will normally receive health services. This includes the health facility identifier and name. HID.28–District. It contains the name and identifier of the district in which the household is location. It may not be required but it is important for statistical purposes. HID.29–Sub District. It contains the name and identifier of the sub district in which the household is located. It may not be required but it is important for statistical purposes. HID.30–Ward. It contains the name and identifier of the ward in which the household is located. It may not be required but it is important for statistical purposes.

HID.21, HID.22, HID.27, HID28, HID.29 and HID.30 provide extra identifiers of a household that do not follow the HL7 standards. However, they provide vital information for the decision making. For example, they can provide information about households whose members may be suffering from a particular disease due to their location.

HID.32 is an indicator for the dispersal of a house. This indicator is equivalent to a state of patient being deceased or not. In this case, a house may be dispersed if it no longer exists or members have separated to form new households.

TABLE I
HID Segments

HID Code	**Description**	**Required**
HID.2	Household Identification number	Yes
HID.3	Household Identifier List	Yes
HID.4	Alternate Household ID	Yes
HID.9	Ownership (Y –> Yes, N –> No, RTA –> Refuse to answer, DK –> Don't know)	Yes
HID.10	Geographic location	No
HID.11	Street address	No
HID.12	Country code	No
HID.13	Head of household contact number	No
HID.21	Municipality account number	No
HID.22	Electricity meter number	No
HID.27	Health facility	No
HID.28	District	No
HID.29	Sub-district	No
HID.30	Ward	No
HID.32	Household Disperse Indicator	Yes

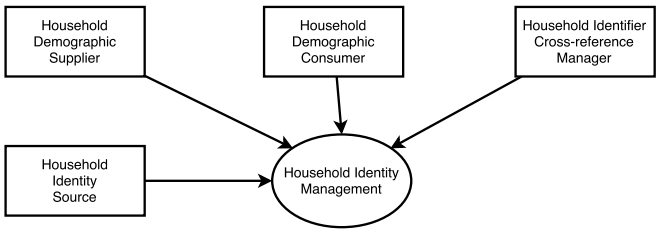

Fig. 1. Usecase In the HIE System. Adapted from [3].

In Figure 1, a usecase that involves exchange of the demographic information of a household is represented. The usecase is adapted from the IHE's IT Infrastructure Technical Framework [3]. The usecase depicts four actors that interact in Household Identity Management which are Household Identity Source, Household Demographic Supplier, Household Demographic Consumer and the Household Identifier Cross-reference Manager. In [3], this usecase involves management of a patient's demographic information. In [3], a Patient Identity Sources Source actor creates unique identifiers for patients in an HIE system. The Patient Demographic Supplier receives update messages from other systems in the HIE and also responds to requests from other systems that require the demographic information that it contains. Patient Household Demographic Consumers queries and consumes the demographic information from the suppliers. The Patient Identifier Cross-reference Manager creates, maintain and provides lists of identifiers that can be used across different in different identifier domains within the HIE.

In the case of the households approach presented in this paper, the same actors are used as they are but in the context of households instead of patients. Hence, in Figure 1 the the actors are renamed to have households instead of patients.

Figure 2 depicts a sequence diagram that shows the Household Demographics Source and the Household Demographic Consumer exchanging messages. In the sequence diagram, the Household Identity Source updates the Household Demographics Consumer that has subscribed of any new household information or changes on details of any existing household information. The notifications include cases whereby a new household is created, household information is updated, two households are merged, change in household identifiers, linking household information and unlinking of household information. Again, instead of Admit, Discharge and Transfer (ADT) which are different messages for different scenarios when handling a patient's information, Register, Disperse and Transfer (RDT). Such naming conversion however is subject to revision as it will be perfected as a it will be revised and prepared for a proposal as a standard with the appropriate standards body.

An implementation of the HID will be further discussed in Section IV and Section V.

IV. Enterprise Master Household Index (MHI)

In this section we discuss the Enterprise Master Household Index (MHI), an equivalent to the Enterprise Master Patient

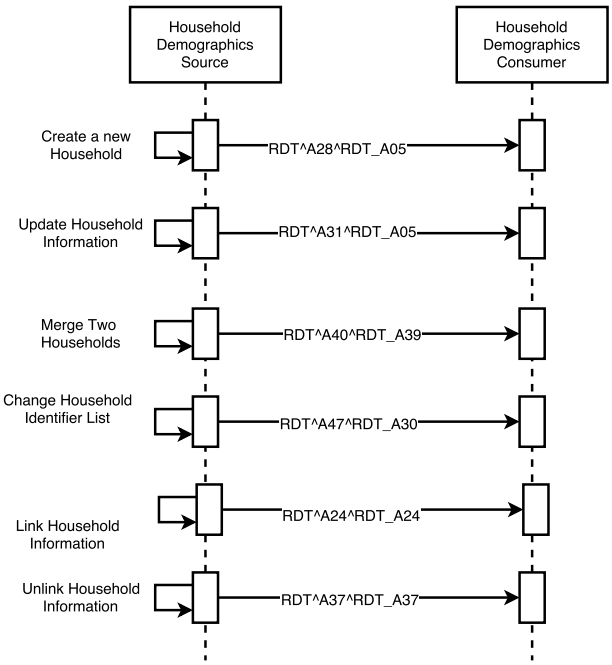

Fig. 2. Sequence In the HIE System. Adapted from [3].

Index (MPI)[16, 13] that is used for the lookup of patients in an Electronic Health Information Enterprise (HIE). The discussion will also include its implementation.

The implementation of the MHI currently involved an extension of the OpenMPI [15], an implementation of an MPI. This included adding a household as a additional entity in the OpenMPI's data model. Since version 3 of the OpenMPI was not generic enough to support additional entities, more household related objects were implemented and incorporated in it as part of its extension. The built in matching algorithms were left intact.

The MHI is implemented as a RESTFul service and the interpretation of the standard format of the household feed messages discussed in Section III does not rely on it. However, the representation of the household in the data model can be mapped to the HID segment. An intermediary library residing in the HIE system is then used for the HID to MHI REST format and back. REST calls can be made directly to the MHI but a standardised communication is through the HIE where message transformer resides.

Listing 1 represents an example of RESTFul API message body that contains the household information that is being sent to the MHI for storage or is being return to a household consumer that queried the MHI API. The message body in the listing can be mapped directly to the HID discussed in Section III and represented in Table I.

This is the implementation that enables the lookup of a household. Household lookups can be useful in cases of outbreaks of diseases that are contact transmitted. The household can be used to identify members of the household of which an infected person is a member which can then be summoned for screening.

In the next section we provide a discussion on the presented HID and its implementation. We also discuss the data obtained while testing the MHI implementation discussed in this section.

Listing 1. MHI Representation of a Household

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<household>
    <countryCode>ZA</countryCode>
    <dateCreated>2015-09-15T20:47:01.844+02:00</dateCreated
        ↪ >
    <dateOfRegistration>1915-07-08T00:00:00+02:00</
        ↪ dateOfRegistration>
     <geoLocation>
        <latitude>67</latitude>
        <longitude>56</longitude>
    </geoLocation>
    <householdownercontactnumber>
                        0128400000
    </householdownercontactnumber>
    <healthFacility>
        <identifier>789929</identifier>
        <name>Tshwane</name>
        <type>HOSPITAAL</type>
    </healthFacility>
    <houseHoldId>32635</houseHoldId>
    <houseHoldIdentifiers>
        <dateCreated>3880-07-05T00:00:00+02:00</dateCreated
            ↪ >
        <dateVoided>3878-04-25T00:00:00+02:00</dateVoided>
        <houseHoldIdentifierId>34256</houseHoldIdentifierId
            ↪ >
        <identifier>84878532</identifier>
        <identifierDomain>
            <dateCreated>3915-09-15T00:00:00+02:00</
                ↪ dateCreated>
            <identifierDomainId>2</identifierDomainId>
        </identifierDomain>
        <userCreatedBy>
            ...
        </userCreatedBy>
    </houseHoldIdentifiers>
    <householdIdentificationNumber>7888</
        ↪ householdIdentificationNumber>
     ...
    <municipalAccountNumber>
        <designation>7892</designation>
        <geographicArea>Nongoma</geographicArea>
        <issuer>Tshwane</issuer>
        <type>MUNK</type>
    </municipalAccountNumber>
    <ownership>YES</ownership>
    <streetAddress>
        19 Mispel
    </streetAddress>
    <subDistrict>
        <identifier>567</identifier>
        <name>District</name>
        <type>SUBDISTRICT</type>
    </subDistrict>
     ...
</household>
```

V. Evaluation and Experimentation

The Enterprise Master Household Index (MHI) was tested in an Health Information Exchange system. The usecase presented in Figure 1 was tested in a HIE system. The HIE has house hold demographic suppliers and household demographic consumers and household identity sources depicted in Figure 1. This was tested by running the activities shown in Figure 2 which are creation and updating of a household, merging two households, changing household identifiers, linking household information and unlinking household information. An example of the messages that are exchanged between the household demographic supplier and household demographic consumer shown in Figure 2 is as shown in Listing 2.

Listing 2. Message Containing HID

```
<RDT_A05 xmlns="urn:hl7-org:v2xml">
<MSH>
 ...
</MSH>
<SFT/>
<EVN>
 <EVN.2>
  <TS.1>20160521151616.687+0200</TS.1>
 </EVN.2>
</EVN>
<HID>
 <HID.2>
  <CX.1>00100041200013</CX.1>
  <CX.4>
   <HD.1>MEZZ2014</HD.1><HD.2>www.householdsupplier.com</HD.2><HD.3>URK</HD.3>
  </CX.4>
  <CX.5>HK</CX.5>
 </HID.2>
 <HID.3>
  <CX.1>00c694bf-8754-487c-9595-67f79b6670dd</CX.1>
  <CX.4>
   <HD.1>MEZZ2014</HD.1><HD.2>www.householdsupplier.com</HD.2><HD.3>URK</HD.3>
  </CX.4>
  <CX.5>HK</CX.5>
 </HID.3>
 <HID.9>Y</HID.9>
 <HID.10>
  <GEO.1>POINT</GEO.1><GEO.2>54,34</GEO.2>
 </HID.10>
 <HID.11>
  <XAD.1>
   <SAD.1>45 Bulawayo Street, Bukinham, 3493</SAD.1>
  </XAD.1>
 </HID.11>
 <HID.12>ZA</HID.12>
 <HID.13>
  <XTN.1>0762345913</XTN.1><XTN.2>PRS</XTN.2>
 </HID.13>
 <HID.21>
  <CX.1>127848923874</CX.1>
  <CX.4>
   <HD.1>TSHWANE</HD.1><HD.2>TestUniId1</HD.2><HD.3>ISO</HD.3>
  </CX.4>
  <CX.5>TN</CX.5>
 </HID.21>
 <HID.22>
  <CX.1>1274783910</CX.1>
  <CX.4>
   <HD.1>TSHWANE</HD.1><HD.2>TestUniId1</HD.2><HD.3>ISO</HD.3>
  </CX.4>
  <CX.5>TN</CX.5>
 </HID.22>
 <HID.27>
  <CE.1>21345676</CE.1><CE.2>Silverton Clinic</CE.2><CE.3>L</CE.3>
 </HID.27>
 <HID.28>
  <CE.1>343443441</CE.1><CE.2>Tshwane</CE.2><CE.3>L</CE.3>
 </HID.28>
 <HID.29>
  <CE.1>343443442</CE.1><CE.2>Kloof</CE.2><CE.3>L</CE.3>
 </HID.29>
 <HID.30>
  <CE.1>343443443</CE.1><CE.2>Klein Karoo</CE.2><CE.3>L</CE.3>
 </HID.30>
 <HID.32>N</HID.32>
</HID>
<XID>
 <XID.3>
 <CE.1>34878432934</CE.1><CE.2>Test service Provider</CE.2><CE.3>MA</CE.3>
 </XID.3>
</XID>
                ...
</RDT_A05>
```

The household demographic supplier that we have tested with in this case comprised of a mobile application used by health workers in the field who were doing the household assessment. The mobile applications uploads data to a central server which is part of the HIE system and assumed a role of being a household demographic supplier. The household demographic supplier then sends the household information to the HIE as the RDTˆA28ˆRDT_A05 message shown in Figure 2. The message in Listing 2 still follows the HL7 Messaging Standard [5] message format with the exception of the use of Register, Disperse and Transfer (RDT) instead of the standard Admit, Discharge and Transfer (ADT) as discussed in Section III. Otherwise all the components of the message excluding the HID segments are as they are in the HL7 Messaging standard.

The MHI presented in Section IV was used for the lookup

and matchmaking of household information. The evaluation has proven as expected that the household demographic information can be exchanged in the HIE system in a standardised way and in the same way that the patient demographic information can be exchanged on the HIE. The next phase of the project will involve taking the system to potential end users whom in this case are community health care worker as the current evaluation was preliminary and focused on functionality.

VI. Discussion

The shortage of health facilities and resources in remote parts of South Africa has prompted the need for healthcare workers to be utilised in reaching out for the healthcare recipients that are located in those remote areas. The approach used by those healthcare workers is that they treat households as recipients of the healthcare services. The administration of those households is therefore conducted in the same way that the patients are administered. The implementation of the Enterprise Master Household Index (MHI) and the proposed Household Identification Segment (HID)presented in this paper has proved that households can be handled in the an HIE system in the same way that patients are handled. The HID segment however still needs to be subjected to reviews and standardisation process.

VII. Conclusion and Future Work

In this paper we have presented the Household Identification (HID) used represent and exchange household information in a Electronic Health Information Exchange (HIE) system. We have also presented the the Electronic Master Household Index (MHI) used for the indexing and discovery of households in the HIE ecosystem. The HID and MHI addresses the administration issues of household information in an HIE in a standardised manner. This has been proved to be feasible in the paper as the household information was exchanged from the sources and suppliers who are the health workers in the South African health department. The household information was exchanged in a similar way as done with patient information.

As part of the future work, the proposed HID will be subjected to expert reviews in preparation for it to be standardised with an appropriate standards body.

References

[1] Ekkarat Boonchieng et al. "Development of mHealth for public health information collection, with GIS, using private cloud: A case study of Saraphi district, Chiang Mai, Thailand". In: *2014 International Computer Science and Engineering Conference (ICSEC)*. IEEE, July 2014, pp. 350–353. ISBN: 978-1-4799-4963-2. DOI: 10.1109/ICSEC.2014.6978221. URL: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=6978221.

[2] Denise Cruz. *Community health workers in South Africa - Information for Provincial Policy Makers*. Durban: Health Systems Trust, 1997. ISBN: 1-919743-13-8. URL: http://www.hst.org.za/publications/community-health-workers-south-africa-information-provincial-policy-makers.

[3] Enterprise Integrating the Healthcare. *IHE IT Infrastructure Technical Framework*. 2016. URL: http://www.ihe.net/uploadedFiles/Documents/ITI/IHE%7B%5C_%7DITI%7B%5C_%7DTF%7B%5C_%7DVol2b.pdf.

[4] *Health Information Exchange (HIE)*. 2014. URL: https://www.healthit.gov/providers-professionals/health-information-exchange/what-hie (visited on 03/26/2017).

[5] Health Level Seven. *HL7 Standards Product Brief - HL7 Messaging Standard Version 2.8.2*. 2015. URL: http://www.hl7.org/implement/standards/product%7B%5C_%7Dbrief.cfm?product%7B%5C_%7Did=403 (visited on 03/27/2017).

[6] William Hersh et al. *Health Information Exchange*. en. URL: http://www.ncbi.nlm.nih.gov/books/NBK343580/.

[7] HL7. *Health Level Seven International*. URL: http://www.hl7.org/ (visited on 08/02/2014).

[8] "IEEE Draft International Standard - Health informatics- Personal health device communication- Part 10419: Device Specialization- Insulin Pump". In: *IEEE P11073-10419/D2, December 2016* (Jan. 2017), pp. 1–138.

[9] IHE. *Integrating the Healthcare Enterprise (IHE)*. 2017. URL: http://ihe.net/ (visited on 03/27/2017).

[10] International Standards Organisation. *ISO 8601 - Time and date format*. 2004. URL: http://www.iso.org/iso/home/standards/iso8601.htm (visited on 03/26/2017).

[11] "ISO/IEC/IEEE International Standard - Health Informatics – Personal Health Device Communication - Part 20601: Application Profile - Optimized Exchange Protocol". In: *ISO/IEEE 11073-20601:2016(E)* (June 2016), pp. 1–252. DOI: 10.1109/IEEESTD.2016.7842820.

[12] Nzanzu Jeremie and Caroline Akinyi. "Utilization of Community Based Health Information Systems; Management and Community Service Delivery in Kenya". In: *American Journal of Clinical Neurology and Neurosurgery* 1.2 (2015), pp. 54–59.

[13] D. Krechel and M. Hartbauer. "The LENUS Master Patient Index: Combining Hospital Content Management with a Healthcare Service Bus". In: *2008 21st IEEE International Symposium on Computer-Based Medical Systems*. June 2008, pp. 170–172. DOI: 10.1109/CBMS.2008.107.

[14] W. Liu et al. "Smart and connected e-Health lab for standards validation and conformance". In: *2016 International Conference on Computing, Networking and Communications (ICNC)*. Feb. 2016, pp. 1–5. DOI: 10.1109/ICCNC.2016.7440623.

[15] *Master Patient Index*. URL: http://www.openempi.org/ (visited on 03/26/2017).

[16] Project Kenai. *Enterprise Master Patient Index*. URL: https : / / openempi . kenai . com / EnterpriseMasterPatientIndexAndOpenEMPI . pdf (visited on 03/26/2017).

[17] Joshua R Vest and Larry D Gamm. "Health information exchange: persistent challenges and new strategies". In: *Journal of the American Medical Informatics Association* 17.3 (2010), pp. 288–294. ISSN: 1067-5027. DOI: 10.1136/jamia.2010.003673. URL: http://jamia.oxfordjournals.org/content/17/3/288.